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Aims and Scope

Journal of Minimally Invasive Spine Surgery & Technique (*JMISST*) is the official journal of the Korean Minimally Invasive Spine Surgery Society (KOMISS) and Minimally Invasive Spine Surgeons Association of Bharat (MISSAB) for the publication of research results about minimally invasive spinal surgery (MISS). JMISST will consider submissions in areas of endoscopic spinal surgery, minimally invasive procedure for degenerative spine disease, pain intervention, minimally invasive surgery for spinal fusion or spine trauma, neuroscience, neurology, molecular biology and biomechanics etc. JMISST provides spine physicians and researchers with peer-reviewed articles on minimally invasive spine surgery to improve patient treatment, education, clinical or experimental research, and professionalism. In particular, minimally invasive spine surgery, including endoscopic spinal surgery, will be the most important field in the future spinal treatment. JMISST is the only journal in the world that is currently focused on minimally invasive spine surgery. We aim to lead the field of minimally invasive spine surgery to be developed in the future, and will contribute to providing a happy life for humans based on academic development.

Research and Publication Ethics

For the policies on the research and publication ethics not stated in this instructions, 'Good Publication Practice Guidelines for Medical Journals (http://kamje.or.kr/publishing_ethics.html)' or 'Guidelines on good publication (http://www.publicationethics.org.uk/guidelines)' can be applied.

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Journal of Minimally Invasive Spine Surgery and Technique

The History of Korean Minimally Invasive Spine Surgery Society (KOMISS) and Global Impact on Spine Surgery

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Korea minimally invasive spine surgery society (KOMISS) celebrated its 20th anniversary this year in 2021. The society was established in 2002 for the purpose of research on novel techniques and instruments in the rapidly developing field of spine surgery, under the leadership of Professor Park, Chun Kun, the first president. Annual meetings have been held every year since. The advanced course focusing on endoscopic surgery was introduced in 2009, while international academic conferences and cadaver workshops have been held since 2012. In 2012, the first textbook was published. In 2015, KOMISS was promoted to an official society by integrating with the Korean Society for Minimally Invasive Spine Surgery, another Korean society for minimally invasive spine surgery (MIS). Additionally, in 2017, the Korean Research Society of Endoscopic Spine Surgery (KOSESS), a research group specialized in spinal endoscopic surgery, was established as its own society. Presently, in the face of the ongoing corona pandemic, there is continuous research efforts through online meetings. For the past 20 years, KOMISS has been educating Korean doctors on MIS surgery through various symposiums and hand on workshops, and has gradually established its ranks and expanded its scope around the world. Most importantly, among the many areas of minimally invasive spinal surgery, KOMISS has developed surgical techniques focusing on endoscopic spinal surgery above all else and has had an unrivaled impact worldwide. Consequently, pioneers and world-renowned surgeons of endoscopic spine surgery in KOMISS have inaugurated the era of endoscopic spine surgery as gold standard of care.

Key Words: Spine, Endoscopy, History, Minimally invasive surgical procedures

THE HISTORY OF KOREAN MINIMALLY INVASIVE SPINE SURGERY SOCIETY (KOMISS, FOUNDING PROCESS, AND CURRENT STATUS)

Since the 1980s, as the use of a surgical microscope became common, interest in minimally invasive surgical treatment has increased in the field of spinal surgery. Various spinal surgical methods and new micro-instruments have been rapidly developed, changing the general perception of surgery for various spinal diseases. Following this trend, the executive board of directors of the Korean Spinal Neurosurgery Society (KSNS) decided to establish a minimally invasive spinal surgery research group under their society. Korean Minimally Invasive Spine Surgery Society (KOMISS) was established in 2002 by Professor Chun Kun Park, of the Catholic University of Korea, to promote academic development and academic exchanges on clinical and basic research in the field of minimally invasive spine surgery (Figure 1).

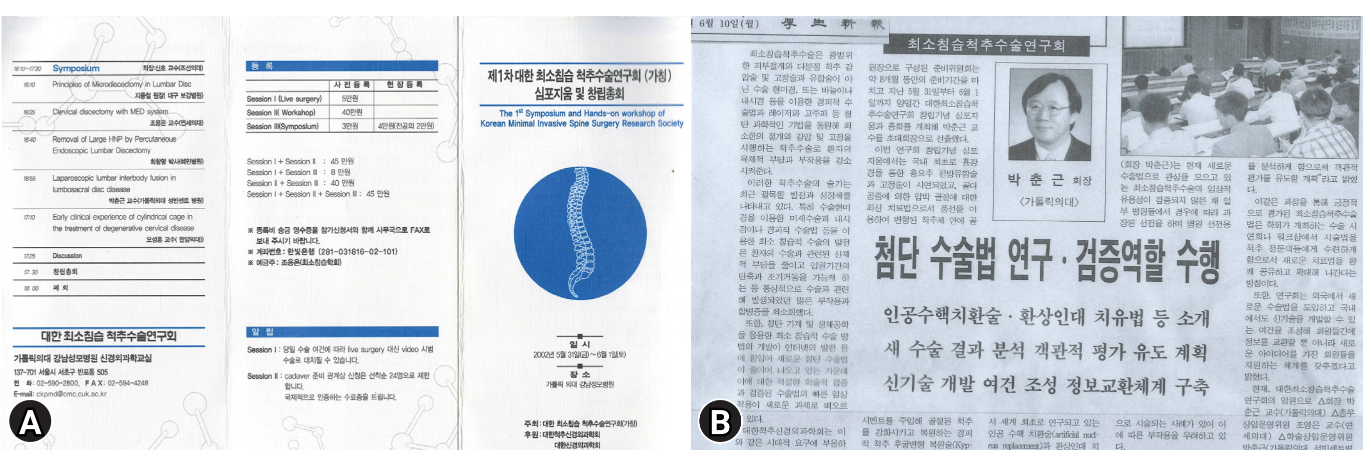
The first president, Park Chun-Kun, advocated that even spine specialists find it challenging to understand newly developed instruments and acquire surgical techniques due to the rapid changes in the field of spinal surgery. Furthermore, he emphasized that the society should research and verify whether the newly developed techniques would actually help patients in the clinical field. In addition to these efforts, Korean neurosurgeons are actively participating in the forefront of spinal surgery, making them global leaders in the field of minimally invasive spine surgery. For that reason, he promoted the necessity of establishing a surgical research group. On June 1, 2002, the first annual meeting of the KOMISS was held in the auditorium on the 2nd floor of the main building of Gangnam St. Mary's Hospital (now Seoul St. Mary's Hospital), The Catholic University of Korea. This first meeting marks the historical beginning of the KOMISS (Figure 2).

Figure 1. Prof. Chun-Kun Park, first president of Korean Minimally Invasive Spine Surgery Society (KOMISS).

Since then, regular academic conferences and general meetings have been held every year. Since 2009, the KOMISS Advanced Course has been additionally held in the fall to keep pace with the rapidly increasing demand for education on minimally invasive surgery.

As Korea's minimally invasive spine surgery technology has been recognized worldwide, the need for an international conference has emerged. Consequenty, the International Symposium and Cadaver Workshop has been held every other year since its introduction in 2012.

In that same year, along with the academic conference, the principle of minimally invasive spine surgery was established. The textbook "Minimally Invasive Spine Surgery," a textbook covering the latest surgical methods, was published, contributing to publicizing the status of minimally invasive spine surgery in Korea. Since 2012 [1], there has been a publishing boom from textbooks published by the editor-in-chief and the board of directors of KOMISS. Presented sequentially, the following are a highlight of these published works: the first English publication of Endoscopic Spine Procedures (SH Lee, Gun Choi, publisher Thieme) [2], Endoscopic Spinal Surgery (SH Lee, JP, 2013) [3], Endoscopic Spine Surgery 2nd edition (SH Lee, Gun Choi, Thieme, 2018) [4], Endoscopic Procedures on the Spine (JS Kim, JH Lee, and Y Ahn, Springer, 2019) [5], and Unilateral Biportal Endoscopic Spine Surgery (DH Heo, CW Park, SK Son,



A

16:10~17:30	Symposium	좌장:신호 교수(조선의대)
16:10	Principles of Microdiscectomy in Lumbar Disc	지용철 원장(대구 보강병원)
16:25	Cervical discectomy with MED system	조용은 교수(연세의대)
16:40	Removal of Large HNP by Percutaneous Endoscopic Lumbar Discectomy	최창명 박사(혜민병원)
16:55	Laparoscopic lumbar interbody fusion in lumbosacral disc disease	박춘근 교수(가톨릭의대 성빈센트 병원)
17:10	Early clinical experience of cylindrical cage in the treatment of degenerative cervical disease	오성훈 교수(한양의대)
17:25	Discussion	
17:30	창립총회	
18:00	폐 회	

대한 최소침습 척추수술연구회

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등 록

	사 전 등 록	현 장 등 록
Session I (Live surgery)	5만원	
Session II(Workshop)	40만원	
Session III(Symposium)	3만원	4만원(전공의 2만원)

Session I + Session II : 45 만원
Session I + Session III : 8 만원
Session II + Session III : 40 만원
Session I + Session II + Session III : 45 만원

※ 등록비 송금 영수증을 참가신청서와 함께 사무국으로 FAX로 보내 주시기 바랍니다.
※ 계좌번호 : 한빛은행 (281-031816-02-101)
※ 예금주 : 조용은(최소침습학회)

알 림

Session I : 당일 수술 여건에 따라 live surgery 대신 video 시범 수술로 대치될 수 있습니다.
Session II : cadaver 준비 관계상 신청은 선착순 24명으로 제한 합니다.
국제적으로 인증하는 수료증을 드립니다.

제1차 대한 최소침습 척추수술연구회 (가칭)
심포지움 및 창립총회

The 1st Symposium and Hands-on workshop of Korean Minimal Invasive Spine Surgery Research Society

일 시
2002년 5월 31일(금)~6월 1일(토)

장 소
가톨릭 의대 강남성모병원

주최 : 대한 최소침습 척추수술연구회(가칭)
후원 : 대한척추신경외과학회
대한신경외과학회

B

6월 10일(월) 厚生新報

최소침습척추수술연구회

첨단 수술법 연구·검증역할 수행

인공수핵치환술·환상인대 치유법 등 소개
새 수술 결과 분석 객관적 평가 유도 계획
신기술 개발 여건 조성 정보교환체계 구축

박 춘 근 회장
〈가톨릭의대〉

최소침습척추수술은 광범위한 피부절개와 다분절 척추 감압술 및 고정술과 유합술이 아닌 수술 현미경, 또는 바늘이나 내시경 등을 이용한 경피적 수술법과 레이저와 고주파 등 첨단 과학적인 기법을 동원해 최소한의 절개와 감압 및 고정을 시행하는 척추수술로 환자의 육체적 부담과 부작용을 감소 시켜준다.

이러한 척추수술의 술기는 최근 괄목할 발전과 성장세를 나타내고 있다. 특히 수술현미경을 이용한 미세수술과 내시경이나 경피적 수술법 등을 이용한 최소 침습적 수술의 발전은 환자의 수술과 관련된 신체적 부담을 줄이고 입원기간의 단축과 조기거동을 가능케 하는 등 통상적으로 수술과 관련해 발생되었던 많은 부작용과 합병증을 최소화했다.

또한, 첨단 기계 및 생체공학을 응용한 최소 침습적 수술 방법의 개발이 인터넷의 발전 등에 힘입어 새로운 첨단 수술법이 쏟아져 나오고 있는 가운데 이에 대한 적절한 학술적 검증과 검증된 수술법의 빠른 임상적용이 새로운 과제로 떠오르고 있다.

대한척추신경외과학회는 이와 같은 시대적 요구에 부응하

원장으로 구성된 준비위원회는 약 8개월 동안의 준비기간을 마치고 지난 5월 31일부터 6월 1일까지 양일간 대한최소침습척추수술연구회 창립기념 심포지움과 총회를 개최해 박춘근 교수를 초대회장으로 선출했다.

이번 연구회 창립기념 심포지움에서는 국내 최초로 흉강경을 통한 흉요추 전방유합술과 고정술이 시연되었고, 골다공증에 의한 압박 골절에 대한 최신 치료법으로서 풍선을 이용하여 변형된 척추체 안에 골

시멘트를 주입해 골절된 척추를 강화시키고 복원하는 경피적 척추 후굴변형 복원술(Kyp-

서 세계 최초로 연구되고 있는 인공 수핵 치환술(artificial nucleus replacement)과 환상인대 치

(회장 박춘근)는 현재 새로운 수술법으로 관심을 모으고 있는 최소침습척추수술의 임상적 유용성이 검증되지 않은 채 일부 병원들에서 경우에 따라 과장된 선전을 하며 병원 선전용

으로 시술되는 사례가 있어 이에 따른 부작용을 우려하고 있다.

를 분석하게 함으로써 객관적 평가를 유도할 계획"라고 밝혔다.

이같은 과정을 통해 긍정적으로 평가된 최소침습척추수술법은 학회가 개최하는 수술 시연회나 워크샵에서 시술법을 척추 전문의들에게 수련하게 함으로서 새로운 치료법을 함께 공유하고 확대해 나간다는 방침이다.

또한, 연구회는 외국에서 새로운 수술법을 도입하고 국내에서도 신기술을 개발할 수 있는 여건을 조성해 회원들간에 정보를 교환할 뿐 아니라 새로운 아이디어를 가진 회원들을 지원하는 체계를 갖추겠다고 밝혔다.

현재, 대한최소침습척추수술연구회의 임원으로 △회장 박춘근 교수(가톨릭의대) △총무상임운영위원 조영은 교수(연세의대) △학술상임운영위원

Figure 2. (A) The first symposium and hands-on workshop of Korean Minimal Invasive Spine Surgery Research Society. (B) Newspaper script announcing the founding of KOMISS.

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and JH Eum, Springer, 2022) [6].

In 2020, an updated textbook with the latest knowledge and techniques for endoscopic surgery of the lumbar spine was published, which was led by KOMISS and KOSESS members (Figure 3) [7].

In 2014, along with the 2nd international symposium, the Korean homepage, which was only open to domestic members, was significantly revised. In addition, an English homepage (www.komiss.org) was established, bridging a way to communicate with spine doctors across the globe (Figure 4).

In 2015, KOMISS was officially approved as a regular society of Korea. Incorporated with the Society of Surgery (International Society for Minimal Intervention in Spinal Surgery, ISMISS Korea, President Chun-Kee Chung), it has established itself as a representative society for minimally invasive spine surgery in Korea in name and reality. KOSMISS, The Korean Chapter of ISMISS was driven by Sang-Ho Lee, the founder of Wooridul Spine Hospital, and was founded in 1997 under the leadership of professor Hwan-Young Jung. The academic annual meeting was held every year for 18 years until 2015. Hwan Yung Chung (1997–2001), Hyun Jip Kim (2002–2009), and Professor Chun-Kee Chung (2010–2015) contributed as past presidents (Figure 5).

The first issue of the Journal of Minimal Invasive Spine Surgery & Technique (JMISTT), an official academic journal of the society, was published along with the 2016 international academic conference, which was held in Jeju at the World Congress of Minimally Invasive Spine Surgery & Techniques (WCMISST). In addition, JMISST has been the co-official journal of the KOMISS and Minimally Invasive Spine Surgeons Association of Bharat (MISSAB) for the publication of research results about minimally invasive spinal surgery from Vol 6, No. 1 published on April 2021 (Figure 6).

In 2017, the Korea Research Society of Endoscopic Spine Surgery (KOSESS), which specializes in spine endoscopic surgery only, was launched as an affiliated organization, with Gun Choi as the first president (Figure 7). In the same year, KOREA UBE (unilateral bi-portal endoscopy), which specializes in bi-directional spinal endoscopic surgery, was also launched having Sang-Kyu Son as its first president.

2022 is the 20th anniversary of KOMISS. In the present corona pandemic era, it has grown into a society that strives to fulfill its mission of minimal invasiveness to patients and to enhance recovery after spine surgery (ERAS) (Table 1, 2, Figure 8).

ACADEMIC ACTIVITIES AND GLOBAL IMPACT OF KOMISS

Starting with the first academic conference on June 1, 2002 and up until 2021, the KOMISS has held a total of 19 regular academic conferences, 9 Advanced Endoscopic Courses, three

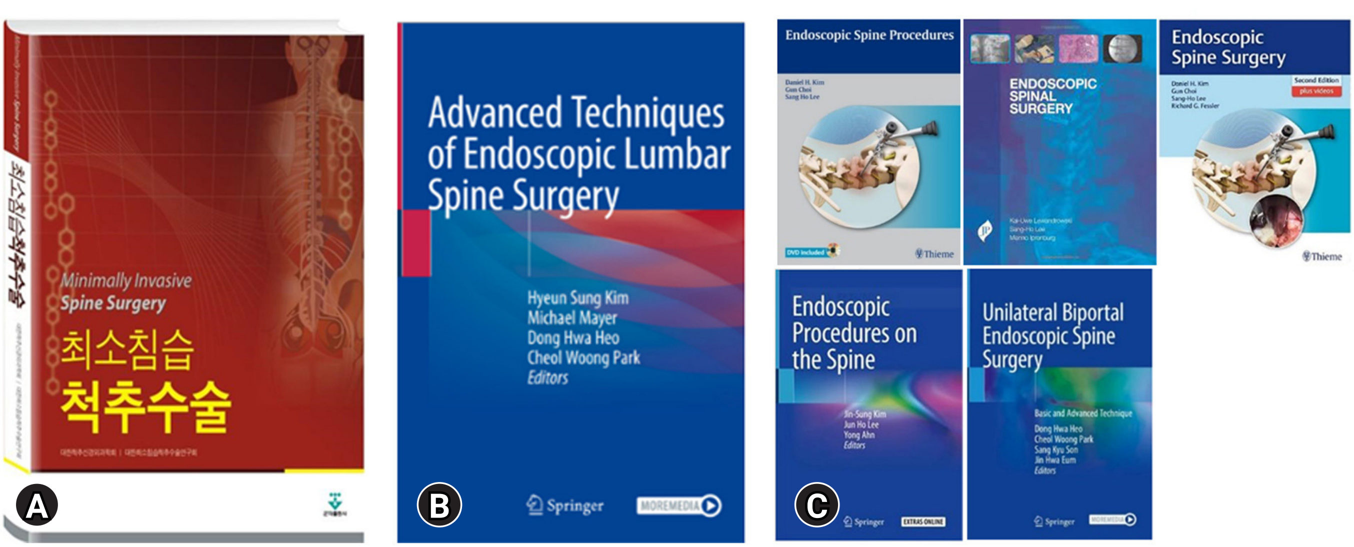

Figure 3. (A) The textbook "Minimally Invasive Spine Surgery" [1]. (B) Advanced Techniques of Endoscopic Lumbar Spine Surgery (2020). (C) Endoscopic Spine Procedures (SH Lee, Gun Choi; publisher Thieme) [2]. Endoscopic Spinal Surgery (SH Lee, JP, 2013) [3]. Endoscopic Spine Surgery 2nd edition (SH Lee, Gun Choi, Thieme, 2018) [4]. Endoscopic Procedures on the Spine (JS Kim, JH Lee, and Y Ahn, Springer, 2019) [5], and Unilateral Biportal Endoscopic Spine Surgery (DH Heo, CW Park, SK Son, and JH Eum, Springer, 2022) [6] (sequentially from left to right).

Figure 4. English homepage (www.komiss.org)

Figure 5. (A) A photograph of the founding International Society for Minimal Intervention in Spinal Surgery (ISMISS). (B) Hwan Yung Chung (1997–2001), Hyun Jip Kim (2002–2009), and professor Chun-Kee Chung (2010–2015), the past presidents of ISMISS (sequentially from left to right).

Figure 6. (A) The first editor-in-chief, Lee, Sang Gu of the Journal of Minimal Invasive Spine Surgery & Technique (JMISTT) and the first publication. (B) Gun Choi, the first president of the Korea Research Society of Endoscopic Spine Surgery (KOSESS).

Figure 7. The Korea Research Society of Endoscopic Spine Surgery (KOSESS), which specializes in endoscopic spine surgery.

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Table 1. Past presidents of KOMISS

Term of office	President	Affiliations
2002. 05. 31–2004. 05. 15	Park, Chun Kun	The Catholic University of Korea, Gangnam St Mary's Hospital
2004. 05. 15–2006. 05. 20	Oh, Sung Hoon	Hanyang University
2006. 05. 20–2008. 05. 23	Do, Jae Won	Soonchunhyang University Hospital, Cheonan
2008. 05. 23–2010. 05. 29	Cho, Yong Eun	Yonsei University, Gangnam Severance Hospital
2010. 05. 29–2012. 05. 12	Rho, Sung Woo	Asan Medical Center
2012. 05. 12–2013. 06. 01	Park, Choon Keun	Wiltse Memorial Hospital
2013. 06. 01–2014. 05. 31	Kim, Eun Sang	Samsung Medical Center
2014. 05. 31–2015. 05. 30	Do, Eun Sik	The Joeun Hospital
2015. 05. 30–2016. 06. 04	Kim, Sung Min	Kyung Hee University
2016. 06. 04–2016. 05. 28	Park, Sung Choon	Myongji Hospital
2017. 05. 28–2018. 05. 27	Lee, Seung Myung	Chosun University Hospital
2018. 05. 28–2019. 05. 26	Choi, Gun	Wooridul Hospital, Pohang
2019. 05. 27–2020. 12. 05	Lee, Sang Gu	Gachon University Gil Medical Center
2020. 12. 06–2021. 12. 03	Kim, Dae-Hyun	Daegu Catholic University
2021. 12. 04–Now	Park, JinGyu	PMC Park Hospital

international symposiums, and 19 Cadaver Workshops. In addition, since 2015, case meetings have been held twice a year.

At the first regular academic conference, starting with percutaneous vertebral body balloon angioplasty, artificial disc insertion, and spinal fixation using thoracoscopic techniques, the newly introduced spinal surgery instruments around the world were presented annualy. Additionally, overseas speakers and domestic experts well-known for their surgical techniques utilizing these novel instruments were also invited to present. Through cadaver workshops, students learn how to use new instrumentation and surgical techniques in practice, translated from theory to clinical application.

Starting with the 1st KOMISS Advanced Endoscopy Course on November 28, 2009, every fall an in-depth symposium and Cadaver Workshop covering various endoscopic surgical methods is held to perform domestic spinal endoscopic surgery [8].

In addition, as Korea's minimally invasive spinal surgery technology has been recognized worldwide, the need for an international conference has emerged. From the 1st International Symposium and Cadaver Workshop held on November 17, 2012, a conglomerate effort has been made in the creation of a learning space for the dissemination of shared knowledge by inviting people from all over the world to spread Korea's advanced minimally invasive techniques to participants overseas [9].

Recently, on June 4, 2016, the 15th regular academic conference of KOMISS was jointly held in Jeju with the WCMISST, a global international society of minimally invasive spine surgery. Moreover, it also hosted a meaningful event with 470 people from 35 participating countries. In 2018, Jin-Sung Kim (vice president of KOMISS) joined the AOSpine MIS Task Force and created an educational curriculum for endoscopic spine surgery. Furthermore, the executive members of KOMISS have been actively engaged in the main stream societies such as Global Spine Congress (GSC) and the North American Spine Society (NASS). As the course chair, Jin-Sung Kim organized the first endoscopic course in the annual meetings of both NASS and GSC with the collaboration of Jun-Ho Lee. AOSpine Davos course, one of the flagship educational events, was also chaired by JS Kim in 2018. Withal, the NASS/Neurospine Endoscopic Spinal Surgery (ESS) Symposium and Cadaver Workshop were both held at NASS in 2018 and 2019 through KOMISS collaboration. In the consecutive years prior to the pandemic, the endoscopic courses were chaired by renowned executive members of KOMISS: JS Kim and HS Kim in 2018 and 2019 respectively (Figure 9).

Based on the recent bibliometric study, KOREA published the second (28.68%) highest number of endoscopic spine surgery related papers after China (30.15%) among 408 total papers published worldwide from 1997 to 2018, while the index was highest in Korea (23) Also, as a single institution, Wooridul Spine Hospital in Korea (10.29%) published the largest number of papers [10]. Since endoscopic surgery started in the early 1990s, there have been many papers and achievements authored by Korean society members that have been milestones in the development of surgerical techniques since 2000, notably mentioned are Sang-Ho Lee, Gun Choi, Yong Ahn, Jin-Sung Kim, Hyeun-Sung Kim, Jin-Hwa Eum, Sang-Kyu Son, and Dong-Hwa Heo (Figure 10) [11].

Table 2. Annual meetings

Meetings	Date	Location
1st Korean Minimally Invasive Spine Surgery Society Annual Meeting	2002. 06. 01	Gangnam St. Mary's Hospital
2nd Korean Minimally Invasive Spine Surgery Society Annual Meeting	2003. 05. 30–31	Gangnam St. Mary's Hospital
3th Korean Minimally Invasive Spine Surgery Society Annual Meeting	2004. 05. 15	Gangnam St. Mary's Hospital
4th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2005. 05. 21	Gangnam St. Mary's Hospital
5th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2006. 05. 20	Gangnam St. Mary's Hospital
6th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2007. 06. 01–02	Gangnam St. Mary's Hospital
7th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2008. 05. 23–24	Gangnam St. Mary's Hospital
8th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2009. 05. 30–31	Yonsei University College of Medicine
1st KOMISS Advanced Course of Spinal Endoscopic Discectomy: Symposium & Cadaver Workshop	2009. 11. 28–29.	Yonsei University College of Medicine
9th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2010. 05. 29–30	Yonsei University College of Medicine
2nd KOMISS Advanced Course - Spinal Endoscopic Discectomy and Neuroplasty Symposium & Cadaver Workshop	2010. 11. 27–28	Yonsei University College of Medicine
10th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2011. 05. 21–22	Seoul Asan Hospital
3rd KOMISS Advanced Course - Spinal Endoscopic Discectomy: PECD & PELD Symposium & Cadaver Hand-On Workshop	2011. 12. 10–11	Yonsei University College of Medicine
11st Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2012. 06. 21–22	Seoul Asan Hospital
1st KOMISS Hands-On Course: International Cadaver Workshop for Percutaneous Endoscopic Spine Surgery	2012. 11. 17–18	Seoul St. Mary's Hospital
12th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2013. 06. 01–02	Seoul St. Mary's Hospital
4th KOMISS Advanced Course of Percutaneous Endoscopic Spinal Surgery: Symposium & Cadaver Hands-On Workshop	2013. 11. 31–12. 01	Seoul Asan Hospital/Seoul St. Mary's Hospital
1st KOMISS-ASIA MISS Symposium	2014. 02. 28–03. 01	Hanoi Medical University Hospital, Vietnam
13th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2014. 05. 31–06. 01	Seoul St. Mary's Hospital
2nd KOMISS International Symposium &Hands-on Cadaver Workshop	2014. 11. 28–30	Songdo Convensia/Seoul St. Mary's Hospital
14th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2015. 05. 30–31	Yonsei University College of Medicine and Clinical Training Center
5th KOMISS Advanced Spinal Endoscopic Course: Symposium & Cadaver Workshop	2015. 11. 28–29	Yonsei University College of Medicine and Clinical Training Center
15th Korean Minimally Invasive Spine Surgery Society Annual Meeting	2016. 06. 04	Jeju ICC
16th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2017. 05. 27–28	Yonsei University College of Medicine and Clinical Training Center
KOMISS International Symposium & Hands-on Cadaver Workshop	2017. 12. 01–03	Songdo Convensia & Yonsei University College of Medicine and Clinical Training Center
17th Korean Minimally Invasive Spine Surgery Society Annual Meeting	2018. 05. 26–27	Yonsei University College of Medicine and Clinical Training Center
KOMISS Advanced Spinal Endoscopic Course Symposium & Cadaver Workshop	2018. 12. 01–12. 02	Sejong University & Yonsei University College of Medicine and Clinical Training Center
2019 ACMISST(Asian Congress of Minimally Invasive Spine Surgery) & Cadaver Workshop & 18th KOMISS Annual Meeting	2019. 05. 24–26	Grand Hilton Hotel & Yonsei University College of Medicine and Clinical Training Center
KOMISS Advanced Spinal Endoscopic Course Symposium & Cadaver Workshop	2019. 12. 07–08	Eunpyeong St. Mary's Hospital & YONSEI University College of Medicine and Clinical Training Center
19th Korean Minimally Invasive Spine Surgery Society Annual Meeting	2020. 12. 05	Swiss Grand Hotel
KOMISS Advanced Spinal Course Symposium & Cadaver Workshop	2021. 05. 29–30	Hotel Inter-Burgo Daegu & Daegu Catholic University School of Medicine
20th Korean Minimally Invasive Spine Surgery Society Annual Meeting & Cadaver Workshop	2021. 12. 03–04	Swiss Grand Hotel & Seoul St. Mary's Hospital

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Figure 8. Past presidents of KOMISS.

Figure 9. The NASS/Neurospine Endoscopic Spinal Surgery (ESS) Symposium and Cadaver Workshop (2019).

Figure 10. Sang Ho Lee, Gun Choi, Yong Ahn, Jin-Sung Kim, HS, Jin-hwa Eum, Sang-Kyu Son, and Dong-Hwa Heo made contributions for the development of endoscopic spine surgery. (sequentially from left).

While the coronavirus pandemic hit the world in 2020, KOMISS continued research and educational opportunities through online broadcasts.

The Korean Society of Minimally Invasive Spine Society has a long history and tradition. It is a progressive and pioneering society that carries out original and substantial academic research by constantly introducing new spinal surgery instruments and techniques without relying on past achievements.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

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REFERENCES

1. Korean Spinal Neurosurgery Society. Minimally Invasive Spine Surgery. Paju: Koonja Publisher; 2012.
2. Kim DH, Choi G, Lee SH. Endoscopic Spine Procedures. New York: Thieme; 2011.
3. Lewandrowski KU, Lee SH, Iprenburg M. Endoscopic Spinal Surgery. London: JP; 2013.
4. Kim DH, Choi G, Lee SH, Fessler RG. Endoscopic Spine Surgery. 2nd ed. New York: Thieme; 2018.
5. Kim JS, Lee JH, Ahn Y. Endoscopic Procedures on the Spine. Singapore: Springer; 2019.
6. Heo DH, Park CW, Son SK, Eum JH. Unilateral Biportal Endoscopic Spine Surgery: Basic and Advanced Technique. Singapore: Springer; 2022.
7. Kim HS, Mayer M, Heo DH, Park CW. Advanced Techniques of Endoscopic Lumbar Spine Surgery. Singapore: Springer; 2020.
8. Park CK. Minimally invasive spine surgery in Korea - a neurosurgeon's view. J Minim Invasive Spine Surg Tech 2016;1:3–4.
9. Ahn Y. Evolution of percutaneous endoscopic lumbar decompression. J Minim Invasive Spine Surg Tech 2019;4:1–4.
10. Lin GX, Kotheeranurak V, Mahatthanatrakul A, Ruetten S, Yeung A, Lee SH, et al. Worldwide research productivity in the field of full-endoscopic spine surgery: a bibliometric study. Eur Spine J 2020;29:153–160.
11. Akbary K, Kim JS. Recent technical advancements of endoscopic spine surgery with disparate or disruptive technologies and patents. World Neurosurg 2021;145:693–701.

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Transforaminal Endoscopic Lumbar Discectomy with Foraminoplasty for Down-migrated Disc Herniation: A Single-center Observational Study

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Objective: Full-endoscopic lumbar discectomy has evolved to be an alternative for the treatment of lumbar disc herniation. Regarding the techniques, the transforaminal approach remains the primary access. The indications of transforaminal endoscopic lumbar discectomy (TELD) have expanded following the evolution of the techniques, especially TELD with foraminoplasty. This study is to evaluate the efficacy of the TELD with foraminoplasty for downward migrated lumbar disc herniation.

Methods: The authors conducted a retrospective study with prospectively collected data in a single center. The study enrolled patients with downward migrated lumbar disc herniation undergoing TELD with foraminoplasty from May 2009 to June 2018. All procedures were performed under local anesthesia. Patients' demographics, clinical outcomes, and satisfaction with surgery were recorded.

Results: There were 126 patients included in the current study. The mean age was 50.7 ± 17.4 years old. The leg pain and functional outcome scores significantly improved after the operation. There was no neurological deficit or iatrogenic instability requiring fusion surgery. The operation time was within 2 hours in most cases (92%). Thirteen patients reported minor complications, but symptoms were self-limited or responded to conservative treatment. The operation satisfied 94.4% of patients. Seven cases underwent revision surgery within six months due to recurrence.

Conclusion: TELD with foraminoplasty under local anesthesia can be an alternative for downward migrated lumbar disc herniation. Nerve root irritation can be detected without intraoperative neurophysiological monitoring when the patient is awake during the procedures. The clinical outcomes were favorable and the risk of complication was low with the current technique.

Key Words: Endoscopes, Discectomy, Percutaneous, Disc herniation, Slipped disc, Enhanced recovery after surgery

INTRODUCTION

Transforaminal endoscopic lumbar discectomy (TELD) has been an alternative for minimally invasive surgery of the soft lumbar disc herniation [1-6]. TELD is usually conducted under local anesthesia with or without conscious sedation to decrease exiting nerve root injury during the procedures. Comparing with open discectomy, TELD is superior in minimizing injury to collateral soft tissue [7], which benefits postoperative pain, shorter hospital stay, and early return to daily life or work [8-11].

With the evolution of surgical instruments and techniques, the indications of TELD have been expanded to treat migrated disc or combined lumbar foraminal stenosis [12,13]. The core procedure to expand the application of TELD is foraminoplasty, which can widen the narrow foramen to allow the working cannula to pass through easily [14,15]. Foraminoplasty can increase the safe working zone by resecting the ventrolateral aspect of the superior articular process (SAP) to avoid injury to the exiting nerve root [16]. However, patients might experience severe pain and cannot cooperate with the surgery during complicated procedures if the local anesthesia is inadequate.

The previous studies mainly focused on different modifications of transforaminal endoscopic techniques. Some authors have described the endoscopic foraminoplasty technique by using a drill or reamer in performing TELD [14,15,17]. Nevertheless, there is a lack of study describing the stepwise anesthetic techniques. Adequate local anesthesia is the first step of the operation and is essential to patients' satisfaction. The standard anesthetic technique of TELD is epidural block before puncturing through annulus and discography. The target and procedures of TELD with foraminoplasty are different from the standard TELD. Therefore, the authors will report their modified technique and patient-reported outcomes in the study.

MATERIALS AND METHODS

The Institutional Review Board approved the study (IRB No. 190905), and all patients had informed consent. The retrospective study enrolled patients with downward migrated lumbar disc herniation undergoing TELD with foraminoplasty in a single institute. Patients having a previous lumbar operation or spondylolisthesis were excluded. The demographics and patient-reported outcomes were recorded prospectively. The operations were done by a single surgeon (corresponding author). The surgical technique was modified from TESSYS with a single endoscopic spine system (VANTAGE BIOTECH CO., LTD., Taoyuan, Taiwan). The clinical outcomes were assessed with the visual analogue scale (VAS) and Oswestry Disability Index (ODI). The patients' satisfaction with the surgery was evaluated on postoperative day 1. The patient satisfaction was categorized as "excellent", "good", "fair", and "poor".

Statistical analysis was conducted using IBM SPSS Statistics (Version 22.0). Continuous variables were expressed as the mean±standard deviation. A paired t-test was used to compare preoperative and postoperative results. A p-value<0.05 was considered statistically significant.

1. TELD with Foraminoplasty Protocol

1) Preparation

A standardized patient education sheet and video clips were provided to patients in the neurosurgical clinic before surgery. Information about the surgery, expectations, and support services was available on the education sheet. The education was reinforced at the preoperative service.

The patient is in the prone position with hips and knees flexion on the Jackson table. C-arm fluoroscopy was used to verify the herniated segment. The entry point on the skin was determined according to the TESSYS technique proposed by Schubert and Hoogland [17].

2) Stepwise Anesthesia and Docking the Working Cannula

After planning the entry point and trajectory, the patient is given local anesthesia with 3 to 5 mL 1% lidocaine at the subcutaneous and fascia layer. Then, a stab incision by 8 mm is made through the skin and fascia with a blade. The cannulated needle is inserted from the entry point. During inserting the needle to the lateral SAP, about 5 to 10 mL 1% lidocaine was infiltrated in the muscle layer (Figure 1). The target of the needle placement is at the junction of the SAP and pedicle, which are away from the exiting root and identified by fluoroscopic guidance easily (Figure 2). Thus, epidurogram and discogram can be omitted. Then, the needle was withdrawn slightly and then inserted at a higher inclination angle through the ventral SAP (Figure 3). After confirming the needle position by fluoroscopy, about 5 to 10 mL 0.5% lidocaine is given to infiltrate and block the ventral facet. Although the diluted lidocaine may fail to infiltrate the epidural space adequately, the pain from irritation to the annulus is minimal with the current technique. Then, a guidewire is inserted through the cannulated needle and followed by sequential dilators to create the track for a working cannula. Patients were awake during the whole procedure and could report their discomfort immediately. The working channel is placed through the dilator and docked on the ventrolater-

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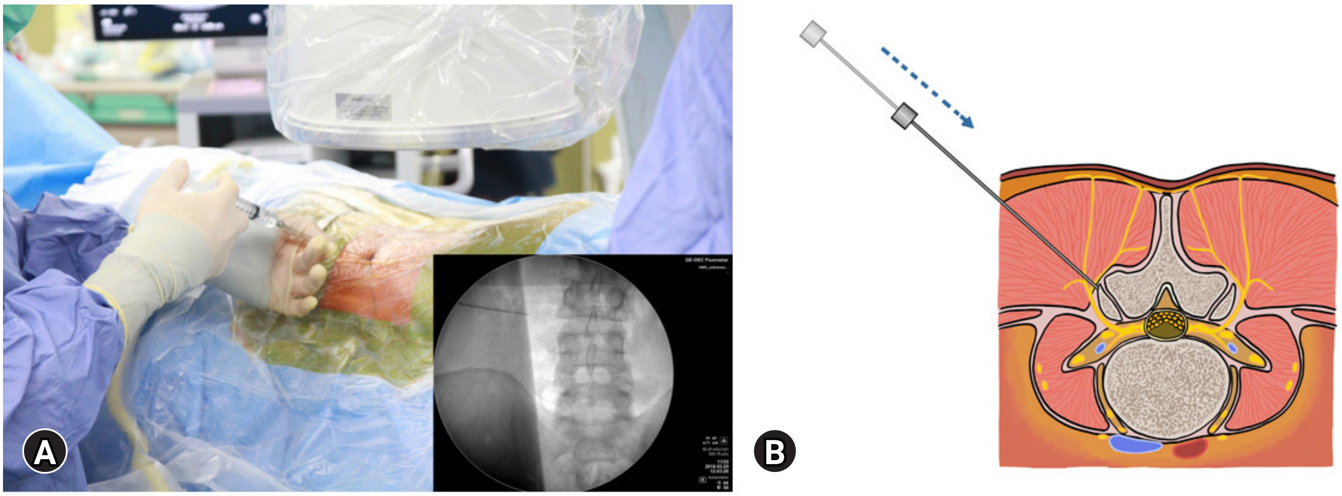

Figure 1. (A) The cannulated needle was inserted from skin through muscle to lateral SAP under C-arm fluoroscopy guidance. (B) Local anesthetics were infiltrated along the way from subcutaneous to lateral SAP.

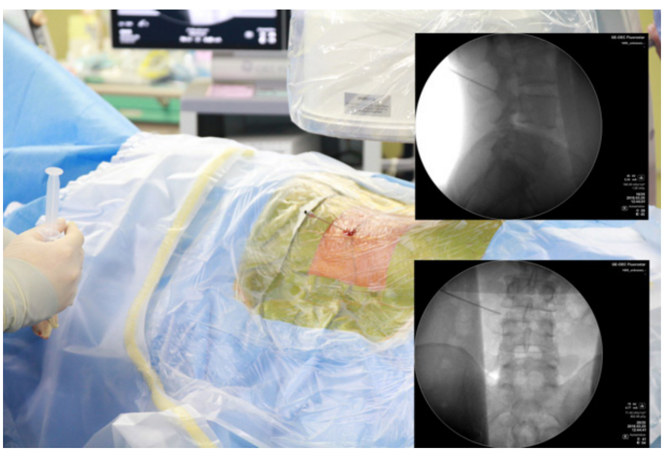

Figure 2. The intraoperative fluoroscopy showed cannulated needle landing on the lateral SAP.

al aspect of the SAP base.

3) Endoscopic Foraminoplasty

The endoscope of the working channel by 4.3 mm was used in operation. The radiofrequency coagulator (VANTAGE BIOTECH CO., LTD., Taoyuan, Taiwan) and grasping forceps are utilized to dissect soft tissue and then define the SAP under direct endoscopic visualization. The author used a high-speed diamond burr (VANTAGE BIOTECH CO., LTD., Taoyuan, Taiwan) to drill the ventral portion of the SAP base for widening the working space in the foramen. The foraminal ligament is then removed with forceps. Sometimes, a bulging disc in the foraminal area can be found and removed partially with forceps or shrank with a bipolar coagulator to maintain the endoscopic vision. After foraminoplasty, the working cannula can be inserted into the lateral recess of the spinal canal easily.

4) Endoscopic Discectomy

The migrated fragment was accessible and able to be pulled out from the canal. After partial discectomy, the annular defect was identified. Annuloplasty and epidural hemostasis are conducted with a bipolar probe. Adequate neural decompression is defined as the grossly free margin of the nerve roots with good pulsation.

5) Monitoring During Operation

The patient undergoing TELD was awake during the whole procedure. We didn't use the intraoperative neurophysiological monitor. The surgeon should communicate with the patient at each phase and be aware of the patient's response. If the patient reports leg dysesthesia during the procedure, the surgeon should halt and adjust the endoscopic or working instruments. Fluoroscopy is sometimes necessary to confirm the orientation of the surgical field. The operator can ask the patient to cough or wriggle the waist during operation to check if there is potentially herniated nucleus pulposus.

RESULTS

From May 2009 to June 2018, there were 126 patients undergoing TELD with foraminoplasty. The demographics are presented in Table 1. The mean age of the patients was 50.7±17.4 years (range from 14 to 82 years old). The mean follow-up time was 56.1 months (range from 17 to 130 months). At the one-

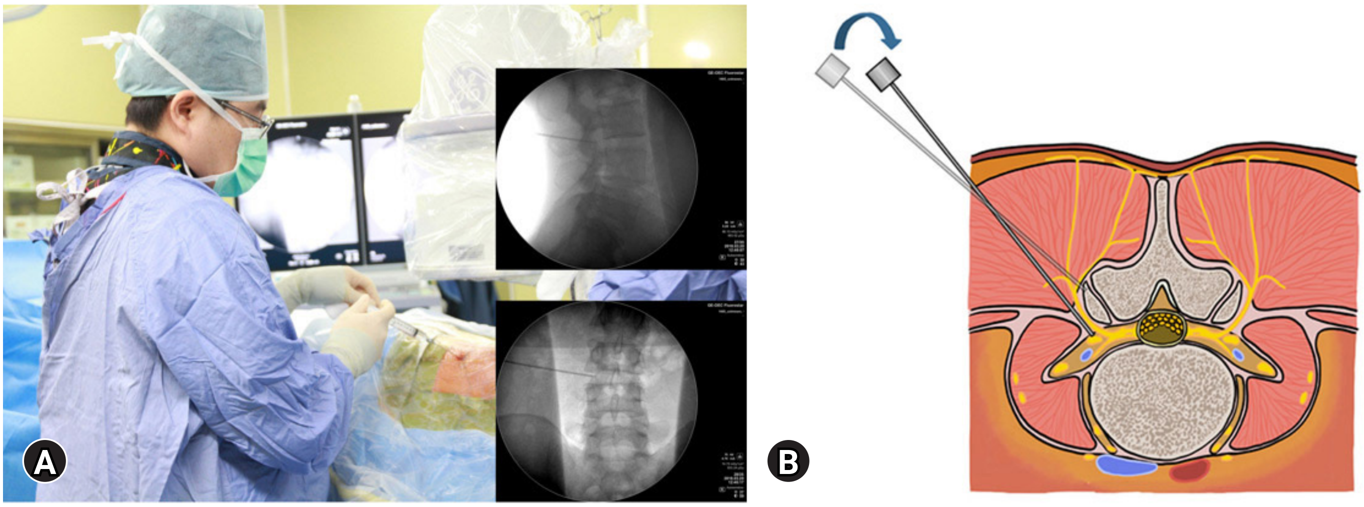

Figure 3. (A) The needle was then withdrawn slightly and inserted by a higher inclination angle into foramen. (B) The intraoperative fluoroscopy showed cannulated needle placed into foramen underneath the ventral surface of SAP.

Table 1. Patient characteristics

Characteristics	Values
Gender	
Male	93 (71.4%)
Female	33 (28.6%)
Age (yr)	
Mean	50.7 ± 17.4
< 65	90 (71.4%)
≥ 65	36 (28.6%)
Surgical level	
L2/3	5 (4.0%)
L3/4	18 (14.3%)
L4/5	94 (74.6%)
L5/S1	8 (6.3%)
L3/4 and L4/5	1 (0.8%)
BMI	
< 30	81 (64.3%)
≥ 30	45 (35.7%)

Values are n (%) or mean±SD.

Table 2. Surgical outcomes

	Values	p-value
ODI		< 0.001
Pre-op	26.1 ± 6.9	
Post-op	2.8 ± 4.0	
VAS		< 0.001
Pre-op	7.4 ± 1.7	
Post-op	0.3 ± 0.9	
Operative time (hr)		NA
< 1	62 (49.2%)	
1–2	54 (42.9%)	
> 2	10 (7.9%)	
Complications		NA
Soreness	2 (1.6%)	
Numbness	8 (6.3%)	
Severe wound pain (VAS > 4)	3 (2.3%)	
Recurrence	7 (6.3%)	

VAS: Visual Analogue Scale, ODI: Oswestry Disability Index.

year follow-up, the VAS scores for leg pain significantly decreased from 7.4±1.7 preoperatively to 0.3±0.9 postoperatively ($p<0.05$). The ODI score significantly improved from 26.1±6.9 to 2.8±4.0 ($p<0.05$) (Table 2). The operation time was within 2 hours in most cases (92%). There was no conversion to open surgery. Minor adverse events included 13 patients reporting minor complications, including back soreness by two patients, ipsilateral leg numbness by eight patients, and significant wound pain. The minor complications were self-limited with conservative treatment. There was no neural injury, epidural hematoma, or iatrogenic instability requiring revision surgery in the current series. Patient satisfaction to surgery was excellent in 106 patients (84.1%) and good in 13 patients (10.3%) (Figure 4). Seven patients had recurrence within six months postoperatively. Two patients underwent repeated TELD successfully, and the other five patients underwent fusion surgery.

DISCUSSION

The indication of endoscopic spine surgery has been expanded in recent years [18,19]. As for lumbar disc herniation, the TELD without foraminoplasty might be limited in patients with a migrated fragment [20]. According to the anatomy of

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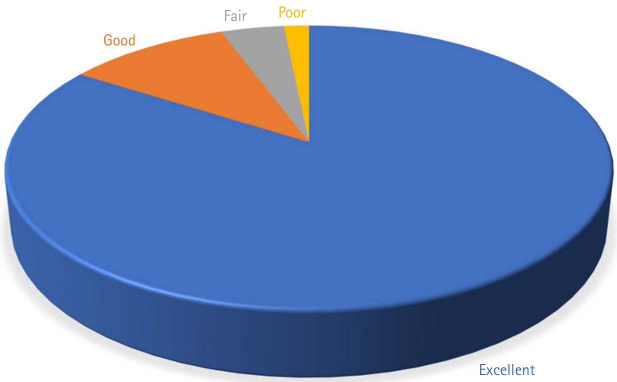

Figure 4. Patient satisfaction.

the intervertebral foramen, the SAP is the main obstacle in transforaminal endoscopic access to the epidural space in the spinal canal. Therefore, techniques of foraminoplasty were proposed to reach the migrated disc by widening the foramen during TELD. After the undercutting of the ventral part of the SAP, the safe working zone can be enlarged. So, the endoscopic trajectory can directly target the migrated fragment at the ventral epidural space [21]. This strategy can avoid exiting root irritation or injury due to increased cranio-caudal inclination for reaching migrated disc. The current study demonstrated the high success rate and safety in treating downward migration of lumbar disc herniation by TELD with foraminoplasty under local anesthesia. Patients could be satisfied with the painless endoscopic procedures, rapid recovery, and free from endotracheal intubation or urinary catheterization.

The first and most crucial step for any awake surgery is the techniques of anesthesia. The patient's cooperation is essential during the operation. Lumbar spine surgery could be one of the most painful procedures. Patients with lumbar disc herniation might be sensitive and irritable to painful sensations. Therefore, adequate analgesia is the core to make the patient cooperate during the surgery. Though TELD under epidural anesthesia is feasible, the intraoperative neurophysiological monitor is necessary to decrease the risk of neural injury [22]. Besides, it would not be cost-effective because of longer preparing time, higher cost of anesthesia and intraoperative monitor. Patients undergoing TELD might feel pain while skin incision, passing dilator through fascia, puncture into the annulus, and foraminoplasty with endoscopic burr or trephine. Therefore, local anesthesia with stepwise injection from the skin to the epidural space is enough to relieve pain during surgery. According to the current study, patients would be satisfied with the local anesthesia even undergoing complicated procedures like foraminoplasty. Besides, the patient may take less anesthetic risk when undergoing TELD, especially for the elderly or patients with multiple comorbidities. Post-anesthetic care is simple without endotracheal intubation or urinary catheterization. The perioperative and postoperative complications rates were lower with the protocol. The cost-effectiveness study also showed that TELD was more cost-effective than microdiscectomy by saving an additional net of $8,064 per quality-adjusted life year [23].

There are some advantages to keeping patients awake during TELD. Iatrogenic neurological deficit is a critical issue of spinal operation. The rates of deficits after lumbar spine surgery ranged from 0.46% to 17% [24]. The utility of neurophysiological monitoring has shown the benefit of decreasing the risk of iatrogenic root injury [25,26]. While doing TELD under local anesthesia, patient's feedback during the operation can effectively replace the neurophysiological monitor. The diluted lidocaine can block the painful feeling but spare the tactile sensation during operation. Patients will report feeling like electric shock at the ipsilateral leg when the nerve root is irritated. The patient's feedback in real-time is straightforward without interpretation of neurophysiological electrography. The risk of injury to the neural structure is minimized and neurophysiological monitoring is unnecessary. Moreover, the patient can report the immediate improvement after decompression of the nerve root. When patients undergo TELD in lateral decubitus position, the surgeon can do a straight leg raising test during operation to confirm the effectiveness.

The extent of discectomy is a critical issue for the recurrence of the lumbar disc. The previous studies revealed that limited discectomy was related to a higher risk of recurrence than subtotal discectomy [27,28]. However, an aggressive discectomy may cause more postoperative back pain [27,29]. There is no standard to determine the adequate extent of discectomy during the operation. The authors proposed an easy way to determine the endpoint during the awake operation. While asking the patient to cough or wriggle the waist, the surgeon can identify the loose disc fragment during operation. It is difficult to do similar tests when patient is under general anesthesia. Therefore, discectomy during awake surgery might balance the disc preservation and recurrent risk during lumbar discectomy.

There are limitations in the current report. It is a retrospective study, and there is a lack of comparative group and prospective data to evaluate differences between anesthetic techniques. Though this technique might be suitable for all TELD, the foraminoplasty is an advanced technique, and the learning curve remains steep for beginners to achieve favorable outcomes steadily. Different surgical techniques and technologies may affect the outcomes and patient satisfaction. The current study emphasized short-term results regarding the anesthetic technique but omitted the discussion of long-term outcomes.

CONCLUSION

Ambulatory surgery is the trend of minimally invasive spine surgery. With skilled anesthesia in awake surgery, the surgeon can widen the intervertebral foramen during transforaminal endoscopic spine surgery to reach the migrated fragment. Intraoperative feedback from patients during awake surgery assures safety by avoiding neural injury. Though TELD has advanced and varied with the expanding indications, the technique of foraminoplasty remains the primary and core skill in the developing field.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

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REFERENCES

1. Kambin P. Arthroscopic microdiskectomy. Mt Sinai J Med 1991;58:159–164.
2. Kambin P, O'Brien E, Zhou L, Schaffer JL. Arthroscopic microdiscectomy and selective fragmentectomy. Clin Orthop Relat Res 1998;(347):150–167.
3. Mathews HH. Transforaminal endoscopic microdiscectomy. Neurosurg Clin N Am 1996;7:59–63.
4. Savitz MH. Same-day microsurgical arthroscopic lateral-approach laser-assisted (SMALL) fluoroscopic discectomy. J Neurosurg 1994;80:1039–1045.
5. Mayer HM, Brock M. Percutaneous endoscopic discectomy. surgical technique and preliminary results compared to microsurgical discectomy. J Neurosurg 1993;78:216–225.
6. Lewandrowski KU, Dowling Á, de Carvalho PST, Calderaro AL, Dos Santos TS, de Lima E Silva MS, et al. Indication and contraindication of endoscopic transforaminal lumbar decompression. World Neurosurg 2021;145:631–642.
7. Akçakaya MO, Yörükoğlu AG, Aydoseli A, Aras Y, Sabancı PA, Altunrende ME, et al; Serum creatine phosphokinase levels as an indicator of muscle injury following lumbar disc surgery. Comparison of fully endoscopic discectomy and microdiscectomy. Clin Neurol Neurosurg 2016;145:74–78.
8. Ahn SS, Kim SH, Kim DW, Lee BH. Comparison of outcomes of percutaneous endoscopic lumbar discectomy, open lumbar microdiscectomy for young adults. a retrospective matched cohort study. World Neurosurg 2016;86:250–258.
9. Barber SM, Nakhla J, Konakondla S, Fridley JS, Oyelese AA, Gokaslan ZL, et al. Outcomes of endoscopic discectomy compared with open microdiscectomy, tubular microdiscectomy for lumbar disc herniations. a meta-analysis. J Neurosurg Spine 2019;31:802–815.
10. Kim M, Lee S, Kim HS, Park S, Shim SY, Lim DJ. A comparison of percutaneous endoscopic lumbar discectomy, open lumbar microdiscectomy for lumbar disc herniation in the Korean. a meta-analysis. Biomed Res Int 2018;2018:9073460.
11. Liu X, Yuan S, Tian Y, Wang L, Gong L, Zheng Y, et al. Comparison of percutaneous endoscopic transforaminal discectomy, microendoscopic discectomy, microdiscectomy for symptomatic lumbar disc herniation. minimum 2-year follow-up results. J Neurosurg Spine 2018;28:317–325.
12. Chen KT, Wei ST, Tseng C, Ou SW, Sun LW, Chen CM. Transforaminal endoscopic lumbar discectomy for L5-S1 disc herniation with high iliac crest. technical note and preliminary series. Neurospine 2020;17:S81–S87.
13. Hasan S, Härtl R, Hofstetter CP. The benefit zone of full-endoscopic spine surgery. J Spine Surg 2019;5:S41–S56.
14. Choi G, Lee SH, Lokhande P, Kong BJ, Shim CS, Jung B, et al. Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working channel endoscope. Spine (Phila Pa 1976) 2008;33:E508–E515.
15. Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003;11:255–263.
16. Zhang L, Yang J, Hai Y, Yin P, Ding Y, Xu C, et al. Relationship of the exiting nerve root and superior articular process in Kambin's triangle: assessment of lumbar anatomy using cadavers and computed tomography imaging. World Neurosurg 2020;137:e336–e342.
17. Schubert M, Hoogland T. Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation. Oper Orthop Traumatol 2005;17:641–661.
18. Chen KT, Jabri H, Lokanath YK, Song MS, Kim JS. The evolution of interlaminar endoscopic spine surgery. J Spine Surg 2020;6:502–512.
19. Khandge AV, Sharma SB, Kim JS. The evolution of transforaminal endoscopic spine surgery. World Neurosurg

https://doi.org/10.21182/jmisst.2021.00346

2021;145:643–656.

20. Choi KC, Lee DC, Shim HK, Shin SH, Park CK. A strategy of percutaneous endoscopic lumbar discectomy for migrated disc herniation. World Neurosurg 2017;99:259–266.
21. Sairyo K, Higashino K, Yamashita K, Hayashi F, Wada K, Sakai T, et al. A new concept of transforaminal ventral facetectomy including simultaneous decompression of foraminal and lateral recess stenosis: technical considerations in a fresh cadaver model and a literature review. J Med Invest 2017;64:1–6.
22. Fang G, Ding Z, Song Z. Comparison of the effects of epidural anesthesia and local anesthesia in lumbar transforaminal endoscopic surgery. Pain Physician 2016;19:E1001–E1004.
23. Choi KC, Shim HK, Kim JS, Cha KH, Lee DC, Kim ER, et al. Cost-effectiveness of microdiscectomy versus endoscopic discectomy for lumbar disc herniation. Spine J 2019;19:1162–1169.
24. Ghobrial GM, Williams KA Jr, Arnold P, Fehlings M, Harrop JS. Iatrogenic neurologic deficit after lumbar spine surgery: a review. Clin Neurol Neurosurg 2015;139:76–80.
25. Bosnjak R, Makovec M. Neurophysiological monitoring of S1 root function during microsurgical posterior discectomy using H-reflex and spinal nerve root potentials. Spine (Phila Pa 1976) 2010;35:423–429.
26. Macdonald DB, Stigsby B, Al Homoud I, Abalkhail T, Mokeem A. Utility of motor evoked potentials for intraoperative nerve root monitoring. J Clin Neurophysiol 2012;29:118–125.
27. Carragee EJ, Spinnickie AO, Alamin TF, Paragioudakis S. A prospective controlled study of limited versus subtotal posterior discectomy: short-term outcomes in patients with herniated lumbar intervertebral discs and large posterior anular defect. Spine (Phila Pa 1976) 2006;31:653–657.
28. Wera GD, Dean CL, Ahn UM, Marcus RE, Cassinelli EH, Bohlman HH, et al. Reherniation, failure after lumbar discectomy. a comparison of fragment excision alone versus subtotal discectomy. J Spinal Disord Tech 2008;21:316–319.
29. McGirt MJ, Ambrossi GL, Datoo G, Sciubba DM, Witham TF, Wolinsky JP, et al. Recurrent disc herniation and long-term back pain after primary lumbar discectomy: review of outcomes reported for limited versus aggressive disc removal. Neurosurgery 2009;64:338–344; discussion 344.

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Tube-assisted Minimally Invasive versus Open Posterior Decompression for Multilevel Degenerative Cervical Myelopathy: A Prospective Comparative Study

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Objective: There have been several reports of minimally invasive decompression for cervical canal stenosis and degenerative myelopathy. Most of these reports are for less than 4 levels and there have not been any comparative studies between Open and MIS cervical decompression for multilevel (≥4) degenerative cervical myelopathy.

Methods: Twenty consecutive patients were allotted to undergo either 'Open' cervical laminectomy (n=10) or MIS posterior cervical decompression (n=10). All patients were evaluated for 1. Clinical, (JOA, MDI, NDI, Nurick grade, Blood loss, Duration of surgery); 2. Radiological (CSA of dural sac and Spinal cord, Muscle edema on post-op T2W MRI); 3. Laboratory (TLC, CRP, ESR, CPK) and 4. Physical (Isometric neck extensor muscle strength). Differences between Open and MIS groups were calculated with respect to above parameters.

Results: The mean number of levels decompressed was 4.4 (range, 4–6). MIS group had significantly longer duration of surgery and lesser blood loss as compared to open group. The patients in open group were more disabled than MIS group pre-operatively, as evidenced by higher MDI and NDI. However, proportionate improvements were seen in both groups post-operatively in terms of all clinical parameters. Postoperative increase in CSA of spinal cord was also identical in both groups. Elevations in CRP and ESR were significantly higher in Open group post-operatively as compared to MIS group. Post-operative extensor neck muscle strength improved to a higher extent in MIS group as compared to open group though this was not statistically significant. No patient had any major post-operative complications.

Conclusion: MIS posterior cervical decompression is safe and effective, can achieve similar extent of decompression and degree of clinical improvement as compared to open surgery. MIS has definite advantages of lesser blood loss, reduced tissue injury and better improvement in post-operative neck muscle strength as compared to open surgery.

Key Words: Cervical myelopathy, Minimally invasive, Posterior cervical decompression, Cervical laminectomy, Tubular retractor, Multilevel cervical decompression

INTRODUCTION

Degenerative cervical Myelopathy is one of the most common progressive conditions affecting the older age groups. It is characterized by a combination of pathological changes in the cervical spine, both anterior (Disc bulges and Osteophytes) and posterior (Facet arthritis and ligamentum flavum hypertrophy). Consequently, surgical procedures to address the condition have utilized both anterior and posterior approaches for relieving spinal cord compression and maintaining/ restoring spinal stability. A posterior approach is generally preferred in cases with >3 level involvement, lordotic/ neutral spinal alignment and patients not fit for a major anterior procedure.

Conventional (Open) posterior cervical approaches necessitate detachment of paraspinal muscles from their attachment to the ligamentum nuchae and spinous processes, and lateral retraction throughout the surgical period. In addition to the direct surgical trauma, this can result in ischemic or denervation injury to the paraspinal muscles, together resulting in post-operative paraspinal muscle atrophy, imbalance between the flexor and extensor group and chronic axial neck pain [1,2]. Several studies have demonstrated reduced incidence of paraspinal atrophy and axial neck pain after using muscle sparing approaches and preserving attachments to C7 and C2 spinous processes during a conventional approach [3-9].

Minimally invasive muscle splitting approaches, introduced for the lumbar spine, have the potential to significantly reduce muscle injury and preserve the posterior tension band [10]. Their superiority in minimizing blood loss, reducing the duration of hospital stay, enabling earlier return to work and improving functional outcomes as compared to conventional procedures has been shown in several studies [11,12]. Recently, several reports of extension of this technique to the cervical spine have appeared in the literature and have shown promising outcomes [13,14].

There have been several reports in the literature describing the technique of minimally invasive posterior cervical decompression techniques for cervical myelopathy [13,15-20]. Almost all of these have utilized the technique for limited levels (2–3 levels) and there have not been any comparative outcome studies between minimally invasive and conventional (open) technique. To the best of our knowledge, ours in the first study to include multilevel cervical canal stenosis for minimally invasive decompression (Minimum 4 levels) and prospectively compare the outcomes against an equal number of patients undergoing conventional (open) multilevel cervical laminectomy and decompression.

MATERIALS AND METHODS

Twenty consecutive cases with at least 4 levels of secondary canal stenosis on MRI studies and progressive symptoms correlating with degenerative cervical myelopathy were selected for the study. Ten patients underwent Conventional (open) posterior cervical decompressive laminectomy (OPEN) and ten patients underwent minimally invasive (Tube assisted) cervical canal decompression by a technique described briefly below. All patients were operated under IONM (Intra-operative neuro-monitoring) with motor (MEP) and sensory (SSEP) evoked potentials.

1. Surgical Technique

1) Conventional (Open) Decompressive Laminectomy

With the patient in prone and head stabilized on a skeletal pin fixation headframe in neutral position and under appropriate aseptic precautions, posterior midline incision was placed and deepened in avascular midline plane (between the lamellar layers of ligamentum nuchae up to the tip of the spinous processes of the lamina needed to be resected. The muscular attachments were subperiosteally dissected from either side of the spinous processes and lamina and retracted laterally with a self-retaining retractor. Full thickness lateral gutters were drilled on either side at the junction of lamina and facet and enbloc laminectomy done. Hemostasis was achieved and wound closed in layers.

2) Minimally Invasive (Tube-assisted) Multi-level Cervical dDecompression Technique

With the patient in prone and head stabilized on a skeletal pin fixation headframe in neutral position and under appropriate aseptic precautions, a double incision technique was used to access multiple levels from C2-7. More commonly, the first incision was placed on side of approach 1 cm lateral to the midline co-axial to the C3-4 disc space and was used to decompress C3 and C4 levels (Figure 1B, C). If C2 needed to be decompressed, the incision was placed co-axial to the C3 vertebral body and used to decompress C2 to C4 levels. A separate second incision was placed on the same side co-axial to the C5-6 disc space and used to decompress C5 and C6 levels (Figure 1F, G). If C7 needed to be decompressed, the tube could be angulated inferiorly with the same incision. The entire surgery was done with a 18 mm tubular retractor under the microscope. At each level, ipsilateral decompression was done and tube angulated to contralateral side to achieve contralateral de-

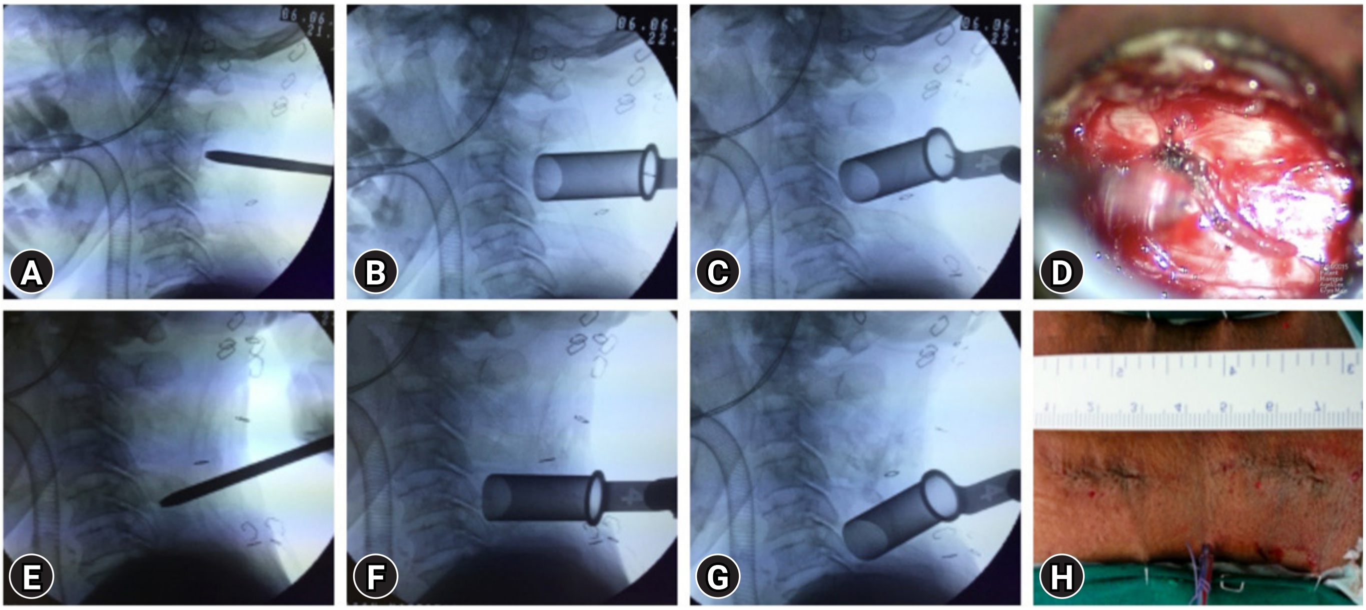

Figure 1. Illustrative case example demonstrating the 2-incision technique (H) used for multilevel posterior cervical MIS decompression. In this case, the upper incision has been used to decompress C3 (B) and C4 (C), while the lower incision has been used to decompress C5 (F) and C6 (G). (A, E) It represents the initial docking site and direction of the first dilator. (D) It shows appearance of decompressed dural sac at one level.

compression (similar to technique used in lumbar area) (Figure 1D). The detailed surgical technique is not described here.

2. Data Collection

1) Clinical Data

Apart from the regular demographic information, VAS score for neck pain and arm pain was collected for each patient. The extent of disability and degree of myelopathy were noted by means of Nurick grade, Myelopathy Disability index (MDI) and Japanese Orthopedic Association (JOA) scores. In addition, Neck disability index (NDI) score was also collected. All the above clinical parameters were collected pre-operatively, POD 7, at 6 weeks and at 3 months.

2) Radiological Data

All patients underwent pre-operative dynamic radiographs to r/o any instability. Magnetic Resonance imaging (MRI) with all relevant sequences and CT scan of the cervical spine (occiput to D2) was done in all patients pre-operatively and on POD 2. On both MRI and CT, routine observations regarding alignment of the spine, levels of involvement, compression of the spinal cord, any intrinsic changes within the cord were observed (Figure 2). The important parameters which were included for analysis are the following: (1) Cross-sectional area – Dural sac – measured pre-operatively and post-operatively (Figure 3); (2) Cross-sectional area – Spinal cord – measured pre-operatively and post-operatively (Figure 3); (3) Post-operative signal change on T2W axial MRI image (Figure 4) – measured separately for Superficial group (paraspinal muscle, PSM) and Deep group (Semispinalis cervicis, SSC) and graded as 1, 0%–25%; 2, 26%–50%; 3, 51%–75% and 4, >75% of cross-sectional area of the muscle group affected. Measurements were taken separately at each disc level from C2-3 to C6-7.

3) Laboratory (Biochemical) Data

Biochemical response to tissue injury was assessed by observing C-reactive protein (CRP), Erythrocyte sedimentation rate (ESR), Total Leucocyte count (TLC) and Creatine Phosphokinase (CPK) levels and trends following surgery in all patients. All the above parameters were assessed pre-operatively, POD 1, POD 3, POD 5 and on POD 7.

4) Physical Data

Evaluation of maximum Isometric contraction strength of Neck Extensor Muscles was done using a pressure biofeedback device (Figure 5). The initial cuff pressure of this device was set at 40 mmHg. The patient was in supine lying with the cuff of the device placed below the external occipital protuberance. The patient was asked to lie down on a hard plinth in relaxed supine position ensuring normal cervical lordosis after the device was placed. The patient was advised to push the cuff down with

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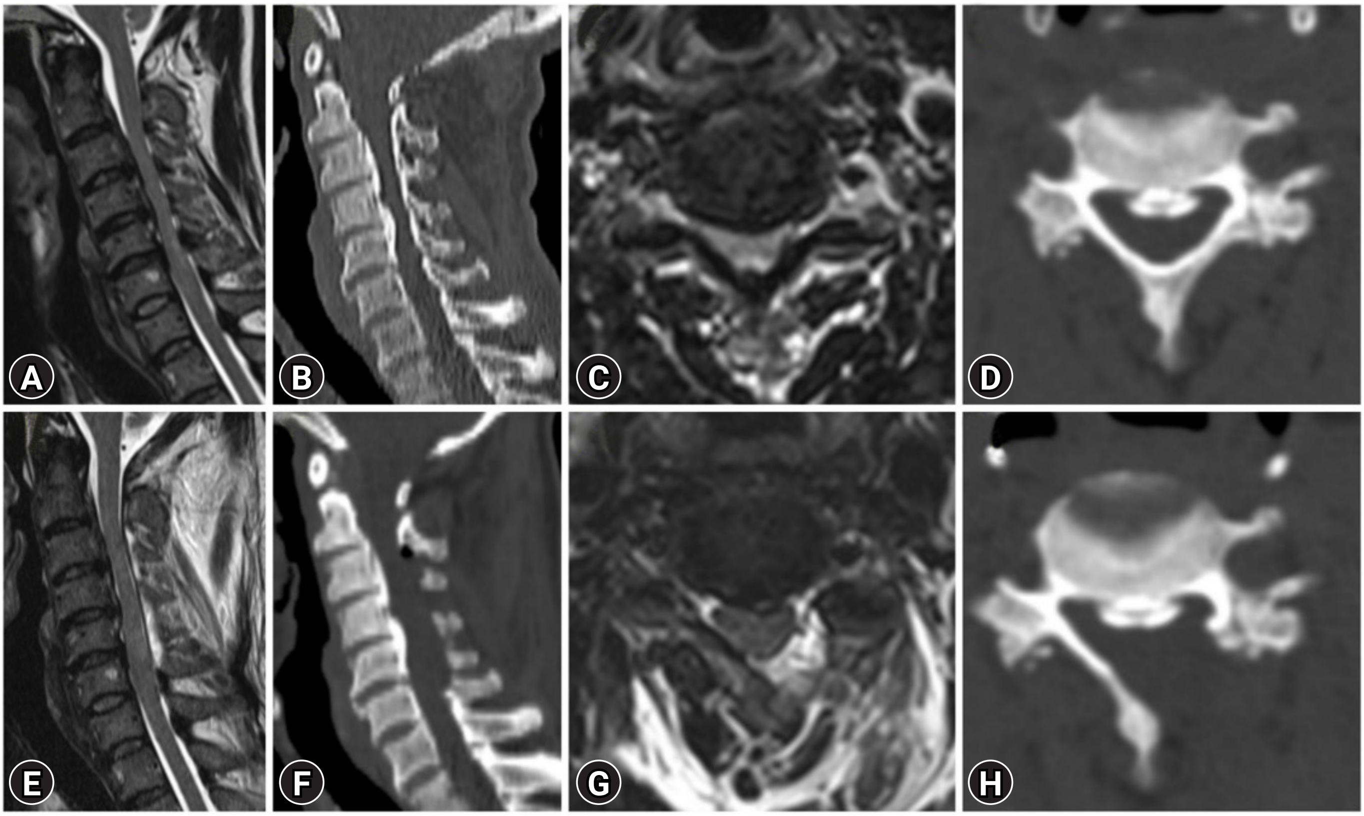

Figure 2. Illustrative case example showing secondary canal stenosis from C3-5 due to continuous OPLL (Ossified posterior longitudinal ligament). (A) Pre-op and (E) post-op mid sagittal T2W MRI image. (B) Pre-op and (F) post-op mid sagittal CT scan image. (C) Pre-op and (G) post-op Axial T2W MRI image. (D) Pre-op and (H) post-op Axial CT scan image.

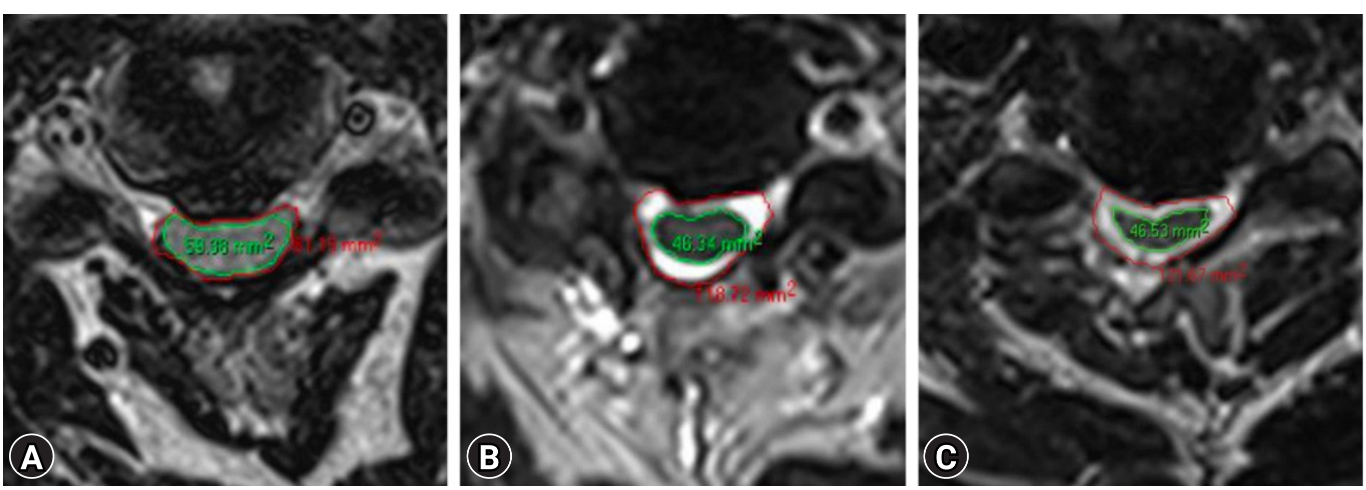

Figure 3. Illustrative case example showing the technique used for measuring CSA of Dural sac and spinal cord pre-operatively (A), post-operatively after open decompressive laminectomy (B), and after MIS decompression (C).

isometric contraction of the neck extensor muscles without contracting the shoulder girdle muscles. Then the change in grade was recorded. Three movements with 2 minutes rest between them were repeated and the averages of obtained scores were recorded as the maximum isometric contraction strength of neck extensor muscles. These measurement were recorded for all patients in both groups pre-operatively and at 6 weeks following surgery.

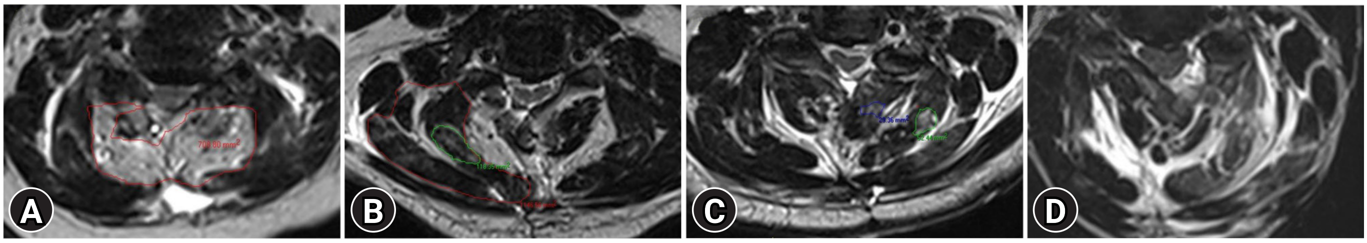

Figure 4. Illustrative case examples showing technique of measuring post-operative muscle edema on T2W axial image after open decompressive laminectomy (A) and MIS decompression (B). (C) Post-op image after MIS decompression showing minimal edema (<25%) on side of entry (left). (D) Post-op image after MIS decompression in a different case showing larger area (>75%) on left side (side of entry) and no changes on contralateral (right) side.

Figure 5. A volunteer demonstrating biofeedback device used to measure posterior neck muscle strength.

3. Statistical Analysis

Statistical analysis was performed using SPSS software (2015, version 23.0; IBM Corp., Armonk, NY). Descriptive statistics with median values and interquartile variations were calculated and tabulated as shown below. Intergroup variations between MIS and Open groups were analyzed using non-parametric longitudinal design tests (Mann-Whitney U and mixed ANOVA).

RESULTS

Of the twenty patients, 10 underwent conventional (open) laminectomy ad decompression (henceforth referred to as "Open" group) while the other ten underwent Minimally invasive decompression (henceforth referred to as "MIS" group). The most common levels decompressed were C3-6 in both MIS and open groups. The most common number of levels decompressed was 4 levels in both groups, which was also the minimum number of levels decompressed in any patient (Figure 6). There was no post-operative neurological deterioration in any patient. One patient in the open group had delayed wound healing with no long-term consequence. There were no complications in any other patient.

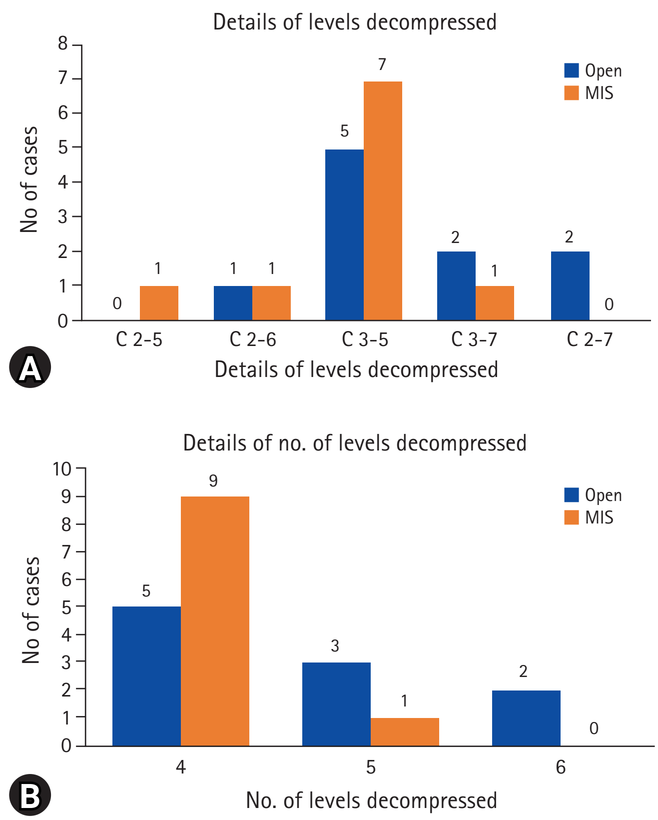

Figure 6. Histograms depicting the details of levels decompressed (A) and median number of levels decompressed (B) in Open and MIS groups.

As enumerated in the Methods section, Results will be discussed under the following sections: 1. Clinical; 2. Radiological; 3. Biochemical; 4. Physical.

1. Clinical Data – Results (Table 1)

The median duration of surgery was significantly longer for MIS group at 190 minutes compared to the open group which was 107 minutes. On the other hand, blood loss was signifi-

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Table 1. Results of clinical and demographic data and comparison between open and MIS groups

		Open group	MIS group	p-value
Age (yr)		61.3 (46–76)	52.5 (39–65)	-
M:F ratio		9:1	7:3	-
Duration of surgery (min)		107 (90–120)	190 (168–258)	< 0.001
Blood loss (mL)		250 (247–305)	150 (122–150)	< 0.001
JoA (median [inter-quartile range])	Pre-op	10.0 (9.0–12.7)	14.5 (11.7–16.0)	0.11
	Pod 7	11.0 (8.7–14.5)	15.5 (11.5–16.25)	0.11
	6 wk	14.0 (12.7–15.2)	16.0 (12.5–17.25)	0.15
	3 mo	15.0 (12.7–16.0)	17.0 (14.5–18.0)	0.06
MDI (in %)	Pre-op	81.6 (55.8–93.3)	24.9 (19.1–56.6)	0.01
	Pod 7	64.9 (55.8–81.6)	20.0 (11.6–49.1)	0.003
	6 wk	51.6 (29.9–77.4)	11.6 (2.4–31.0)	0.02
	3 mo	28.3 (10.0–70.8)	10.0 (2.4–19.5)	0.07
NDI (in %)	Pre-op	40.0 (19.2–46.4)	18.5 (12.8–26.4)	0.04
	Pod 7	35.7 (7.8–46.4)	14.2 (10.0–25.7)	0.17
	6 wk	17.1 (5.7–30.7)	8.5 (5.0–12.8)	0.15
	3 mo	10.0 (4.2–26.4)	5.7 (4.2–9.2)	0.29
Nurick grade	Pre-op	4.0 (3.0–5.0)	3.0 (2.0–3.5)	0.07
	Pod 7	4.0 (3.5–4.0)	2.5 (1.7–3.2)	0.06
	6 wk	2.5 (2.0–4.0)	1.5 (1.0–2.2)	0.059
	3 mo	2.0 (1.0–3.2)	1.0 (1.0–1.2)	0.059

Data figures represent median values with inter-quartile variations (in parenthesis).
NDI: Neck Disability Index, JOA: Japanese Orthopedic association, MDI: Myelopathy Disability Index, min: minutes, mL: milliliters, Pod: Post-operative day.

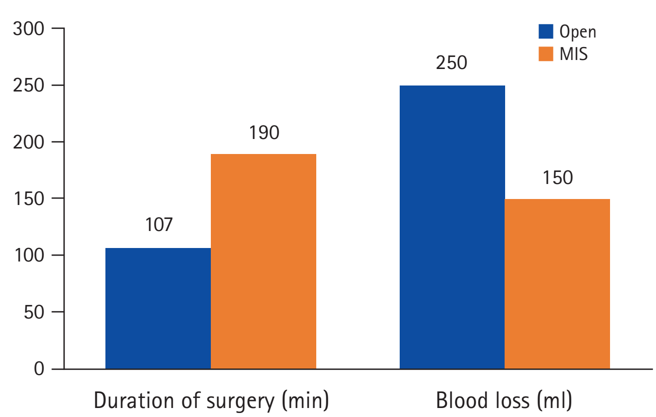

Figure 7. Histogram depicting comparison of duration of surgery and Intra-operative blood loss between Open and MIS groups.

cantly less in the MIS group with a median value of 150 mL as compared to open group in which it was 250 mL (Figure 7).

The extent of disability and myelopathy was more pronounced in the open group pre-operatively, as evidenced by the higher pre-operative median MDI, NDI and Nurick grades and lower JOA scores as compared to the MIS group, with the difference reaching significance for MDI and NDI (Table 1). Post-operatively, proportionate improvements were noted in both MIS and open groups in all the above parameters (Figure 8). The pre-operative difference of higher MDI, NDI, Nurick and lower JOA scores in open group was maintained in the post-operative period at 7 days, 6 weeks and 3 months follow-up periods, though the margin of difference reduced for all parameters post-operatively. While MDI maintained significant difference between open and MIS groups at 7 days and 6 weeks post-operative and lost significance at 3 months post-operative follow-up, significance was lacking for the other parameters (JOA, NDI, Nurick grade) at all post-operative points of evaluation. To enumerate, though patients in open group were more disabled pre-operatively than those in MIS group, proportionate improvements were seen in both groups post-operatively with no significant difference between the groups at 3 months with respect to any clinical parameter assessed.

2. Radiological Data – Results (Table 2)

There was no noticeable difference in the CSA of the dural sac or spinal cord between the MIS and Open groups pre-operatively. As expected, there was significant improvements in CSA of both dural and spinal cord post-operatively in both groups (Figure 9). The dural sac CSA increased more in the open group as compared to MIS group, which could be explained by the

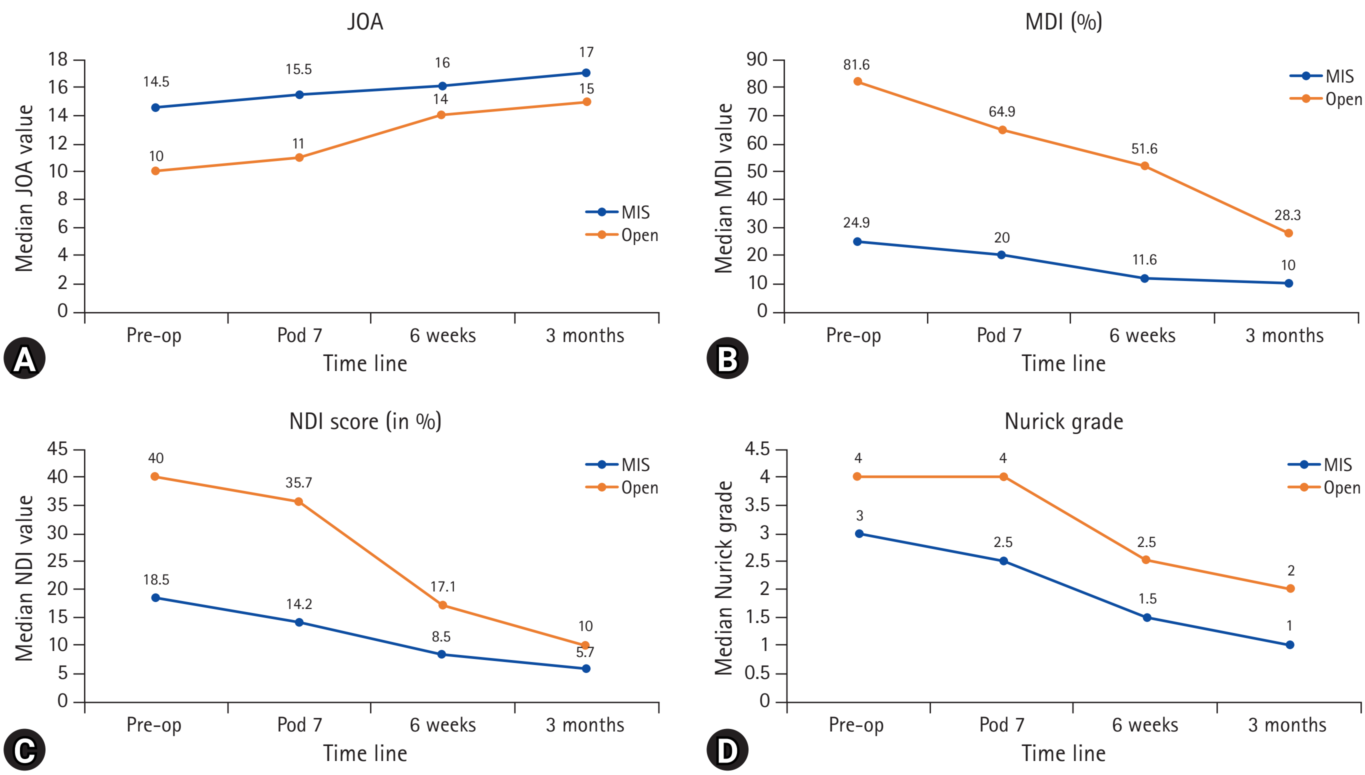

Figure 8. Line charts illustrating the comparison of pre-operative values and post-operative trends at various time points between Open and MIS groups with respect to JOA (A), MDI (B), NDI (C), and Nurick grade (D).

Table 2. Results of radiological parameters considered for analysis and comparison between open and MIS groups

		Open group	MIS group	p-value
CSA – dural sac (sq.mm)	Pre-op	124 (107–145)	128 (120–145)	
	Post-op	178 (162–192)	159 (133–187)	
	Difference of median	54.6 (30–64)	31.2 (18–44)	0.21
CSA – spinal cord (sq.mm)	Pre-op	60 (46–77)	56 (49–62)	
	Post-op	71 (55–83)	68 (58–79)	
	Difference of median	10.6 (6–12)	9.1 (8–12)	0.96

Data figures represent median values with inter-quartile variations (in parenthesis).
CSA: Cross-sectional area, sq.mm: Square millimeters.

inherent nature of the surgery where entire laminectomy was performed in open group while only a hemilaminectomy and decompression was performed in MIS group. However, this difference was not statistically significant. More importantly, what mattered was that improvements in CSA of spinal cord remained proportional with no noticeable difference between the two groups (Figure 9B). The change in the CSA of dural and spinal cord was also calculated for each level independently. While dural sac dimensions increased more in the open group as compared to MIS group at all individual levels (Figure 9A), there was no significant difference at any level with respect to change in CSA of spinal cord or dural sac between pre-operative and post-operative values.

Post-operative signal changes in the muscles assessed on T2W axial MR sequences were evidently more prominent in the open group as compared to MIS group. Statistically significant differences were obviously found on the side contralateral to entry in MIS group as compared to open group, since there was no muscle dissection at all on that side in MIS group as compared to open group wherein bilateral muscle groups were dissected from their attachments and retracted for performing laminectomy. More noticeably, even on side ipsilateral to entry, MIS resulted in significantly lesser muscle signal changes at peripheral levels (C2-3 and C6-7) in the deep group (semispinalis

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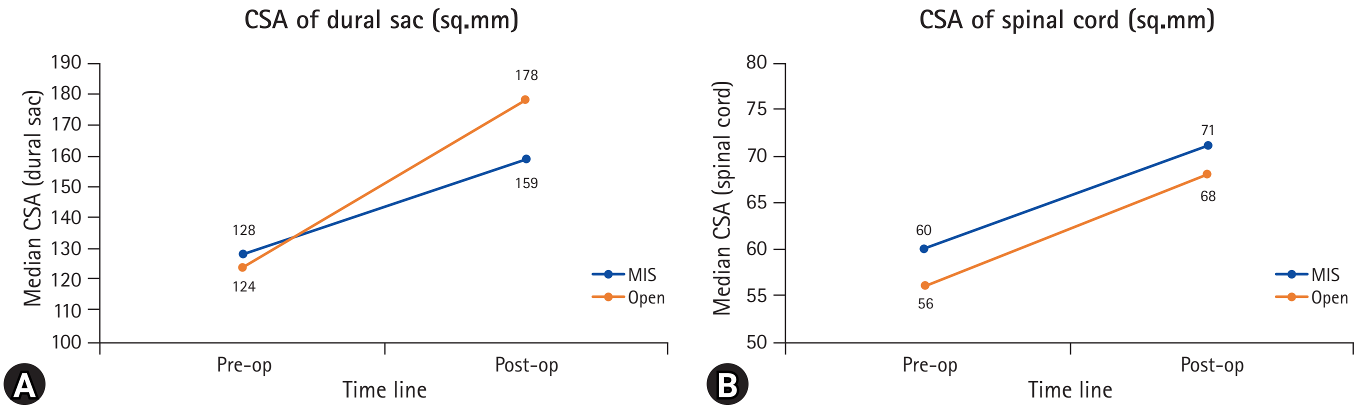

Figure 9. Line charts illustrating the comparison of pre-operative and post-operative values between Open and MIS groups with respect to CSA of dural sac (A) and spinal cord (B).

Table 3. Results of post-operative signal changes on T2W axial MRI sequence and comparison between open and MIS groups

	MIS ipsilateral	Open ipsilateral	p-value	MIS contralateral	Open contralateral	p-value
PSM 2–3	0 (0–0)	1 (0–1)	0.028	0 (0–0)	1 (0–1)	0.005
PSM 3–4	1 (1–2)	1 (0–1)	0.118	0 (0–0)	1 (0–1)	0.010
PSM 4–5	1 (1–1)	1 (1–1)	0.427	0 (0–0)	1 (1–1)	0.000
PSM 5–6	1 (1–1.75)	1 (1–1)	0.518	0 (0–0)	1 (1–1)	0.001
PSM 6–7	0 (0–0)	1 (0–1)	0.129	0 (0–0)	0 (0–1)	0.015
SSC 2–3	0 (0–0)	2 (1–2)	0.014	0 (0–0)	2 (0–4)	0.002
SSC 3–4	2 (2–2.75)	2 (2–4)	1.000	0 (0–0)	2 (2–4)	0.000
SSC 4–5	2 (1.25–2)	2 (2–3)	0.380	0 (0–0)	2 (2–4)	0.000
SSC 5–6	2 (1.25–2)	2 (2–4)	0.122	0 (0–0)	2 (2–3)	0.000
SSC 6–7	0 (0–0.75)	1 (1–2)	0.013	0 (0–0)	1 (1–2)	0.001

Data figures represent median values with inter-quartile variations (in parenthesis) of the degree/extent of signal changes graded as mentioned in methods section. The degree of signal changes has been measured at each level. For eg 2-3 is at C2-3 level.
PSM: Paraspinal muscle superficial group, SSC: Semispinalis cervicis (deep group).

cervicis, SSC) as compared to the open group (Table 3).

3. Laboratory Data – Results (Table 4)

There were no significant pre-operative differences between the open and MIS groups with respect to TLC, CRP, ESR or CPK. Post-operatively, the elevations in CRP levels showed marked difference between open and MIS groups, with open group having significantly higher elevations in CRP as compared to MIS group, remaining statistically significant till 7th post-operative day (Figure 10). Elevations in TLC and CPK were higher in open group as compared to MIS group, but were not statistically significant. Unexpectedly, ESR elevations were also significantly higher in open group as compared to MIS group from first until the fifth post-operative day.

4. Physical Data – Results (Table 5) (Figure 11)

Changes in isometric extensor muscle strength were calculated with a biofeedback mechanism as described in methods section. Compared to pre-operative levels, muscle strength significantly improved post-operatively in both open and MIS groups. The degree of improvement was higher in the MIS group (27.5%) as compared to open group (15.7%). However, this difference did not reach statistical significance.

DISCUSSION

There have been several reports of minimally invasive posterior cervical decompression for degenerative myelopathy in the literature in the last 2 decades with an inconsistent frequency. In an early reported series of 13 patients, Boehm et al. [16] reported on 9 patients who underwent interlaminar decompression through a tube for myelopathy with most of the patient in their series being only single level, basically using this procedure as an alternative for anterior cervical discectomy. Using

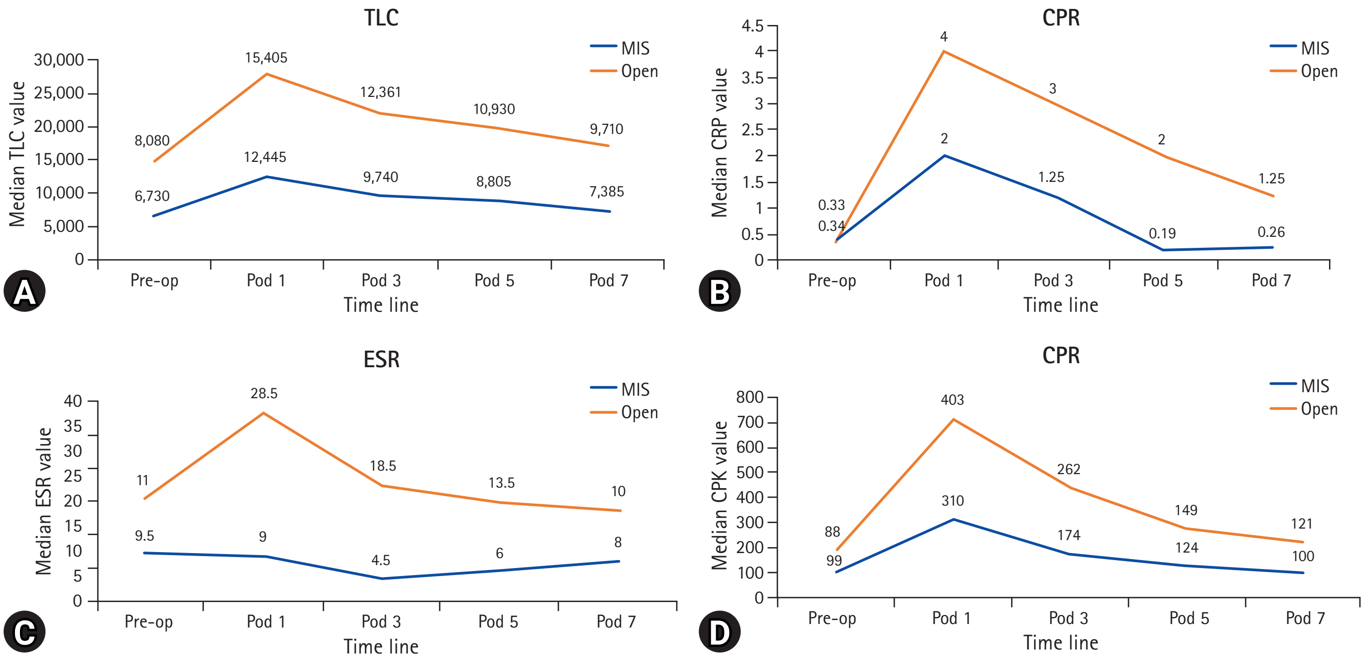

Figure 10. Line charts illustrating the comparison of pre-operative values and post-operative trends at various time points between Open and MIS groups with respect to laboratory parameters such as TLC (A), CRP (B), ESR (C), and CPK (D).

Table 4. Results of laboratory values and comparison between Open and MIS groups

		Open group	MIS group	p-value
TLC	Pre-op	8,080 (6,425–8,657)	6,730 (5,770–7,928)	0.29
	Pod 1	15,405 (13,350–18,852)	12,445 (11,672–15,645)	0.10
	Pod 3	12,361 (9,527–14,737)	9,740 (8,435–13,272)	0.22
	Pod 5	10,930 (9,617–11,560)	8,805 (7,427–11,370)	0.11
	Pod 7	9,710 (8,450–10,645)	7,385 (6,437–9,755)	0.04
CRP	Pre-op	0.33 (0.24–0.80)	0.34 (0.18–0.60)	0.73
	Pod 1	4.0 (3.0–4.7)	2.0 (1.7–2.4)	< 0.001
	Pod 3	3.0 (2.08–3.6)	1.25 (0.6–2.0)	< 0.001
	Pod 5	2.0 (1.9–2.7)	0.19 (0.13–1.14)	0.001
	Pod 7	1.25 (0.54–2.0)	0.26 (0.12–0.85)	0.02
ESR	Pre-op	11.0 (5.2–20.2)	9.5 (5.7–20.7)	0.97
	Pod 1	28.5 (12.0–39.7)	9.0 (4.0–26.0)	0.02
	Pod 3	18.5 (13.7–25.0)	4.5 (1.7–19.2)	0.03
	Pod 5	13.5 (10.0–29.0)	6.0 (2.7–16.5)	0.04
	Pod 7	10.0 (7.7–23.5)	8.0 (2.0–14.0)	0.23
CPK	Pre-op	88 (63–120)	99 (84–147)	0.44
	Pod 1	403 (314–649)	310 (207–400)	0.07
	Pod 3	262 (195–490)	174 (136–284)	0.16
	Pod 5	149 (127–272)	124 (69–151)	0.12
	Pod 7	121 (83–206)	100 (56–110)	0.17

Data figures represent median values with inter-quartile variations (in parenthesis).
TLC: Total Leukocyte count, CRP: C-reactive protein, ESR: Erythrocyte sedimentation rate, CPK: Creatinine phosphokinase, Pod: Post-operative day.

a tube assisted technique similar to the one used in our series, Santiago and Fessler reported adequate decompression at 6 of the 8 levels decompressed in 4 patients [13]. Hur et al. [17] also used a tube assisted technique to decompress 13 levels in

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Table 5. Results of isometric extensor neck muscle strength (measured with a biofeedback device) and comparison between Open and MIS groups

Neck extensor isometric strength	Open group	MIS group	p-value
Pre-op (in mmHg)	90.8 (77.4–108.1)	112.5 (83.7–131.6)	0.18
Post-op (in mmHg)	105 (98.6–25.4)	143.3 (113.7–149.6)	
Difference (in % improvement as compared to pre-op level)	15.7	27.5	
p-value	0.009	0.005	

P-values in the lower row represent intra-group changes compared between pre-op and post-op values. P-values in the right column represent inter-group variations – between Open and MIS.

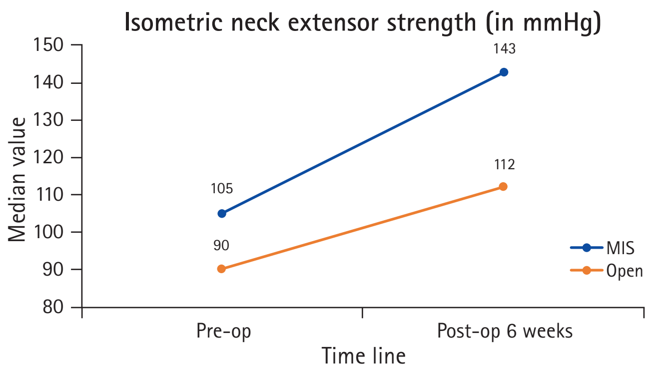

Figure 11. Line chart illustrating the comparison of pre-operative and post-operative values between Open and MIS groups with respect to Isometric neck extensor muscle strength.

6 patients, with a maximum of 3 levels in any patient and reported good outcomes in all their patients. Hernandez et al. [18] described a 10-step technique to report the safety and efficacy of minimally invasive cervical decompression with a tubular retractor in 15 patients, with majority being single level decompression (range, 1–3). There have also been several reports of endoscope assisted decompression for cervical canal stenosis, all of them restricting to 3 levels of decompression with the majority patients undergoing one or 2-level decompression [15,20,21]. To the best of our knowledge, there are no reports of minimally invasive techniques being employed in decompressing 4 or more levels in the cervical spine.

Comparative studies between 'MIS' and 'Open' posterior cervical decompression are the only effective means to ascertain the safety and benefits of a technically challenging MIS cervical decompression as compared to the much simpler, more widely practiced technique of 'Open' posterior cervical laminectomy. To the best of our knowledge, ours is the first and only study so far to prospectively and comprehensively compare and report the differences between 'Open' and 'MIS' posterior cervical decompression. Abbas et al compared the outcomes between anterior fusion surgery (ACDF, 29 patients) with posterior minimally invasive cervical decompression (45 patients, Mean 2.8 levels) and reported similar outcomes in both groups [19].

In the course of the study, the authors aimed to answer these three primary questions: 1. Does MIS achieve adequate decompression as Open?; 2. Is the extent of clinical improvement same in MIS and Open techniques?; 3. Are there benefits of MIS technique compared to Open?

1. Does MIS Achieve Adequate Decompression as Open?

This was the primary and the most important question the authors aimed to answer in the present study. Though there are several reports of MIS posterior cervical decompression in the literature, none of them had compared the extent of decompression achieved with respect to radiological parameters and had reported on improvement in clinical variables alone [13,15,16,18]. In the present study, improvements in CSA of spinal cord (the factor directly representing adequacy of decompression) were similar in both open and MIS groups. The dural sac CSA improved more in 'open' group as compared to 'MIS' group, understandably due to a wider laminectomy than the unilateral laminotomy of MIS procedure. Since the spinal cord CSA improved proportionately in both groups, the additional increase in dural sac CSA offered by 'open' laminectomy was probably not clinically relevant. It is hence safe to infer that adequacy of spinal cord decompression in MIS is similar to that of open technique.

2. Is the Extent of Clinical Improvement Same in MIS and Open Techniques?

The patients in the open group were more disabled pre-operatively as compared to those in MIS group, as evidenced by the intergroup pre-operative differences in MDI, JOA and Nurick grades. This is an inherent bias in case selection, presumably because the authors were reluctant in the earlier part of the study to select cases which were more disabled for the newer, yet unproven MIS technique. However, significant clinical improvement was seen in both groups post-operatively, with patient in open group continuing to exhibit more disability than patients in MIS group, though statistically insignificant. Notwithstanding the pre-operative selection bias, patients in both groups showed significant clinical improvement post-operatively.

3. Are There Benefits of MIS Technique Compared to Open?

The authors compared several parameters – biochemical, radiological and Physical – to ascertain the benefit, if any, of MIS technique over its well-established counterpart, the open technique. Biochemical markers of tissue injury and acute phase reactants (CRP) showed significantly higher post-operative elevations in open group which was sustained for longer periods as compared to MIS technique. Post-operative muscle edema was significantly lesser in MIS group, obviously on the side contralateral to entry in MIS and at peripheral levels on the ipsilateral side as well. Post-operative isometric neck extensor strength improved by a better margin in patients who underwent MIS as compared to those underwent open decompression, though the difference was not statistically significant. Even with a small sample size, the above findings suggest considerable benefits for MIS procedure as compared to an open technique.

4. Limitations of the Study

The authors understand the limitations of the present study. It's a small group comparison and may not be an adequate sample to conclusively prove or disprove the observations of the study. A larger group with prospective analysis of all above sample is the need of the hour. Also, the follow-up period is limited to 3 months, primarily since the main objective of the study was to prove the adequacy of surgical decompression, extent of clinical improvement, and safety of MIS posterior cervical multilevel decompression as compared to open cervical decompression. Long term follow-up with documentation for sustained clinical improvement and benefits of MIS technique will conclusively answer the same questions over a long term.

CONCLUSION

Despite certain limitations, the present study is the first to prospectively and comprehensively compare 'MIS' and 'open' posterior multilevel (≥4) cervical decompression. Minimally invasive posterior multilevel cervical decompression for degenerative cervical myelopathy is a safe and effective technique, that can achieve similar extent of spinal cord decompression and degree of clinical improvement as a conventional 'open' posterior cervical decompression, in the form a laminectomy, can achieve. MIS cervical decompression has obvious benefits of reduced blood loss, less tissue injury and better post-operative extensor muscle function as compared to open laminectomy.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Wang SJ, Jiang SD, Jiang LS, Dai LY. Axial pain after posterior cervical spine surgery. a systematic review. Eur Spine J 2011;20:185–194.
2. Ono A, Tonosaki Y, Numasawa T, Wada K, Yamasaki Y, Tanaka T, et al. The relationship between the anatomy of the nuchal ligament, postoperative axial pain after cervical laminoplasty. cadaver and clinical study. Spine (Phila Pa 1976) 2012;37:E1607–E1613.
3. Cho CB, Chough CK, Oh JY, Park HK, Lee KJ, Rha HK. Axial neck pain after cervical laminoplasty. J Korean Neurosurg Soc 2010;47:107–111.
4. Kotani Y, Abumi K, Ito M, Sudo H, Takahata M, Ohshima S, et al. Minimum 2-year outcome of cervical laminoplasty with deep extensor muscle-preserving approach. impact on cervical spine function and quality of life. Eur Spine J 2009;18:663–671.
5. Lee YS, Lee S, Ko MJ, Cho DC, Kim KT. Preservation of deep cervical extensor muscle volume. comparison between conventional open-door and muscle preserving laminoplasty approaches in the same patients. World Neurosurg 2020;141:e514–e523.
6. Shiraishi T, Kato M, Yato Y, Ueda S, Aoyama R, Yamane J, et al. New techniques for exposure of posterior cervical spine through intermuscular planes and their surgical application. Spine (Phila Pa 1976) 2012;37:E286–E296.
7. Kato M, Nakamura H, Konishi S, Dohzono S, Toyoda H, Fukushima W, et al. Effect of preserving paraspinal muscles on postoperative axial pain in the selective cervical laminoplasty. Spine (Phila Pa 1976) 2008;33:E455–E459.
8. Takeuchi K, Yokoyama T, Aburakawa S, Saito A, Numasawa T, Iwasaki T, et al. Axial symptoms after cervical laminoplasty with C3 laminectomy compared with conventional C3-C7 laminoplasty. a modified laminoplasty preserving the semispinalis cervicis inserted into axis. Spine (Phila Pa 1976) 2005;30:2544–2549.
9. Takeuchi T, Shono Y. Importance of preserving the C7 spi-

 https://doi.org/10.21182/jmisst.2021.00325

nous process and attached nuchal ligament in French-door laminoplasty to reduce postoperative axial symptoms. Eur Spine J 2007;16:1417–1422.
10. Rahman M, Summers LE, Richter B, Mimran RI, Jacob RP. Comparison of techniques for decompressive lumbar laminectomy. the minimally invasive versus the “classic” open approach. Minim Invasive Neurosurg 2008;51:100–105.
11. Fan S, Hu Z, Zhao F, Zhao X, Huang Y, Fang X. Multifidus muscle changes, clinical effects of one-level posterior lumbar interbody fusion. minimally invasive procedure versus conventional open approach. Eur Spine J 2010;19:316–324.
12. Tian NF, Wu YS, Zhang XL, Xu HZ, Chi YL, Mao FM. Minimally invasive versus open transforaminal lumbar interbody fusion. a meta-analysis based on the current evidence. Eur Spine J 2013;22:1741–1749.
13. Santiago P, Fessler RG. Minimally invasive surgery for the management of cervical spondylosis. Neurosurgery 2007;60:S160–S165.
14. Celestre PC, Pazmiño PR, Mikhael MM, Wolf CF, Feldman LA, Lauryssen C, et al. Minimally invasive approaches to the cervical spine. Orthop Clin North Am 2012;43:137–147, x.
15. Song JK, Christie SD. Minimally invasive cervical stenosis decompression. Neurosurg Clin N Am 2006;17:423–428.
16. Boehm H, Greiner-Perth R, El-Saghir H, Allam Y. A new minimally invasive posterior approach for the treatment of cervical radiculopathy. surgical technique and preliminary results. Eur Spine J 2003;12:268–273.
17. Hur JW, Kim JS, Shin MH, Ryu KS. Minimally invasive posterior cervical decompression using tubular retractor. the technical note and early clinical outcome. Surg Neurol Int 2014;5:34.
18. Hernandez RN, Wipplinger C, Navarro-Ramirez R, Soriano-Solis S, Kirnaz S, Hussain I, et al; Ten-step minimally invasive cervical decompression via unilateral tubular laminotomy. technical note and early clinical experience. Oper Neurosurg (Hagerstown) 2020;18:284–294.
19. Abbas SF, Spurgas MP, Szewczyk BS, Yim B, Ata A, German JW. A comparison of minimally invasive posterior cervical decompression and open anterior cervical decompression and instrumented fusion in the surgical management of degenerative cervical myelopathy. Neurosurg Focus 2016;40:E7.
20. Yabuki S, Kikuchi S. Endoscopic partial laminectomy for cervical myelopathy. J Neurosurg Spine 2005;2:170–174.
21. Dahdaleh NS, Wong AP, Smith ZA, Wong RH, Lam SK, Fessler RG. Microendoscopic decompression for cervical spondylotic myelopathy. Neurosurg Focus 2013;35:E8.

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Full-endoscopic Foraminotomy in Degenerative Spondylolisthesis: A "Module-based" Approach for Surgical Planning and Execution

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Objective: Degenerative Lumbar Spondylolisthesis (DSL) is a common spinal pathology characterized by the anterior slippage of one vertebral body on another. DSL is caused mainly by degeneration of the intervertebral disc in the first place, with subsequent degeneration of the facet joints that end causing the slippage. As the disease evolves, stability is restored as a result of advanced degeneration and disc collapse. But while this natural evolution takes place, DSL may produce radicular symptoms by different mechanisms. To present a "module-based" approach for the surgical planning and execution of full-endoscopic foraminotomy in DSL, combined with case examples of the most common surgical scenarios.
Methods: We propose a "module-based surgery" using the standard endoscopic foraminotomy technique as a baseline. According to the patient's clinical and imaging characteristics, several "modules" can be added. The resulting endoscopic surgery is a summation of the basic endoscopic foraminotomy plus all the additional required modules.
Results: Surgical modules description and case examples are provided.
Conclusion: Transforaminal lumbar endoscopic foraminotomy represents a minimally invasive technique to treat foraminal and combined foraminal-lateral recess stenosis. DSL and its multiple scenarios represent a challenge to the endoscopic surgeon. Module-based approach can help systematize and execute these demanding endoscopic procedures.

Key Words: Endoscopic, Foraminotomy, Lumbar, Spondylolisthesis, Minimally, Invasive

INTRODUCTION

Lumbar spondylolisthesis is a common spinal pathology characterized by the anterior slippage of one vertebral body on another. First described in 1931 [1], this pathology can be classified according to broad etiologies [2], being degenerative spondylolisthesis (DSL) the most frequent variety encountered in clinical practice [3]. DSL is caused mainly by degeneration of the intervertebral disc in the first place, with subsequent degeneration of the facet joints that end causing the slippage [4]. As the disease evolves, stability is restored as a result of advanced degeneration and disc collapse. But while this natural evolution takes place, DSL may produce three different types of pain patterns by different mechanisms [5]:

1. Low back pain and referred pain in the back of the thigh, mostly caused by the affected intervertebral disc and facet joints that suffer the stress of the slippage and instability.
2. Radicular pain or motor deficit, caused by narrowing of the foramen and/or lateral recess compressing the exiting or the traversing nerve root, as the case may be.
3. Neurogenic claudication, produced by combined central stenosis secondary to slippage as well as hypertrophy of the ligamentum flavum and facet joints.

These conditions can present isolated or more commonly combined with other degenerative changes such as disc herniations, etc. configuring different scenarios.

Percutaneous or full-endoscopic procedures have shown good outcomes and decompression effectiveness in patients with lumbar central, lateral recess, and foraminal stenosis [6-9]. Due to the minimally invasive nature of the procedure, transforaminal endoscopic approaches minimize the surgical footprint sparing the stabilizing structures such as ligaments, muscles, and facet joints. This makes endoscopic decompression especially attractive in the setting of DSL. It can become a method to ease the radicular and stenotic symptoms while allowing the DSL to continue its natural path to re-stabilization. Taking into consideration that, as with many minimally invasive procedures, the effectiveness of endoscopic decompression relies on a thorough analysis of the pathology and surgical planning, DSL and its multiple scenarios represent a challenge to the endoscopic surgeon.

We present a "module-based" approach for the surgical planning and execution of full-endoscopic foraminotomy in DSL.

MODULE-BASED APPROACH

Foraminal stenosis in DSL represents a challenge to the endoscopic surgeon, mainly because of its multiple anatomical and clinical variations that results in changes in the standard endoscopic foraminotomy surgical strategy and technique.

To address and systematize these variations, we propose a "module-based surgery" using the standard endoscopic foraminotomy technique as a baseline. According to the patient's clinical and imaging characteristics, several "modules" can be added. The resulting endoscopic surgery is a summatory of the basic endoscopic foraminotomy plus all the additional required modules.

The inclusion criteria to apply this module-based approach are the following:

- Stable DSL, defined as no radiological instability on dynamic lateral lumbar X-Rays.
- Symptomatic radiculopathy with concordant foraminal stenosis demonstrated on imaging studies.

The exclusion criteria for this approach are:

- Radiological instability on dynamic lateral lumbar X-Rays.
- Significant lumbar pain (lumbar VAS> radicular VAS).
- Central stenosis causing neurogenic claudication.
- Non-degenerative Spondylolisthesis.

Likewise, non-surgical aspects of the patient that can affect the decision-making process and can override the inclusion/exclusion criteria: Patient/family preferences and expectations, possibility of revision surgery, comorbidities (as measured in the Charlson Comorbidity Index).

The proposed modules are detailed in Figure 1 [10].

1. Endoscopic Modules: Technical Description

Each endoscopic module can be considered as an independent technical unit. Different modules can be combined according to the patient's characteristics. The modules are assembled and executed according to a logical rule: first from medial to lateral, and then from caudal to cranial.

2. Standard SAP-based Foraminal Decompression

The transforaminal resection of SAP tip serves as baseline for endoscopic foraminoplasty in the setting of DSL. As a consequence it is considered as the first and indispensable surgical module.

Endoscopic transforaminal SAP resection follows the technique described by Ahn et al. [11]: Puncture site is calculated using preoperative MRI. Needle is advanced until the tip contacts the transition between pedicle and SAP. An 8 mm skin incision is made, and guidewire, blunt dilator and beveled working sheath are placed sequentially. The opening of the beveled working sheath must be "floating free" into the foramen, in gentle contact with the SAP surface. The endoscope is placed through the working sheath and then the resection of the tip of the SAP is carried out under endoscopic visualization using an endoscopic high speed drill. Redundant

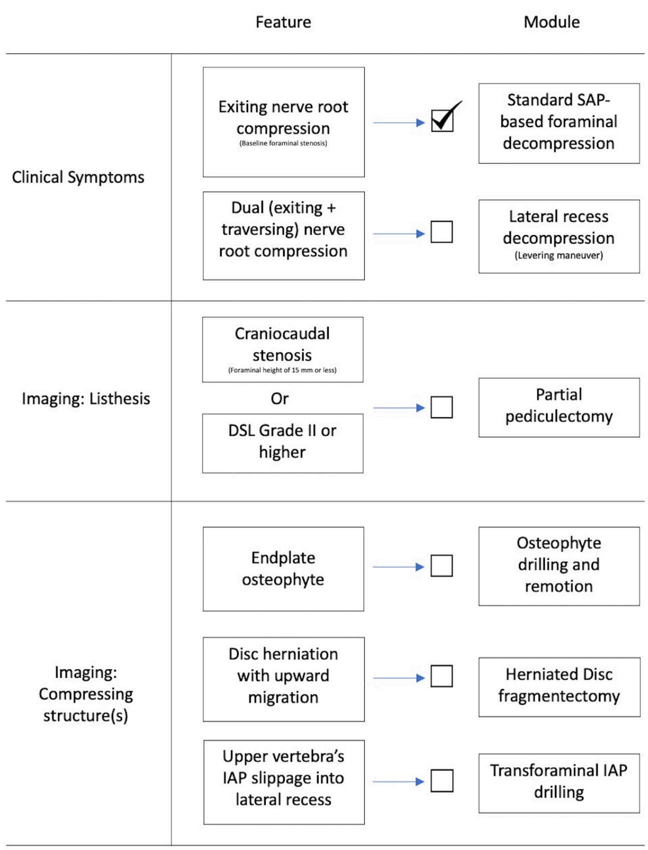

Figure 1. Proposed endoscopic surgical modules. Craniocaudal compression: Foraminal height of 15 mm or less [10].

ligamentum flavum must be removed as well to complete the decompression.

3. Transforaminal Lateral Recess Decompression: Levering Maneuver

Lateral recess decompression can be accomplished both through interlaminar access or transforaminal access [6]. The latter requires a "levering maneuver" that consists in tilting the tip of the endoscope anterior and medial to advance through the previously enlarged foramen into the limits of the lateral recess. An extended resection of the SAP is carried out, and the loosened ligamentum flavum is removed. The resection ends when the traversing nerve root is freed from the axilla of the exiting nerve root (cranial limit) to the inferior pedicle (caudal limit).

4. Partial Pediculectomy

Craniocaudal dimension of the lumbar vertebral foramen can be enlarged by removing the upper portion of the inferior vertebra's pedicle. The starting point to carry out this partial pediculectomy [6] becomes visible after resecting the base of the SAP: From the lateral and superior margin of the pedicle, the drilling with a diamond burr follows a medial and caudal direction until the upper third of the pedicle is resected (caudal limit), and the ligamentum flavum is exposed (medial limit).

5. Osteophyte Resection

Osteophytes arising from superior or inferior vertebrae's endplate can be responsible for ventral foraminal stenosis and contribute to exiting nerve root compression. To safely remove these formations, it is preferable to rotate the working sheath until the bevel is covering and protecting the exiting nerve root. Then, proceed to "cavitate" the osteophyte with a diamond burr, keeping intact the bone layer that is in contact with the nerve root. Finally, with a blunt dissector, gently fracture the remaining thin layer of osteophyte away from the nerve root, as described by Lee et al. [12].

6. Disc Fragmentectomy

Another structure that can cause ventral foraminal stenosis and therefore exiting nerve root compression is a herniated intervertebral disc. The disc fragment can be removed according to the outside-in technique described by Schubert and Hoogland [13], simplified by the previous foraminotomy. However, when dealing with a voluminous disc herniation, an early access to the disc nucleus and a subsequent debulking can ease the resection of the herniated fragment.

7. Transforaminal Inferior Articular Process (IAP) Drilling

In DSL with a Meyerding grade II or higher, the vertebral slippage can cause changes in the pattern of lateral recess compression. Instead of the usual SAP related stenosis observed in non DSL patients, the structure often occupying the lateral recess and therefore compressing the traversing nerve root is the slipped tip of the superior vertebra's IAP. This demands to take the foraminal decompression a step further and include the IAP tip in the drilling plan. According to this, after removing the SAP the endoscope must be advanced medially. Instead of the ligamentum flavum attached to the medial border of the SAP, the IAP will present as a medially situated bony structure that needs to be removed to ensure the complete decompression of the lateral recess. To avoid facet joint injury and instability, IAP

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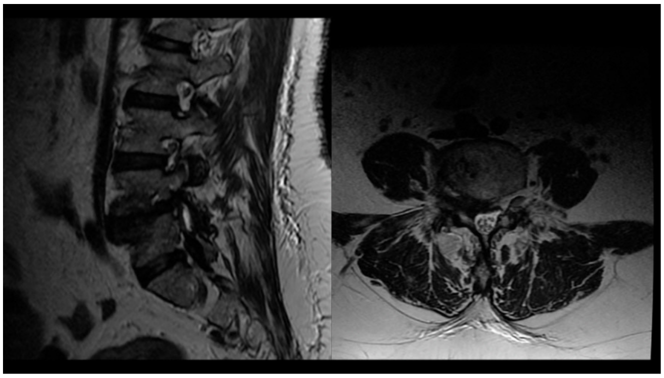

Figure 2. Preoperative MRI showing grade II DSL with right L4-L5 foraminal stenosis.

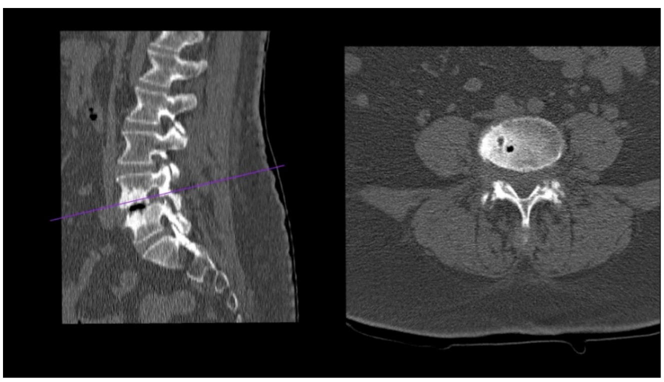

Figure 3. Preoperative CT. L4-L5 disc herniation and osteophytic L5 SAP causing foraminal stenosis.

resection must be stopped as soon as traversing nerve root is freed.

SURGICAL SCENARIOS

1. Lumbar Mono-radiculopathy Caused by Pure Foraminal Stenosis without Cranio-caudal Compression

1) Case Presentation

A 66 year old female patient with right L4 sciatica pain (VAS 9/10) for the past four months, with no response to medication or physical therapy. Mild lumbar pain (VAS 2/10).

MRI showed Grade II DSL with right L4-L5 foraminal stenosis (Figure 2). CT confirmed that compressing structures were L4-L5 disc herniation and L5 SAP (Figure 3).

2) Modules Assemble

According to the clinical and radiological analysis, the surgery was planned with the following modules: (1) Standard SAP-based foraminotomy; (2) Herniated disc fragmentectomy.

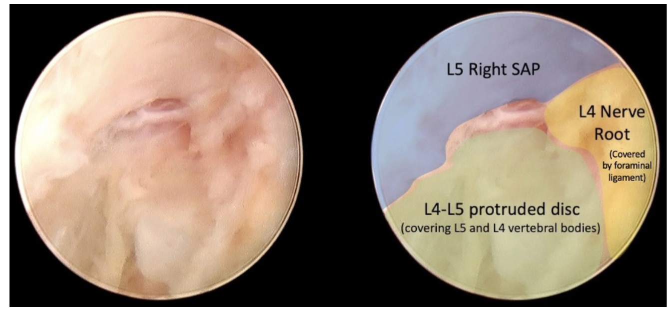

Figure 4. Initial view showing L5 right SAP, L4-L5 protruded disc, and foraminal ligament covering L4 nerve root.

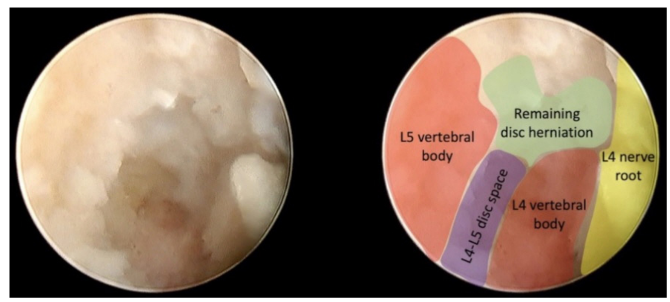

Figure 5. Following the initial remotion of the herniated and migrated disc, L4-L5 disc space comes into view.

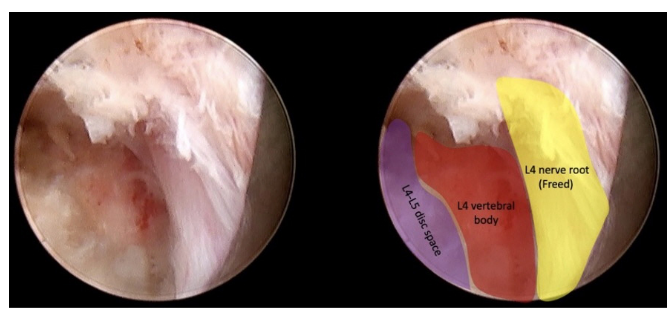

Figure 6. Final view: Released L4 nerve root and dorsal portion of L4 vertebral body where the disc herniation was formerly located.

3) Surgical Technique

An L4-L5 right posterolateral endoscopic access was performed, 8 cm lateral to midline. The working sheath initially landed on L5 SAP (Figure 4).

After drilling L5 SAP, a safe disc remotion was carried out due to the enlarged dimensions of the foramen.

Following the initial remotion of the herniated and migrated disc, L4-L5 disc space came into view, and the slippage between both vertebral bodies became evident (Figure 5).

The final view showed the released L4 nerve root and the dorsal portion of the L4 vertebral body where the disc herniation was formerly located (Figure 6).

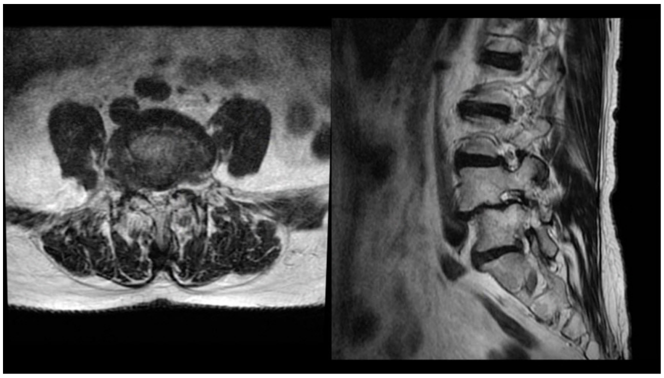

Figure 7. MRI showing Grade II listhesis with L4-L5 right foraminal stenosis.

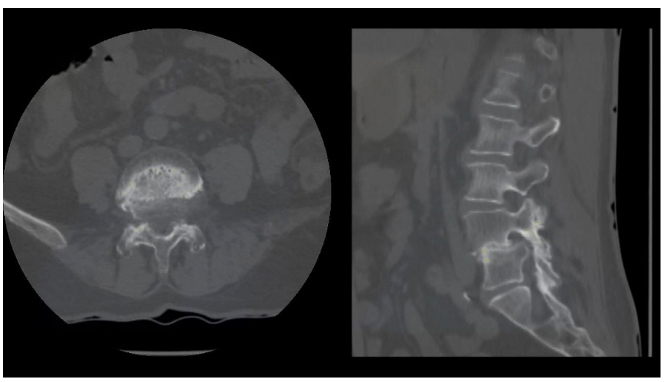

Figure 8. Preoperative CT. Foraminal stenosis caused by L5 superior endplate and osteophyte.

2. Lumbar Mono-radiculopathy Caused by Pure Foraminal Stenosis, with Cranio-caudal Compression

1) *Case Presentation*

A 77 years old female patient with 3 months old right L4 radicular pain. No lumbar pain was present.

MRI and CT scan showed a Grade II listhesis with L4-L5 right foraminal stenosis, mainly caused by L5 superior endplate and osteophyte, with severe craniocaudal compression (Figure 7, 8). Dynamic X-Rays showed stability of the segment.

2) *Modules Assemble*

The surgical plan included the following modules: (1) Standard SAP-based foraminotomy; (2) Osteophyte remotion; (3) Partial pediculectomy.

3) *Surgical Technique*

A right L4-L5 transforaminal approach was performed docking the working sheath on the L5 SAP. Thus, endoscopic navigation started at L5 SAP and following the pedicle approached the L5 endplate.

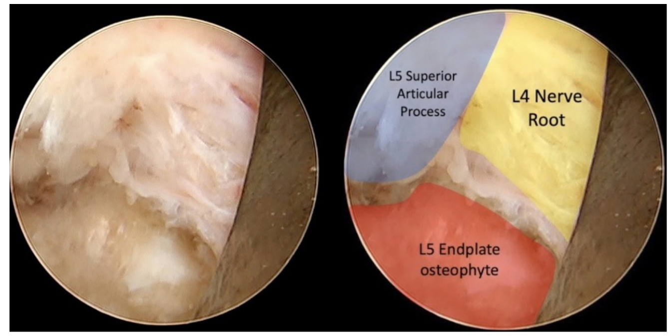

Figure 9. Right L4 nerve root secured by turning the working sheath bevel towards it.

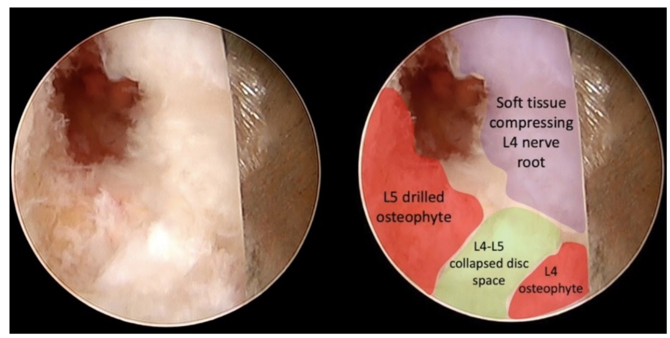

Figure 10. After the L4 osteophyte is removed, the L4-L5 disc space becomes visible.

Once the right L4 nerve root was recognized and secured by turning the working sheath bevel towards it (Figure 9), drilling of the pathological L5 endplate and osteophyte was performed.

The objective was to cavitate the compressing bone and then gently fracture it with a dissector to avoid direct contact of the burr with the nerve root. After the L4 osteophyte is removed, the L4-L5 disc space becomes visible (Figure 10), and the L4 osteophyte can be removed. Finally, partial pediculectomy of the upper portion of L5 pedicle allowed complete craniocaudal decompression.

Finally, soft tissue covering the L4 nerve root was removed (Figure 11) ensuring that a tridimensional decompression was achieved.

Postoperative CT scan showed restitution of cranio-caudal foraminal dimension (Figure 12, 13).

3. Lumbar Dual-radiculopathy from Foraminal and Lateral Recess Stenosis

1) *Case Presentation*

A 66 years old male patient, with an 8 months history of left

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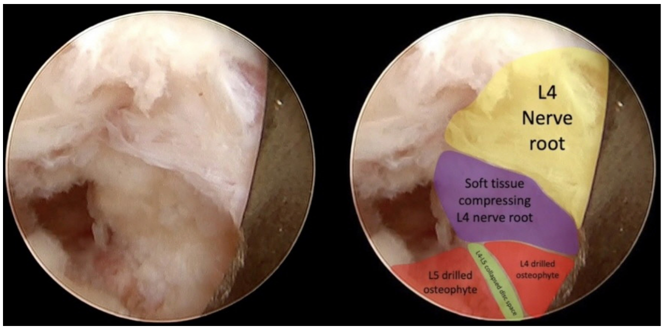

Figure 11. Soft tissue covering the L4 nerve root is removed ensuring that a tridimensional decompression was achieved.

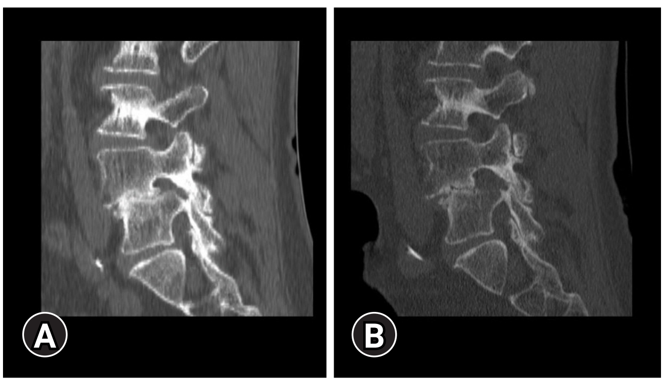

Figure 12. (A) Preoperative CT scan with former foraminal stenosis. (B) Postoperative CT scan showing restitution of cranio-caudal foraminal dimension.

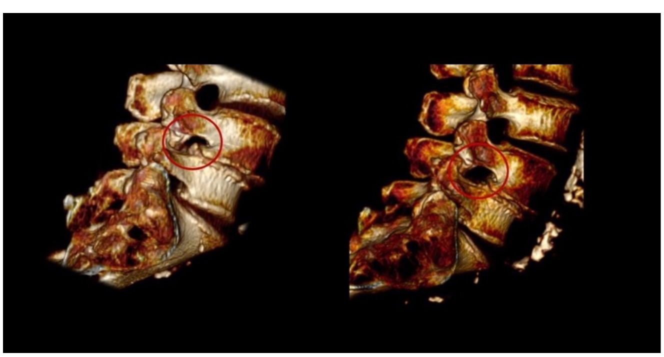

Figure 13. 3D reconstruction of preoperative (left) and postoperative CT scan illustrating the osseus modifications following endoscopic foraminotomy.

sciatica pain. Clinical examination revealed both left L4 and L5 affected territories. MRI showed Grade I DSL with left foraminal and lateral recess stenosis (Figure 14).

CT scan revealed that lateral recess stenosis was attributable to slipped IAP, osteophytic formations and soft disc herniation, and foraminal stenosis was caused mainly by a migrated soft disc herniation (Figure 15).

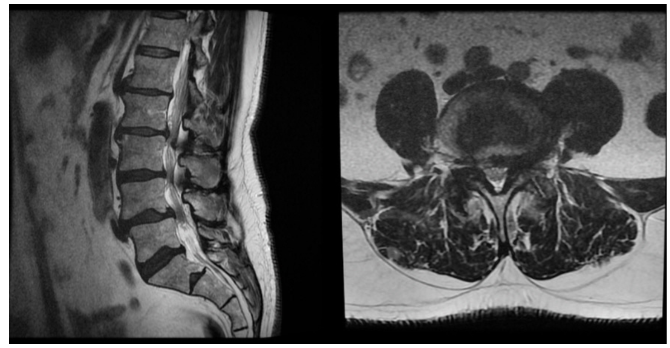

Figure 14. Preoperative MRI showing Grade I DSL with left foraminal and lateral recess stenosis.

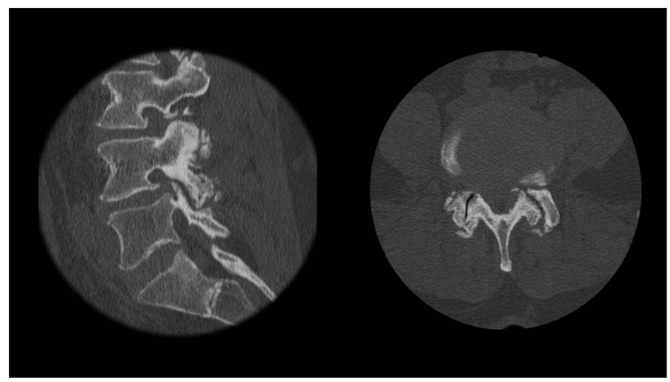

Figure 15. CT scan revealed that lateral recess stenosis was attributable to slipped IAP, osteophytic formations and soft disc herniation, and foraminal stenosis was caused mainly by a migrated soft disc herniation.

2) Modules Assemble

After clinical and imaging studies were reviewed, the surgical strategy included these modules in the following order: (1) Standard SAP-based foraminotomy; (2) Lateral recess decompression (levering maneuver); (3) Transforaminal IAP drilling; (4) Herniated disc fragmentectomy.

3) Surgical Technique

As usual, needle tip was placed on L5 SAP, with the working sheath docked on the facet's surface. Then SAP was drilled under endoscopic visualization and using the levering maneuver, the endoscope was advanced underneath the drilled SAP into the lateral recess and slipped IAP was also drilled ("lateral to medial" rule). Once the ligamentum flavum was exposed, a partial remotion of such structure revealed the compressed L5 nerve root in the lateral recess (Figure 16).

After removing the remaining ligamentum flavum and soft disc herniation in the lateral recess, the traversing nerve root was released (Figure 17).

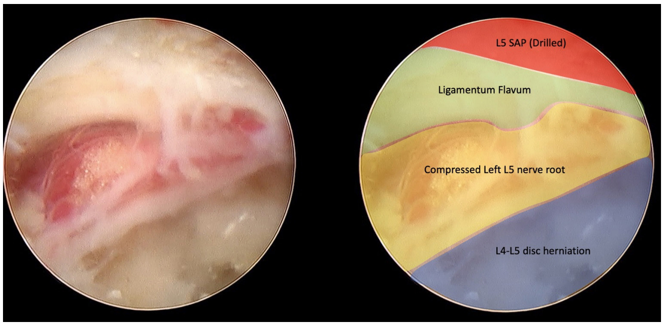

Figure 16. Once the ligamentum flavum is exposed, a partial remotion of such structure reveals the compressed L5 nerve root in the lateral recess.

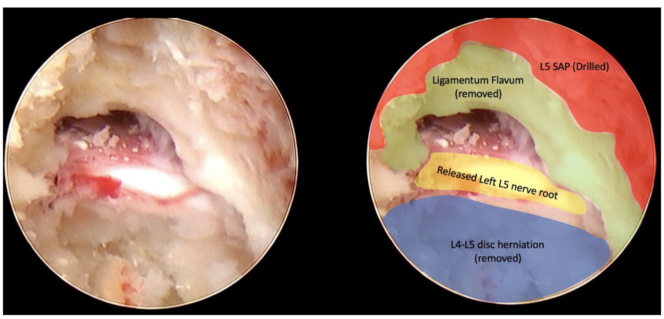

Figure 17. Released traversing nerve root after remotion of ligamentum flavum and disc herniation.

Finally, following the "caudal to cranial" rule, the endoscope is moved laterally to the foraminal zone. A careful navigation towards the cranial portion of the foramen allows the removal of the remaining disc herniation to decompress the exiting L4 nerve root.

DISCUSSION

DSL affects 5%–10% of the adult population worldwide. In elderly populations (>65 years) can reach an overall prevalence of 19.1% and 25% for men and women respectively [14]. It is usually classified by Meyerding in five grades [15], according to the degree of slippage of the vertebral bodies. Despite being commonly associated with instability, DSL rarely exceeds Meyerding's grade II [3]: As disc height decreases and facet degenerative changes advance, DSL naturally evolves to stability. But even as natural fixation is achieved, slippage can produce foraminal and/or lateral recess stenosis with subsequent nerve root compression. According to the SPORT study results, radicular pain is greater or at least equal to back pain in 74% of cases of DSL [16].

Radicular symptoms often motivate surgical interventions to alleviate neuropathic pain: as open approaches disrupt the osteo-muscular and ligament structures that maintain spine stability, the most commonly used surgical approach involves decompression and instrumentation [17]. In other words, despite DSL being a stable pathology, open surgery causes potential instability that motivates instrumentation.

In this setting, full endoscopic techniques can provide a surgical approach that effectively decompresses the neural structures while preserving stability and avoiding instrumentation.

Endoscopic foraminotomy techniques were developed in the early 2000s to treat foraminal stenosis in non-listhetic segments [18]. Technological and technical improvements allowed to increase the effectiveness of decompression and expand the approach to other pathologies [11]. However, anatomical changes associated with DSL still represent a major challenge to the endoscopic surgeon.

In this paper, we presented a module-based approach to plan and execute a transforaminal endoscopic foraminotomy in patients with DSL. Three of the most common scenarios encountered were provided as case examples.

To correctly select and assemble the surgical modules, the endoscopic surgeon must answer three main questions:

1. Which is the nerve root(s) responsible for the patient's symptoms?
2. Where is that nerve root(s) compressed?
3. Which structure(s) is responsible for the compression?

Conducting a thorough clinical examination to identify the neural structure that is causing the symptoms is of paramount relevance in this setting: DSL is usually accompanied by other degenerative changes in the lumbar spine, and clinical-radiological dissociation is frequent: multiple stenotic segments may be evident in MRI or CT scans, but the clinical manifestations usually are more limited. In cases when the clinical manifestations are elusive, selective nerve root blocks can help in the diagnosis of the pain generator [19].

In the same way, slippage and degenerative changes present in DSL change the usual pattern of foraminal stenosis seen in non-listhetic patients: exiting nerve root can be compressed by vertebrae endplates, osteophytes, and/or disc herniations. Likewise, in cases when foraminal stenosis is combined with lateral recess stenosis, the responsible structure of the latter usually is superior vertebra IAP. These modifications demand a more refined and targeted endoscopic decompression, as well as a final revision to ensure that the nerve root has been freed

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in all three dimensions.

Full endoscopic surgery in degenerative listhesis. The evidence so far: Biomechanical studies have shown that transforaminal partial facetectomy has minimal impact on the biomechanics of the lumbar spine [20], and even the total endoscopic removal of the facet joint has less consequences than open laminectomy [21].

Specifically in patients with DSL and stenosis, the concept that decompression without fusion can be advantageous has been established in the spinal surgery community for several years. Minimally invasive spine surgery such as tubular techniques, or even open surgery approaches to the lumbar spine have proven to be successful in managing stenosis in patients suffering DSL without fusing or compromising spinal stability [22]. This notion motivated the hypothesis that, being endoscopic spine surgery a less invasive method than open surgery, endoscopic decompression would be effective in patients with lumbar stenosis and concomitant DSL. Starting in 2015, Yeung published a series of level 4 and level 5 evidence-based medicine opinion articles about the author's experience with endoscopic foraminotomy in patients with DSL [23-26]. Despite lacking methodological rigor and statistical analysis, the richness of the texts illustrates the rationale behind the author's experience.

Nevertheless, high-level evidence respecting endoscopic foraminotomy in degenerative listhesis is limited. Published papers about this specific topic include mainly case reports and case series with short follow-up periods. A recently published systematic review and meta-analysis regarding endoscopic lumbar foraminotomy included only 14 studies with a total of 600 patients (without taking into consideration case reports) [27]. Of those 14 studies, only one included patients with spondylolisthesis [18].

The terminology barrier: The evidence concerning endoscopic lumbar foraminotomy is not only scarce but also severely fragmented into multiple terms for similar, if not the same, procedures. Foraminoplasty, foraminotomy and transforaminal decompression often relate to the same surgical goal: visualize and decompress the exiting nerve root passing through the foramen. To homogenize this and others multiple terms, in 2020 a "Global Consensus Paper on Nomenclature for Working-Channel Endoscopic Spinal Procedures" was published [28], suggesting to unify all the previous denominations under "Transforaminal Endoscopic Lumbar Foraminotomy". However, this process will only affect future publications and is expected to take several years to complete. For that reason, when conducting literature search regarding this topic it is advisable to include multiple terms.

For example, Cheng et al. [29] presented in 2020 a case series of 40 consecutive patients with DSL who underwent transforaminal endoscopic decompression (transforaminal endoscopic lumbar foraminotomy). Follow-up period ranged from 12 to 24 months, with 87.5% of patients achieving a good-to-excellent outcome according to modified MacNab criteria. Interestingly, the vertebral slippage before surgery and after follow-up period was not significantly different. This study and its conclusions was not included in endoscopic foraminotomy meta-analysis because the terminology used to describe the procedure eluded the database search.

CONCLUSIONS

Transforaminal lumbar endoscopic foraminotomy represents a minimally invasive technique to treat foraminal and combined foraminal-lateral recess stenosis. DSL and its multiple scenarios represent a challenge to the endoscopic surgeon. Module-based approach can help systematize and execute these demanding endoscopic procedures. Due to its muscle, facet joint and ligament sparing nature, case series suggest that it would not alter segmental stability in patients with degenerative spondylolisthesis. However, powerful and well-designed studies are needed to accurately prove this statement.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Junghanns H. Spondylolisthesen ohne Spalt im Zwischengelenkstück. Arch orthop Unfall-Chir 1931 29:118–127. German
2. Wiltse LL. Classification, terminology and measurements in spondylolisthesis. Iowa Orthop J 1981;1:52–57.
3. Wang YXJ, Káplár Z, Deng M, Leung JCS. Lumbar degenerative spondylolisthesis epidemiology: a systematic review with a focus on gender-specific and age-specific prevalence. J Orthop Translat 2016;11:39–52.
4. Cinotti G, Postacchini F, Fassari F, Urso S. Predisposing factors in degenerative spondylolisthesis. A radiographic and CT study. Int Orthop 1997;21:337–342.
5. Rampersaud YR, Fisher C, Yee A, Dvorak MF, Finkelstein J, Wai E, et al. Health-related quality of life following decompression compared to decompression and fusion for degenerative lumbar spondylolisthesis: a Canadian multicentre

study. Can J Surg 2014;57:E126–E133.
6. Ahn Y, Keum HJ, Lee SG, Lee SW. Transforaminal endoscopic decompression for lumbar lateral recess stenosis: an advanced surgical technique and clinical outcomes. World Neurosurg 2019;125:e916–e924.
7. Hasan S, McGrath LB, Sen RD, Barber JK, Hofstetter CP. Comparison of full-endoscopic and minimally invasive decompression for lumbar spinal stenosis in the setting of degenerative scoliosis and spondylolisthesis. Neurosurg Focus 2019;46:E16.
8. Komp M, Hahn P, Oezdemir S, Giannakopoulos A, Heikenfeld R, Kasch R, et al. Bilateral spinal decompression of lumbar central stenosis with the full-endoscopic interlaminar versus microsurgical laminotomy technique: a prospective, randomized, controlled study. Pain Physician 2015;18:61–70.
9. Yoshikane K, Kikuchi K, Okazaki K. Lumbar endoscopic unilateral laminotomy for bilateral decompression for lumbar spinal stenosis provides comparable clinical outcomes in patients with and without degenerative spondylolisthesis. World Neurosurg 2021;150:e361–e371.
10. Lee S, Lee JW, Yeom JS, Kim KJ, Kim HJ, Chung SK, et al. A practical MRI grading system for lumbar foraminal stenosis. AJR Am J Roentgenol 2010;194:1095–1098.
11. Ahn Y, Oh HK, Kim H, Lee SH, Lee HN. Percutaneous endoscopic lumbar foraminotomy: an advanced surgical technique and clinical outcomes. Neurosurgery 2014;75:124–133; discussion 132.
12. Lee HY, Ahn Y, Kim DY, Shin SW, Lee SH. Percutaneous ventral decompression for L4-L5 degenerative spondylolisthesis in medically compromised elderly patients: technical case report. Neurosurgery 2004;55:435.
13. Schubert M, Hoogland T. Die transforaminale endoskopische Nukleotomie mit Foraminoplastik bei lumbalen Bandscheibenvorfällen. Oper Orthop Traumatol 2005 17:641–661. German
14. He LC, Wang YX, Gong JS, Griffith JF, Zeng XJ, Kwok AW, et al. Prevalence and risk factors of lumbar spondylolisthesis in elderly Chinese men and women. Eur Radiol 2014;24:441–448.
15. Koslosky E, Gendelberg D. Classification in brief: the Meyerding classification system of spondylolisthesis. Clin Orthop Relat Res 2020;478:1125–1130.
16. Pearson A, Blood E, Lurie J, Abdu W, Sengupta D, Frymoyer JW, et al. Predominant leg pain is associated with better surgical outcomes in degenerative spondylolisthesis and spinal stenosis: results from the Spine Patient Outcomes Research Trial (SPORT). Spine (Phila Pa 1976) 2011;36:219–229.
17. Kepler CK, Vaccaro AR, Hilibrand AS, Anderson DG, Rihn JA, Albert TJ, et al. National trends in the use of fusion techniques to treat degenerative spondylolisthesis. Spine (Phila Pa 1976) 2014;39:1584–1589.
18. Ahn Y, Lee SH, Park WM, Lee HY. Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note. J Neurosurg 2003;99:320–323.
19. Eckel TS, Bartynski WS. Epidural steroid injections and selective nerve root blocks. Tech Vasc Interv Radiol 2009;12:11–21.
20. Li XR, Yu J, Zhang W, Gao GM, Han L, Chen L, et al. Biomechanical model study of the effect of partial facetectomy on lumbar stability under percutaneous endoscopy. World Neurosurg 2020;139:e255–e264.
21. Matsumoto K, Shah A, Kelkar A, Parajuli D, Sudershan S, Goel VK, et al. Biomechanical evaluation of a novel decompression surgery: transforaminal full-endoscopic lateral recess decompression (TE-LRD). N Am Spine Soc J 2020;5:100045.
22. Austevoll IM, Hermansen E, Fagerland MW, Storheim K, Brox JI, Solberg T, et al. Decompression with or without fusion in degenerative lumbar spondylolisthesis. N Engl J Med 2021;385:526–538.
23. Yeung AT. Moving away from fusion by treating the pain generator: the secrets of an endoscopic master. J Spine 2015; 4:e121.
24. Yeung AT. Endoscopic decompression, foraminalplasty and dorsal rhizotomy for foraminal stenosis and lumbar spondylosis: a hybrid procedure in lieu of fusion. J Neurol Disord 2016;4:322.
25. Yeung A, Kotheeranurak V. Transforaminal endoscopic decompression of the lumbar spine for stable isthmic spondylolisthesis as the least invasive surgical treatment using the YESS Surgery technique. Int J Spine Surg 2018;12:408–414.
26. Yeung AT. The evolution and advancement of endoscopic foraminal surgery: one surgeon's experience incorporating adjunctive techologies. SAS J 2007;1:108–117.
27. Giordan E, Billeci D, Del Verme J, Varrassi G, Coluzzi F. Endoscopic transforaminal lumbar foraminotomy: a systematic review and meta-analysis. Pain Ther 2021;10:1481–1495.
28. Hofstetter CP, Ahn Y, Choi G, Gibson JNA, Ruetten S, Zhou Y, Let al. AOSpine consensus paper on nomenclature for working-channel endoscopic spinal procedures. Global Spine J 2020;10:111S–121S.
29. Cheng XK, Cheng YP, Liu ZY, Bian FC, Yang FK, Yang N, et al. Percutaneous transforaminal endoscopic decompression for lumbar spinal stenosis with degenerative spondylolisthesis in the elderly. Clin Neurol Neurosurg 2020;194:105918.

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Minimally Invasive versus Conventional Lumbar Interbody Fusion at L5–S1: A Retrospective Comparative Study

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Objective: This study aimed to evaluate the radiologic and clinical outcomes of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) and conventional posterior lumbar interbody fusion (PLIF) at the L5–S1.

Methods: We retrospectively reviewed patients who underwent posterior lumbar fusion (MIS-TLIF and PLIF) at only the L5–S1 and were followed up for more than 12 months. Age, sex, body mass index (BMI), bone mineral density (BMD), diagnosis, comorbid conditions, fusion rate, perioperative results, and pre- and postoperative radiographic parameters at the L5–S1 level, pelvic parameters and degree of spondylolisthesis, and clinical results were analyzed.

Results: A total of 102 patients (46 male, 56 female) with a mean age of 57.1 years were evaluated. Fifty and fifty-two patients underwent MIS-TLIF and PLIF surgeries, respectively. Radiologic parameters increased from their preoperative measures at the last follow-up study; similarly, there were no intergroup differences. The fusion rates in the MIS-TLIF and PLIF groups were 86% and 82.7%, respectively. The subsidence rates in the MIS-TLIF and PLIF groups were 6% and 3.8%, respectively. There was no intergroup difference in terms of fusion rate and subsidence. Clinical outcomes also gradually improved after surgery in both groups without intergroup differences.

Conclusion: In L5–S1 posterior spinal surgery, there was no significant difference between MIS-TLIF and conventional PLIF. Considering the operation time and estimated blood loss, MIS-TLIF is more effective than PLIF surgery in terms of postoperative health care and economics.

Key Words: Spinal fusion, Lumbar vertebrae, Sacral vertebrae, Minimally invasive surgery

INTRODUCTION

Transforaminal lumbar interbody fusion (TLIF) was introduced by Harms and Rolinger [1] in 1982 and has been still widely used until recently. TLIF usually approaches the disc space through one-sided facetectomy, which has the advantage of reducing tissue damage and thecal sac retraction. Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF)

uses a tubular retractor and percutaneous pedicle screw fixation system to reduce the requirement of skin incisions, blood loss, and postoperative pain, thereby reducing the duration of hospital stay [2-4].

MIS-TLIF has many such advantages for patients, but some surgeons doubt its usefulness at the L5–S1. Structures containing the L5–S1 have been of particular interest because of their unique anatomy, the transition from the movable segment to the stationary segment, which results in higher mechanical stress and loads compared to other segments of the lumbar spine [5,6]. For this reason, several studies have revealed that the fusion rate of L5–S1 is lower than that of other lumbar segments [7-9]. Although many studies have examined the clinical and functional outcomes of conventional posterior lumbar interbody fusion (PLIF) surgery between L5–S1 level and other lumbar levels, none have compared radiologic and clinical outcomes and fusion rates between MIS-TLIF and conventional PLIF limited to the L5–S1.

This study aimed to evaluate the radiologic and clinical outcomes of MIS-TLIF and conventional PLIF at the L5–S1. This research question was based on how the unique structure of L5–S1 affects the union of MIS-TLIF and conventional PLIF. Therefore, it is necessary to examine patients' radiologic parameters and functional outcomes. We hypothesize that fusion rates after MIS-TLIF and PLIF were equivalent in L5-S1 level.

MATERIALS AND METHODS

1. Patients

This retrospective study was performed at a single institution. A total of 580 consecutive patients who underwent posterior lumbar fusion (69 MIS-TLIF, 511 conventional PLIF) at only the L5–S1 level were enrolled. The inclusion criteria were as follows: 1) age>18 years; 2) symptomatic spinal stenosis, spondylolisthesis, or herniated lumbar disc disease; 3) at least 12 months of follow-up; and 4) underwent postoperative computed tomography (CT) to confirm fusion. Patients with tumors, infection, trauma, or multilevel fusion were excluded. Two-hundred-and-eighty-five patients were excluded from our study because they underwent multi-level surgery or were lost to follow-up. The first cohort of 50 patients with MIS-TLIF was matched with 52 patients from the group with conventional PLIF surgery. All patients were matched with a patient of the sex, age and diagnosis. Then we had two matched cohorts (I and II) of 50 and 52 patients, respectively (Figure 1).

These patients underwent mono-segmental posterior lumbar interbody fusion at L5–S1 using MIS-TLIF (Figure 2A) or conventional PLIF (Figure 2B) with a screw and double rod system and a polyetheretherketone (PEEK) cage with a 10° lordotic angle according to the different surgical methods performed by one different senior surgeon with more than 10 years' surgical experience. All patients underwent CT and radiography before surgery and at least 1 year after surgery. This study was reviewed and approved by our local institutional review board (IRB No: 3-2021-0378).

2. Surgical Procedure

MIS-TLIF is performed through a standard 2–3 cm paramedian approach, with the patient in the prone position. Using a tubular retractor (METRx®; Medtronic Sofamor Danek, Memphis, TN, USA), the incisions were opened one after the other and a 24-mm working channel was inserted. A facetectomy was performed on the unilateral side. The ascending and descending articular processes were removed using an osteotome and drill. The foraminotomy was performed unilaterally or bilaterally according to the patient's symptoms. Complete discectomy and end plate preparation were performed using pituitary rongeurs and curettes. After discectomy, autologous bone from the laminectomy filled the disc space. A single lordotic PEEK cage (Capstone; Medtronic Sofamor Danek) which was filled with only autologous local bone fragment were inserted into the disc space. Then, a percutaneous pedicle screw and rod system (Sextant; Medtronic Sofamor Danek) were inserted under C-arm fluoroscopic images [10].

Conventional PLIF was performed through a midline approach in the prone position. Laminectomy and bilateral medial facetectomy were performed using a Carrison rongeur and drill. Complete discectomy and endplate preparation were performed as in MIS-TLIF. Two PEEK cages (Concorde; Dupey Synthes, West Chester, PA, USA) was filled with autologous bone and inserted into the disc space. Subsequently, bilateral pedicle screw and rod fixation (CD Horizon Legacy; Medtronic Sofamor Danek) was performed [11].

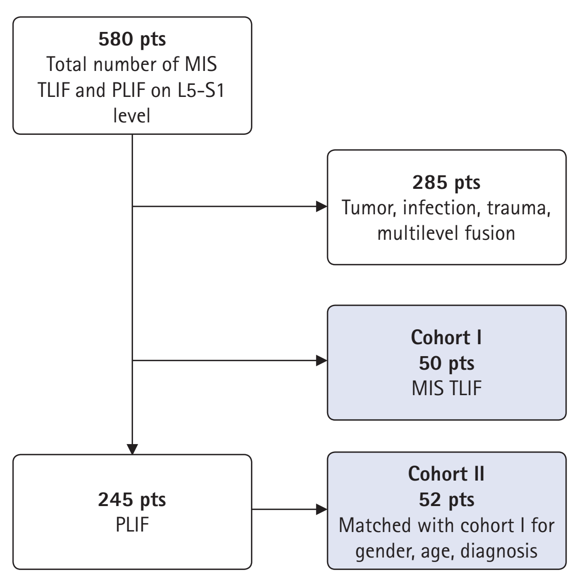

Figure 1. Flowchart of the patient selection process. MIS-TLIF: minimally invasive transforaminal interbody fusion, PLIF: posterior lumbar interbody fusion.

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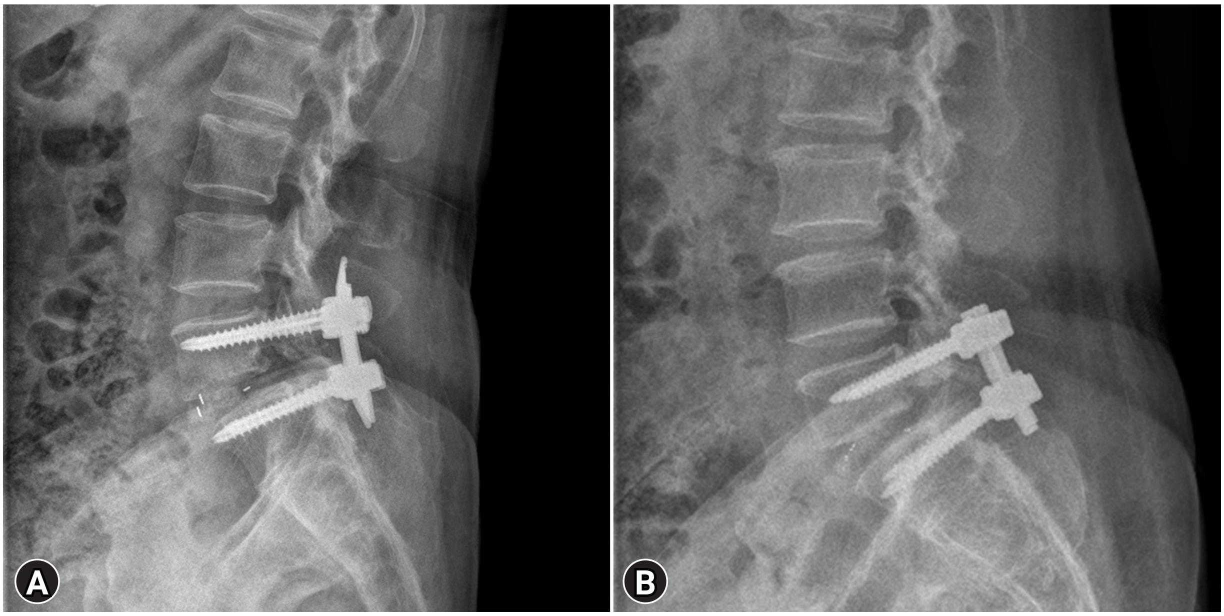

Figure 2. Lumbar spine lateral radiographs (A) showing the posterior lumbar interbody fusion at L5–S1 using MIS-TLIF and (B) showing the conventional PLIF.

3. Radiographic Assessment

Radiological evaluation was performed using plain radiography (standing lumbosacral anteroposterior, lateral, flexion, extension, whole spine anteroposterior, and lateral) and CT scans preoperatively, immediately postoperatively, and at 12 months postoperatively. Disc height (DH), disc slope angle (DSA), disc angle (DA), segmental lordotic angle (SLA) at the L5– S1 level, pelvic parameters, and degree of spondylolisthesis were measured using X-ray scanning.

The DH measured the distance between the L5 lower endplate and the S1 upper endplate, which is measured as the sum of a line drawn in the middle between the endplates and a vertical line drawn from the corners of the upper and lower segmental vertebrae, then divided in half (Figure 3) [12]. The DA was the angle between the L5 lower endplate and the S1 upper endplate. DSA was defined as the angle between the horizontal line and the line connecting the midpoint between the anterior and posterior disc spaces [7]. The SLA was measured in degrees between the L5 upper endplate and the S1 upper endplate (Figure 4). Pelvic parameters included the lumbar lordotic angle (LL), pelvic incidence (PI), pelvic tilt, PT, and sacral slope (SS). The degree of spondylolisthesis was measured as the percentage of the distance between the posterior border of the L5 vertebra and the posterior border of the rostral vertebra.

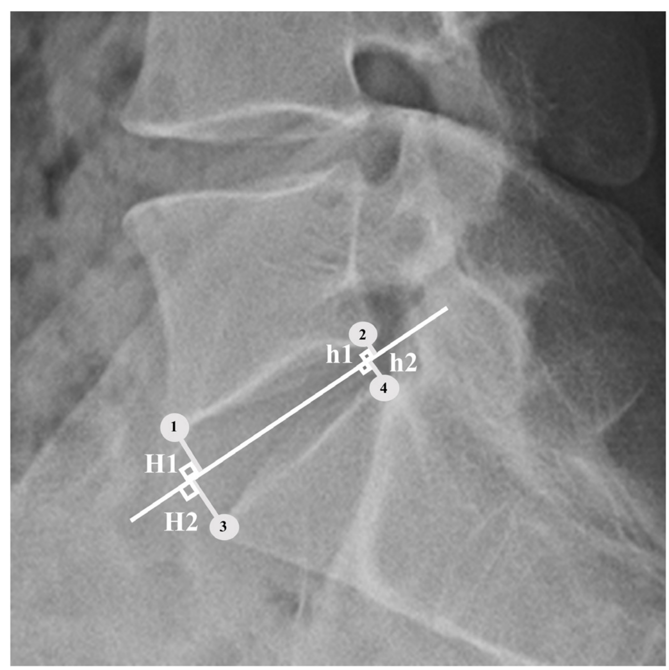

Figure 3. Disc height measurement according to the Frobin method. The four corners of the vertebral segments are designated on the lateral radiographs (1, 2, 3, 4). The medial point, medial plane (median line), and its bisector are shown. Disc height is the sum of the lines perpendicular to the bisector from the corners of the upper and lower segmental vertebrae divided in half. Disc height=(H1+H2+h1+h2)/2.

Bony fusion, cage subsidence, and hardware failure were assessed on CT. Lumbar spine CT scan was performed preoperatively and at 12 months postoperatively. The modified Bridwell fusion criteria [13,14] were also measured on CT scans. Using

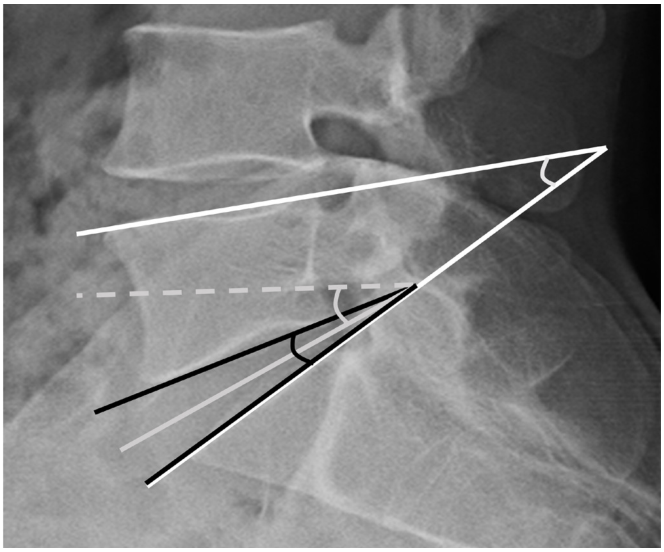

Figure 4. Overview of the radiographic parameters. Disc angle (DA): angle between the L5 lower endplate and the S1 upper endplate (black line). Disc slope angle (DSA): angle between the horizontal line and the line connecting the midpoint between the anterior and posterior of disc spaces (gray line). Segmental lordotic angle (SLA): angle between the L5 upper endplate and the S1 upper endplate (white line).

these criteria, the fusion rate could be defined as follows: grade 1, fused with remodeling and trabeculae present; grade 2, graft intact, not fully remodeled and incorporated, but no lucency present; grade 3, graft intact, potential lucency present at the graft's top and bottom; and grade 4, fusion absent, with graft collapse/resorption. Therefore, fusion was identified when grade 1 or 2 was accepted through these criteria. Subsidence means that the disc height was lowered by 2 mm or more in the follow-up plain lateral X-ray scan.

4. Functional Evaluation

Demographic and baseline data included the number of patients, sex, age at surgery, postoperative outpatient follow-up duration, body mass index (BMI), bone mineral density (BMD), primary diagnosis, and comorbid conditions such as diabetes mellitus and smoking status were recorded. Operation time, estimated blood loss, and length of hospital stay were also assessed from the patients' hospital records. We used the visual analog scale (VAS) and the Oswestry Disability Index (ODI) to compare the MIS-TLIF and PLIF groups preoperatively, immediately postoperatively, and at 1 year postoperatively.

5. Statistical Analysis

The statistical analysis was performed using SPSS version 25.0 software (IBM Corporation, Armonk, NY, USA). All continuous data are presented as mean and standard deviation and were tested for normal distribution using the Kolmogorov–Smirnov test. Differences in baseline data and radiologic parameters were analyzed using the t-test or the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables. Statistical significance was set at $p<0.05$.

RESULTS

1. Patients Demographics

A total of 102 patients (50 in the MIS-TLIF group, 52 in the PLIF group) were included in the study. The patients' demographic characteristics are shown in Table 1. The mean age at surgery (57.00 vs. 57.17 years; p=0.929) and mean follow-up duration (23.42 vs. 22.37 months; p=0.791) did not differ significantly between groups. The BMI (25.02 vs. 25.06 kg/m2; p=0.945) and BMD (–1.55 vs. –1.41; p=0.591) were also comparable. In both group, isthmic spondylolisthesis was the main pathology (20/50 [44%] and 22/50 [42.3%]).

2. Radiologic Outcomes

All radiologic parameters are presented in Table 2. Radiologic parameters were evaluated using the preoperative, immediately postoperative, and 12 months postoperative plain radiographs as mentioned above. The pre- and postoperative DH did not differ significantly between the two groups immediately postoperatively or at 12 months postoperatively. DA and DSA did also not differ significantly between the two groups in the preoperative and postoperative states. However, the SLA of L5–S1 was 16.5° and 18.34° in the MIS-TLIF group and 13.95° and 17.10° in the PLIF group pre-and postoperatively, respectively. There was a significantly difference between the preoperative SLA of L5–S1 (p=0.047).

LL and SS increased slightly after surgery in both groups, but the difference was not significant. There was no significant difference in pre- or postoperative PI in either group. PT decreased slightly after surgery; however, there was no significant difference in either group. The pre- and postoperative values of the spondylolisthesis rate in patients with both degenerative and isthmic spondylolisthesis were reduced, and there was no

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Table 1. Patients' demographic and baseline data

Characteristic	Total	MIS-TLIF	PLIF	p-value
Number of patients	102	50	52	
Sex (%)				0.975*
Female	43 (42.2)	21 (42)	22 (42.3)	
Male	59 (57.8)	29 (58)	30 (57.7)	
Age at surgery (yr)	57.09 ± 9.28	57.00 ± 10.1	57.17 ± 9.36	0.929
Follow-up period (mo)	22.88 ± 19.99	23.42 ± 20.68	22.37 ± 19.46	0.791
Body mass index (kg/m^2)	25.04 ± 3.21	25.02 ± 2.62	25.06 ± 3.72	0.945
Bone mineral density (T-score)	−1.47 ± 1.05	−1.55 ± 1.00	−1.41 ± 1.09	0.591
Diagnosis (%)				1.000*
Foraminal stenosis	24 (23.5)	12 (24)	12 (23.1)	
Central stenosis	6 (5.9)	3 (6)	3 (5.8)	
Degenerative spondylolisthesis	16 (15.7)	8 (16)	8 (15.4)	
Isthmic spondylolisthesis	42 (41.2)	20 (40)	22 (42.3)	
Massive lumbar disc herniation	14 (13.7)	7 (14)	7 (13.5)	
Comorbid conditions				
Diabetes mellitus	13	8	5	0.334*
Smoking status (%)	22 (21.6)	13 (26)	9 (17.3)	0.286*

MIS-TLIF: minimally invasive transforaminal lumbar interbody fusion, PLIF: posterior lumbar interbody fusion.
*chi-square test.

significant intergroup difference.

Table 3 shows the perioperative results and fusion rates of the two groups. Regarding perioperative outcomes, the operation time and the estimated blood loss were significantly lower in the MIS-TLIF group (MIS-TLIF: 101.92 min, 164.8 mL vs. PLIF: 172.27 min, 675.38 mL; p<0.001). There was no significant intergroup difference in the length of hospital stay (MIS-TLIF, 11.14 vs. PLIF, 12.63 days; p=0.285). The fusion rate was analyzed using the modified Bridwell fusion criteria. The fusion rate of the MIS-TLIF group was 86%, while that of the PLIF group was 82.7%. Cage subsidence was observed in 6% (3/50) of the patients with MIS-TLIF and 3.8% (2/52) of PLIF patients. However, there were no statistically significant intergroup differences.

3. Functional Outcomes

The mean VAS scores notably decreased in both groups from 5.94±2.24 preoperative to 2.50±1.49 immediately postoperatively and 1.52±1.73 at 12 months postoperatively in the MIS-TLIF group, and from 5.81±2.11 preoperatively to 2.15±1.90 immediately postoperatively and 1.92±1.88 at 12 months postoperatively in the PLIF group, respectively. The perioperative mean VAS score in both groups improved significantly, and there was no intergroup difference. Likewise, there were significant improvements in the ODI in both groups: from 41.41±13.51 preoperatively to 24.68±9.29 immediately postoperatively and 16.32±8.90 at 12 months postoperatively in the MIS-TLIF group, and from 48.27±13.31 preoperatively to 27.87±9.37 immediately postoperatively to 20.13±7.15 at 12 months postoperatively in the PLIF group. There were no significant intergroup differences.

DISCUSSION

Minimally invasive spinal fusion surgery has been widely used for the treatment of lumbar degenerative diseases, with many advances. MIS-TLIF uses a tubular retractor localized in the paraspinal area to prevent excessive muscle destruction. Additionally, unlike PLIF, MIS-TLIF does not require dural or nerve root over retraction, reduces dural damage, and can reduce intraoperative bleeding with smaller incisions than in conventional PLIF [3,10,15]. As it is possible to increase the foraminal height through removal of the facet complex, foraminal stenosis is also a suitable indication for MIS-TLIF. In addition, as reported in many other studies, MIS-TLIF is preferred for degenerative and isthmic spondylolisthesis [16-18]. The L5–S1 is one of the most affected levels of spondylolisthesis, especially in patients with isthmic spondylolisthesis. In our study, the fusion rate of L5–S1 was 86% in the MIS-TLIF group and 82.7% in the PLIF group, which was similar to the results of previous studies but lower than that of other lumbar levels. Ito et al. [19]

Table 2. Patients' radiological parameters by group

Parameter	MIS-TLIF	PLIF	p-value
Disc height (mm)			
Preoperative	9.00 ± 2.74	8.78 ± 2.94	0.701
Immediately postoperative	11.90 ± 1.53	12.42 ± 2.00	0.147
Last follow-up	11.00 ± 1.64	11.64 ± 1.85	0.067
Disc angle (°)			
Preoperative	3.90 ± 2.38	4.45 ± 2.33	0.249
Immediately postoperative	5.07 ± 2.07	5.45 ± 2.23	0.386
Last follow-up	4.85 ± 2.08	5.51 ± 2.04	0.110
Disc slope angle (°)			
Preoperative	29.68 ± 8.75	27.17 ± 9.95	0.180
Immediately postoperative	27.03 ± 9.57	27.18 ± 9.78	0.936
Last follow-up	24.72 ± 11.43	27.90 ± 9.90	0.136
Segmental lordotic angle of L5–S1 (°)			
Preoperative	16.50 ± 7.09	13.95 ± 5.70	0.047*
Immediately postoperative	19.34 ± 5.07	17.96 ± 6.65	0.242
Last follow-up	18.34 ± 5.55	17.10 ± 6.15	0.288
Lumbar lordosis (°)			
Preoperative	33.57 ± 12.64	30.39 ± 14.09	0.234
Immediately postoperative	33.19 ± 11.67	30.10 ± 12.44	0.199
Last follow-up	35.59 ± 13.73	35.47 ± 14.23	0.965
Pelvic incidence (°)			
Preoperative	49.89 ± 12.67	49.57 ± 11.36	0.894
Immediately postoperative	48.44 ± 11.43	48.36 ± 11.13	0.971
Last follow-up	49.97 ± 11.81	49.64 ± 11.80	0.888
Pelvic tilt (°)			
Preoperative	16.79 ± 10.52	17.27 ± 7.59	0.790
Immediately postoperative	16.00 ± 8.40	14.78 ± 7.68	0.445
Last follow-up	15.06 ± 8.80	15.80 ± 6.81	0.635
Sacral slope (°)			
Preoperative	33.21 ± 8.93	31.49 ± 9.19	0.342
Immediately postoperative	32.05 ± 9.50	32.72 ± 9.28	0.720
Last follow-up	34.82 ± 8.52	33.84 ± 9.26	0.581
Spondylolisthesis rate (%)			
Preoperative	20.17 ± 10.05	22.44 ± 8.72	0.366
Immediately postoperative	8.24 ± 5.62	8.95 ± 7.94	0.701
Last follow-up	10.01 ± 5.93	10.51 ± 7.69	0.790

MIS-TLIF: minimally invasive transforaminal lumbar interbody fusion, PLIF: posterior lumbar interbody fusion.
*p<0.05, statistically significant difference.

Table 3. Patients' perioperative results and fusion rates by group

Parameter	MIS-TLIF (n = 50)	PLIF (n = 52)	p-value
Operation time (min)	101.92 ± 21.18	172.27 ± 41.31	< 0.001*
Estimated blood loss (mL)	164.8 ± 175.60	675.38 ± 360.01	< 0.001*
Length of hospital stay (d)	11.14 ± 8.34	12.63 ± 5.46	0.285
Fusion rate (%)	43/50 (86)	43/52 (82.70)	0.169
Bridwell grade I	20 (40)	26 (50)	
Bridwell grade II	23 (46)	17 (32.7)	
Cage subsidence (%)[a]	3 (6)	2 (3.8)	0.615[b]

* p<0.05, statistically significant difference.
[a]Cage subsidence means that the disc height was lowered by 2 mm or more on follow-up plain lateral X-ray scanning.
[b]chi-square test.

reported a fusion rate of 96.4% at L4–L5 and 87.5% at L5–S1. Han et al. [7] reported a fusion rate of 89.8% (53/59) at L4–L5 and 42.9% (6/14) at L5–S1. Bassani et al. [20] compared posterior and anterior techniques in single-level L5–S1 interbody fusion and reported that the fusion rate of ALIF was 88.65%, while that of TLIF was 91.9% (p=0.23). Mun et al. [21] reported a fusion rate of both oblique lumbar interbody fusion (OLIF) and TLIF at L5–S1 single level. Accordingly, the fusion rates were 81.8% and 87.8% for OLIF and TLIF, respectively. This low fusion rate for L5–S1 may be due to several factors.

First, the DSA was higher than at other lumbar levels. In our study, the DSA of L5–S1 was 28.40°, twice as high as that of L4–L5 in a previous study [7]. As the DSA increased, the shear force in the disc space also increased. Therefore, this may be a factor of the fusion rate being lower for L5–S1 than for L4–L5. Second, the compression strength of L5–S1 is lower than that of L4–L5 [22]. Because the lordosis of the lumbar spine originates from the L3 or L4 vertebrae, the compressive strength may be lower than that of the L5 vertebra. Third, the range of motion of L5–S1 was greater than that of other lumbar vertebral levels. This means that after PLIF, translational motion between the L5 vertebra and the sacrum may occur on a larger scale than at other lumbar segments. Fourth, the conical shape of the L5–S1 disc space also lowered the fusion rate. The posterior margin of L5–S1 is narrower than the anterior margin compared to that in other lumbar levels [7,23]. Because the entrance is narrow, if the cage is placed in the same way as in other lumbar levels, a large space is left, which lowers the fusion rate. Because of the low fusion rate of L5–S1, this study attempted to increase the contact area of the cage and increase the contact force between the cage and the bony endplate. In addition, to reduce the empty space in the disc space after cage insertion, one must maximize bone packing in the disc space to improve the fusion rate. In addition, a larger cage was inserted by drilling or osteotomy of part of the caudal endplate of L5 and part of the cranial endplate of S1. For these reasons, the fusion rates of MIS-TLIF and conventional PLIF surgery were improved in this study compared to those in previous studies.

1n a previous study, TLIF could cause a kyphotic change; in another study, 57% of patients who were normal before surgery developed lumbar kyphosis after TLIF [24,25]. Kyphosis

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progression was also observed in MIS-TLIF [26,27]. However, in several studies, LL and SLA improved after MIS-TLIF. Le et al. [28] reported that LL was improved or preserved in 86% of cases, while SLA improved in 97.4% of cases. Choi et al. [29] reported that LL improved from 44.3° to 47.1° at 12 months postoperative, while SL improved from 13.3° to 15.5° at 12 months after surgery. In our study, LL improved from 33.57° to 35.59° at the last follow-up, while SL improved from 16.5° to 18.34° at the last follow-up. This showed the same results in MIS-TLIF and conventional PLIF surgery, with no significant intergroup differences. This is because the cage was placed as high as possible anterior to the disc space and the angle was made through sufficient compression of the rod between screws.

In most cases, the reduction of spondylolisthesis is performed using open techniques as the general standard of care. However, surgical management of spondylolisthesis using MIS-TLIF has been studied extensively, and the clinical results are good [30,31]. In recent studies, techniques for reduction of spondylolisthesis such as the “swing technique” and “rocking technique” have been introduced, and correction was successfully performed through improvement of segmental deformity and reduction in spondylolisthesis patients [32,33]. Kim et al. [30] reported that the spondylolisthesis rate was reduced from 16.77% to 9.79% with MIS-TLIF in isthmic spondylolisthesis and from 11.33% to 3.78% in degenerative spondylolisthesis. In our study, the spondylolisthesis rate was reduced from 20.17% to 10.01% in the MIS-TLIF group and from 22.44% to 10.51% in the PLIF group. There was no statistically significant difference in reduction between the two surgeries, and spondylolisthesis was corrected.

In our study, VAS and ODI were significantly improved after both MIS-TLIF and conventional PLIF surgery. In addition, there was no significant intergroup difference in the improved results. This means that the results are equivalent between the MIS-TLIF and conventional PLIF procedures. However, Cheng et al. [34] showed that although there was no difference in VAS after surgery, the use of morphine or equivalent pain medication during hospitalization was lower after MIS-TLIF. This is because MIS-TLIF features a smaller skin incision and less intraoperative bleeding. In our study, compared to conventional PLIF, the operative time and the amount of perioperative bleeding were significantly less for MIS-TLIF. This means that the burden on patients and surgeons was reduced.

There were some limitations to this study. First, it was a retrospective study conducted at a single center. Second, the follow-up period was comparatively short. However, this is the first comparative study of fusion rate through the analysis of radiological parameters of patients who underwent MIS-TLIF and conventional PLIF at the L5–S1 level. Further studies involving long-term follow-up with a multicenter study should be performed.

CONCLUSION

Both MIS-TLIF and conventional PLIF at the L5–S1 level showed good clinical and radiological outcomes. Although there was no significant intergroup difference in postoperative VAS and ODI values, MIS-TLIF was more effective than conventional PLIF because it reduced burden on the patient and surgeon due to the small amount of perioperative bleeding and short operation time.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Harms J, Rolinger H. Die operative Behandlung der Spondylolisthese durch dorsale Aufrichtung und ventrale Verblockung [A one-stager procedure in operative treatment of spondylolistheses: dorsal traction-reposition and anterior fusion (author’s transl)]. Z Orthop Ihre Grenzgeb 1982 120:343–347. German
2. Gum JL, Reddy D, Glassman S. Transforaminal lumbar interbody fusion (TLIF). JBJS Essent Surg Tech 2016;6:e22.
3. Lee KH, Yue WM, Yeo W, Soeharno H, Tan SB. Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. Eur Spine J 2012;21:2265–2270.
4. Parker SL, Mendenhall SK, Shau DN, Zuckerman SL, Godil SS, Cheng JS, et al. Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: comparative effectiveness and cost-utility analysis. World Neurosurg 2014;82:230–238.
5. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C. Minimum 5-year analysis of L5-S1 fusion using sacropelvic fixation (bilateral S1 and iliac screws) for spinal deformity. Spine (Phila Pa 1976) 2006;31:303–308.
6. Pateder DB, Park YS, Kebaish KM, Cascio BM, Buchowski JM, Song EW, et al. Spinal fusion after revision surgery for pseudarthrosis in adult scoliosis. Spine (Phila Pa 1976) 2006;31:E314–E319.
7. Han SH, Hyun SJ, Jahng TA, Kim KJ. A comparative radio-

graphic analysis of fusion rate between L4-5 and L5-S1 in a single level posterior lumbar interbody fusion. Korean J Spine 2015;12:60–67.
8. Agazzi S, Reverdin A, May D. Posterior lumbar interbody fusion with cages: an independent review of 71 cases. J Neurosurg 1999;91:186–192.
9. Ito Z, Matsuyama Y, Sakai Y, Imagama S, Wakao N, Ando K, et al. Bone union rate with autologous iliac bone versus local bone graft in posterior lumbar interbody fusion. Spine (Phila Pa 1976) 2010;35:E1101–E1105.
10. Lee CK, Park JY, Zhang HY. Minimally invasive transforaminal lumbar interbody fusion using a single interbody cage and a tubular retraction system : technical tips, and perioperative, radiologic and clinical outcomes. J Korean Neurosurg Soc 2010;48:219–224.
11. DiPaola CP, Molinari RW. Posterior lumbar interbody fusion. J Am Acad Orthop Surg 2008;16:130–139.
12. Frobin W, Brinckmann P, Biggemann M, Tillotson M, Burton K. Precision measurement of disc height, vertebral height and sagittal plane displacement from lateral radiographic views of the lumbar spine. Clin Biomech (Bristol, Avon) 1997;12 Suppl 1:S1–S63.
13. Bridwell KH, Lenke LG, McEnery KW, Baldus C, Blanke K. Anterior fresh frozen structural allografts in the thoracic, lumbar spine. Do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects. Spine (Phila Pa 1976) 1995;20:1410–1418.
14. Bridwell KH, O'Brien MF, Lenke LG, Baldus C, Blanke K. Posterior spinal fusion supplemented with only allograft bone in paralytic scoliosis. Does it work. Spine (Phila Pa 1976) 1994;19:2658–2666.
15. Brantigan JW, Steffee AD, Lewis ML, Quinn LM, Persenaire JM. Lumbar interbody fusion using the Brantigan I/F cage for posterior lumbar interbody fusion and the variable pedicle screw placement system: two-year results from a Food and Drug Administration investigational device exemption clinical trial. Spine (Phila Pa 1976) 2000;25:1437–1446.
16. Park Y, Ha JW, Lee YT, Sung NY. Minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis and degenerative spondylosis: 5-year results. Clin Orthop Relat Res 2014;472:1813–1823.
17. Pan J, Li L, Qian L, Zhou W, Tan J, Zou L, et al. Spontaneous slip reduction of low-grade isthmic spondylolisthesis following circumferential release via bilateral minimally invasive transforaminal lumbar interbody fusion: technical note and short-term outcome. Spine (Phila Pa 1976) 2011;36:283–289.
18. Wang J, Zhou Y, Zhang ZF, Li CQ, Zheng WJ, Liu J. Comparison of one-level minimally invasive and open transforaminal lumbar interbody fusion in degenerative and isthmic spondylolisthesis grades 1 and 2. Eur Spine J 2010;19:1780–1784.
19. Ito Z, Imagama S, Kanemura T, Hachiya Y, Miura Y, Kamiya M, et al. Bone union rate with autologous iliac bone versus local bone graft in posterior lumbar interbody fusion (PLIF): a multicenter study. Eur Spine J 2013;22:1158–1163.
20. Bassani R, Morselli C, Querenghi AM, Nuara A, Sconfienza LM, Peretti GM. Functional and radiological outcome of anterior retroperitoneal versus posterior transforaminal interbody fusion in the management of single-level lumbar degenerative disease. Neurosurg Focus 2020;49:E2.
21. Mun HY, Ko MJ, Kim YB, Park SW. Usefulness of oblique lateral interbody fusion at L5-S1 level compared to transforaminal lumbar interbody fusion. J Korean Neurosurg Soc 2020;63:723–729.
22. Panjabi MM, White AA 3rd. Basic biomechanics of the spine. Neurosurgery 1980;7:76–93.
23. Kimura H, Shikata J, Odate S, Soeda T, Yamamura S. Risk factors for cage retropulsion after posterior lumbar interbody fusion: analysis of 1070 cases. Spine (Phila Pa 1976) 2012;37:1164–1169.
24. Madhavan K, Shamrock AG, Chieng LO, Vanni S, Wang MY. Assessment of sagittal balance post TLIF - are we kyphosing the lumbar spine? Paper presented at: 2017 AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves; 2017 Mar 8-11; Las Vegas, NV
25. Dorward IG, Lenke LG, Bridwell KH, O'Leary PT, Stoker GE, Pahys JM, et al. Transforaminal versus anterior lumbar interbody fusion in long deformity constructs: a matched cohort analysis. Spine (Phila Pa 1976) 2013;38:E755–E762.
26. Lee HJ, Kim JS, Ryu KS. Minimally invasive TLIF using unilateral approach and single cage at single level in patients over 65. Biomed Res Int 2016;2016:4679865.
27. Shen X, Wang L, Zhang H, Gu X, Gu G, He S. Radiographic analysis of one-level minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) with unilateral pedicle screw fixation for lumbar degenerative diseases. Clin Spine Surg 2016;29:E1–E8.
28. Le H, Anderson R, Phan E, Wick J, Barber J, Roberto R, et al. Clinical and radiographic comparison between open versus minimally invasive transforaminal lumbar interbody fusion with bilateral facetectomies. Global Spine J 2021;11:903–910.
29. Choi WS, Kim JS, Ryu KS, Hur JW, Seong JH. Minimally Invasive transforaminal lumbar interbody fusion at L5-S1 through a unilateral approach: technical feasibility and outcomes.

 https://doi.org/10.21182/jmisst.2022.00472

Biomed Res Int 2016;2016:2518394.
30. Kim JY, Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, et al. Minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis: comparison between isthmic and degenerative spondylolisthesis. World Neurosurg 2015;84:1284–1293.
31. Massel DH, Mayo BC, Shifflett GD, Bohl DD, Louie PK, Basques BA, et al. Minimally invasive transforaminal lumbar interbody fusion: comparison of isthmic versus degenerative spondylolisthesis. Int J Spine Surg 2020;14:115–124.
32. Park B, Noh SH, Park JY. Reduction and monosegmental fusion for lumbar spondylolisthesis with a long tab percutaneous pedicle screw system: "swing" technique. Neurosurg Focus 2019;46:E11.
33. Rajakumar DV, Hari A, Krishna M, Sharma A, Reddy M. Complete anatomic reduction and monosegmental fusion for lumbar spondylolisthesis of Grade II and higher: use of the minimally invasive "rocking" technique. Neurosurg Focus 2017;43:E12.
34. Cheng JS, Park P, Le H, Reisner L, Chou D, Mummaneni PV. Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: is there a difference. Neurosurg Focus 2013;35:E6.

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Single Incision Tubular Decompression to Treat Multi-level Lumbar Spinal Stenosis: A Retrospective Review

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Objective: To evaluate the technical feasibility and assess the clinical outcomes of tubular decompression (TD) in cases of multilevel lumbar canal stenosis operated through a single incision. TD has established itself in the surgical management of single level lumbar stenosis. Literature on performance of TD for multilevel stenosis through a single incision are non-existent.
Methods: All patients undergoing TD for multilevel lumbar stenosis through a single incision from January 2007 to January 2018 were included. Patient demographics, operative and peri-operative details were documented. Patient based clinical outcomes, namely Visual Analogue Scale (VAS) scale for back and leg pain and Oswestry Disability Index (ODI) were assessed.
Results: Favorable tube trajectory and adequate decompression could be achieved through a single incision to decompress multiple levels. The VAS improved from mean 3 ± 1.5 (2–5) to 2 ± 0.8 (1–4) and 7 ± 1.4 (4–9) to 2 ± 1 (1–5) for back and leg pain respectively; while the ODI improved from a mean 44.6 ± 8.6 (32–68) to 20.2 ± 5.3 (16–42) at 3 months post-op and was maintained at 1 ± 0.8 (1–4), 1.6 ± 0.67 (1–3) and 19 ± 2.9 (16–26) respectively at 2 years follow-up.
Conclusion: TD for multilevel stenosis done through a single incision is a feasible option with good to excellent results.

Key Words: Multi-level lumbar spinal stenosis, Micro-lumbar decompression, Lumbar canal stenosis, Neurogenic claudication, Tubular decompression, Micro-endoscopic decompression

INTRODUCTION

Lumbar canal stenosis (LCS) is one of the most common degenerative spinal disorders affecting the elderly with an incidence of 1.7%–8% [1,2]. Out of these 60% is multilevel LCS [3]. More elderly are being diagnosed with LCS due to increased survival rates, advent of MRI and a demanding lifestyle. Failure of conservative treatment is an indication for surgical intervention which may range from decompression to decompression plus fusion. While laminectomy has been the gold standard procedure for LCS, the proponents of minimally invasive spine surgery have refined the technique with goals to minimize morbidity and promote early recovery. The advantages of minimally invasive spinal decompression are well established in literature [4-11]. While, the outcomes of tubular decompression for single level LCS are well recognised, the nuances and results of their application in multilevel stenosis have been rarely reported in literature. The aim of this study was to assess the surgical outcomes of cases with multilevel stenosis that were operated using a tubular retractor through a single incision.

MATERIALS AND METHODS

After approval of the institutional review board of Bombay Hospital and Medical Research Centre (approval no. BHIRB7989), a retrospective analysis of prospectively collected data of patients undergoing TD for neurogenic claudication from January 2007 to January 2018 was performed. 502 patients with neurogenic claudication operated using tubular retractors by a single surgeon were identified. The inclusion criteria for the surgery was disabling pain due to neurogenic claudication unresponsive to a conservative line of treatment and who had an adequate clinico-radiological correlation with two-three level spinal stenosis on the MRI.

1. Surgical Technique

The patient was positioned on a radiolucent operating table on two well-padded horizontal bolsters and a silicone face support under general anaesthesia. The midline was marked with manual palpation of the spinous processes, in reference to which a para-median vertical line was drawn at a distance of 0.8–1 cm from the midline. An antero-posterior (AP) c-arm image to mark the midline may be necessary in extremely obese patients in whom the spinous processes were not palpable. A 20G spinal needle was then inserted through the para-median line such that the needle trajectory bisects the disc space of the involved level under c-arm control. The same spinal needle can be re-oriented in the trajectory/ies of the adjacent levels to verify the feasibility of decompression of those levels. This manoeuvre gives a sense of confidence to the operating surgeon about the feasibility of performing decompression of the adjacent levels through the same port. Once the spinal needle was docked on the inferior part of the superior lamina of the level to be decompressed first, the needle track was infiltrated with local anaesthetic (15 mL of normal saline and 5 mL 0.5% Bupivacaine) to provide pre-emptive analgesia. A vertical skin incision of 20 mm length centring over the entry point of the needle was scored along the paramedian line. The dissection was then carried deeper and the lumbar fascia incised. Tubular dilators (METRx System, Medtronic SofamorDanek, Memphis, TN) were inserted in the increasing order of diameters to dilate the muscular opening and a 18 mm diameter tube of appropriate length was docked over the inferior part of the superior lamina. C-arm was then used to verify the correct placement of the tube (Figure 1). It is important to create a sub-fascial plane initially at all the 2 or 3 levels that would require decompression by elevating the soft-tissues with the first dilator. This step has the advantage of re-assessing the feasibility of introducing and operating through a single port even before the surgery commences. The other advantage is that it will prevent the calamity of causing any kind of dural or

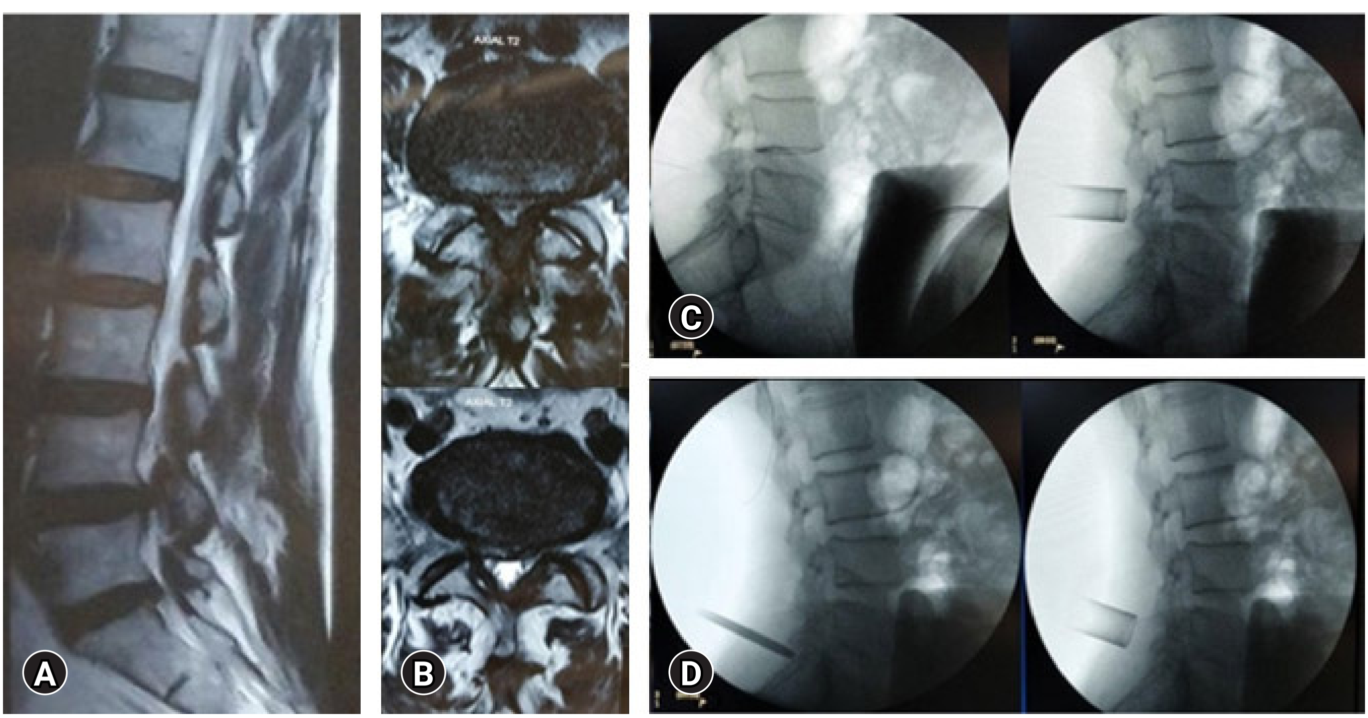

Figure 1. A 59-year-old male (case 12) with L4-5 stenosis and L5-S1 lateral recess stenosis as seen in the sagittal (A) and axial (B) MRI images. The fluoroscopy images demonstrate docking of the tubes at L4-L5 (C) and L5-S1 (D) levels through a single incision.

neurological injury while re-introducing the dilators to execute decompression at the adjacent levels since the dilators will tend to march through the least resistant track of the operated index level. Once the tube position was ascertained, soft tissue was cleaned up and a high-speed burr (MidasRex, Medtronic SofamorDanek, Memphis, TN) and Kerrison punches were used to perform laminotomy of the superior lamina of the affected level. This was followed by an over the top decompression, that starts with drilling the base of the spinous process and the inner cortex of the contralateral lamina all the way to the lateral recess of the other side followed by step-wise excision of the ligamentum flavum (Figure 2). It is important to perform all the bony work before starting the flavectomy. Following flavectomy, the lateral recesses with traversing nerve roots on both sides were decompressed. This was followed by similar decompression at subsequent levels after angulating the dilators and the tubular retractors through the previously traced channels for the adjacent levels. The skin on the lumbar spine is mobile and can be slid downwards or upwards to aid in achieving a desired tube trajectory. The authors noticed that it was easier to re-dock the tube and achieve a good trajectory at the adjacent levels in obese patients with thick skin, subcutaneous tissue and para-spinal muscles (Figure 3, 4). This 'posterior obesity' necessitated the use of longer tubes and helped achieve a favourable tube trajectory. Skin was closed using 2-0 vicryl and 3-0 monocryl for subcutaneous and sub-cuticular layers respectively.

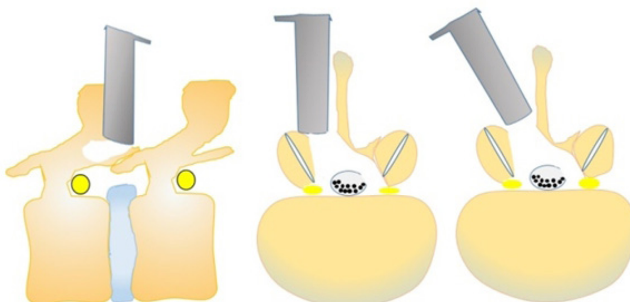

Figure 2. Representative figure showing over the top decompression.

The authors timed the length of operation in minutes, from skin incision till the application of surgical dressing and calculated the blood loss in millilitres. The hospital stay was counted in days. All the patients completed a pre-operative Visual Analogue Scale (VAS) scale and ODI (Oswestry Disability Index) questionnaire and at post-operative day 1, 3 months, 6 months and 24 months and latest follow-up.

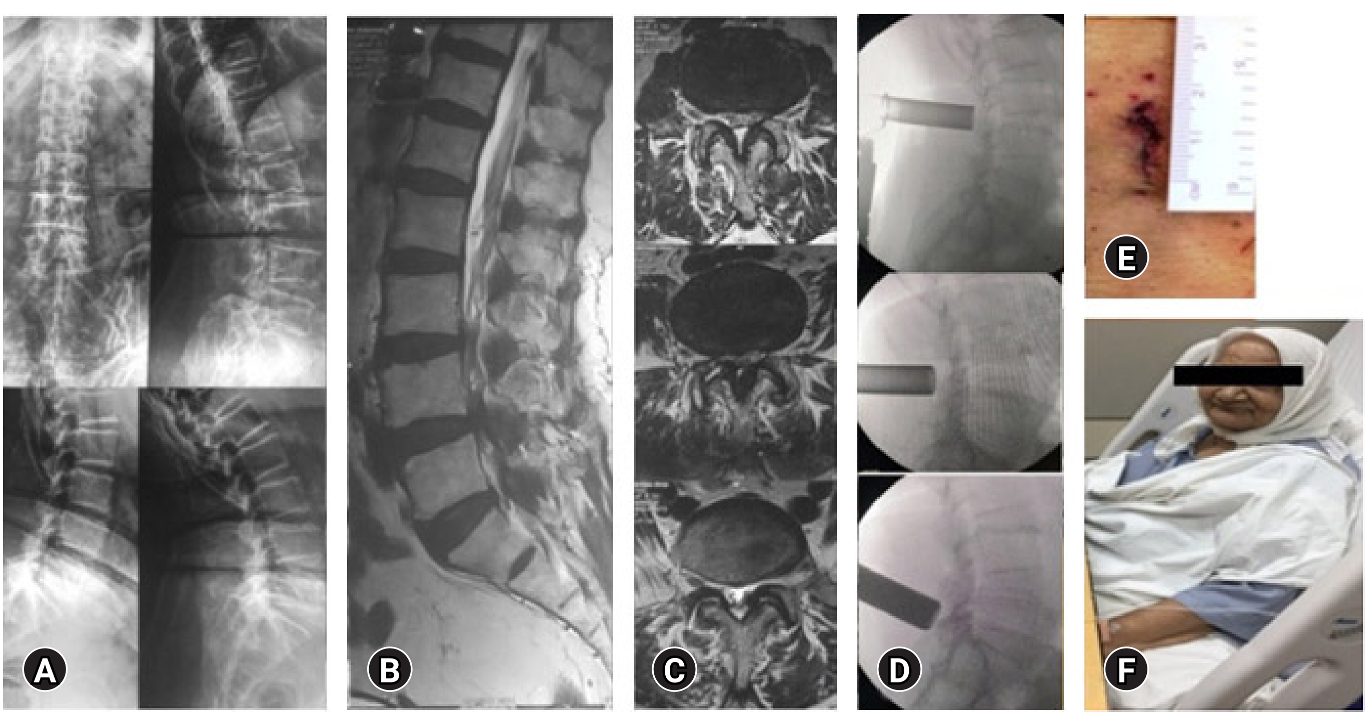

Figure 3. A 75-year-old morbidly lady (case 27) with L3-L4, L4-L5 and L5-S1 stenosis: AP and lateral X-rays (A), MRI sagittal films (B), MRI axial films (C). Fluoroscopic sequential docking of the tube at all three levels (D) and post-operative scar measuring 18 mm (E). Patient lying comfortably in the bed on the evening of the surgery (F).

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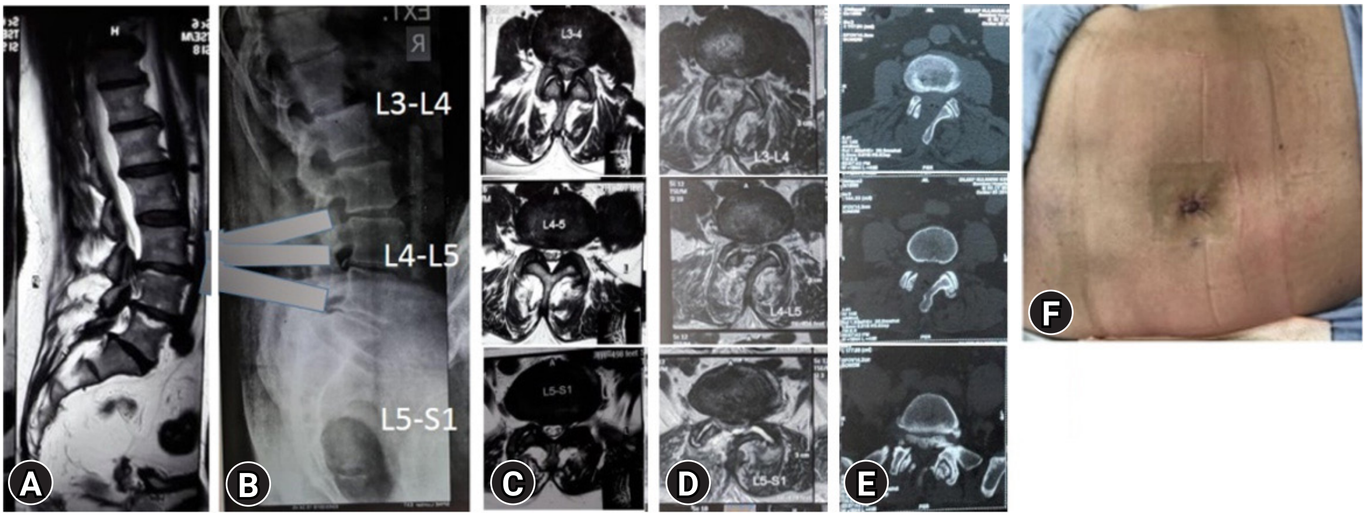

Figure 4. A 68-year-old male (case 41) - preoperative MRI sagittal and axial (A, C) and lateral radiograph showing tube trajectories (B). 6 months post-operative axial MRI and CT scan (D, E) showing adequate decompression. Post-operative single surgical scar (F).

2. Statistical Analysis

Statistical analysis was performed using SPSS (version 23, IBM Inc.). The Univariate analysis included tabulating frequencies for ordinal and categorical variables and calculating the standard deviation, ranges and means for the continuous variables. The ODI and VAS scores between pre-operative and post-operative day 1, 3 months, 6 months, 24 months and the latest follow-up were compared. Statistical significance was set at $p<0.05$ at 95% confidence interval.

Table 1. Demographics and peri-operative parameters

	Tubular decompression (TD)
Demographics	
Total number of cases	63
Mean age (in years)	63 ± 10.3 (50–88)
Sex (M/F)	37 (59%)/26 (41%)
BMI (kg/m^2)	28 ± 3.9 (23.6–38.4)
LCS levels	
L2-L3 and L3-L4	4 (6.34%)
L3-L4 and L4-L5	20 (31.7%)
L4-L5 and L5-S1	31 (49.20%)
L2-L3, L3-L4 and L4-L5	3 (4.76%)
L3-L4, L4-L5 and L5-S1	5 (7.93%)
Peri-operative parameters	
Mean hospital stay (d)	
Two-level	2.5 ± 0.6 (2–3)
Three-level	2.75 ± 0.5 (2–3)
Mean operating time (min)	
Two-level	123.5 ± 15.6 (110–178)
Three-level	128 ± 16.2 (112–148)
Mean blood loss (mL)	
Two-level	106 ± 18 (80–142)
Three-level	128 ± 22 (108–156)
Mean follow-up (mo)	30.6

RESULTS

Of the 502 patients of lumbar canal stenosis operated for TD, 68 (13.54%) satisfied the inclusion criteria. Five patients were lost to follow-up and study was completed on 63 patients. All the patients agreed to take part in the study and to fill in the patient-based clinical outcome questionnaires. The mean duration of follow-up was 30.4 months (6–40 months). The mean age was 63.4 years (50–88) with a standard deviation of 18.6 years. There were 37 males (59%) and 26 females (41%). The mean BMI of the patients was 28 kg/m^2 (23.6–38.4 kg/m^2) (Table 1).

1. ODI and VAS Scores

The VAS improved from mean 3 (2–5) to 2 (1–4) and 7 (4–9) to 2 (1–5) for back and leg pain, respectively; while the ODI improved from a mean 44.6 (32–68) to 20.2 (16–42). The improvement on modified VAS and ODI was statistically significant ($p<0.05$) when a comparison was made between pre-op scores and most recent follow-up score (Table 2).

2. Complications

Two (3.17%) patients had dural tear with CSF leaks. Both the

Table 2. Pre-operative (Pre-op) and post-operative (Po) VAS and ODI parameters for two-level and three-level TD (significance set at p<0.05)

Patient outcome parameters	Levels	Pre-op	Po day 1	Po 3 months	Po 6 months	Po 24 months
VAS (back)	Two-level	2.9 ± 1.5 (2–5)	2.1 ± 1 (1–4) ($p < 0.05$)	1.7 ± 0.7 (1–4) ($p < 0.05$)	1.95 ± 0.7 (1–3) ($p < 0.05$)	1.0 ± 0.8 (1–4) ($p < 0.05$)
	Three-level	3.25 ± 1.2 (2–6)	2.5 ± 1.3 (1–4) ($p < 0.05$)	2.5 ± 1 (1–3) ($p < 0.05$)	2.5 ± 1 (1–3) ($p < 0.05$)	2.2 ± 1 (1–3) ($p < 0.05$)
VAS (leg)	Two-level	6.8 ± 1.3 (4–9)	2.2 ± 1 (1–5) ($p < 0.05$)	1.9 ± 0.8 (1–3) ($p < 0.05$)	1.85 ± 0.8 (1–4) ($p < 0.05$)	1.6 ± 0.67 (1–3) ($p < 0.05$)
	Three-level	7.5 ± 1.7 (5–9)	2 ± 1.1 (1–3) ($p < 0.05$)	2 ± 1.4 (1–4) ($p < 0.05$)	2.25 ± 1 (1–3) ($p < 0.05$)	2 ± 1 (1–3) ($p < 0.05$)
ODI	Two-level	44.8 ± 9.42 (32–68) ($p < 0.05$)	20.4 ± 5.86 (16–42) ($p < 0.05$)	18.5 ± 2.6 (16–22) ($p < 0.05$)	18.6 ± 1.95 (16–22) ($p < 0.05$)	19 ± 2.93 (16–26) ($p < 0.05$)
	Three-level	43 ± 3.4 (38–46)	19 ± 1.1 (18–20) ($p < 0.05$)	19 ± 2.2 (16–22) ($p < 0.05$)	19 ± 2 (18–22) ($p < 0.05$)	18.5 ± 1.9 (16–20) ($p < 0.05$)

cases were diagnosed intra-operatively and the muscle and fascial layers as well as the skin were closed in a water-tight fashion. The mobilization protocol was similar to others without dural tears. One patient (1.6%) had persistent S1 dermatomal leg pain (index L3-4, L4-5 and L5-S1 decompression). He demonstrated radiographic evidence of persistent lateral recess stenosis at L5-S1 level and was re-operated with a tubular approach successfully. None of patients had any evidence of surgical site infections, medical complications or death.

DISCUSSION

Multilevel lumbar canal stenosis is not an uncommon situation. Conventional laminectomy necessitates a longer incision, a deeper dissection leaving behind a large dead-space, scarring of the paraspinal muscles and the possibility of spinal instability [12]. Tubular decompression has gained popularity over the last decade and has established itself in the management of single level LCS. The benefits in terms of cosmesis, minimal collateral damage of supporting bony and soft tissue structures, minimal dead-space, low rate of infection and early recovery make it a much more attractive option in the management of multi-level stenosis. The outcomes and technical nuances of performing tubular decompression for multilevel stenosis through a single incision are non-existent in literature. The current paper highlights the technical feasibility and positive clinical outcomes of tubular decompression performed in patients that suffer from multi-level LCS. The patient-based clinical outcomes like ODI and modified VAS showed a positive trend during the post-operative period of the procedure and were maintained at the last follow-up. The patients were immediately mobilized either on the day of surgery or the next day and discharged either on the first or second post-operative day. There was no requirement for a closed suction drain and the infection rate was zero with no instances of hematoma formation/soakage, etc. None of the patient needed a delayed stabilization procedure as a result of post-operative instability. This issue finds resonance in the cadaver study by Lu et al. [13] in 1999 which proved that multi-level laminotomies/fenestrations do not affect the lumbar spine stability in lateral bending and axial rotation. They concluded that as compared to laminectomy, multi-level laminotomies are effective in preserving stability of the lumbar spine. After an extensive literature search, we could only find one published manuscript in relevance to our study. The recent study by Lim et al. [14] involving 450 patients with multilevel stenosis operated by percutaneous lumbar decompression. They achieved good results with the use of an endoscopic technique.

1. Posterior Obesity

Obesity plays a significant factor in these cases. Obese patients benefit the most from this single-incision-multi-level minimal access decompression. On one hand obese patients tend to have problems like difficult exposure, retraction of tissues, increased dead-space leading to hematoma formation, need for a drain, infection, poor healing etc. in reference to conventional laminectomy. These issues can lead to significant morbidity and poor recovery. On the other hand, this technique of single-incision-multi-level minimal access decompression appears tailor-made for obese patients. The authors realised that tubular retractors are held better by the tamponade effect of surrounding soft-tissues in obese patients, compared to thin patients. Again, the need for the use of longer tubes (60 mm/70 mm) in obese patients (increased distance between entry point on the skin surface and the docking point over the lamina) that

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act as lever in achieving the desired tube trajectory (Figure 5–7). Additionally, an increased skin elasticity in the lumbar area helps in decompressing 2–3 levels through the same skin incision.

All five three-level stenosis cases (L3-L4, L4-L5, L5-S1) operated in the study were obese (BMI>32) and their vertebral column was deep. All of these cases had a thick back. Hence, we coined the term "Posterior Obesity" in these cases with thick para-spinal musculature and subcutaneous fat.

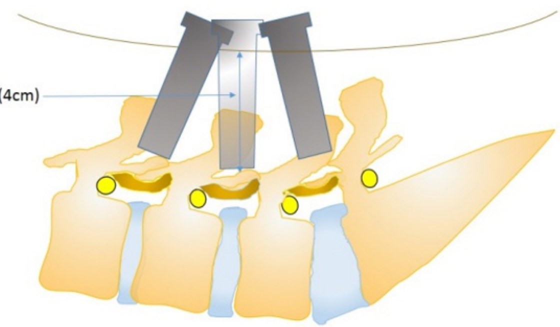

Figure 5. Tube trajectory possible through the same skin incision (distance of skin from the ideal docking point - X is a hypothetical distance).

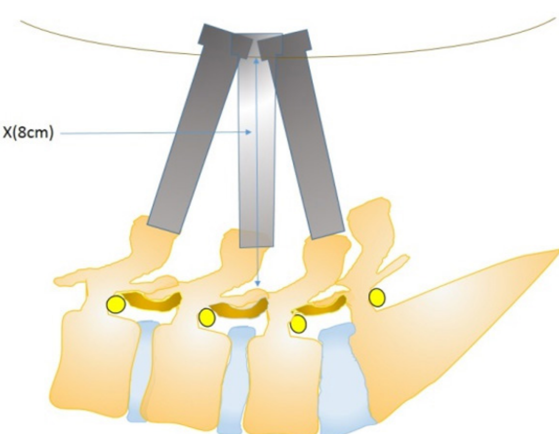

Figure 6. Ease of achieving an ideal tube trajectory if the distance between the skin and ideal docking point is increased to 2X.

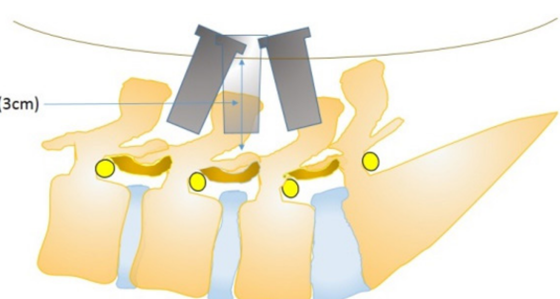

Figure 7. Relative difficulty in achieving desired tube trajectory if distance of the skin to the ideal docking point is reduced to 0.75X.

2. Limitations of the Study

The limitations to the study are the retrospective nature of the study and absence of a comparative matched cohort operated through multiple incisions or conventional laminectomy which could have increased the strength of the study.

CONCLUSION

The outcomes support the feasibility of performing TD through a single incision in cases of multilevel lumbar canal stenosis. This is probably the first paper in literature elaborating on the technical aspects and clinical results of performing a two-level or three-level TD through a single incision. Posterior obesity marked by increased distance between the skin surface and the lamina as shown in this study helps in getting a precise tube trajectory for multi-level decompression through the same skin incision.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Roberson GH, Llewellyn HJ, Taveras JM. The narrow lumbar spinal canal syndrome. Radiology 1973;107:89–97.
2. De Villiers PD, Booysen EL. Fibrous spinal stenosis. A report on 850 myelograms with a water-soluble contrast medium. Clin Orthop Relat Res 1976;(115):140–144.
3. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Blood E, Hanscom B, et al., SPORT Investigators. Surgical versus nonsurgical therapy for lumbar spinal stenosis. N Engl J Med 2008;358:794–810.
4. Kulkarni AG, Patel RS, Dutta S. Does minimally invasive spine surgery minimize surgical site infections. Asian Spine J 2016;10:1000–1006.
5. Kulkarni AG, Patel R, Dutta S, Patil V. Stand-alone lateral recess decompression without discectomy in patients presenting with claudicant radicular pain and MRI evidence of lumbar disc herniation: a prospective study. Spine (Phila Pa 1976) 2017;42:984–991.
6. Phan K, Mobbs RJ. Minimally invasive versus open laminectomy for lumbar stenosis: a systematic review and me-

ta-analysis. Spine (Phila Pa 1976) 2016;41:E91–E100.
7. Alimi M, Hofstetter CP, Torres-Campa JM, Navarro-Ramirez R, Cong GT, Njoku I Jr, et al. Unilateral tubular approach for bilateral laminotomy: effect on ipsilateral and contralateral buttock and leg pain. Eur Spine J 2017;26:389–396.
8. Jackson RK. The long-term effects of wide laminectomy for lumbar disc excision. A review of 130 patients. J Bone Joint Surg Br 1971;53:609–616.
9. Neidre A, MacNab I. Anomalies of the lumbosacral nerve roots. Review of 16 cases and classification. Spine (Phila Pa 1976) 1983;8:294–299.
10. Fourney DR, Dettori JR, Norvell DC, Dekutoski MB. Does minimal access tubular assisted spine surgery increase or decrease complications in spinal decompression or fusion. Spine (Phila Pa 1976) 2010;35:S57–S65.
11. Anderson DG, Patel A, Maltenfort M, Vaccaro AR, Ratliff J, Hilibrand A, et al. Lumbar decompression using a traditional midline approach versus a tubular retractor system: comparison of patient-based clinical outcomes. Spine (Phila Pa 1976) 2011;36:E320–E325.
12. Iguchi T, Kurihara A, Nakayama J, Sato K, Kurosaka M, Yamasaki K. Minimum 10-year outcome of decompressive laminectomy for degenerative lumbar spinal stenosis. Spine (Phila Pa 1976) 2000;25:1754–1759.
13. Lu WW, Luk KD, Ruan DK, Fei ZQ, Leong JC. Stability of the whole lumbar spine after multilevel fenestration and discectomy. Spine (Phila Pa 1976) 1999;24:1277–1282.
14. Lim KT, Nam HGW, Kim SB, Kim HS, Park JS, Park CK. Therapeutic feasibility of full endoscopic decompression in one- to three-level lumbar canal stenosis via a single skin port using a new endoscopic system, percutaneous stenoscopic lumbar decompression. Asian Spine J 2019;13:272–282.

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A Two-year Outcome of Various Techniques of Discectomy On Complications: A Multicentric Retrospective Study

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Objective: Various techniques of performing lumbar discectomy are prevalent, each having its rationale and claimed benefits. The authors ventured to assess the total complication rate of lumbar discectomy as well as the complication rates of individual complications, namely CSF leaks, superficial wound infections, deep wound infections, recurrence rates, re-operation rates, and wrong level surgery.

Methods: This was a retrospective study of patients operated using open discectomy (OD), microdiscectomy (MD), microendoscopic discectomy (MED), interlaminar endoscopic lumbar discectomy (IELD), transforaminal endoscopic lumbar discectomy (TELD), and Destandau techniques (DT) with a minimum follow-up of 2 years. The inclusion criteria were age > 15 years, failed conservative treatment for 4-6 weeks, and the involvement of a single lumbar level.

Results: There is no statistically significant association between surgical technique and complications. The total complication rate was 12.89% in 946 operated cases. The most common complication was recurrence (5.81%), followed by re-operation (3.69%), CSF leak (1.90%), wrong level surgery (0.63%), superficial infection (0.52%) and deep infection (0.31%). There were minor differences in the incidence of complications between techniques.

Conclusion: This is the first study to compare the complication rates of all the prevalent discectomy techniques across the globe in 946 patients. Although there were minor differences in incidences of complications between individual techniques, there was no statistical significance. The various rates of individual complications provide a reference value for future studies related to complications following discectomy.

Key Words: Diskectomy, Comparative study, Complications, Multicenter trials

INTRODUCTION

Lumbar discectomy is one of the most commonly performed spinal surgeries. It was first reported by Mixter and Barr [1] in 1934, that has changed the management of lumbar disc herniations. In 1973, Kambin and Savitz [2] introduced the concept of endoscopic lumbar discectomy. In the late 1970s, Caspar [3] Yasargil [4] and Williams [5] independently reported microsurgical techniques for the treatment of lumbar radiculopathy. These techniques provided the surgeon with excellent magnification of the operative field, which enabled the use of a smaller incision and facilitated less traumatic procedures. Foley and Smith [6] in 1997 introduced an operative endoscope with the tubular system terming it "endoscopic discectomy" and later in 2003, Foleys modified the tubular retractors to include a microscope, which is termed "microtubular discectomy". The full endoscopic procedures like transforaminal and interlaminar techniques, which use continuous water irrigation have been performed since the late 1990s. All these techniques of performing lumbar discectomy are prevalent, each having its rationale and claimed benefits [7-10]. The primary goal of each technique is to relieve symptoms without causing any complications. Although the level of evidence as well as data in the literature is low, there is a claim of 'one technique being better than the other'. While each technique has its exclusivity and distinct flair, each technique also carries its unique set of complications [11]. While outcomes of all individual techniques are widely documented in the literature [12-14], along with a few comparative studies [8-10,15-19], as per the author's knowledge, there is scarcity in the literature comparing complication rates of all the techniques that are commonly performed across the globe. The authors ventured to assess the total complication rate of lumbar discectomy as well as the complication rates of individual complications, namely CSF leaks, superficial wound infections, deep wound infections, recurrence rates, re-operation rates, and wrong level surgery.

MATERIALS AND METHODS

This was a retrospective study of consecutive patients operated between May 2012 to April 2017 using various techniques, namely open discectomy (OD), microdiscectomy (MD), microendoscopic discectomy (MED), interlaminar endoscopic lumbar discectomy (IELD), transforaminal endoscopic lumbar discectomy (TELD), and Destandau techniques (DT) at ten centres with a follow-up period of minimum 2 years, with data collection initiated in July 2019 after approval from the ethical and review committee. Each surgeon included in the study performed only a single surgical technique that they are familiar with and had a minimum experience of 5 years in performing the procedure. The different techniques used by different surgeons are based on their experience and the availability of infrastructure and are not randomised. The basic concept of performing lumbar discectomy i.e., removal of the herniated disc fragment and adequate decompression of the nerve root is the same in all the techniques, however, the armamentarium required and the approach for each technique is different and is explained briefly in Table 1). These surgical techniques are broadly divided into a minimally invasive group which includes TD, IELD, TELD and DT and open groups which includes OD and MD. The informed consent was taken from every patient included in the study. The inclusion criteria were age>15 years, symptoms and signs of radiculopathy with failed conservative treatment for at least 4–6 weeks in any form based on the surgeon's criteria, the involvement of single lumbar level disc herniation, and exclusion criteria were the presence of associated instability in the form of translation and angulation in dynamic plain radiographs, spondylolisthesis, and stenosis with background claudication pain and the presence of radiological stenosis on MRI. Incidence of total and individual complications in the perioperative period and during the follow-up period was evaluated. Descriptive statistics were used to summarise data and categorical data was represented in frequency and percentage. Chi-square with Pearson's test was used for comparative analysis. All analysis was performed with SPSS 25 version and a p-value<0.05 was considered as statistically significant.

RESULTS

A total of 946 patients were included in the study. Table 2 depicts the demographic data in terms of age, height, weight, body mass index (BMI), lumbar levels, and disc type. The mean age is 44.3 (15–82) years, average BMI is 26.3, average height is 5.2 feet and the average weight is 70kgs. The most common level operated is L4-5 (57.5%) followed by L5-S1 (34.46%), with no statistical difference between the level of disc operated.

The total number of complications accounted for is 122 (12.89%) and distribution is represented in Table 3. The highest complications are recurrence, which accounts for 5.81%, followed by re-operation (3.69%), and the least in deep infection that accounts for 0.31%. The distribution of individual complications within a particular technique is depicted in Table 4. The various causes of re-operation are depicted in Table 5. The

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Table 1. Salient features of each surgical technique

	Technique	Description
1	Open discectomy	General anaesthesia
		Midline posterior subperiosteal approach
		Mollison mastoid retractors
		Naked eye
		Laminectomy and flavectomy
2	Microdiscectomy	General anaesthesia
		Midline posterior subperiosteal approach
		Microscopic magnification
		McCullough retractors
		Hemilaminectomy and flavectomy
3	Microendoscopic discectomy	General anaesthesia
		Paramedian muscle splitting approach
		Microscopic magnification
		Use of METRxTM tubular retractor system (Medtronics Sofamor-Danek, Memphis, TN, USA)
		Laminotomy and flaval dissection
4	Interlaminar endoscopic lumbar discectomy	Local anaesthesia/general anaesthesia
		Endoscopic magnification
		Paramedian muscle splitting approach
		Constant irrigation for better visualisation
		Full-endoscopic surgical system "Riwospine (Spinendos, Munchen, Germany)"
		Laminotomy and flaval dissection
5	Transforaminal endoscopic lumbar discectomy	Local anaesthesia/general anaesthesia
		Endoscopic magnification
		Far lateral approach
		Constant irrigation for better visualisation
		Full-endoscopic surgical system "Riwospine (Spinendos, Munchen, Germany)"
		Foraminotomy
		Access through Kambins triangle
6	Destandau technique	General anaesthesia
		Endoscopic magnification
		Paramedian muscle splitting approach
		Destandau Endospine System (Karl Storz, Tuttlingen, Germany), which comprises an endospine tube, trocar, and working insert
		Laminotomy and flaval dissection

calculated chi-square statistics is χ (25)=27.54, p-value=0.329. This reveals that there is no statistically significant association between surgical technique and complications, the complications being equal in an open discectomy (OD), microdiscectomy (MD), microendoscopic discectomy (MED), interlaminar endoscopic lumbar discectomy (IELD), transforaminal endoscopic lumbar discectomy (TELD), and Destandau techniques (DT) (Table 4).

DISCUSSION

Lumbar discectomy can be performed in various ways [19]. The leaders and followers of these various techniques claim certain merits of their technique over the others [7-10]. The merits include better surgical and functional outcomes and also minimized rates of complications. While outcomes of all individual techniques are widely documented in the literature [12-14], along with a few comparative studies of various techniques [8-10,15-18], there is no single study comparing all the techniques that are commonly performed across the globe, which adds credence to this study. A large volume of patients contributed by 10 centres and performed by surgeons with a minimum of 5 years experience, increases the external validity. This study helps in providing solid evidence regarding the out-

Table 2. Demographic data

SNO		MED	MD	DT	IELD	TELD	OD	p-value
1	Total patients	79	351	199	86	86	145	
2	Male	55	211	105	54	55	88	0.142
3	Female	24	140	94	32	31	57	(chi-sqaure)
4	Age (yr)	44.5 (14.12)	44.3 (12.76)	48.42 (14.57)	39.4 (10.23)	39.4 (12.38)	37.6 (7.39)	0.001 ANOVA
5	Age range	16–78	17–82	18–74	18–74	15–69	18–76	
6	Height (feet)	5.16 (0.51)	5.58 (0.43)	5.2 (1.28)	5.45 (0.68)	5.3 (0.42)	5.41(1.37)	0.001 ANOVA
7	Weight (kg)	71.8 (8.65)	72.32 (10.25)	69.35 (7.28)	71.85 (9.37)	71.35 (11.43)	73.6 (12.17)	0.003 ANOVA
8	Body mass index (kg/m^2)	29.76 (6.70)	26.53 (5.82)	26.36 (4.32)	25.78 (6.28)	25.56 (5.49)	26.4 (4.25)	0.001 ANOVA
9	Lumbar levels							
	L1-l2	1 (1.3%)	0	0	0	1 (1.2%)	0	0.214 chi-square
	L2-l3	1 (1.3%)	11 (3.13%)	1 (0.5%)	0	6 (6.97%)	2 (1.4%)	
	L3-l4	8 (10.1%)	19 (5.41%)	11 (5.5%)	3 (3.48%)	8 (9.3%)	4 (2.8%)	
	L4-l5	43 (54.4%)	211 (60.13%)	101 (50.8%)	37 (43%)	66 (76.74%)	86 (59.3%)	
	L5-s1	26 (32.9%)	110 (31.33%)	86 (43.2%)	46 (53.48%)	5 (5.81%)	53 (36.6%)	
10	Disc type							
	Central	6 (7.6%)	39 (11.1%)	18 (91.%)	2 (2.3%)	24 (27.9%)	26 (17.9%)	0.001-chi square
	Lateral recess	47 (59.49%)	243 (69.23%)	114 (57.28%)	79 (91.86%)	35 (40.69%)	77 (53.1%)	
	Foraminal	23 (29.11%)	91 (25.92%)	73 (36.68%)	5 (5.81%)	30 (34.88%)	54 (37.24%)	
	Extra foraminal	3 (3.79%)	17 (4.84%)	12 (6.03%)	2 (2.32%)	21 (24.41%)	14 (9.65%)	

MED: microendoscopic discectomy, MD: microdiscectomy, DT: destandau technique, IELD: interlaminar endoscopic discectomy, TELD: transforaminal endoscopic lumbar discectomy, OD: open discectomy.

Table 3. Total complications

Complication	Incidence
CSF leaks	18 (1.90%)
Superficial infection	5 (0.52%)
Deep infection	3 (0.31%)
Recurrence	55 (5.81%)
Re-operation rate	35 (3.69%)
Wrong level surgery	6 (0.63%)
Total complication rate	122/946 = 12.89%

comes and complications of different techniques.

There were some interesting findings that emerged from this study. There is no technique that is immune from complications. While there were minor differences in the incidence of various complications between the various techniques, there was a certain visible pattern noticed (Table 4). Recurrence was the most common complication across all the techniques. This probably means that irrespective of the invasiveness of the procedure, recurrence can manifest and is probably primarily related to the stability of the segment, previously described risk factors such as the size of the annular defect, the volume of the disc, characteristics of the patient, etc [20]. Recurrence, although controversial, may also be related to the post-operative regimen, which could vary among surgeons and centres. Being a retrospective study, understandably, there was no control on this factor. The reoperation rate was the second most common complication following recurrence. Many causes like recurrence, instability, residual symptoms, wrong level surgery, and many other non-surgical factors like age of the patient, non-compliance to the postoperative protocol can lead to re-operation [21] (Table 5). Regardless of the technique, the re-operation rate was between 12%–20% [21]. Dural tears leading to CSF leaks were also a common set of complications, again across the board. Although the incidence was zero in the endoscopic interlaminar approach and highest in the open discectomy group and within this range in the other techniques there was no statistical significance. The statistical significance was not strong enough to suggest that magnification plays a pivotal role in preventing dural tears. The incidence of superficial infections (0.52%) and deep infections (0.31%) was relatively low. This could be related to the low morbidity of the approach, relatively a shorter duration of surgery translat-

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Table 4. Individual complications

Complications	Technique						p-value
	TD (n = 71)	DT (n = 199)	MD (n = 238)	OD (n = 122)	ILD (n = 86)	TFD (n = 86)	
CSF leak	2 (20%)	2 (22.23%)	3 (8.34%)	10 (20.83%)	0 (0.00%)	1 (11.13%)	0.088
Superficial infection	2 (20%)	1 (11.13%)	1 (2.78%)	1 (2.083%)	0 (0.00%)	0 (0.00%)	
Deep infection	0 (0.00%)	1 (11.13%)	2 (5.56%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	
Recurrence	3 (30%)	2 (22.23%)	17 (47,23%)	19 (39.58%)	8 (80.00%)	6 (66.67%)	
Re-operation	3 (30%)	2 (22.23%)	11 (30.56%)	15 (31.25%)	2 (20%)	2 (22.23%)	
Wrong level surgery	0 (0.00%)	1 (11.13%)	2 (5.56%)	3 (6.25%)	0 (0.00%)	0 (0.00%)	
Total	10 (100.00%)	9 (100.00%)	36 (100.00%)	48 (100.00%)	10 (100.00%)	9 (100.00%)	

CSF: cerebrospinal fluid, TD: tubular microdiscectomy, MD: microdiscectomy, DT: destandau technique, ILD: endoscopic interlaminar discectomy, TFD: endoscopic transforaminal discectomy, OD: open discectomy.

Table 5. Causes of reoperation

	Technique					
	TD	DT	MD	OD	ILD	TFD
Recurrence	2	0	5	7	1	1
Instability	1	0	3	4	0	0
Residual symptoms	0	1	2	2	1	1
Wrong level surgery	0	1	1	2	0	0

TD: tubular microdiscectomy, MD: microdiscectomy, DT: destandau technique, ILD: endoscopic interlaminar discectomy, TFD: endoscopic transforaminal discectomy, OD: open discectomy.

ing into lower retraction time, and the non-implant nature of the surgery. However, on one hand, there is a potential risk of infection as a result of contamination from the drapes/image intensifier and procedural equipments [22] in minimal access surgeries using microscope or endoscope, while on the other hand there is a potential risk of infection from a relatively larger dead space and wider tissue exposure in open surgeries [22,23]. Wrong-level surgery is an unfortunate event that has far-reaching medico-legal implications. Although it was more evident in certain techniques, the comparison did not reach any statistical level of significance. This unfortunate event was mostly witnessed in open and micro discectomies which generally need surgical exposure and verification of the level, even after marking and verifying the level before incising the skin. One of the distinct advantages of minimal access surgeries relates to the low to nil risk of performing a wrong level surgery since imaging is required till the endoscope or the tubular retractor is positioned over the segment of interest [24].

The study also brings to light the overall complication rate of lumbar discectomy, which is generally considered as one of the most common and seamless surgeries, irrespective of the technique. A complication rate of as high as 12.89% in 946 cases is an eventuality even with a procedure that is considered to be one of the simplest of spine surgeries. This high incidence was noted amongst established surgeons with a minimum of five years of experience since that was the inclusion criteria in this study. This criterion was necessary to have a level playing field since it is well known that minimal access surgeries have a steep learning curve [25,26]. It will be interesting to note and compare the complication rates of various techniques amongst a group of surgeons that have recently started spine practice.

The other important limitation of the current study pertains to the anatomical location of the disc herniation. This aspect was not considered and the study was a mixed bag of all locations such as posterolateral, central, cranially, and caudally migrated as well as foraminal and extra-foraminal. One of the main reasons to include this mixed bag was to have a large volume of cases. There is some merit in segregating foraminal and extraforaminal herniations as a separate group since the transforaminal endoscopic route is an extremely simple procedure to treat this particular location of disc herniation. Nevertheless, this study provided a comprehensive comparison of all the techniques irrespective of the anatomical location.

The study has certain limitations. The main limitation is the retrospective nature of the study. All the limitations of the retrospective study apply to this study. While the study period extended to a two-year follow-up, a longer study would reveal events happening at longer follow-ups. The other important limitation of the current study pertains to the anatomical location of the disc herniation. This aspect was not considered, and the study was a mixed bag of all locations such as posterolateral, central, cranially, and caudally migrated as well as foraminal and extra-foraminal. One of the main reasons to include this mixed bag was to have a large volume of cases. There is some merit in segregating foraminal and extraforaminal herniations as a separate group since the transforaminal endoscopic route is an extremely simple procedure to treat this particular location of disc herniation. The other drawback is that the study doesn't reflect the incidence of disc prolapse at different lumbar levels, because fusion sometimes resorts to the management of disc herniations at the upper lumbar levels.

CONCLUSION

This is the first study to compare the complication rates of all the prevalent discectomy techniques across the globe in 946 patients. Although there were minor differences in incidences of complications between individual techniques, there was no statistical significance. The various rates of individual complications provide a reference value for future studies related to complications following discectomy.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Mixter WJ, Barr JS. Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 1934;211:210–215.
2. Kambin P, Savitz MH. Arthroscopic microdiscectomy: an alternative to open disc surgery. Mt Sinai J Med 2000;67:283–287.
3. Caspar W. A new surgical procedure for lumbar disc herniation causing less tissue damage through a microsurgical approach. In: Wüllenweber R, Brock M, Hamer J, Klinger M, Spoerri O, editors. Lumbar Disc Adult Hydrocephalus. Advances in Neurosurgery, Vol. 4. Heidelberg: Springer; 1977. p. 74–80.
4. Yasargil MG. Microsurgical operation of herniated lumbar disc. In: Wüllenweber R, Brock M, Hamer J, Klinger M, Spoerri O, editors. Lumbar Disc Adult Hydrocephalus. Advances in Neurosurgery, Vol. 4. Berlin, Heidelberg: Springer; 1977. p. 81.
5. Williams RW. Microlumbar discectomy: a conservative surgical approach to the virgin herniated lumbar disc. Spine (Phila Pa 1976) 1978;3:175–182.
6. Foley KT, Smith MM. Microendoscopic discectomy. Tech Neurosurg 1997;3:301–307.
7. Türeyen K. One-level one-sided lumbar disc surgery with and without microscopic assistance: 1-year outcome in 114 consecutive patients. J Neurosurg 2003;99:247–250.
8. Schick U, Döhnert J, Richter A, König A, Vitzthum HE. Microendoscopic lumbar discectomy versus open surgery: an intraoperative EMG study. Eur Spine J 2002;11:20–26.
9. Barber SM, Nakhla J, Konakondla S, Fridley JS, Oyelese AA, Gokaslan ZL, et al. Outcomes of endoscopic discectomy compared with open microdiscectomy and tubular microdiscectomy for lumbar disc herniations: a meta-analysis. J Neurosurg Spine 2019;31:802–815.
10. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. Spine (Phila Pa 1976) 2008;33:931–939.
11. Chen X, Chamoli U, Vargas Castillo J, Ramakrishna VAS, Diwan AD. Complication rates of different discectomy techniques for symptomatic lumbar disc herniation: a systematic review and meta-analysis. Eur Spine J 2020;29:1752–1770.
12. Kulkarni AG, Bassi A, Dhruv A. Microendoscopic lumbar discectomy: technique and results of 188 cases. Indian J Orthop 2014;48:81–87.
13. Tsou PM, Yeung AT. Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique. Spine J 2002;2:41–48.
14. Kim HS, Park JY. Comparative assessment of different percutaneous endoscopic interlaminar lumbar discectomy (PEID) techniques. Pain Physician 2013;16:359–367.
15. Garg B, Nagraja UB, Jayaswal A. Microendoscopic versus open discectomy for lumbar disc herniation: a prospective randomised study. J Orthop Surg (Hong Kong) 2011;19:30–34.
16. Righesso O, Falavigna A, Avanzi O. Comparison of open discectomy with microendoscopic discectomy in lumbar disc herniations: results of a randomized controlled trial. Neurosurgery 2007 61:545–549. discussion 549
17. Cong L, Zhu Y, Tu G. A meta-analysis of endoscopic discectomy versus open discectomy for symptomatic lumbar disk herniation. Eur Spine J 2016;25:134–143.
18. Zhang B, Liu S, Liu J, Yu B, Guo W, Li Y, et al. Transforaminal endoscopic discectomy versus conventional microdiscectomy for lumbar discherniation: a systematic review and meta-analysis. J Orthop Surg Res 2018;13:169.
19. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Hanscom B, Skinner JS, et al. Surgical vs nonoperative treatment for lumbar disk herniation: the Spine Patient Outcomes Research Trial (SPORT): a randomized trial. JAMA 2006;296:2441–2450.
20. McGirt MJ, Eustacchio S, Varga P, Vilendecic M, Trummer M,

https://doi.org/10.21182/jmisst.2022.00409

Gorensek M, et al. A prospective cohort study of close interval computed tomography and magnetic resonance imaging after primary lumbar discectomy: factors associated with recurrent disc herniation and disc height loss. Spine (Phila Pa 1976) 2009;34:2044–2051.
21. Suk KS, Lee HM, Moon SH, Kim NH. Recurrent lumbar disc herniation: results of operative management. Spine (Phila Pa 1976) 2001;26:672–676.
22. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. Spine (Phila Pa 1976) 1996;21:941–944.
23. Kulkarni AG, Patel RS, Dutta S. Does minimally invasive spine surgery minimize surgical site infections. Asian Spine J 2016;10:1000–1006.
24. Kulkarni AG, Gupta S, Patil VM. The 'Nightmare' of Wrong level in spine surgery: is minimally invasive spine technique more forgiving. J Minim Invasive Spine Surg Tech 2017;2:39–43.
25. Jain S, Kundnani V, Kire N, Merchant ZA, Patel J. Learning curve of tubular micro-endoscopic decompression in patients with degenerative lumbar canal stenosis over 200 cases. Indian Spine J 2020;3:238–242.
26. Hsu HT, Chang SJ, Yang SS, Chai CL. Learning curve of full-endoscopic lumbar discectomy. Eur Spine J 2013;22:727–733.

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Minimally Invasive Iliac Screw Insertion: Clinical Case Series and Technical Note

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Objective: To describe the technique of minimally invasive iliac screw insertion by freehand technique and using intraoperative navigation guidance.

Methods: Bilateral iliac screws were inserted in total of seven patients. Five patients underwent navigation guided iliac screw placement and freehand technique was performed in 2 patients.

Results: Total of 7 patients underwent minimally invasive iliac screw fixation in our series. The pathology in 4 of the cases was spondylodiscitis, among them 2 cases each at L5-S1 and L4-L5, one with the destruction of L5 vertebral body and the other with the destruction of both L4 and L5 vertebral bodies. Of the remaining cases, two cases , one case of sacral insufficiency fracture and the last case was implant failure after L2-L5 oblique lumbar fusion. None of the cases required conversion to open procedure or had wound or hardware related complications till the last follow-up. All patients had an uneventful post-operative period with improvement in pain scores and were mobilized on the 1st postoperative day. One 50-year-old female patient suffering from L5-S1 tubercular spondylodiscitis died due to underlying chronic kidney disease three months post-surgery.

Conclusion: Minimal invasive iliac screw placement with or without navigation offers the same biomechanical stability as the open approach but without the need for extensive soft tissue exposure needed for a conventional/open procedure; thereby reducing exposure-related complications , enhancing post-operative recovery and early mobilization. Incorporating intra-operative 3D navigation provides real-time multi-planar images which help in easy planning and safe screw placement whilst reducing radiation exposure.

Key Words: Iliac screws, Minimally invasive iliac screw, Percutaneous iliac screw, Navigation guided iliac screw, Lumbo-pelvic stabilization

INTRODUCTION

Posterior lumbo-pelvic instrumentation is used to treat spinal instability caused by a spectrum of lumbosacral or sacral pathologies. The objective is to provide segmental stabilization and superior biomechanical stability across the lumbosacral junction and to prevent failure of long segment constructs. Lumbo-pelvic fixation involves the insertion of the iliac screws which can be either a conventional iliac screw or S2 alar-iliac (S2AI) screw [1].

The conventional open iliac screw requires extensive exposure of the posterior portion of the iliac crest and dorsal surface of sacrum up to S2 body and proximal extent depending upon the length of the construct. This exposure requires subperiosteal stripping at the origin of gluteus maximus at posterior superior iliac spine (PSIS), attachments of erector spinae, and multifidus at the medial and lateral surface of the posterior part of the sacrum for anatomically orientation, screw entry point, trajectory guidance and to accommodate rod and lateral connectors.

This extensive exposure damages the dorsal sacroiliac, iliolumbar and sacrotuberous ligaments losing their primary restraints function. Disruption of these muscles and ligaments in open technique will lead to soft issue devascularization leading to wound healing problems, deep hematoma formation, and requiring early secondary surgical procedures in 26% of the patients for wound-related complications [2-4].

Minimal invasive (MI) techniques can overcome the disadvantages of traditional open techniques with better biomechanical stability rates and clinical results. MI approach follows the principles of percutaneous pedicle screw insertion and offers several advantages such as minimizing blood loss and tissue trauma-minimizing paraspinal muscle injury, preserving the attachments to the sacrum and posterior superior iliac spine, lesser infection rates, and faster recovery than the standard open techniques [5]. The intraoperative image guidance assists the surgeons to determine the ideal entry point of the screw and screw trajectory [6,7] in real-time reducing the radiation exposure.

Iliac screws can be inserted either in a conventional open method or by MI technique which can be either navigated (2D/3D) or non-navigated. The non-navigated freehand technique involves screw placement relying on anatomical landmarks minimizing extensive exposure of the ilium to access the entry point and does not require extensive intraoperative fluoroscopy for screw trajectory guidance. On the other hand, navigated iliac screw insertions are entirely image-dependent. This article describes the least invasive techniques of iliac screw insertion which can add to the surgeon's armamentarium for a better outcome.

MATERIALS AND METHODS

A consecutive series of seven patients were treated with lumbo-pelvic instrumentation for various diseases of the lumbosacral junction. All patients had significant back pain and or leg pain affecting their daily activities. All patients underwent MI insertion of iliac screw bilaterally using navigation guidance (2D/3D) (n=5) or using the free hand-guided technique (n=2). Patients with underlying spondylodiscitis (n=4), osteoporosis (n=2) received antibiotics, antitubercular therapy, and osteoporosis treatment respectively. Post-operative outcome was assessed with respect to post-operative ambulatory status, status of primary disease, wound and implant related complication at last follow up.

1. Description of Technique

1) Freehand Non-Navigated-Guided Iliac Screw Insertion

The patient is positioned prone on the operative table. The required area is scrubbed and draped maintaining sterile precautions. A 2–3 cm vertical skin incision is made approximately 2 cm medial to PSIS on either side of the midline, using AP (Anterior-posterior) fluoroscopy. Pre-operative assessment of the iliac slope and direction can guide us towards choosing our skin incision. In cases with a wide pelvis, the angulation for the screw may be higher and skin incisions converge more towards the midline, whereas in patients with a narrow pelvis, the iliac wings are more straighter and the screw angulation will be less angulated, placing the skin incisions relatively farther away from the midline. Sharp dissection is carried down towards the PSIS and the fascia over PSIS is split along the entire length of the incision. It is important to correctly orient the direction in which dissection is being to expose the PSIS. After exposure of PSIS, a bony prominence can be palpated at the inferior portion of PSIS and the entry point is 1 cm cranial and medial to that point. Choosing this entry point is important as the ridge of PSIS buries the screw head avoiding screw head prominence. The entry point is again confirmed with an AP fluoroscopic image. Once the entry point is chosen, a cortical window is made using a high-speed drill.

Using a blunt curved pedicle gear shift probe at the entry point directed towards the anterior inferior iliac spine (AIIS) (Figure 1A), the probe is initially aimed laterally avoiding entry into the sacroiliac joint and rotated medially after a length of 2 cm advancing towards AIIS. As the blunt tip of the instrument encounters the dense cortical bone, the probe needs to rotated 180 degree, thus guiding between the inner and outer iliac tables via tactile feedback maintaining trajectory cephalad to sciatic notch and acetabulum with intermittent AP fluoroscopy (Figure 1B). The screw path is palpated with a ball tip probe to check for cortical breach in the walls of the ilium. If there is doubt of cortical breach, teardrop view after placing a probe can be used to confirm appropriateness on intraosseous screw

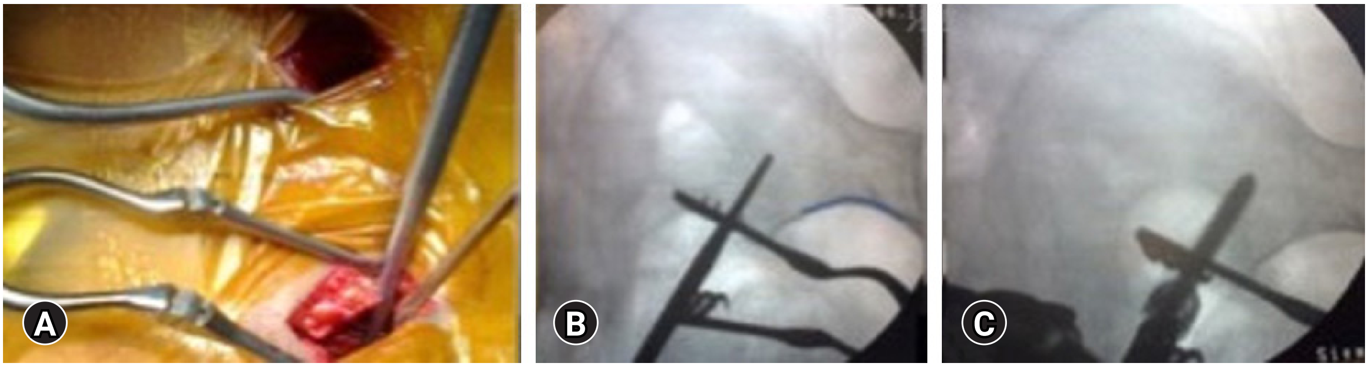

Figure 1. Intraoperative photograph showing PIS insertion using free hand technique. (A) Using self-retaining retractor the PSIS is exposed and pedicle probe is placed at starting point and advanced towards AIIS. (B) Intraoperative AP fluoroscopy showing pedicle probe to establish the iliac screw pathway above sciatic notch (blue outline) directing towards AIIS. (C) Intraoperative fluoroscopy showing iliac screw in the desired trajectory.

path. Dilatation is carried out in standard fashion and an iliac screw of appropriate length and diameter is inserted after tapping along the screw trajectory (Figure 1C) and screws are interconnected with the rod.

2) Image-Guided Navigated Iliac Screw Insertion

The patient is positioned prone on allen table and draping of the patient is performed as illustrated before. PSIS is palpated and the reference frame for navigation is inserted either on the right or left side at the superior lateral margin of PSIS via stab incision. The frame is angled slightly caudally to have an unobscured working field and is important to remain at a fixed position throughout the procedure which is essential for the accuracy of navigation. Next is the image acquisition phase during which the O arm (O-arm® O2 Imaging System, Medtronic, 300 Foster St, Littleton, MA 01460, United States) is centred over the lumbosacral junction and spin is performed after confirming the required extent on AP and lateral images. On completion, image data is transferred to the navigation system.

There are many techniques and entry points for iliac screw insertion. Choosing an optimal screw entry point is based on the patient's anatomy and required trajectory which is aimed towards AIIS above the greater sciatic notch not penetrating the sacroiliac joint. With the help of a navigable probe, the skin incision is planned after visualizing the intended trajectory on the navigation screen (Figure 2A) and entry points are marked. 1.5 cm vertical incision, either a paramedian incision on both sides (Figure 3A) or a midline (Figure 3B) incision is made based on the entry points chosen under navigation guidance. Skin, subcutaneous tissue, and fascia are incised without the need for any subperiosteal dissection and without disrupting the muscular and ligamentous attachments. After choosing the optimal trajectory a navigable jamshidi needle is docked at the starting point and is advanced simultaneously allowing for real-time multiplanar images on the navigation screen (Figure 2B). Once the jamshidi crosses around 50 mm to 60 mm in length, the guidewire (K wire) is inserted internally and the jamshidi needle is removed. Cannulated cancellous screw tap is threaded over the guidewire and is tapped along the trajectory of the screw and ideal screw length is measured on the navigation screen. Iliac screw of adequate length and diameter is inserted under navigation guidance and similar steps are performed on the opposite side. Pedicle screws are cannulated proximally across the lumbar spine in a standard percutaneous fashion. The entire construct is interconnected with the rod after contouring it in the coronal and sagittal plane (two planes) and is passed in sub facial plane from the cephalad to the caudal direction. Wounds are closed in a subcuticular fashion (Case examples; Figure 4–6). Case example 1, 77-year-old female who presented with low back pain affecting her daily activities, examination revealed no deficits. X ray of lumbar spine revealed collapse of L5 vertebral body with endplate destruction at L4 (Figure 4A B). MRI showed L5 vertebral body collapse with altered signal intensity with spondylodiscitis at L4-L5 with enhancing prevertebral soft tissue component causing nerve root compression (Figure 4C–E). Patient was planned for L3 – pelvis stabilization, decompression at L4-L5 with biopsy. Histopathology report was suggestive of tubercular spondylodiscitis and antitubercular therapy was initiated. Follow up MRI and X ray at 1 year revealed disease resolution with symptomatic improvement (Figure 4F–I).

Case example 2, 69-year-old female, known case of rheumatoid arthritis presented with severe low back pain, inability to stand and walk, normal neurology on examination. Imaging

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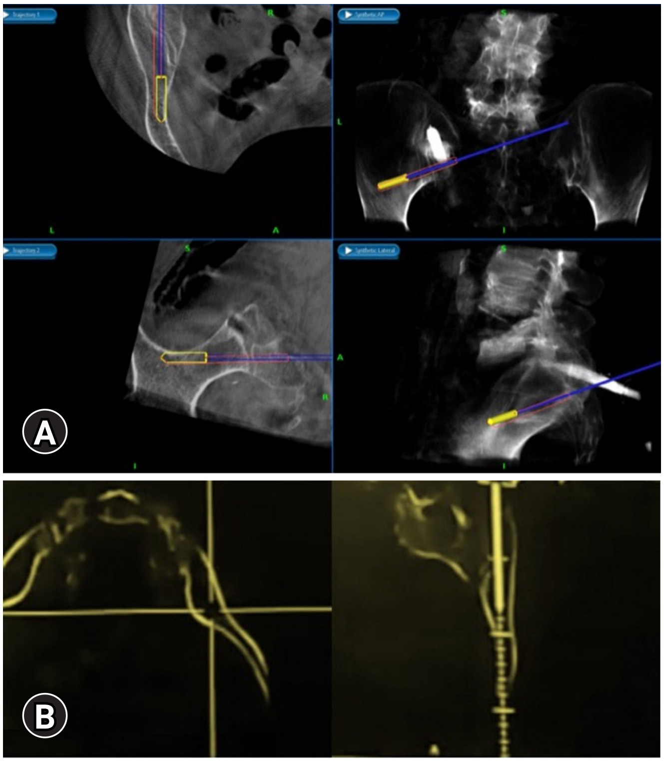

Figure 2. (A) Showing multiplanar navigated image demonstrating planned trajectory (red line) and real-time screw trajectory (blue line) and estimating screw length (yellow box). (B) Real-time navigation multiplanar images showing screw trajectory.

revealed zone 1 sacral insufficiency with displacement (Figure 5A–D) with T score of –3.3 on DEXA scan. Patient underwent MI pedicle and iliac screw fixation (L3-pelvis) and was mobilized on day 1 with good reduction in her back pain. Immediate postoperative X-ray showing lumbopelvic construct from L3 to the pelvis (Figure 5E).

Case example 3, a 50-year-old male presented with low back pain, bilateral lower limb radiculopathy, and difficulty in walking. Imaging and biopsy at L4-L5, was suggestive of bacterial spondylodiscitis. Because of his worsening clinical condition, repeat imaging was performed revealed progression of disease with L5-S1 endplate irregularity, enhancing intervertebral disc and epidural collection causing neural compression (Figure 6A–D). Patient underwent MI L5-S1 transforaminal interbody fusion, pedicle, and iliac screw placement. Postoperatively, patient had good reduction of radicular and back pain with the resolution of disease in follow up period (Figure 6E–H).

RESULTS

A total of 7 patients (5 women and 2 men) underwent per-

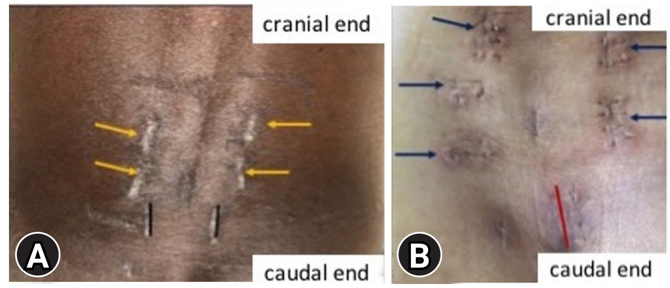

Figure 3. Showing iliac screw entry points. (A) Paramedian region (black line). (B) Midline (redline). Yellow and blue arrows indicate pedicle screw entry points.

cutaneous iliac screw (PIS) fixation (5 navigated and 2 non navigated- freehand) for various pathological conditions of the lumbosacral spine. Two patients had interbody cages with allografts within and around them placed at the L5-S1 level. The majority of the cases (n=4) were spondylodiscitis. All patients underwent successful PIS fixation, with no intraoperative and immediate postoperative complications. No patients required conversion to open procedure and all patients were mobilized on postoperative day 1 with significant relief in pre-operative back pain. None of the patients had wound or hardware related complications till the last follow-up. However, one patient of L5-S1 tubercular spondylodiscitis succumbed three months post-surgery due to a cause unrelated to surgery but due to pre-existing chronic kidney disease (Table 1).

DISCUSSION

The objective of the lumbo-pelvic construct is to produce triangulation effect, reducing screw pull-out, torsional stability [8], reducing stress on S1 screw, and provide adequate stabilization.

Although there are several methods for pelvic fixation which have been described, iliac screws offer superior biomechanical stability as it involvesplacing the screw in zone III-both iliac wings (O'Brien et al. classification) making the construct biomechanically superior as the screw is inserted anterior to the lumbosacral pivot point in sagittal and lateral to it in coronal plane acting as stable distal anchors [9].

Conventional open iliac screw fixation has been the standard of treatment for various conditions requiring lumbo-pelvic fixation, but owing to its potential complication there is an increasing trend towards adapting MI technique of iliac screw insertion. MI placement of iliac screws requires accurate pre-operative strategy in terms of incision planning and placement, desired screw trajectory, appropriate rod contouring, and opti-

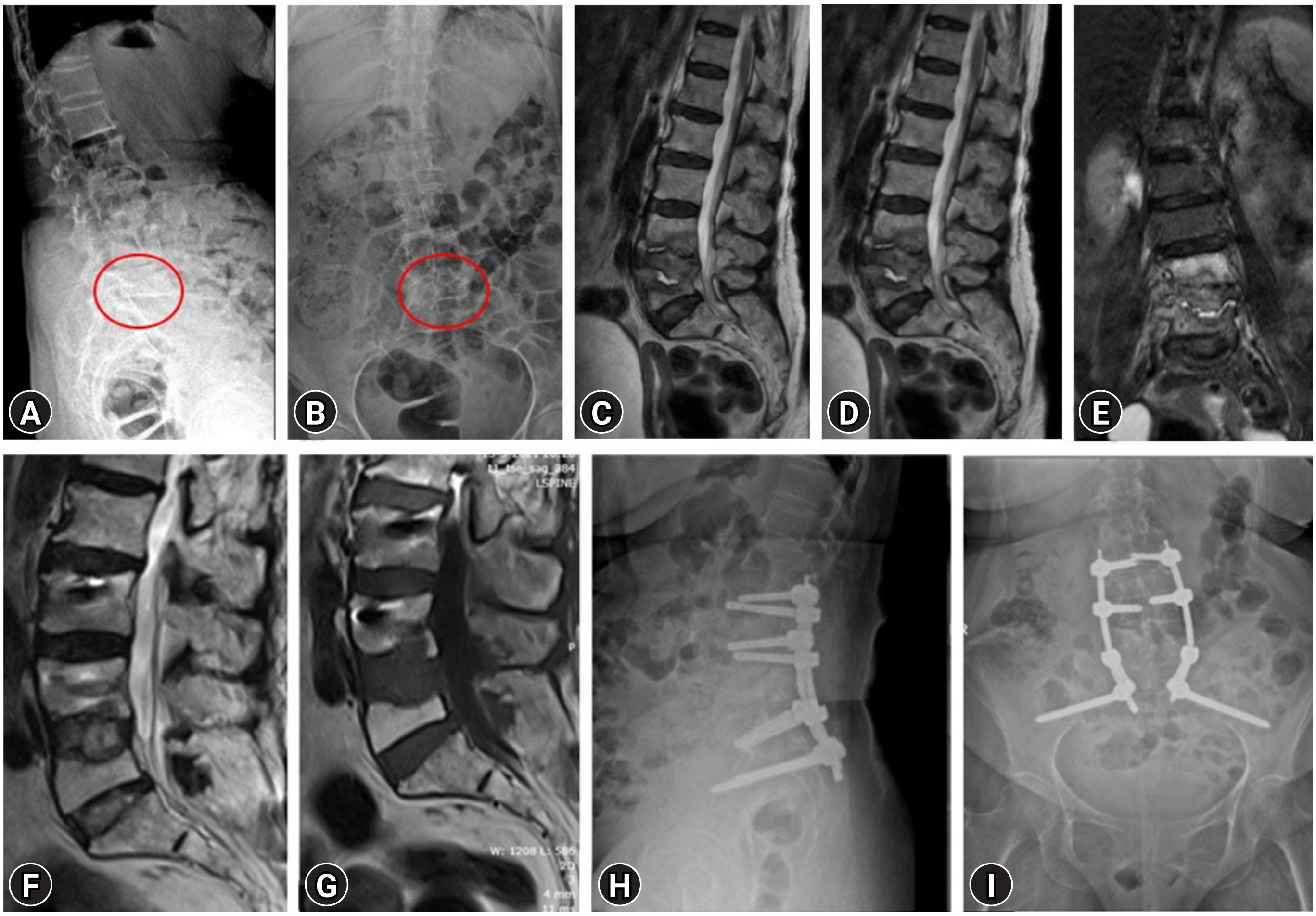

Figure 4. Case example 1. (A, B) Preoperative AP/lateral X rays showing 50% collapse of L5 vertebral body with the destruction of the inferior endplate of L4 and superior endplate L5 (red circle). (C–E) Sagittal T2 and coronal STIR images showing L5 vertebral body collapse with loss of 50%–60% height with alerted signal intensity involving inferior endplate of L4 and superior endplate of L5 with prevertebral enhancing soft tissue component causing nerve root compression. (F, G) Postoperative MRI sagittal T1 and T2 at 1 year follow up (after completion of full course of antitubercular therapy) showing remodelling of L5 vertebral body with signal intensity changes. (H, I) Post-operative lateral/AP X-rays showing L3 – pelvis instrumentation at 1 year follow up.

mal screw characteristic in terms of screw diameter and length.

In MI insertion a midline incision can be planned based on navigation and in a non-navigated freehand technique, an incision can be placed medial to PSIS. The advantage with the midline incision is, there would be roughly 1.5–2 cm depth at which screw head is placed and soft tissue acts as an envelope covering the screw head and avoiding screw head prominence especially in thin individuals. The other advantage of a single midline incision is it would reduce the total number of incisions.

About trajectory planning, two trajectories are available for iliac screw placement, the first one is guided towards the superior rim of the acetabulum, and the second one directs to AIIS [10], with entry points starting at the PSIS. The trajectory towards AIIS offers a longer screw and avoids the risk of acetabular violation [11]. Irrespective of the technique and image assistance used the ideal trajectory would aim to direct screw towards AIIS above 1–2 cm of the sciatic notch, above the acetabulum with 20–45 degrees caudal inclination and lateral inclination of around 30–45 degrees.

Imaging is the key to safe screw placement, with intraoperative O arm and navigation multiplanar real-time images are obtained on the screen which facilitates choosing the right screw entry point, desired trajectory, and right screw length and diameter. On the other hand, freehand techniques are based on anatomical points.

The freehand technique as described by Fridley et al. [12] uses the superior edge of the lamina and spinous process of L5 as anatomical landmarks. The shafts of the pedicle probe should be parallel to the L5 lamina and the shaft of the pedicle

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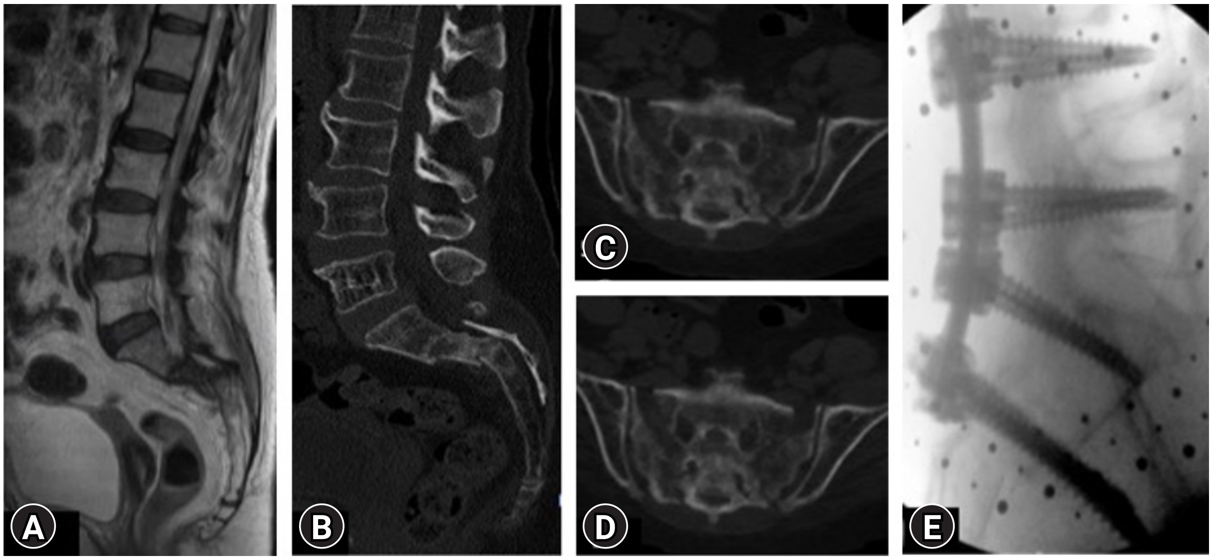

Figure 5. Case example 2. (A–D) MRI T2 sagittal, CT sagittal, and axial sections revealed zone 1 sacral insufficiency with displacement with linear fracture extending from S1 to S5 on the right side, and S1 to S3 left side. (E) Postoperative X-ray (lateral view) showing lumbopelvic construct from L3 to the pelvis.

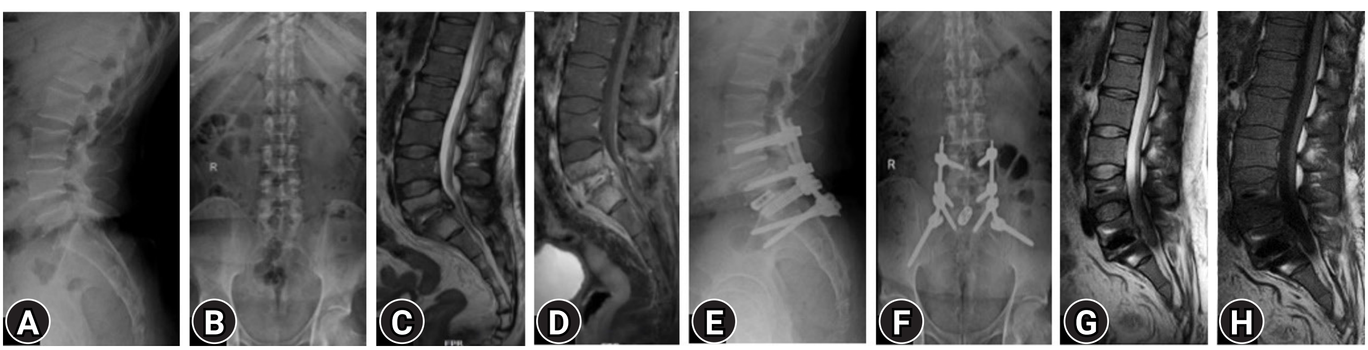

Figure 6. Case example 3. (A, B) Preoperative AP/lateral X-rays showing with endplate irregularity (L5 lower and S1 upper endplate). (C, D) Preoperative MRI-Sagittal T2 and T1+C showing signal changes in vertebral bodies with erosions of adjoining endplates involving L5 & S1 and the intervening disc with epidural collection causing compression on thecal sac and nerve roots. (E, F) Post-operative X-rays AP/lateral at one month showing L4-L5 interbody cage, pedicle, and iliac screw at 1 month. (G, H) Post-operative MRI sagittal T2 , T1 at 6 months revealing remodelling of L5, S1 vertebral body with no evidence of epidural collection.

probe of both sides should intersect each other at the L5 spinous process. If the screw follows the correct path, the path of the probe never goes over the L5-S1 facet joint on the AP fluoroscopy view, and also AP view will assist in preventing sciatic notch violations.

Intraoperative fluoroscopy is of absolute necessity, there are numerous fluoroscopic views and true lateral view in which sciatic notches are superimposed is the primary view for screw insertion. The teardrop view will help in inserting a screw in the widest part ilium which is the centre part on the teardrop view and the screw should be confined within the bony margins of the teardrop on the obturator outlet view. The others additional views which can be used are the obturator inlet view and iliac oblique view. Screw characteristics are of paramount importance, the most commonly used iliac screws are 7.5 cm in diameter and length of 60–80 mm [13,14]. In our series, all screws were more than 6.5 mm in diameter and 60 mm in length with the largest measuring 7 mm in diameter and 70 mm in length. Another technical difficultly is rod contouring and connecting to the proximal construct which needs special attention, rod is always fashioned in two planes – coronal and sagittal. The rod has to be contoured to have a hyperacute lordotic bend of around 30 degrees in the distal-most segment of the rod to facilitate easier connection and the rod has to be always passed from cephalad to caudal. The presence of S1 screw necessitates contouring of a shorter segment of the rod to link S1 and iliac screw head. In indicated cases, it is always preferable to have anterior support especially those constructs extending into the dorsal spine. The use of an interbody cage in anterior reconstruction will not only remove stress on posterior instruments but also promotes fusion. The objective of any lumbo-pelvic construct is to prevent failure and increase the stability of construct, whether a single or dual iliac screw (DIS) is adequate depends on clinical situations. DIS when compared with a single iliac screw, DIS is optimum in terms of stability at the caudal part of the spinopelvic construct and offers higher construct stiffness with respect to compression and torsion. DIS can also be performed by MIS fashion which is described by Hasan and Liu [15].

Use of O arm and navigation renders 3D visualization of bony structures, helps in planning the desired trajectory and guiding the screw with real-time multiplanar images eliminating fluoroscopic exposure and determine the suitable entry point of the screw, screw trajectory [7,13] and maximizing screw length and diameter. Utilizing a submuscular or MI approach to the PSIS and sacrum may reduce soft tissue complications avoiding disruption of erector spinae muscle, posterior sacroiliac, and interosseous iliac ligament contributing to lower infection rates and more rapid recovery than the standard open techniques.

Emami et al. [13] and Tsuchiya et al. [14] group reported various wound and hardware-related complications following the open screw technique. Though there are direct no comparative data between open and percutaneous techniques to assess hardware and wound complications, Liu et al. [16] and Wang et al. [17] group reported no wound or hardware related complications in their case series of PIS insertion.

Liu et al. [16] and Wang et al. [17] group performed PIS insertion in 5 and 24 patients respectively using intraoperative fluoroscopy as a key primary tool for image guidance and screw insertion with the removal of cortical bone to accommodate the screw head [17]. In contrast, our technique of freehand MIS iliac screw placement is based on anatomical landmarks which reduce the overall time of radiation exposure with minimal insult to supporting structure of ilium and PSIS and use of navigation would facilitate in planning appropriate and accurate entry points, trajectory, and screw insertion.

Wound closure should always be in a layered fashion and all efforts should be made to close the fascia to avoid hardware prominence especially in the paramedian incision. Ultimately, larger clinical series is required to demonstrate the safety of this technique.

Table 1. Showing demographic details of clinical series

	Age	Sex	Diagnosis	Procedure	Post-operative ambulatory status	Primary pathology	Follow up duration (mo)	Implant status at last follow-up	Wound Complications
1	50	M	L4-L5 tubercular spondylodiscitis destruction of L5 body	MIS L3-Iliac navigated screw fixation	Independent	Healed	15	No implant related complication	None
2	77	F	L4-L5 tubercular spondylodiscitis destruction of L4, L5 body	MIS L3-Iliac non navigated screw fixation	Independent	Healed	24	No implant related complication	None
3	59	F	Zone 1 sacral insufficiency fracture with linear fracture along with S2 with osteoporosis and RA	MIS L4-S1-Iliac navigated screw fixation	Independent	Healed	36	No implant related complication	None
4	50	M	Zone 2 sacral insufficiency fracture osteoporosis	MIS L4-S1-Iliac non navigated screw fixation	Independent	Healed	24	No implant related complication	None
5	60	F	Implant failure with screw loosening in operated case of L2-3, L3-4, L4-5 OLIF	MIS L1-Iliac navigated screw fixation	Independent	Healed	12	No implant related complication	None
6	50	F	L5-S1 tubercular spondylodiscitis with chronic kidney disease	RT MIS L5-S1 navigated TLIF with L4 to Iliac screw fixation	Independent	Death at 3 months due to underlying chronic kidney disease	3	No implant related complication	None
7	69	F	L5-S1 E. coli spondylodiscitis with cirrhosis of the liver	RT MIS L5-S1 navigated TLIF with L4 to Iliac screw fixation	Independent	Healed	36	No implant related complication	None

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CONCLUSION

Lumbo-pelvic instrumentation technique has been redefined over the decade. Percutaneous insertion of the iliac screw can safely be performed without bony violation along screw trajectory with limited soft tissue damage offering the same biomechanical stability and overcoming the disadvantages of open iliac screw insertion.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Esmende SM, Shah KN, Daniels AH. Spinopelvic fixation. J Am Acad Orthop Surg 2018;26:396–401.
2. Sagi HC, Militano U, Caron T, Lindvall E. A comprehensive analysis with minimum 1-year follow-up of vertically unstable transforaminal sacral fractures treated with triangular osteosynthesis. J Orthop Trauma 2009 23:313–319. discussion 319-321
3. Bellabarba C, Schildhauer TA, Vaccaro AR, Chapman JR. Complications associated with surgical stabilization of high-grade sacral fracture dislocations with spino-pelvic instability. Spine (Phila Pa 1976) 2006 31:S80–S88. discussion S104
4. Schildhauer TA, Bellabarba C, Nork SE, Barei DP, Routt ML Jr, Chapman JR. Decompression and lumbopelvic fixation for sacral fracture-dislocations with spino-pelvic dissociation. J Orthop Trauma 2006;20:447–457.
5. Foley KT, Gupta SK, Justis JR, Sherman MC. Percutaneous pedicle screw fixation of the lumbar spine. Neurosurg Focus 2001;10:E10.
6. Mason A, Paulsen R, Babuska JM, Rajpal S, Burneikiene S, Nelson EL, et al. The accuracy of pedicle screw placement using intraoperative image guidance systems. J Neurosurg Spine 2014;20:196–203.
7. Silbermann J, Riese F, Allam Y, Reichert T, Koeppert H, Gutberlet M. Computer tomography assessment of pedicle screw placement in lumbar and sacral spine: comparison between free-hand and O-arm based navigation techniques. Eur Spine J 2011;20:875–881.
8. Fujibayashi S, Neo M, Nakamura T. Palliative dual iliac screw fixation for lumbosacral metastasis. Technical note. J Neurosurg Spine 2007;7:99–102.
9. O'Brien MF, Kuklo TR, Lenke LG. Sacropelvic instrumentation: anatomic and biomechanical zones of fixation. Semin Spine Surg 2004;16:76–90.
10. Berry JL, Stahurski T, Asher MA. Morphometry of the supra sciatic notch intrailiac implant anchor passage. Spine (Phila Pa 1976) 2001;26:E143–E148.
11. Santos ER, Sembrano JN, Mueller B, Polly DW. Optimizing iliac screw fixation: a biomechanical study on screw length, trajectory, and diameter. J Neurosurg Spine 2011;14:219–225.
12. Fridley J, Fahim D, Navarro J, Wolinsky JP, Omeis I. Free-hand placement of iliac screws for spinopelvic fixation based on anatomical landmarks: technical note. Int J Spine Surg 2014;8:3.
13. Emami A, Deviren V, Berven S, Smith JA, Hu SS, Bradford DS. Outcome and complications of long fusions to the sacrum in adult spine deformity: luque-galveston, combined iliac and sacral screws, and sacral fixation. Spine (Phila Pa 1976) 2002;27:776–786.
14. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C. Minimum 5-year analysis of L5-S1 fusion using sacropelvic fixation (bilateral S1 and iliac screws) for spinal deformity. Spine (Phila Pa 1976) 2006;31:303–308.
15. Hasan MY, Liu G. Minimally invasive dual iliac screw, dual rod fixation in a rare case of pathological sacral fracture from a paraganglionoma: a technique description. J Neurosurg Spine 2017;27:316–320.
16. Liu G, Hasan MY, Wong HK. Minimally invasive iliac screw fixation in treating painful metastatic lumbosacral deformity: a technique description and clinical results. Eur Spine J 2016;25:4043–4051.
17. Wang MY, Williams S, Mummaneni PV, Sherman JD. Minimally invasive percutaneous iliac screws: initial 24 case experiences with CT confirmation. Clin Spine Surg 2016;29:E222–E225.

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End-points of Decompression of in Lumbar Transforaminal Endoscopic Spine Surgery: A Narrative Review of Objective and Subjective Criteria to Prevent Failures

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Objective: Executions of indications/extended indications are associated with higher than normal rates of symptomatic recurrences and treatment failures, especially for novice surgeons incorporating Percutaneous Transforaminal endoscopic lumbar discectomy/decompression (PTELD) techniques. Causes of failures can be manifold and can occur because of a residual or a complete fragment causing persistent compression or associated unaddressed stenosis. To prevent this problem, proper training, multiple instrument inventory, variable techniques are needed with progressive learning. Authors aim to suggest objective and subjective criteria to define end-points/adequacy of decompression (EPD).

Methods: PubMed database search was limited to locate only adequacy of decompression of PTELD and thus included specific keywords: "ENDPOINT" OR "ADEQUATE" AND "DECOMPRESSION" AND "TRANSFORAMINAL" AND "ENDOSCOPY". Authors added their experience to refine and define multiple EPD.

Results: In the search we found 12 articles total. Upon reviewing these, we found 7 articles matching our criteria. Cross references of included articles were searched, 5 additional articles were included. EPD were described in only 9 articles. Author's experience with other relevant references were added to complete the viewpoint (EPD, n = 29). Direct observed/provoked EPD and inferred EPD were defined separately. Videos, illustrations and descriptions of each EPD are illustrated to provide the ideation.

Conclusion: EPD are variable and not all signs may be elicited in every case and may change with surgeon experience. The ability to recognize EPD is the crux for successful outcomes and maximum possible EPD's should be aimed in every surgery to avoid failures.

Key Words: End point, Decompression, Percutaneous, trans foraminal, Endoscopy, Spine, Surgery

INTRODUCTION

In the last quarter of 20th century and early 21st century, PTELD has rapidly evolved as an alternative for lumbar disc herniations (LDH) [1]. Advantages of PTELD are remarkable due to surgery under local anaesthesia (LA), though general (GA) and regional anaesthesia can also be used. Minimal damage to muscles/bone/other soft vertebral tissue restraints, rapid recovery, nominal post-operative pain, reduced procedure related morbidity, and a high patient satisfaction rate [2,3] are the other specific advantages. The technique of PTELD has come a long way in the last few decades through experiences of pioneers along with numerous advancements in the field of optics, instrumentation and enabling technology (Magnetic Resonance Imaging [MRI], Radio-frequency [RF], Laser, Ultrasound, Navigation etc.) [4,5]. Initial cases of discectomy were limited to soft para-central LDH. But, gradually it has also been used for treating central, highly migrated, foraminal and extraforaminal LDH, cauda equina syndrome (CES), lumbar spinal stenosis (LSS), stable listhesis, separation surgery, discitis/epidural abscesses and also for performing fusion surgeries [1,6-12].

However, these extended indications and increasing surgical numbers may be associated with higher rates of symptomatic recurrences and treatment failures, especially for novice surgeons incorporating newer ESS techniques [13]. The endpoint of PTELD needs to be identified and differentiated; it is different when PTELD is used only as a pain procedure and when decompression is the surgical goal. Pre-operative evaluation and case selection is of utmost importance in any ideal or advanced indication of ESS. The authors in this review article aim to describe objective and subjective criteria to define the endpoint/adequacy of decompression (EPD) in PTELD.

MATERIALS AND METHODS

For this narrative review, database search was limited to locate only adequacy of decompression of a transforaminal endoscopic lumbar surgery. The search words were limited to specific keywords: "ENDPOINT" OR "ADEQUATE" AND "DECOMPRESSION" AND "TRANSFORAMINAL" AND "ENDOSCOPY". We started the search with above mentioned keywords and the search was done in "PubMed" data base [14]. Required articles language was English. Additional repeat confirmation by two independent researcher reviewers were done for validation and confirmation of the literature review. None of the correspondent authors were contacted for any kind of doubt or other query & resolution. Author's experience with the other needed references are added to further refine and define EPD. Key literature pertinent to the current topic have been cited and emphasis has been placed on literature published within the last decade to provide the most current recommendations.

RESULTS

In the search, we found a total 12 articles (Figure 1). Upon reviewing the 12 articles, we found 7 articles matching with our criteria and the 5 articles that were excluded were unrelated to ESS. Cross references of the included articles (7) were searched and 5 additional articles were included. EPD were defined in 9 articles only and they were tabulated (Table 1). In PTELD the suggested EPD is by pre-operative planning, achieving the planned EPD with its optimal confirmations per- operatively and documenting decompression post-operatively by objective and subjective parameters. Authors re-identified and describe 29 EPD's separately. Videos, illustrations and descriptions of each of the EPD is added to prove the ideation.

DISCUSSION

In MIS (minimally invasive spine surgery) or more importantly in ESS (endoscopic spine surgery), the optimum decompression goal should get as close to the COSS (conventional open spine surgery) decompression goal. This needs very specific diagnosis and target unlike COSS which focuses on an exploratory decompression solutions and hence is more forgiving [15]. It is known that for Inter-laminar ESS (Unilateral Biportal, Destandeau, Uniportal Interlaminar Lumbar Decompression) [16-19] the endpoint is still the same as COSS. However, in PTELD the suggested EPD is three tier. Firstly by pre-operative planning, then achieving the planned EPD with its optimal

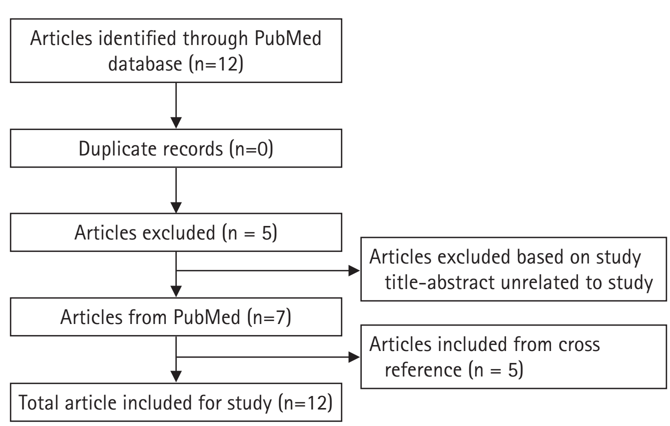

Figure 1. Flowchart of PubMed literature search.

Table 1. EPD (end-point of decompression) in transforaminal endoscopy defined in PubMed literature search

Sr No	Author	Year	Defined EPD
1	Martin Komp [83]	2014	The operation was finished when the complete cyst was resected and the neural structure was clearly decompressed under visual observation.
2	Osama Nezar Kashlan [84]	2020	Exposure of the exiting nerve root superiorly after adequate decompression is achieved.
3	Zhen-zhou Li [85]	2016	Direct visualization and excision of the herniated disc and hypertrophied posterior longitudinal ligament could be finished. After that, the decompression of traversing root and dura sac can be confirmed easily.
4	Pengfei Li [86]	2021	The protruding nucleus pulposus was removed using a clamp under the protection of a trocar. Then, the nerve root was explored and released. Finally, under endoscopy, the nerve root was seen to fall back and the surrounding space was fully decompressed. A negative intraoperative straight-leg elevation test further indicated that the decompression was definitive and effective. This was a sign of the end of the procedure.
5	Guodong Yin [87]	2021	Following removal of the disk protrusion, ventral facet of the SAP, and ligamentum flavum, the traversing nerve root and dural sac were exposed with adequate mobility and good pulse, indicating complete decompression. It was necessary to eliminate residua along the entire traversing nerve root up to the lateral recess.
6	Yong Ahn [88]	2021	The endpoint of the procedure should be adequately determined by a free mobilization of the neural tissue and strong pulsation of the dural sac.
			For lateral recess, the tip of the SAP may be typically removed by a bone trephine or endoscopic burrs. After sufficient removal of the bony stenosis, the exposed ligamentum flavum can be subsequently removed by micropunches or forceps. For the lateral recess stenosis, the caudal part of the foramen and the traversing nerve root are decompressed, whereas for the foraminal stenosis, the cranial part of the foramen and the exiting nerve root are decompressed. Additional pedicle resection may enhance the decompression effect. The key to success in this technique is the adequate landing of the working cannula and sufficient decompression of the critical point, which is usually located around the hypertrophied SAP and thickened ligamentum flavum.
7	Gun Choi [2]	2017	Free movement of thecal sac and traversing root, fresh epidural bleeding, and subsidence of pain are the signs of an adequate decompression.
8	Seungcheol Lee [6]	2007	The well-decompressed nerve roots are confirmed by visualization of the thecal sac and nerve root pulsation following respiration and valsalva.
9	Sagar B Sharma [12]	2019	A radiopaque dye Iobrix® is flushed through the catheter to obtain an epidurogram. In some cases, we also use the O-arm to obtain a 3D image of the epidurogram. Comparison between pre-discectomy and post-discectomy epidurogram enables the surgeon to judge the adequacy of discectomy and canal clearance achieved. A free flow of the dye above the affected disc space and into the involved nerve root suggests adequate decompression. The free passage of catheter across the disc space may also be visualized with the endoscope.

confirmations per-operatively and finally documenting decompression post-operatively by objective and subjective parameters. Factors influencing the EPD include the underlying pathology (LSS vs. LDH: soft/hard LDH), level of surgery, the site of compression (dorsal/ventral), approach technique used (IO: Inside Out/OI: Outside In, and FEE: Flat Entry Epidural [1]), duration of symptoms (acute/chronic), radiological patient specific features, experience, school of thought and expertise of the surgeon.

1. Pre-operative Planning for Target EPD

We recommend an immediate pre-operative MRI (Magnetic Resonance Imaging) to assess the pathology and for clinico-radiological correlation. This is not only for pre-operative planning, but also to assess the size of fragment for intra- operative assessment of completion of surgical decompression. Not to forget that there may be a change in the location of the fragment after initial presentation, which can only be confirmed by an immediate pre-operative screening MRI. This is essential to curtail chances of a missed fragment, as PTELD is a minimalistic procedure and does not allow change of trajectory of approach and visualization as compared to exploratory COSS [20]. Plotting of LDH fragment and stenosis can be drawn on the radiographs (antero-posterior and lateral views) (Figure 2D, E). This is helpful during initial learning because stenosis or spatial configuration of LDH fragments in spinal canal is based on 2D MRI films or 3D imagined PACS visualization. But, our per-operative endoscope tip and working instruments jaws location is guided on image intensifier radiographic images only.

2. Intra-operative Assessment of EPD

1) EPD in PTELD for LDH

The transforaminal approach in "inside out" technique refers to a postero-lateral approach to the disc or epidural space through the foraminal window [21]. The detailed techniques can be referred to in previous literature and is not the focus of present study [1, 22-24]. EPD defined in previously published literature in the PubMed search is limited (Table 1). The Au-

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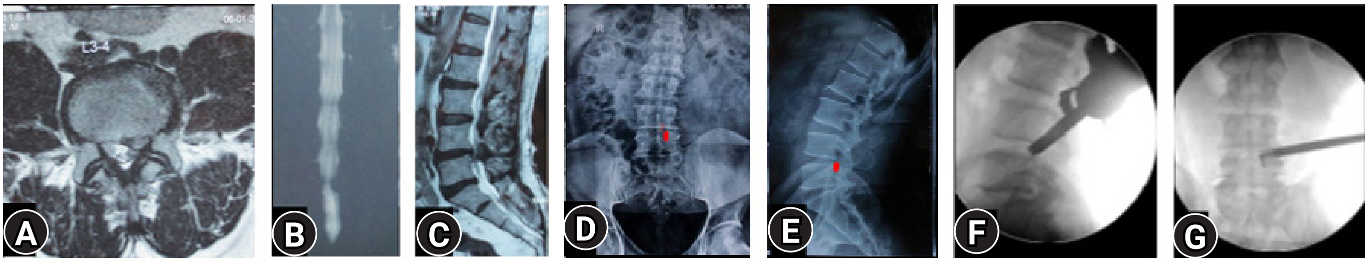

Figure 2. (A–C) MRI of L3-4 para-central location low migrated LDH on left side. (D, E) Superimposed traced fragment (Red) in a antero-posterior and lateral radiograph. (F, G) The position of the endoscope tip and the articulated hook checked on C-arm for target area location assessment. End point decompression (EPD) is confirmed after fragment retrieval and inferred with target area location and re-affirmed with a post-operative MRI later.

thor's recommend multiple EPD in addition to previously mentioned literature EPD (Table 2). For ease of understanding many non provocative and provocative direct EPD along with inferred EPD are suggested. After multiple release and decompression techniques, confirm decompression by direct and indirect evidences. Though debatable, we also believe that the direct visualization of neural elements is the best documentation to avoid failures [25]. Authors' EPD includes complete direct visualization of the Traversing Nerve Root (TNR) when it is the focus of decompression. The extent of direct visualization is from superjacent lower endplate unto the inferjacent pedicle by angulating the endoscope. This can be further extended in cases of up-migrated or down-migrated fragments by doing additional maneuvers like a partial pediculectomy. In cases with central LDH, central stenosis or CES, direct visualization of the central dural sac is taken as the EPD [1]. Once the EPD is reached, neural fall back occurs and neural tissue occupies the space that was previously occupied by LDH fragment (Figure 3).

These EPD vary depending on the pathology. In para-central protrusions even an intact annulus with free epidural fat pop-out signals adequate decompression [1]. This fat pop-out is usually seen in acute LDH, para-central LDH and is more pronounced in high BMI (Body Mass Index) patients (Figure 4). In fact, the fat may hinder in actual visualization of decompressed neural structures. In these type of cases, probing along the length of TNR is especially important to avoid false positive EPD. In cases of LDH extrusion, major fragment retrieval (Figure 5, Supplementary Video 1), i.e., removal of the culprit fragment is the best sign of a complete decompression and EPD. Fragmented epidural components may remain and should be looked for especially when migrated or extruded fragments with more than a week-old presentation are addressed. This is more likely when epidural trans-PLL (posterior longitudinal ligament) fragment is present due to the body's phagocytic response to the antigenic nucleus pulposus [26,27]. This major fragment retrieval does not occur in disc bulge, stenosis and calcification. In this later type of cases slow crab eating technique is what is needed. Usually, a gush of epidural blood comes out, called as "Red-Out" after the fragment retrieval indicating unobstructed epidural space (Figure 6) [1,28]. Visibility is always gained in a while with fluid ingress and washout, when the dura expands and creates a normal haemostatic tamponade. False positive red out are also noted in sudden multiple bleeder points especially with cutting burr, major bleed or any fluid inflow blockade in the endoscope [28]. After the fragment removal is achieved, opposite annular fissure visualization is possible (Figure 3, 7). This is the EPD in a protrusion or extrusion followed by most experienced surgeons (Supplementary Video 2). Habit of eyeballing the size of fragment (Figure 8) removed by the instrument and matching it with an extruded or sequestrated fragment size on MRI should be the dictum. If in any case with fragmented nucleus (extrusion, sequestration) there is no red coloured part in the removed disc pieces, then it suggests that the culprit nuclear fragment is still pending to be removed. The red area depicts the epidural outer surface (Figure 5), while yellowish area is unexposed part, though degenerated. Sometimes, a whitish coloured area is noted and is the most inside part of the major fragment within the disc space confines itself (Figure 9). At the same time a red staining fragment retrieved but not matched to size on MRI should arouse suspicions. Small fragment miss outs are common in sequestration. Use of live dye Indigo-carmine is used for spotting the fragment easily and identifying degenerated fragments. This is useful for EPD judgment and used at many centres worldwide [29,30].

In extra-foraminal or foraminal LDH, the exiting nerve root is visualized and probed below it against the vertebral body and the disc annulus after retrieving the fragments. Many times crab eating of the compressing annular hardening, calcified LDH and ventral LSS is required. Variable use of burr, osteo-

Table 2. Authors recommended EPD (End Point Decompression)

Sr. no	Direct EPD (observed or provoked)	Sr. no	Inferred EPD
1	Major fragment retrieval (MFR).	18	Epidural fat pop-out (EFP)
2	Red-out (RO)	19	Epidural probing (EP)
3	Neural fall back (NFB)	20	Annular flap mobility (AFM)
4	Eyeballing size of disc fragment removed & it is matched with MRI (ESF)	21	Dye stained fragment clearance
5	Direct visualization of nerve root/dural sac in its course (DV)	22	Target area location (TAL) with instrument tip
6	Epidural pulsation (EP)	23	Smooth sweeping of the floor (SSF)
7	Breathing dura	24	Scoliotic list correction
8	Soft dural flutter (SDF)	25	Heart rate/blood pressure correction
9	Valsalva manoeuvre like cough, sneeze, deep breathing, Shows violent dural flutter (VDF)	26	Free Straight Leg Raising Test (Intra and Post Operative)
10	Opposite annular-fissure visualization (OFV)	27	Subsidence of pain
11	Epidural darks (ED)	28	Short Nap
12	Post-operative MRI (PMRI) & myelogram (PMRM)	29	VAS and ODI scores (post-operative) or other PROM (patient reported outcome measures improvement)
13	Epidurography		
14	X- MRI		
15	Future directions: MRI compatible endoscope and Operative set Up, Visualisation with epiduroscope, Trans-Foraminal per-operative Ultrasonography.		

The tabulation has clubbed all EPD of literature search, personal recommendations and futuristic directions.The author utilizes a variety of end-point/adequacy of decompression (EPD) in PTELD to assess decompression, both direct and inferred. A few are observed and a few are provocative.

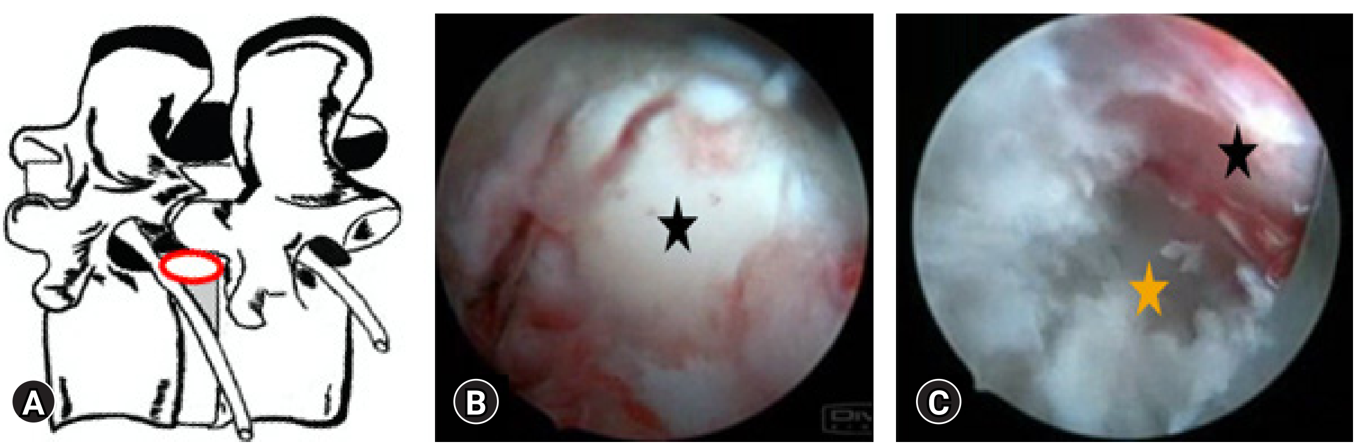

Figure 3. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) para-central location. (B) At the start of the left side approach to L4-5, Endoscopic "Inside out" epidural view showing starting endoscopic view with the nucleus pulposus fragment, lying just ahead after having cut the near side annular anchorage. (C) After the completion of Transforaminal, Full Endoscopic Spine surgery (ESS) the End Point Decompression (EPD) clearly showing the neural fall back with epidural vessels (black*), into the space created by removal of the disc fragment. Opposite annular fissure visualisation (orange*) at the depth of the annular tear which was on the other side of the cut side annular anchorage.

tomes, hooks, dissectors and articulated scoops are needed to decompress them optimally. Once the EPD is reached in these cases there is neural fall back and visualization of the TNR and dural sac. In cases of sub annular LDH, the PLL will be free and is considered as the EPD. Depending on the location of the annular tear, annular flap mobility must be considered as the EPD (Figure 7, Supplementary Video 2). In cases where there is no annular flap mobility, look for chronicity features: end plate spur/hardened annulus (Figure 10). This may help locate the associated stenosis in addition to a disc fragment. If it is tackled optimally, it will avoid a failure. These are all "non-provocative EPD".

When the EPD is reached, movements of the dural sac and neural elements can be elicited by various "Provocative" maneuvers. Visualization of strong epidural pulsation of the and TNR are the confirmed EPD. EP can be seen in-sync with the

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patient's breathing as well (Supplementary Video 3). Dural Flutter (DF), soft and violent can be provoked as additional EPD. Soft DF can be elicited by thumb pressure on water flow at the outer end of the working channel (Supplementary Video 4). DF may be deceptive in cases of obese patients because of epidural fat popping [1,31]. Another conceptual change is to understand that disc prolapse material can have associated end plate cartilage or/and annulus in addition to nucleus fragment. This may have to be removed for complete decompression especially with acute on chronic clinical history. There may be small to big end plate junction failure or posterior rim apophysis fracture [1,32,33]. This may be healed or avulsed or non-united and may necessitate removal when needed. So, a careful assessment of pre-operative MRI is a must. EPD of violent DF can be elicited by a violent cough impulse/deep breathing or any valsalva maneuver. But this method does not hold in case of patients under general anesthesia, and in those cases input from anesthetist with an Ambu bag becomes necessary. Also, to note, Violent Cough or sneeze is now painless unlike pre-operatively, where any valsalva maneuver is usually painful in an LDH (Supplementary Video 2).

Various subtle and obvious clinical changes occur which signals an inferred EPD. A pre-operatively obvious scoliotic list/ tilt/ stoop can correct on operation table itself with subsidence of pain once neural compression is relieved. A changed spasmodic prominence of paraspinal muscles is also observed in many cases. Systemic parameters change and we have consistently observed a fall in heart rate post- decompression after removal of the nociceptive stimulus. Good coordination with

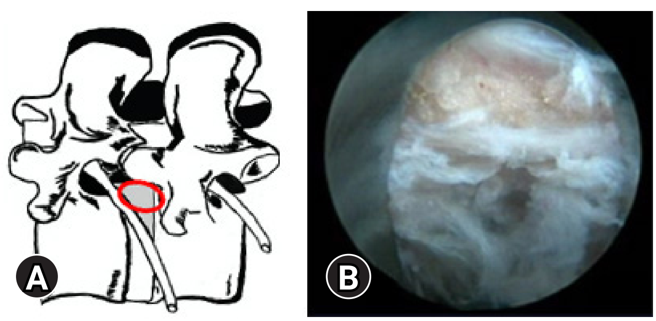

Figure 4. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) at para-central location. (B) Epidural fat pop-out and epidural vessels that gets visualized in obese patients rather than neural fall back.

Figure 6. Red out; epidural gush of blood that wipes out visibility.

Figure 5. After the major fragment retrieval, habit of eyeballing the size of fragment removed and matching it with an extruded or sequestrated fragment size on MRI should be the dictum. Variable colours are valuable to identify the major fragment. Red area shows the epidural outer surface, while yellowish area is unexposed part, though degenerated. Some times a more whitish coloured area is noted and is the most inside part of the major fragment within the disc space confines itself.

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the anesthesiologist can help record this finding [34]. Usually, patients of acute, severely painful LDH gets relieved of symptoms and many times goes for a short nap in absence of the severe pain which had given them sleepless previous nights. SLRT (Straight leg raising test) can be elicited by dropping the affected side leg side table of an orthopaedic table or shifting the patient to table side (Figure 11). This can be done supine or lateral as well. This signifies the free sliding of the TNR and can be documented directly. Surgeons must remember that false negative SLRT can be elicited when a chronic disc with a soft disc fragment is operated by PTELD. The focus of the surgery by most surgeon is usually the removal of the soft fragment. Inspite of the adequate removal of the soft fragment, and acute pain relief, the SLRT may not improve due to the bumpy remaining ventral stenosis (Figure 12). False positive free SLR can be elicited in cases of smaller fragments even if they are not removed, under the strong transient action of sensorcaine and

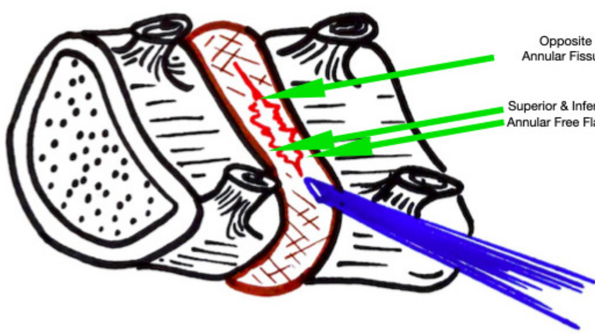

Figure 7. Illustrative image showing the annular tear through which the nucleus has prolapsed. After PTELD (removal of fragment), the Opposite annular fissure visualization and annular flaps mobility are EPD's (End Point of Decompression)

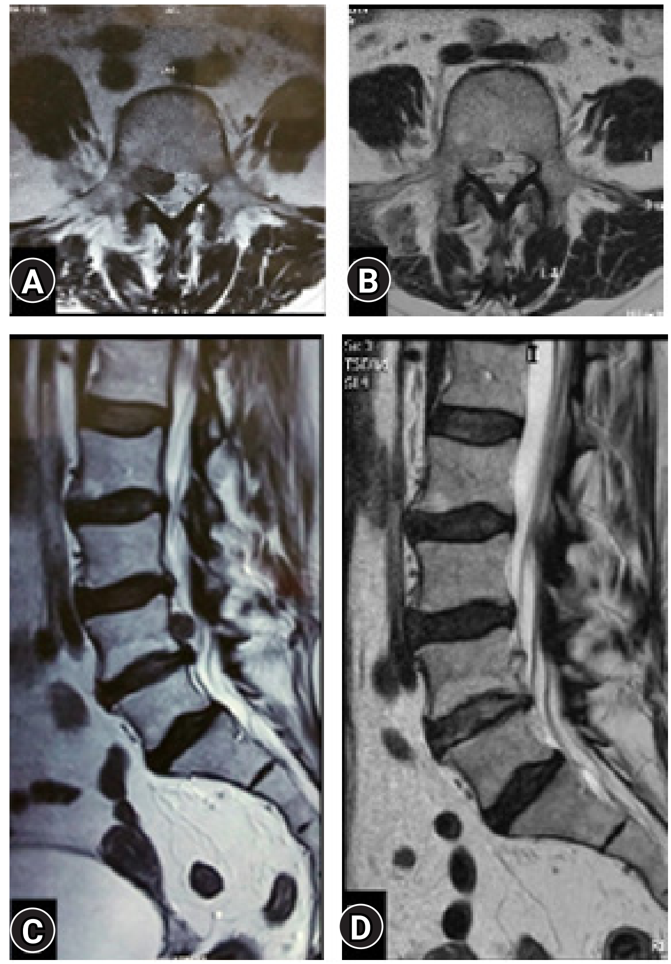

Figure 9. (A, C) An operated case of up-migrated disc prolapse (L 4-5: Right side) by transforaminal "Inside Out" approach. (B, D) Near complete decompression in the Post-operative confirmatory MRI showing the achieved decompression. A small residual asymptomatic fragment remains and at 6 years' post-operative the outcome is excellent.

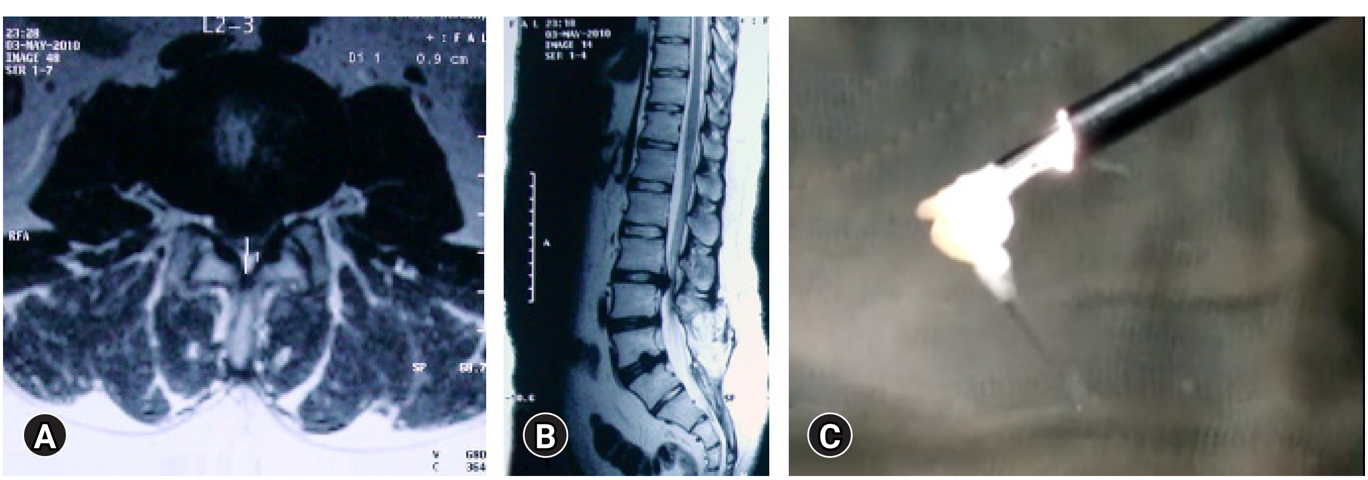

Figure 8. Eye balling the size of fragment and comparing with the MRI. Previous two level operated Open surgery patient with a new L2-3-disc herniation (A, B), with a matched fragment en-masse removal (C).

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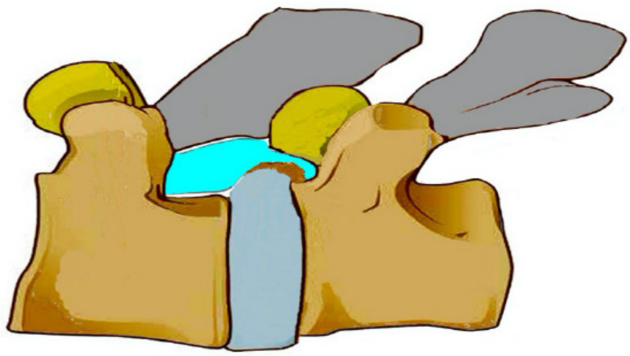

Figure 10. Illustration of a calcified disc, superior end plate spur of inferior vertebra, causing hard ventral lateral recess stenosis. Similar spur may exist in upper or lower endplate and even bilaterally.

Figure 11. Straight leg raising test elicited in prone position on table (per-operative) which if free in comparison to the restricted pre-operative test, suggesting inferred EPD (End Point Decompression).

washout of the chemical mediators. Epidural Probing (Supplementary Video 5) with a RF probe, hook, dissector, straight probe or steerable probe or articulated hook adds to surgeon's confidence and confirms epidural clearance. After adequate decompression the articulated hook can be used for the smooth sweeping of the floor of the room that is cleared (i.e., the space ventral to the dura on the annulus and adjoining vertebral body). This also confirms the EPD (Supplementary Video 6, 7). But again, it is inventory based and the extended tactile feedback can be developed by experience only. Usually a Epidural Darks (ED) region is well noticed as empty space many times after the LDH decompression indicating unobstructed epidural space. They are apparent due to decompression and collapsing dura due to irrigating fluid pressure. They start appearing after a decompression indicating EPD but not regularly seen in LDH (Supplementary Video 8, 9). This is usually visible when doing a migrated big LDH removal. A trans-ligamentous sequestration may not show ED. A sub-ligamentous sequestration even after decompression, does not allow the PLL to fall back to its natural position there by preventing typical neural fall back and at times showing false positive ED. Neural tissue visualization is also incomplete in cases of sub ligamentous small protrusions, extrusions and sequestrations. False positive ED is noted in cases of calcified disc adjoining regions even before decompression is completed (Figure 13). Proper in-depth MRI understanding of the patho-anatomy is essential to corroborate these EPD finding. A classification based understanding of ESS is recommended for more specific target identification and execution [1,35].

Instrument tip like a RF probe or hook can be placed and target area location on fluoroscopy can be confirmed (Figure 14). The position of the instrument tip is matched with the location of the pathology on the pre-operative scan to confirm the fact that the surgical decompression was carried out at the correct target pathological area. This maneuver is especially useful in cases with migrated LDH. Recording a video of the entire procedure if feasible or at least the maximum possible EPD's is recommended by the author for documentation and medico-legal purposes. All the above mentioned EPD are of IO approach. In OI approach also the visualization is similar, but docking is different and maneuverability of the endoscope is limited. The aiming and trajectory have to reach to the head or tail of the fragment. Though after an IO approach burred foraminoplasty can be done to do additional targets of decompression to combine the benefits of IO and OI approaches of PTELD. But the reverse to change from OI to IO approach is technically impossible. In FEE technique the approach is more flatter, visualization is more anatomical and many of the above EPD can be elicited. But, it's wide spread acceptance is not observed. At the same time the recurrence rates and advanced applications of FEE approach is limited in literature [36,37].

2) EPD in PTELD for Stenosis

The detailed techniques of execution of stenotic decompression can be referred to in previous literature and is not the focus of present study [1]. Many suggested EPD, found in literature search, are there in transforaminal endoscopic lateral recess decompression, lumbar foraminotomy and ventral decompression (Table 1). The commonest pathology in degenerative stenosis is hypertrophy of the SAP (superior articular process),

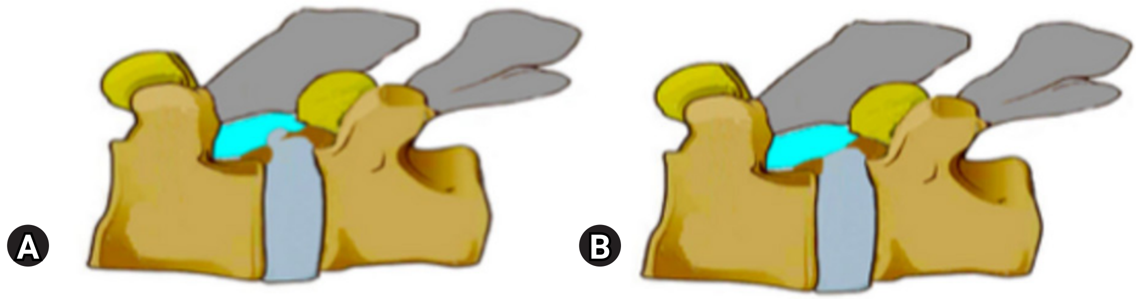

Figure 12. (A) Showing a calcified end plate spur causing ventral stenosis with a small disc prolapse that causes an acute presentation. (B) Even after removal of the disc fragment by PTELD, the ventral stenosis remains. In this case acute symptoms may resolve but SLRT restriction may remain in moderation. The myelo-block in myelogram can also persist.

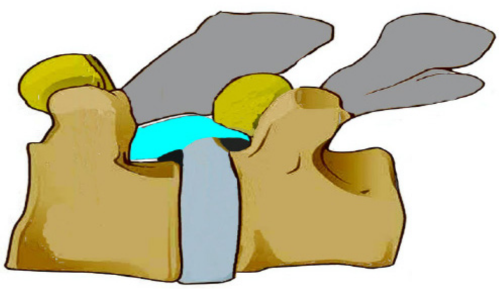

Figure 13. Black shadow in ventral epidural space adjoining the discogenic compression, suggestive of false positive Epidural darks. These are dead spaces and are present in severe ventral stenosis.

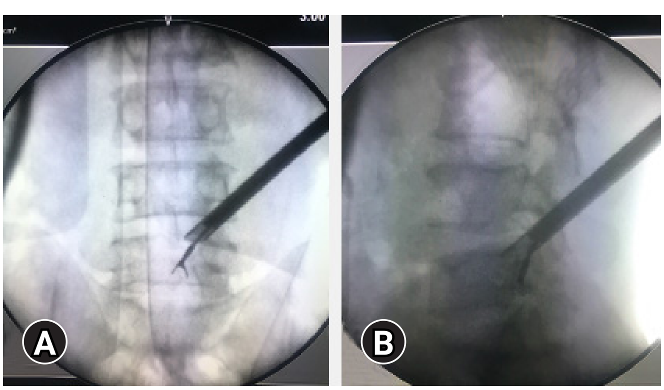

Figure 14. The position of the endoscope tip and the articulated grasper can be checked on fluoroscopy for target location assessment target area location. (A, B) In case of a highly migrated disc prolapse tackled with a transforaminal "Outside In" approach, End-point decompression (EPD) confirmed after major fragment retrieval and inferred by reach and position of the instrument tip.

LF (ligamentum flavum) hypertrophy, disc space settling (annulus buckling) with or without LDH, osteophyte formation and associated dynamic or static translation. As a result, the TNR is compressed in cases of lateral recess stenosis (LRS) and the exiting nerve root is compressed in the foraminal stenosis (FS) [38,39]. LSS according to pathological zones is classified into three categories: central LSS, LRS and FS. PTELD can be suitable for the treatment of the LRS/FS by resection of the hypertrophied SAP [40-42]. Reaching to the central dorsal aspect is difficult by PTELD. Though tricky, indirect decompression by removing the ventral upper endplate spur of lower vertebra can enlarge the central canal as well [41]. In FS, the focus is on the cranial foramen and removal of the tip of SAP, capsule and LF. Visualization of the pulsatile exiting nerve root is the EPD. For the LRS, the caudal foramen is focussed, and additional adjoining pedicle removal is needed many times in addition to sculpting of SAP, inferior articular process, LF and capsule. Visualisation of the entire pulsatile TNR on ventral, lateral and dorsal aspect confirms the EPD (Supplementary Video 9) [43]. For central LSS, or unilateral ventral stenosis, ventral decompression by removal of the LDH, buckling annulus (which is usually hardened or calcified) and removal of the superior vertebral end plate spur of the inferior vertebra is done (Supplementary Video 10). Visualisation of the entire pulsatile TNR and dural sac affirms the EPD. For bilateral symptomatic cases further flattening of the endoscope trajectory and ventral decompression of contralateral traversing root and visualization is to be done [44]. In cases with a high degree of stenosis, bilateral symptoms, conus/ cauda equina syndrome, bilateral transforaminal endoscopy with two working ports ensures adequate EPD (Figure 15) [1]. Usually a epidural dark region is well noticed many times after the decompression indicating unobstructed epidural space (Supplementary Video 8, 9). This can be ventral or dorsal. False positive epidural dark are visible at some times especially at elevated dura junction of calcified disc/end plate spur and represent dead spaces due to chronicity (Figure 13).

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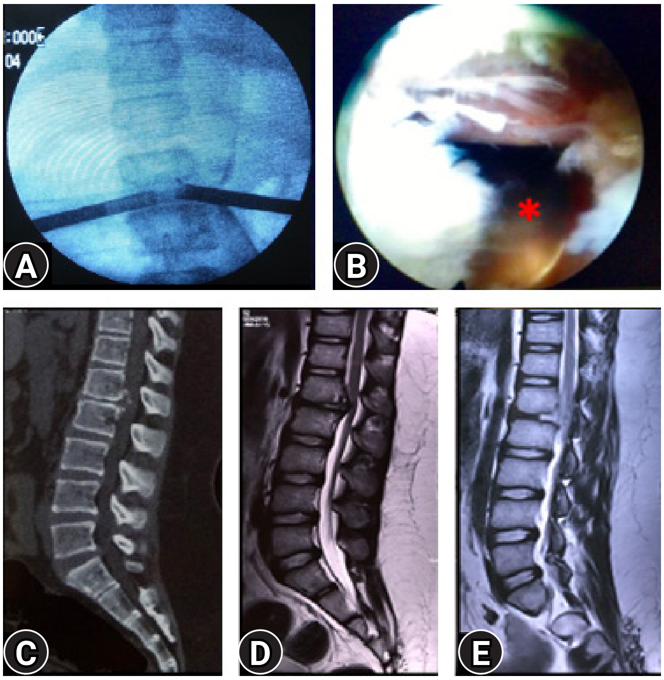

Figure 15. (A) Image intensifier view of a bilateral transforaminal endoscopy with two working ports. (B) The one side view showing the opposite working sheath with removed ventral stenosis and with neural fall back suggesting the EPD (End point decompression). (C, D) CT scan and MRI showing calcified ventral disc and posterior longitudinal ligament in a case for Conus syndrome L1-L2 with paraparesis. (E) Post-operative MRI conforming the extend of decompression. Patient recovered completely in two weeks' time and 7 years follow-up.

3. Post-operative Assessment

SLRT can be utilized pre-operatively with diagnostic implications and intra-operatively/post-operatively to confirm the EPD [45,46]. There may be a component of hamstring tightness [47] which may remain; however, the characteristic radicular pain subsides [48]. It is important to note that this is a "passive" SLRT [49] to be performed by the surgeon only and not to be done by the patient on his own.

Post-operative VAS (visual analogue scale) score can be compared with the pre-operative baseline [50]. This assumes importance as the PTELD elicited VAS is very specific and not confounded by surgical site pain as in COSS [51]. PROM (Patient Reported Outcome Measures) evaluations follow few weeks to months and objectifies the recovery and optimum decompression achieved. But, patient satisfaction Index or other Likart scales can be taken immediately to quantify the subjective outcomes [51,52].

The incidence of scoliotic list has been reported to range between 8.9% to 18% in patients with LDH who have undergone a discectomy [53]. Disappearance of a pre-operative list either intra-operatively on table or post operatively is observed and confirms the adequacy of decompression.

We routinely do immediate post-operative MRI (PMRI) combined with Magnetic Resonance Myelography (MRM) [54,55] to objectively assess the extent of decompression in all patients. PMRI (Figure 16) is best confirmatory for all PTELD. A resolved MRM block also facilitates documentation of the EPD. Myelo-block after decompression are visible in many cases because of unaddressed endplate spur ventral stenosis (Figure 12). Even with multiple EPD achieved per-operatively and annular flap mobility, myelo-block may be there (False positive) (Figure 17). Pseudobulges are noted in some cases. This is very important to record in consultation with radiologist as it can invite medicolegal problems especially in profound deficits, despite an optimal EPD achieved [1,56].

4. Future Directions

Intra-operative ultrasound [57,58] guided PTELD is a new adjunct that gives radiation free real time guidance. Ultrasound has been utilized in COSS, not only for identification of spinal pathologies operated, but also to confirm the degree of decompression of the neural elements [59-61]. In PTELD the need is an appropriate probe, engineered to go through the working sheath. We can also use epiduroscope/bronchoscope through the working cannula to visualize the EPD (Figure 18). This can be utilized when highly migrated fragments are there, which can be fragmented. UBS (ultrasonic bone scalpel) in COSS shows several advantages including decreased risk of mechanical injury, reduced thermal injury, and reduction in osseous bleeding, which improves visibility in the surgical field and provides significant reduction in surgical time [62-65]. Given the precision offered by UBS, and the fact that PTELD is such a selective, targeted procedure, the day when UBS will be introduced in ESS is not far away. Navigation is another development in spine surgery and PTELD [66,67]. It will enhance the surgeon's ease of learning and performing PTELD and likely save radiation years of surgeon [68]. When combined with intra-operative CT scan based navigation, EPD can be confirmed when PTELD is applied for bony stenosis. Possibility of endoscopic vision with projection of 3D digital hologram defining the EPD can be planned pre-operatively and confirmed per-operatively, based on interactive user interface on an head mounted device based navigation [69,70]. Robotic spine systems are rapidly changing the landscape of modern surgery. Once appropriate user interfaces are in play, RSS will be useful

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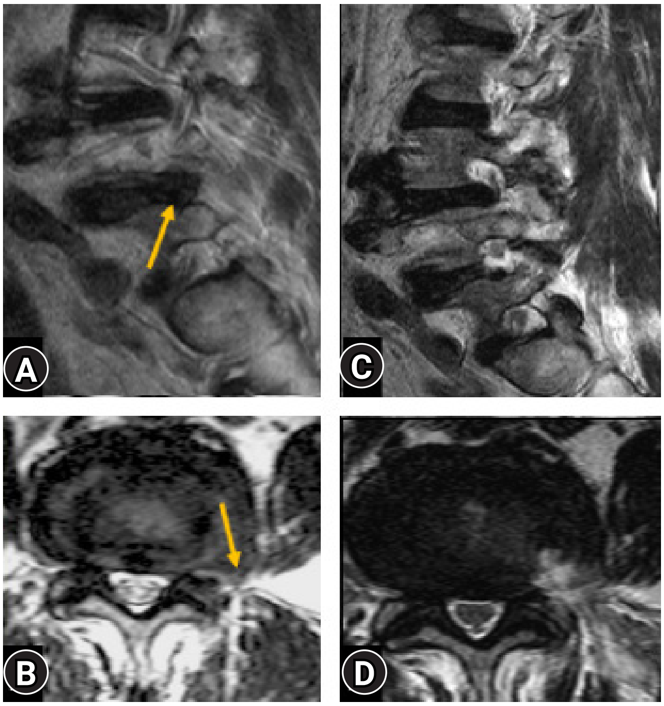

Figure 16. Post-operative confirmatory MRI (C, D) of a case with extra-foraminal disc prolapse (Yellow arrow) (A, B) showing complete decompression and documentation.

Figure 18. Use of epiduroscope/bronchoscope through working cannula to visualise EPD.

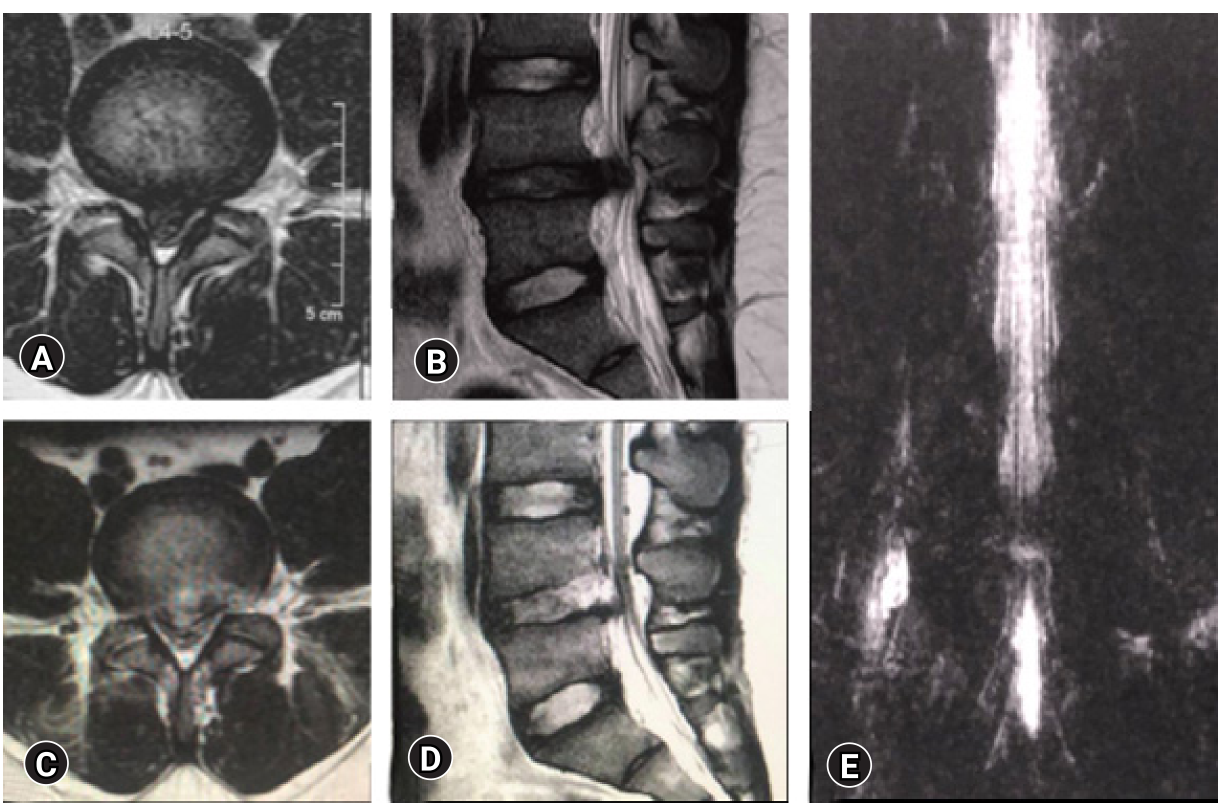

Figure 17. False Positive MRI myelo-block. In spite of removal of the culprit fragment and EPD achieved with soft dural flutter, opposite annular fissure visualization), epidural probing, and annular flap mobility, a pseudobulge is visible on the post-operative MRI. The patient was non-symptomatic and excellent clinical outcome.

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for decompression procedures as well [71,72]. Again, the EPD can be programmed pre-operatively and reached per-operatively using external image guidance and surgeon inputs [73-75]. Choi et al. [76] used a specially designed fluoroscope with MRI-equipped operative suite (XMR) which would objectively confirm the EPD per-operatively thereby reducing the chances of failures [74-76].

Limitations exists to the authenticity of observations and write-up of this article. This is a narrative review and not a systematic review or a meta-analysis [77]. The search was restricted to English literature in PubMed database only. Hence, there are literature focussed on the topic that may have been missed. This article contains information, observations, personal views, suggestions and experience-based statements which needs to be validated by more experienced pioneers' world over before following it as a thumb rule. Sensitivity and specificity validation needs to be done in series of consecutive patients. But each of the EPD has been defined, objectified and supported with an image, illustration or video. However, the figures and videos are focussed specifically on EPD and this article is targeted towards surgeons already performing PTELD. Detailed step by step videos/technique description is not included as this was not the prime focus of this article. But we believe that our attempt is justified with the fact that in COSS and MIS surgeries also the EPD are not yet fully defined. PTELD technique has been proven through randomized trials and meta-analyses as an excellent alternative surgical option to MIS and COSS [78-81]. Defining and reaching the EPD will ensure reduced failures and in-turn improve the wider acceptability of this procedure [82].

CONCLUSION

The EPD is variable and depends on numerous factors, not all signs may be elicited in every case and may change with surgeon experience. The ability to recognize the EPD is the crux for a successful complete decompression. Though debatable, maximum EPD's should be aimed in every surgery to avoid failures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

Supplementary Materials

Supplementary Video 1. Major Fragment Retrieval (MFR) (https://doi.org/10.21182/jmisst.2022.00444.v001).

Supplementary Video 2. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) at para-central location. (B) Showing a pulsatile, moving dural sac with opposite annular fissure visualisation (AFV) and probing with a flexible ball tip to confirm End point decompression (EPD) of the dural sac and the opposite side traversing nerve root (TNR). Also to note are annular flap mobility (superior and inferior both) (AFM). Violent dural flutter also is elicited with deep breathing (https://doi.org/10.21182/jmisst.2022.00444.v002).

Supplementary Video 3. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) at supra-pedicular lateral location, having removed ventro-lateral part of superior facet by blind foraminoplasty. (B) After a transforaminal "Outside In" (OI) approach (Oblique view is Obvious) decompression of a migrated fragment is achieved with visualised ligamentam flavum curtain (black*), ventral annular tear (orange*) and decompressed traversing nerve root (ventral and lateral aspect). The nerve root is pulsatile and matching with the heart rate, indicating End point decompression (EPD) (https://doi.org/10.21182/jmisst.2022.00444.v003).

Supplementary Video 4. Video in video of the external generated fluid ripples that get reflected inside to elicit dural flutter (DF) which is a provocative end point Decompression (EPD). Even more violent EPD can be generated by asking patient to cough or with a Valsalva maneuver (VM) (https://doi.org/10.21182/jmisst.2022.00444.v004).

Supplementary Video 5. (A) Illustrative prone anatomy-patient Orientation with area of docked endoscope tip (red outline) at para-central location after an "Inside Out" (IO) approach for paracentral small disc protrusion. Lateral Recess visualisation of decompressed traversing nerve root (TNR) is not clear as posterior longitudinal ligament (PLL) and annulus both are not cut. So this is an inferred End-point decompression (EPD) with use of the radio frequency probe wanding and feeling below and above the Annulo-PLL tissue (https://doi.org/10.21182/jmisst.2022.00444.v005).

Supplementary Video 6. (A) Illustrative prone anatomy-patient Orientation with area of docked endoscope tip (red outline) at inferior left foraminal para-central location in an "Inside out" (IO) approach. After removal of a trans-ligamentous (PLL: posterior longitudinal ligament) extruded central disc fragment. Video (B) Smooth Sweeping of the floor (SSF). Pulsations and dural flutter are present to confirm End point decompression (EPD) as well. The fluffy annulus tear with PLL appears compressive. But, actually it's mobile and does not contribute to any stenosis (https://doi.org/10.21182/jmisst.2022.00444.v006).

Supplementary Video 7. Fluoroscopy live image intensifier video showing the articulated hook used for the floor (SSF) as End point decompression (EPD). Video 20/8: (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) supra-pedicular lateral location, having removed ventro-lateral part of superior facet and part of pedicle by endoscopic burred-visualised foraminoplasty. (B) After a transforaminal “Outside In” (OI) approach decompression of a migrated fragment is achieved with visualised decompressed traversing nerve root (TNR) (ventral and lateral aspect), is pulsatile and matching with heart rate. Additionally, Epidural darks (ED) is visible ventrally indicating End point decompression (EPD) (https://doi.org/10.21182/jmisst.2022.00444.v007).

Supplementary Video 8. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) supra-pedicular lateral location, having removed ventro-lateral part of superior facet and part of pedicle by endoscopic burred-visualised foraminoplasty. (B) After a transforaminal “Outside In” (OI) approach decompression of a migrated fragment is achieved with visualised decompressed traversing nerve root (TNR) (ventral and lateral aspect), is pulsatile and matching with heart rate. Additionally, Epidural darks (ED) is visible ventrally indicating End point decompression (EPD) (https://doi.org/10.21182/jmisst.2022.00444.v008).

Supplementary Video 9. (A) Illustrative prone anatomy-patient Orientation with area of docked endoscope tip (red outline) at para-central location after foraminoplasty. The ligaments flavum (LF) is also removed dorsally (B) Lateral Recess visualisation of decompressed traversing nerve root (TNR) dorsal as well as ventral: Dural Flutter (DF), epidural darks (ED) clearly confirms the End point decompression (EPD) in a lateral recess stenosis (LRS). Tuft of capsule of facet joint and LF in superior foramen, not causing any TNR compression is left as it is (https://doi.org/10.21182/jmisst.2022.00444.v009).

Supplementary Video 10. (A) Illustrative prone anatomy-patient orientation with area of docked endoscope tip (red outline) inferior foraminal para-central location (B). The EPD (End point decompression) in ventral stenosis due to bony spurs is a very small focussed area following removal of the ventral stenosis with burrs and osteotome, showing the fluttering pulsatile traversing nerve root (TNR) (https://doi.org/10.21182/jmisst.2022.00444.v010).

REFERENCES

1. Krishnan A, Kim HS, Raj A, Dave BR. Expanded indications of full endoscopic spine sugery. J Minim Invasive Spine Surg Tech 2021;6:S130–S156.
2. Choi G, Pophale CS, Patel B, Uniyal P. Endoscopic spine surgery. J Korean Neurosurg Soc 2017;60:485–497.
3. Telfeian AE, Veeravagu A, Oyelese AA, Gokaslan ZL. A brief history of endoscopic spine surgery. Neurosurg Focus 2016;40:E2.
4. Moon ASM, Rajaram Manoharan SR. Endoscopic spine surgery: current state of art and the future perspective. Asian Spine J 2018;12:1–2.
5. Kim M, Kim HS, Oh SW, Adsul NM, Singh R, Kashlan ON, et al. Evolution of spinal endoscopic surgery. Neurospine 2019; 16:6–14.
6. Lee S, Kim SK, Lee SH, Kim WJ, Choi WC, Choi G, et al. Percutaneous endoscopic lumbar discectomy for migrated disc herniation: classification of disc migration and surgical approaches. Eur Spine J 2007;16:431–437.
7. Ahn Y, Jang IT, Kim WK. Transforaminal percutaneous endoscopic lumbar discectomy for very high-grade migrated disc herniation. Clin Neurol Neurosurg 2016;147:11–17.
8. Choi KC, Lee DC, Shim HK, Shin SH, Park CK. A strategy of percutaneous endoscopic lumbar discectomy for migrated disc herniation. World Neurosurg 2017;99:259–266.
9. Krishnan A, Barot MP, Dave BR, Bang P, Devanand D, Patel D, et al. Percutaneous transforaminal endoscopic decompression and cageless percutaneous bone graft transforaminal lumbar interbody fusion: a feasibility study. J Orthop Allied Sci 2018;6:S21–S27.
10. Krishnan A, Barot MP, Dave BR, Bang P, Devanand D, Patel D, et al. Percutaneous transforaminal endoscopic discectomy and drainage for spondylodiscitis: a technical note and review of literature. J Orthop Allied Sci 2018;6:S16–S20.
11. Zuckerman SL, Laufer I, Sahgal A, Yamada YJ, Schmidt MH, Chou D, et al. When less is more: the indications for MIS techniques and separation surgery in metastatic spine disease. Spine (Phila Pa 1976) 2016;41 Suppl 20:S246–S253.
12. Sharma SB, Lin GX, Jabri H, Sidappa ND, Song MS, Choi KC, et al. Radiographic and clinical outcomes of huge lumbar disc herniations treated by transforaminal endoscopic discectomy. Clin Neurol Neurosurg 2019;185:105485.
13. Kim HS, Sharma SB, Wu PH, Raorane HD, Adsul NM, Singh R, et al. Complications and limitations of endoscopic spine surgery and percutaneous instrumentation. Indian Spine J 2020;3:78–85.
14. Sood A, Ghosh AK. Literature search using PubMed: an essential tool for practicing evidence-based medicine. J Assoc Physicians India 2006;54:303–308.
15. Gadiya AD, Borde MD, Kumar N, Patel PM, Nagad PB, Bho-

 https://doi.org/10.21182/jmisst.2022.00444

jraj SY. Response to: analysis of functional and radiological outcome following lumbar decompression without fusion in patients with degenerative lumbar scoliosis. Asian Spine J 2020;14:588–589.
16. Gupta S, Marathe N, Chhabra HS, Destandau J. Long-term functional outcomes of endoscopic decompression with Destandau technique for lumbar canal stenosis. Asian Spine J 2021;15:431–440.
17. Lin GX, Huang P, Kotheeranurak V, Park CW, Heo DH, Park CK, et al. A systematic review of unilateral biportal endoscopic spinal surgery: preliminary clinical results and complications. World Neurosurg 2019;125:425–432.
18. Nam HGW, Kim HS, Lee DK, Park CK, Lim KT. Percutaneous stenoscopic lumbar decompression with paramedian approach for foraminal/extraforaminal lesions. Asian Spine J 2019;13:672–681.
19. Patgaonkar P, Marathe NA, Goyal V, Agrawal U, Patel V. Adolescent lumbar disc herniation with a peculiar gait pattern managed by transforaminal endoscopic spine surgery. J Orthop Case Rep 2020;10:93–96.
20. Elsig JP, Kaech DL. Imaging-based planning for spine surgery. Minim Invasive Ther Allied Technol 2006;15:260–266.
21. Yoshinari H, Tezuka F, Yamashita K, Manabe H, Hayashi F, Ishihama Y, et al. Transforaminal full-endoscopic lumbar discectomy under local anesthesia in awake and aware conditions: the inside-out and outside-in techniques. Curr Rev Musculoskelet Med 2019;12:311–317.
22. Lee SG, Ahn Y. Transforaminal endoscopic lumbar discectomy: basic concepts and technical keys to clinical success. Int J Spine Surg 2021;15(suppl 3):S38–S46.
23. Lewandrowski KU. The strategies behind “inside-out” and “outside-in” endoscopy of the lumbar spine: treating the pain generator. J Spine Surg 2020;6:S35–S39.
24. Lewandrowski KU, Yeung A. Lumbar endoscopic bony and soft tissue decompression with the hybridized inside-out approach: a review and technical note. Neurospine 2020;17:S34–S43.
25. Komp M, Hahn P, Ozdemir S, Merk H, Kasch R, Godolias G, et al. Operation of lumbar zygoapophyseal joint cysts using a full-endoscopic interlaminar and transforaminal approach: prospective 2-year results of 74 patients. Surg Innov 2014;21:605–614.
26. Gorth DJ, Ottone OK, Shapiro IM, Risbud MV. Differential effect of long-term systemic exposure of TNFα on health of the annulus fibrosus and nucleus pulposus of the intervertebral disc. J Bone Miner Res 2020;35:725–737.
27. Di Martino A, Merlini L, Faldini C. Autoimmunity in intervertebral disc herniation: from bench to bedside. Expert Opin Ther Targets 2013;17:1461–1470.
28. Wu C, Lee CY, Chen SC, Hsu SK, Wu MH. Functional outcomes of full-endoscopic spine surgery for high-grade migrated lumbar disc herniation: a prospective registry-based cohort study with more than 5 years of follow-up. BMC Musculoskelet Disord 2021;22:58.
29. Kim IS, Kim KH, Shin SW, Kim TK, Kim JI. Indigo carmine for the selective endoscopic intervertebral nuclectomy. J Korean Med Sci 2005;20:702–703.
30. Yeung AT. The evolution and advancement of endoscopic foraminal surgery: one surgeon’s experience incorporating adjunctive techologies. SAS J 2007;1:108–117.
31. Wang YP, Zhang W, An JL, Zhang J, Bai JY, Sun YP. Evaluation of transforaminal endoscopic discectomy in treatment of obese patients with lumbar disc herniation. Med Sci Monit 2016;22:2513–2519.
32. Krishnan A, Patel JG, Patel DA, Patel PR. Fracture of posterior margin of lumbar vertebral body. Indian J Orthop 2005;39:33–38.
33. Rajasekaran S, Bajaj N, Tubaki V, Kanna RM, Shetty AP. ISSLS prize winner: the anatomy of failure in lumbar disc herniation: an in vivo, multimodal, prospective study of 181 subjects. Spine (Phila Pa 1976) 2013;38:1491–1500.
34. Krishnan A, Degulmadi D, Ranjan R, Mayi S, Nitherwal N, Reddy L, et al. Hemodynamic neuromonitoring, a proposed spino-cardiac protective reflex: prospective study in 200 patients of lumbar surgery. Back Bone: Spine J 2021-2022;2:71–78.
35. Hofstetter CP, Ahn Y, Choi G, Gibson JNA, Ruetten S, Zhou Y, et al. AOSpine consensus paper on nomenclature for working-channel endoscopic spinal procedures. Global Spine J 2020;10:111S–121S.
36. Ruetten S, Komp M, Godolias G. An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-endoscopic uniportal transforaminal approach-technique and prospective results of 463 patients. Spine (Phila Pa 1976) 2005;30:2570–2578.
37. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. Spine (Phila Pa 1976) 2008;33:931–939.
38. Terai T. Outside-in Direct Fragmentectomy of TELD after Foraminoplasty. In: Sairyo K, editors. Transforaminal Full-endoscopic Lumbar Surgery under the Local Anesthesia. Singapore: Springer; 2021. p. 37–45.

39. Chen C, Ma X, Zhao D, Yang H, Xu B, Wang Z, et al. Full endoscopic lumbar foraminoplasty with periendoscopic visualized trephine technique for lumbar disc herniation with migration and/or foraminal or lateral recess stenosis. World Neurosurg 2021;148:e658–e666.
40. Kim JY, Kim HS, Jeon JB, Lee JH, Park JH, Jang IT. The novel technique of uniportal endoscopic interlaminar contralateral approach for coexisting L5-S1 lateral recess, foraminal, and extraforaminal stenosis and its clinical outcomes. J Clin Med 2021;10:1364.
41. Sairyo K, Higashino K, Yamashita K, Hayashi F, Wada K, Sakai T, et al. A new concept of transforaminal ventral facetectomy including simultaneous decompression of foraminal and lateral recess stenosis: technical considerations in a fresh cadaver model and a literature review. J Med Invest 2017;64:1–6.
42. Yamashita K. Full-endoscopic Lateral Recess Decompression (Ventral Facetectomy). In: Sairyo K, editors. Transforaminal Full-endoscopic Lumbar Surgery under the Local Anesthesia. Singapore: Springer; 2021. p. 63–67.
43. Krishnan A, Kulkarni M, Singh M, Reddy C, Mayi S, Devanand D, et al. Trans-foraminal endoscopic uniportal decompression in degenerative lumbar spondylolisthesis: a technical and case report. Egypt J Neurosurg 2019;34:34.
44. Choi KC, Shim HK. Full Endoscopic Approach with Foraminoplasty. In: Kim HS, Mayer M, Heo DH, Park CW, editors. Advanced Techniques of Endoscopic Lumbar Spine Surgery. Singapore: Springer; 2020. p. 103–113.
45. Kumar N, Wijerathne SI, Lim WW, Barry TW, Nath C, Liang S. Resistive straight leg raise test, resistive forward bend test and heel compression test: novel techniques in identifying secondary gain motives in low back pain cases. Eur Spine J 2012;21:2280–2286.
46. Ahn JS, Lee JK, Kwon YS, Hong UP. Intraoperative straight leg raising test during arthroscopic microdiscectomy. J Korean Soc Spine Surg 2003 10:25–29. Korean
47. Atalay A, Akbay A, Atalay B, Akalan N. Lumbar disc herniation and tight hamstrings syndrome in adolescence. Childs Nerv Syst 2003;19:82–85.
48. Samolsky Dekel BG, Sorella MC, Vasarri A, Melotti RM. Reliability of the buttock applied strain test to diagnose radicular pain in patients with low back pain. Pain Pract 2020;20:829–837.
49. Rebain R, Baxter GD, McDonough S. A systematic review of the passive straight leg raising test as a diagnostic aid for low back pain (1989 to 2000). Spine (Phila Pa 1976) 2002;27:E388–E395.
50. Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M. Entwicklung und Validierung des VAS-Wirbelsäulenscores [Development and validation of the Visual Analogue Scale (VAS) Spine Score]. Unfallchirurg 2001 104:488–497. German
51. Gadjradj PS, van Tulder MW, Dirven CM, Peul WC, Harhangi BS. Clinical outcomes after percutaneous transforaminal endoscopic discectomy for lumbar disc herniation: a prospective case series. Neurosurg Focus 2016;40:E3.
52. Gadjradj PS, Harhangi BS, Amelink J, van Susante J, Kamper S, van Tulder M, et al. Percutaneous transforaminal endoscopic discectomy versus open microdiscectomy for lumbar disc herniation: a systematic review and meta-analysis. Spine (Phila Pa 1976) 2021;46:538–549.
53. Suk KS, Lee HM, Moon SH, Kim NH. Lumbosacral scoliotic list by lumbar disc herniation. Spine (Phila Pa 1976) 2001;26:667–671.
54. Leonardi MA, Zanetti M, Saupe N, Min K. Early postoperative MRI in detecting hematoma and dural compression after lumbar spinal decompression: prospective study of asymptomatic patients in comparison to patients requiring surgical revision. Eur Spine J 2010;19:2216–2222.
55. Floris R, Spallone A, Aref TY, Rizzo A, Apruzzese A, Mulas M, et al. Early postoperative MRI findings following surgery for herniated lumbar disc. Acta Neurochir (Wien) 1997;139:169–175.
56. Namboothiri S, Gore S, Veerasekhar G. Treatment of low back pain by treating the annular high intensity zone (HIZ) lesions using percutaneous transforaminal endoscopic disc surgery. Int J Spine Surg 2018;12:388–392.
57. Ganau M, Syrmos N, Martin AR, Jiang F, Fehlings MG. Intraoperative ultrasound in spine surgery: history, current applications, future developments. Quant Imaging Med Surg 2018;8:261–267.
58. Harel R, Knoller N. Intraoperative spine ultrasound: application and benefits. Eur Spine J 2016;25:865–869.
59. Vasudeva VS, Abd-El-Barr M, Pompeu YA, Karhade A, Groff MW, Lu Y. Use of intraoperative ultrasound during spinal surgery. Global Spine J 2017;7:648–656.
60. Prada F, Vetrano IG, Filippini A, Del Bene M, Perin A, Casali C, et al. Intraoperative ultrasound in spinal tumor surgery. J Ultrasound 2014;17:195–202.
61. Yan CX, Goulet B, Pelletier J, Chen SJ, Tampieri D, Collins DL. Towards accurate, robust and practical ultrasound-CT registration of vertebrae for image-guided spine surgery. Int J Comput Assist Radiol Surg 2011;6:523–537.
62. Dave BR, Degulmadi D, Dahibhate S, Krishnan A, Patel D. Ultrasonic bone scalpel: utility in cervical corpectomy. A technical note. Eur Spine J 2019;28:380–385.

 https://doi.org/10.21182/jmisst.2022.00444

63. Krishnan A, Samal P, Mayi S, Degulmadi S, Rai RR, Dave B. Thoracic spine stenosis: does ultrasonic osteotome improve outcome in comparison to conventional technique. Malays Orthop J 2021;15:62–69.
64. Dave BR, Krishnan A, Rai RR, Degulmadi D, Mayi S, Gudhe M. The effectiveness and safety of ultrasonic bone scalpel versus conventional method in cervical laminectomy: a retrospective study of 311 patients. Global Spine J 2020;10:760–766.
65. Krishnan A, Patil S, Reddy C, Mayi S, Degulmadi D, Rai RR, et al. Ventral sculpting decompression: a novel bone scalpel-based technique in thoracic ventral stenosis/kyphosis with myelopathy. Egypt J Neurosurg 2020;354:4.
66. Sangondimath G, Mallepally AR, Marathe N, Mak KC, Salimath S. Degenerative cervical myelopathy: recent updates and future directions. J Clin Orthop Trauma 2020;11:822–829.
67. Dave BR. Integrated operation theater spine suite (IOTSS) history of spine surgery: Lord Krishna the first eternal spine surgeon. Back Bone: Spine J 2021-2022;2:56–59.
68. Gebhard FT, Kraus MD, Schneider E, Liener UC, Kinzl L, Arand M. Does computer-assisted spine surgery reduce intraoperative radiation doses. Spine (Phila Pa 1976) 2006 31:2024–2027. discussion 2028
69. Rasouli JJ, Shao J, Neifert S, Gibbs WN, Habboub G, Steinmetz MP, et al. Artificial intelligence and robotics in spine surgery. Global Spine J 2021;11:556–564.
70. Joseph JR, Smith BW, Liu X, Park P. Current applications of robotics in spine surgery: a systematic review of the literature. Neurosurg Focus 2017;42:E2.
71. Ghasem A, Sharma A, Greif DN, Alam M, Maaieh MA. The arrival of robotics in spine surgery: a review of the literature. Spine (Phila Pa 1976) 2018;43:1670–1677.
72. Staub BN, Sadrameli SS. The use of robotics in minimally invasive spine surgery. J Spine Surg 2019;5:S31–S40.
73. Mao JZ, Agyei JO, Khan A, Hess RM, Jowdy PK, Mullin JP, et al. Technologic evolution of navigation and robotics in spine surgery: a historical perspective. World Neurosurg 2021;145:159–167.
74. Woodard EJ, Leon SP, Moriarty TM, Quinones A, Zamani AA, Jolesz FA. Initial experience with intraoperative magnetic resonance imaging in spine surgery. Spine 2001;26:410–417.
75. Narain AS, Hijji FY, Yom KH, Kudaravalli KT, Haws BE, Singh K. Radiation exposure and reduction in the operating room: perspectives and future directions in spine surgery. World J Orthop 2017;8:524–530.
76. Choi G, Modi HN, Prada N, Ahn TJ, Myung SH, Gang MS, et al. Clinical results of XMR-assisted percutaneous transforaminal endoscopic lumbar discectomy. J Orthop Surg Res 2013;8:14.
77. Pae CU. Why systematic review rather than narrative review. Psychiatry Investig 2015;12:417–419.
78. Zhang B, Liu S, Liu J, Yu B, Guo W, Li Y, et al. Transforaminal endoscopic discectomy versus conventional microdiscectomy for lumbar discherniation: a systematic review and meta-analysis. J Orthop Surg Res 2018;13:169.
79. Phan K, Xu J, Schultz K, Alvi MA, Lu VM, Kerezoudis P, et al. Full-endoscopic versus micro-endoscopic and open discectomy: a systematic review and meta-analysis of outcomes and complications. Clin Neurol Neurosurg 2017;154:1–12.
80. Kamper SJ, Ostelo RW, Rubinstein SM, Nellensteijn JM, Peul WC, Arts MP, et al. Minimally invasive surgery for lumbar disc herniation: a systematic review and meta-analysis. Eur Spine J 2014;23:1021–1043.
81. Lewandrowski KU, Soriano-Sánchez JA, Zhang X, Ramírez León JF, Soriano Solis S, Rugeles Ortíz JG, et al. Regional variations in acceptance, and utilization of minimally invasive spinal surgery techniques among spine surgeons: results of a global survey. J Spine Surg 2020;6:S260–S274.
82. Bhanot A, Raiturker PP, Kashyap A, Arora M. Transforaminal endoscopic surgery in lumbar spine: technical aspects, current status, and evolving scope. Indian Spine J 2020;3:54–65.
83. Komp M, Hahn P, Ozdemir S, Merk H, Kasch R, Godolias G, et al. Operation of lumbar zygoapophyseal joint cysts using a full-endoscopic interlaminar and transforaminal approach: prospective 2-year results of 74 patients. Surg Innov 2014;21:605–614.
84. Kashlan ON, Kim HS, Khalsa SS, Singh R, Yong Z, Oh SW, et al. Percutaneous endoscopic Transforaminal approach for far lateral lumbar discectomy: 2-dimensional operative video. Oper Neurosurg (Hagerstown) 2020;18:E8.
85. Li ZZ, Hou SX, Shang WL, Cao Z, Zhao HL. Percutaneous lumbar foraminoplasty and percutaneous endoscopic lumbar decompression for lateral recess stenosis through transforaminal approach: technique notes and 2 years follow-up. Clin Neurol Neurosurg 2016;143:90–94.
86. Li P, Yang F, Chen Y, Song Y. Percutaneous transforaminal endoscopic discectomy for different types of lumbar disc herniation: a retrospective study. J Int Med Res 2021; 49:03000605211055045.
87. Yin G, Huang B, Wang C, Liu SQ. Therapeutic effects of full endoscopic spine surgery via transforaminal approach in elderly patients with lumbar spinal stenosis: a retrospective clinical study. Acta Orthop Traumatol Turc 2021;55:166–170.
88. Ahn Y. A historical review of endoscopic spinal discectomy. World Neurosurg 2021;145:591–596.

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Full-endoscopic Intradiscal Surgery: State of the Art

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Two types of full-endoscopic intradiscal surgery have been described in the literature. The first is full-endoscopic thermal annuloplasty, which was introduced in 2004 for discogenic pain. The proposed pain generator is a high signal intensity zone or a toxic annular tear, which can be treated by full- endoscopic thermal annuloplasty using a bipolar radio-pulse device. The second is full-endoscopic disc cleaning surgery, which is more recent and has been used to treat intractable chronic low back pain due to type 1 Modic change. In this review, we describe the current status of full-endoscopic intradiscal surgery.

Key Words: Full-endoscopic spine surgery, Thermal annuloplasty, Disc cleaning, Local anesthesia

INTRODUCTION

The basic surgical treatment for spinal disorders is decompression and fusion. By the late 20th century, spine surgery had become less invasive with the introduction of the microscope [1] and micro-endoscope [2]. Now, early in this new century, the establishment of full-endoscopic spine surgery (FESS) [3,4] and subsequent refinement of the technique has made it possible to perform minimally invasive discectomy [5,6], decompression for stenosis [7-9], and trans-Kambin lumbar interbody fusion surgery [10,11].

More recently, FESS has been proposed as a surgical strategy for pain management. Three types of FESS for pain management have been reported, namely, rhizotomy [12,13], radio-pulse thermal annuloplasty [14,15], and disc cleaning [16]. In this review article, we focus on the current status of intradiscal FESS, which includes thermal annuloplasty and disc cleaning.

THERMAL ANNULOPLASTY

1. Surgical Indications

Thermal annuloplasty is indicated for discogenic low back pain. Two features can help us to clinically understand discogenic pain: a high-intensity zone (HIZ) and a toxic annular tear (TAT).

The HIZ is an area of high signal intensity at the posterior annulus seen on sagittal and axial T2-weighted magnetic resonance images (MRI) (Figure 1). It was first described in 1992 by Aprill and Bogduk [17], who found an 86% incidence of concordant painful discography in lumbar discs with an HIZ in patients with low back pain (LBP). They proposed a HIZ on MRI as a significant diagnostic sign of discogenic LBP. Figure 1 and 2 show representative cases of HIZ on MRI. Figure 1 shows the scans of a male professional baseball player who experienced severe LBP when playing. He was successfully treated by intradiscal injection for the pain. Figure 2 shows the

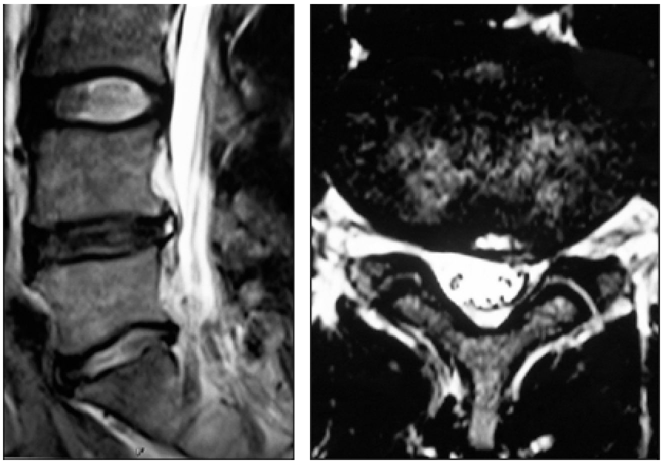

Figure 1. Sagittal and axial T2-weighted magnetic resonance images showing a high-intensity zone at the posterior annulus. The patient is a professional baseball player who experienced severe low back pain when playing. His pain was successfully treated by intradiscal injection.

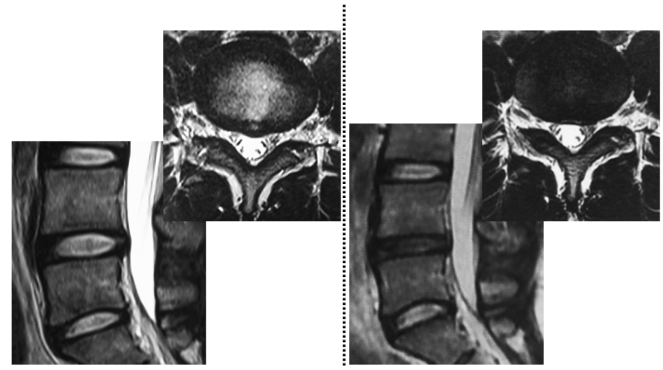

Figure 2. Magnetic resonance images showing a high-intensity zone before and after intradiscal injection in a female elite skier and Olympian. Intradiscal injection was effective in decreasing the pain, and she was able to attend the next Olympic Games. Three years after the injection, although her disc degeneration had advanced, the high-intensity zone was smaller.

scans of a female elite skier who was referred to us with severe LBP. Intradiscal injection relieved her pain and she was able to attend the subsequent Olympic games. Three years after the injection, although her disc degeneration had advanced, the HIZ was smaller and she had no LBP (Figure 2). There are several reports suggesting that an HIZ could be a marker of discogenic LBP [18-20]; however, its clinical significance remains controversial.

The TAT, named by Yeung [21], refers to an annular tear that is symptomatic. It is characterized by pain-sensitive granulation tissue within the tear. Bernard [22] investigated 250 patients with chronic LBP using both computed tomography (CT) discography and MRI and concluded that CT discography is more sensitive, especially for a painful annular tear with a normal disc on MRI. Discography continues to be a useful functional test for understanding discogenic pain. Manchikanti et al. [23] reviewed the role of discography in the diagnosis of discogenic LBP and found it to be useful for identifying a subset of patients with chronic LBP secondary to an intervertebral disc disorder.

2. Surgical Technique

Radio-pulse thermal annuloplasty is a surgical technique that was first performed by Tsou et al. [15]. It involves utilization of full-endoscopic discectomy [3-5]. A cannula is installed into the disc space under local anesthesia via the transforaminal approach. An outside-in foraminoplasty technique is used when the intervertebral foramen is narrow or there are concerns about exiting nerve root injury [24]. First, the area of the TAT is ablated using the bipolar radio-pulse device. The cannula is then advanced towards the posterior annulus to determine if there is an HIZ. Figure 3A shows the endoscopic view of a TAT. In Figure 3B, a vascularized disc fragment can be seen in the area showing an HIZ. After ablation of the TAT and HIZ, the radio-pulse thermal annuloplasty is completed.

3. Clinical Results

In the initial report by Tsou et al. [15], the outcome was excellent in 17 of 113 patients (15%) and good in 32 (28.3%). Therefore, only 43.3% of patients in their series has favorable results. On the other hand, Pan et al. [25] reviewed 62 consecutive patients who underwent thermal annuloplasty and reported an overall success rate of 75.8%. Ahn and Lee [26] reported a similar success rate of 70% and better clinical results in patients who also had central disc protrusion. Manabe et al. [14] reviewed 12 elite athletes who underwent radio-pulse thermal annuloplasty. Nine (75.0%) were found to have an HIZ at the level of the affected disc. The LBP disappeared soon after the surgery in 10 patients (83.3%), all of whom could returned to play within 3 months of surgery.

4. Representative Case

Figure 4 shows the preoperative MRI and CT discography findings in another male baseball player with a clinical diagnosis of chronic discogenic pain. MRI indicates disc degeneration

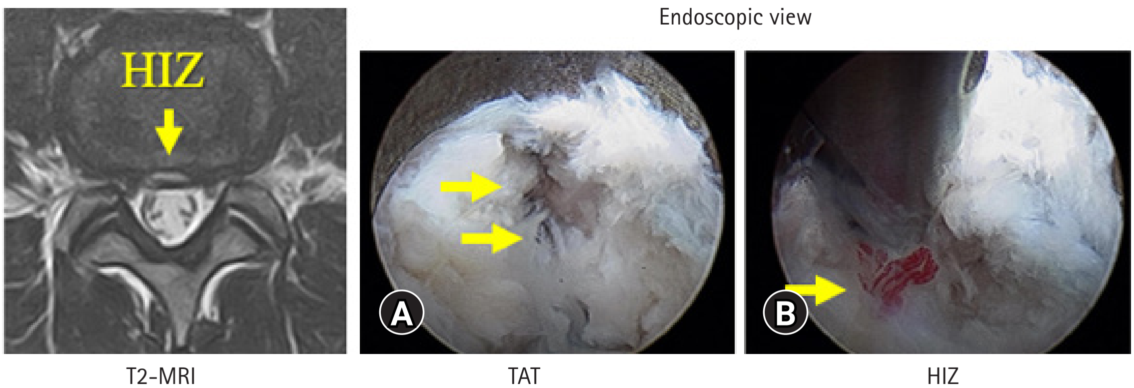

Figure 3. Endoscopic views showing a TAT (A) and HIZ (B). The TAT is seen as a clear fissure at the posterior annulus fibrosus. A vascularized disc fragment is obvious in the area containing the HIZ. HIZ: high-intensity zone, TAT: toxic annular tear.

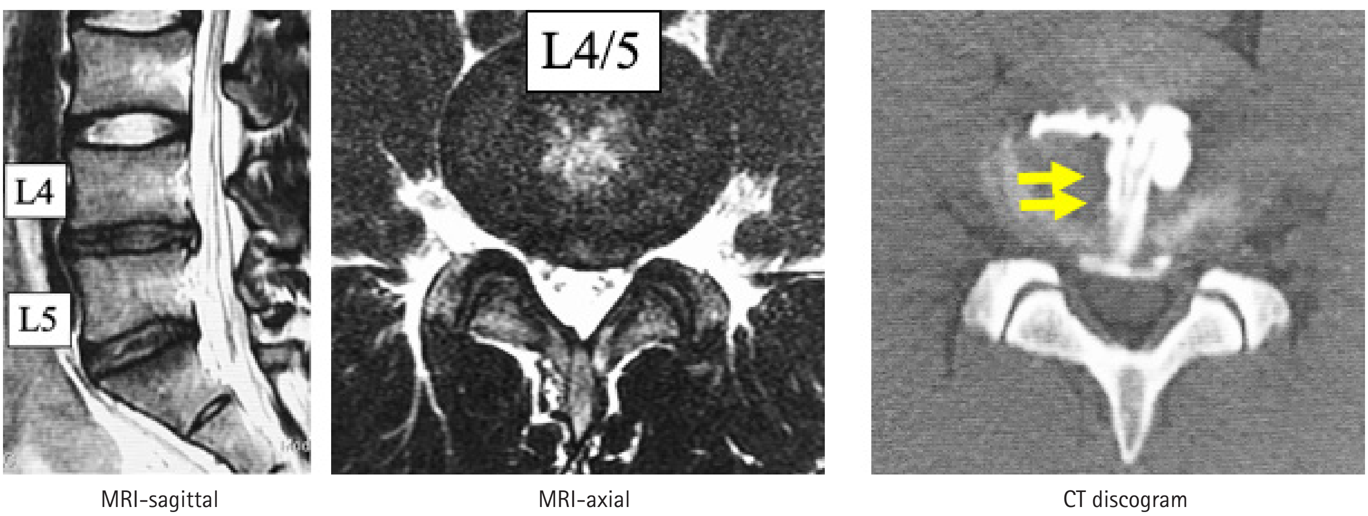

Figure 4. Findings on MRI and CT discography before thermal annuloplasty in a male baseball player with a clinical diagnosis of chronic discogenic pain. MRI shows disc degeneration at L4/5 and L5/S1. A slight high-intensity zone can be seen at L4/5 and a toxic annular tear is evident in the same level (arrows).

at L4/5 and L5/S1. Slight HIZ is seen at L4/5 and a clear annular tear is evident at the same level. The patient's LBP disappeared immediately after surgery. He has been very active in the ensuing season and has achieved his best performance to date.

DISC CLEANING

1. Surgical Indication

Disc cleaning is a recently reported technique and there is as yet no consensus about it in the literature. Based on the initial report by Sairyo et al. [16], disc cleaning is indicated for intractable chronic LBP due to type 1 Modic change. Of the three types of Modic change—type 1 (inflammation), type 2 (fatty marrow), and type 3 (bone sclerosis)—only type 1 is painful [27]. Intradiscal injection would be the non-surgical treatment for painful Modic type 1 change [28,29]. Figure 5 shows MRI scans obtained before and after intradiscal therapy in a former world martial arts champion. His LBP disappeared after a couple of intradiscal injections and MRI scans revealed conversion from type 1 to type 3 Modic change.

Although fusion would be the gold standard surgical treatment for painful Modic change [30], full-endoscopic disc cleaning may be a new alternative for type 1 change.

2. Surgical Technique and Clinical Results

Full-endoscopic disc cleaning is another application of full-endoscopic discectomy [3-5]. Using either an outside-in or an inside-out technique, a cannula is inserted into the disc

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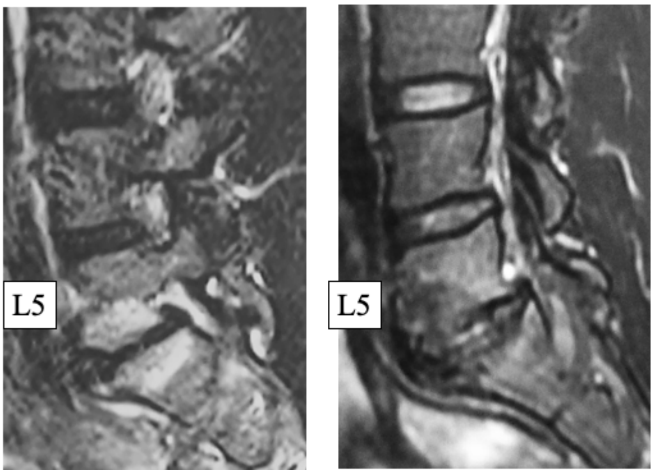
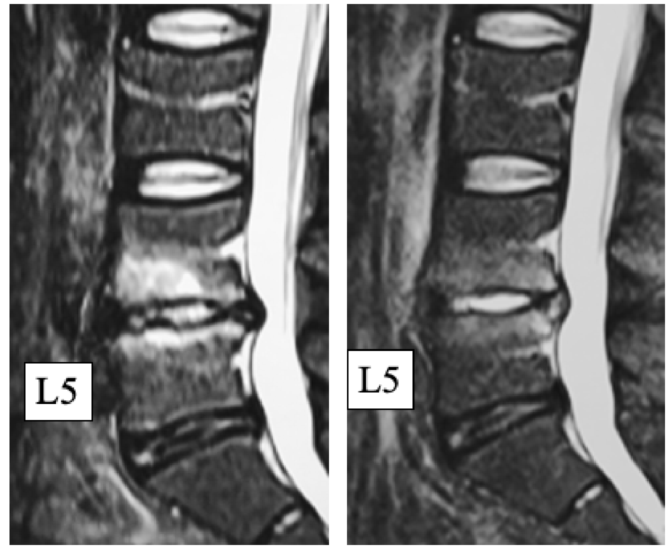


Before intradiscal therapy After intradiscal therapy

Figure 5. Short tau inversion recovery magnetic resonance images obtained before and after treatment for Modic change in a male martial arts fighter, who was a former world champion. Type 1 inflammation was clearly present before treatment but subsided following a couple of intradiscal injections. After intradiscal treatment, the Modic type was downgraded to type 3 sclerotic change.



Before disc cleaning After disc cleaning

Figure 6. Short tau inversion recovery magnetic resonance images showing the effect of full-endoscopic disc cleaning surgery in a 37-year-old man. The image obtained before surgery clearly suggests type 1 change and another taken 2 months after surgery shows a decrease in the high signal change, indicating that the inflammation has subsided.

space, which normally contains cartilaginous tissue. However, a disc space with type 1 Modic change may contain fibrotic scar tissue instead [31]. This fibrous tissue should be removed and then be followed by copious irrigation and washing given that type 1 Modic change is thought to be caused by low-grade infection [32-36]. There have been two case reports in which disc cleaning was effective for alleviating LBP [16,31]. Kishima [37] reviewed his initial 10 cases of disc cleaning surgery for type 1 Modic change and found that the procedure was effective in 8 of them. Thus, it is necessary to clarify what kind of type 1 Modic change would be a good indication for disc cleaning.

3. Representative Case

Figure 6 shows short tau inversion recovery MRI scans obtained before and after disc cleaning surgery in a 37-year-old man with a history of severe LBP for more than a year. The preoperative image clearly suggests type 1 inflammation surrounding the L4 and L5 endplates. The image obtained 2 months after surgery shows a decrease in the high signal change, indicating that the inflammation has subsided. Clinically, the patient's visual analog scale score for LBP when performing normal activities decreased from 8/10 to 1/10.

CONCLUSION

In this paper, we have reviewed two types of full-endoscopic intradiscal surgery. The gold standard worldwide for discogenic pain and type 1 Modic change is fusion surgery. However, full-endoscopic surgery could avoid the need for fusion and may surpass the present gold standard treatment. The clinical outcome is generally acceptable, although the exact indications for such surgery have yet to be confirmed.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. McCulloch JA. Focus issue on lumbar disc herniation: macro- and microdiscectomy. Spine (Phila Pa 1976) 1996;21:45S–56S.
2. Foley KT, Smith MM, Rampersaud YR. Microendoscopic approach to far-lateral lumbar disc herniation. Neurosurg Focus 1999;7:e5.
3. Yeung AT. The evolution of percutaneous spinal endoscopy and discectomy: state of the art. Mt Sinai J Med 2000;67:327–332.

4. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. Spine (Phila Pa 1976) 2002;27:722–731.
5. Sairyo K, Egawa H, Matsuura T, Takahashi M, Higashino K, Sakai T, et al. State of the art: transforaminal approach for percutaneous endoscopic lumbar discectomy under local anesthesia. J Med Invest 2014;61:217–225.
6. Choi G, Lee SH, Lokhande P, Kong BJ, Shim CS, Jung B, et al. Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working channel endoscope. Spine (Phila Pa 1976) 2008;33:E508–E515.
7. Kim HS, Singh R, Adsul NM, Oh SW, Noh JH, Jang IT. Management of root-level double crush: case report with technical notes on contralateral interlaminar foraminotomy with full endoscopic uniportal approach. World Neurosurg 2019;122:505–507.
8. Sairyo K, Higashino K, Yamashita K, Hayashi F, Wada K, Sakai T, et al. A new concept of transforaminal ventral facetectomy including simultaneous decompression of foraminal and lateral recess stenosis: technical considerations in a fresh cadaver model and a literature review. J Med Invest 2017;64:1–6.
9. Sairyo K, Yamashita K, Manabe H, Ishihama Y, Sugiura K, Tezuka F, et al. A novel surgical concept of transforaminal full-endoscopic lumbar undercutting laminectomy (TE-LUL) for central canal stenosis of the lumbar spine with local anesthesia : a case report and literature review. J Med Invest 2019;66:224–229.
10. Ishihama Y, Morimoto M, Tezuka F, Yamashita K, Manabe H, Sugiura K, et al. Full-endoscopic trans-kambin triangle lumbar interbody fusion: surgical technique and nomenclature. J Neurol Surg A Cent Eur Neurosurg 2021 doi: 10.1055/s-0041-1730970
11. Nagahama K, Ito M, Abe Y, Murota E, Hiratsuka S, Takahata M. Early clinical results of percutaneous endoscopic transforaminal lumbar interbody fusion: a new modified technique for treating degenerative lumbar spondylolisthesis. Spine Surg Relat Res 2018;3:327–334.
12. Yeung A, Gore S. Endoscopically guided foraminal and dorsal rhizotomy for chronic axial back pain based on cadaver and endoscopically visualized anatomic study. Int J Spine Surg 2014;8:23.
13. Lee JH, Chen KT, Chang KS, Chen CM. How I do it? Fully endoscopic rhizotomy assisted with three-dimensional robotic C-arm navigation for sacroiliac joint pain. Acta Neurochir (Wien) 2021;163:3297–3301.
14. Manabe H, Yamashita K, Tezuka F, Takata Y, Sakai T, Maeda T, et al. Thermal annuloplasty using percutaneous endoscopic discectomy for elite athletes with discogenic low back pain. Neurol Med Chir (Tokyo) 2019;59:48–53.
15. Tsou PM, Alan Yeung C, Yeung AT. Posterolateral transforaminal selective endoscopic discectomy and thermal annuloplasty for chronic lumbar discogenic pain: a minimal access visualized intradiscal surgical procedure. Spine J 2004;4:564–573.
16. Sairyo K, Maeda T, Yamashita K, Tezuka F, Morimoto M, Yagi K, et al. A new surgical strategy for the intractable chronic low back pain due to type 1 Modic change using transforaminal full-endoscopic disc cleaning (FEDC) surgery under the local anesthesia: a case report and literature review. J Med Invest 2021;68:1–5.
17. Aprill C, Bogduk N. High-intensity zone: a diagnostic sign of painful lumbar disc on magnetic resonance imaging. Br J Radiol 1992;65:361–369.
18. Schellhas KP, Pollei SR, Gundry CR, Heithoff KB. Lumbar disc high-intensity zone. Correlation of magnetic resonance imaging and discography. Spine (Phila Pa 1976) 1996;21:79–86.
19. Peng B, Hou S, Wu W, Zhang C, Yang Y. The pathogenesis and clinical significance of a high-intensity zone (HIZ) of lumbar intervertebral disc on MR imaging in the patient with discogenic low back pain. Eur Spine J 2006;15:583–587.
20. Lam KS, Carlin D, Mulholland RC. Lumbar disc high-intensity zone: the value and significance of provocative discography in the determination of the discogenic pain source. Eur Spine J 2000;9:36–41.
21. Yeung AT. In-vivo endoscopic visualization of pain generators in the lumbar spine. J Spine 2017;6:385.
22. Bernard TN Jr. Lumbar discography followed by computed tomography. Refining the diagnosis of low-back pain. Spine (Phila Pa 1976) 1990;15:690–707.
23. Manchikanti L, Glaser SE, Wolfer L, Derby R, Cohen SP. Systematic review of lumbar discography as a diagnostic test for chronic low back pain. Pain Physician 2009;12:541–559.
24. Yoshinari H, Tezuka F, Yamashita K, Manabe H, Hayashi F, Ishihama Y, et al. Transforaminal full-endoscopic lumbar discectomy under local anesthesia in awake and aware conditions: the inside-out and outside-in techniques. Curr Rev Musculoskelet Med 2019;12:311–317.
25. Pan F, Shen B, Chy SK, Yong Z, Liu X, Ba Z, et al. Transforaminal endoscopic system technique for discogenic low back pain: a prospective Cohort study. Int J Surg 2016;35:134–138.
26. Ahn Y, Lee SH. Outcome predictors of percutaneous endoscopic lumbar discectomy and thermal annuloplas-

 https://doi.org/10.21182/jmisst.2022.00395

ty for discogenic low back pain. Acta Neurochir (Wien) 2010;152:1695–1702.

27. Modic MT, Masaryk TJ, Ross JS, Carter JR. Imaging of degenerative disk disease. Radiology 1988;168:177–186.
28. Mefford J, Sairyo K, Sakai T, Hopkins J, Inoue M, Amari R, et al. Modic type I changes of the lumbar spine in golfers. Skeletal Radiol 2011;40:467–473.
29. Mineta K, Higashino K, Sakai T, Fukui Y, Sairyo K. Recurrence of type I Modic inflammatory changes in the lumbar spine: effectiveness of intradiscal therapy. Skeletal Radiol 2014;43:1645–1649.
30. Ohtori S, Yamashita M, Yamauchi K, Inoue G, Koshi T, Suzuki M, et al. Change in Modic type 1 and 2 signals after posterolateral fusion surgery. Spine (Phila Pa 1976) 2010;35:1231–1235.
31. Nakajima D, Yamashita K, Takeuchi M, Sugiura K, Morimoto M, Tezuka F, et al. Full-endoscopic spine surgery for discogenic low back pain with high-intensity zones and Modic type 1 change in a professional baseball player. NMC Case Rep J 2021;8:587–593.
32. Albert HB, Kjaer P, Jensen TS, Sorensen JS, Bendix T, Manniche C. Modic changes, possible causes and relation to low back pain. Med Hypotheses 2008;70:361–368.
33. Albert HB, Lambert P, Rollason J, Sorensen JS, Worthington T, Pedersen MB, et al. Does nuclear tissue infected with bacteria following disc herniations lead to Modic changes in the adjacent vertebrae. Eur Spine J 2013;22:690–696.
34. Albert HB, Manniche C, Sorensen JS, Deleuran BW. Antibiotic treatment in patients with low-back pain associated with Modic changes type 1 (bone oedema): a pilot study. Br J Sports Med 2008;42:969–973.
35. Albert HB, Sorensen JS, Christensen BS, Manniche C. Antibiotic treatment in patients with chronic low back pain and vertebral bone edema (Modic type 1 changes): a double-blind randomized clinical controlled trial of efficacy. Eur Spine J 2013;22:697–707.
36. Manniche C, O'Neill S. New insights link low-virulent disc infections to the etiology of severe disc degeneration and Modic changes. Future Sci OA 2019;5:FSO389.
37. Kishima K. A new intradiscal therapy for painful Modic change: full-endoscopic disc cleaning (FEDC) surgery. Paper presented at: The 7th World Congress of Minimally Invasive Spine Surgery (WCMISST) and Techniques and The 29th International Intradiscal Therapy Society (ITTS); 2021 Nov 24-25; Tokyo, Japan. S1-6

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Oblique Lateral Lumbar Interbody Fusion at L2-L5: Proposal of a New CT-based Preoperative Assessment to Minimize Risks

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Objective: Oblique anterior to psoas (ATP) interbody lumbar fusion is associated with advantages such as sufficient indirect decompression and restoration of lordosis. Therefore, a comprehensive preoperative assessment that includes the location of entry into the disc space, a feasible trajectory to complete the intervertebral space procedure, and the possible retraction of the psoas muscle is necessary to correctly and safely perform the technique.

Methods: From January 2019 to January 2020, 160 lumbar CT scans were evaluated. Only 124 images from the L2-L3, L3-L4, and L4-L5 levels met the inclusion criteria. The length of the anterior vertebral line (AVL) and the middle-third of the disc in the anteroposterior axis were measured to localize the entry point (EP). The distance between the anterior arterial vessel (AV) and the EP was also measured. The trajectory commonly used to set the surgical instruments into the disc space was called α, and a new proposed trajectory termed β was calculated. The psoas cross-sectional area anterior to the β angle trajectory was measured to determine any possible retraction using this parameter.

Results: The EP-AVL distances were L2-L3 11.49 ± 0.89 mm, L3-L4 11.54 ± 0.88 mm, and L4-L5 11.57 ± 0.87 mm. The EP-AV lengths were 17.64 ± 5.62 mm, 19.36 ± 5.49 mm, and 16.48 ± 6.47 mm at L2-L3, L3-L4, and L4-L5, respectively. The average α and β trajectory angles reported were 39.91° and 14.48°, respectively. Psoas muscle retraction was primarily noted at the L4-L5 level.

Conclusion: This article's proposed parameters represent a routine preoperative safety assessment in patients previously selected for oblique ATP lumbar interbody fusion.

Key Words: Lumbar region, Minimally invasive surgical procedures, Oblique, Psoas muscle, Retroperitoneal, Spine

INTRODUCTION

Since Mayer [1] described the retroperitoneal anterior to psoas (ATP) microsurgical approach for the interbody fusion of L2 to L5 in 1997, and Silvestre et al. [2] reported the first retrospective outcomes of 179 patients who underwent the same approach in 2012, the oblique ATP lumbar interbody fusion has been adopted by spine surgeons worldwide.

The procedure-related advantages over the transpsoas technique are the lower incidence of lumbar plexus injury and the minor retraction of the psoas muscle leading to a lower postoperative neuromuscular deficit in the thigh [3-6].

The primary concern is the intricate anatomy of the surgical corridor available to address the degenerated disc in specific cases. The oblique surgical entry is limited by the left lateral border of the aorta or left iliac artery and the anterior medial border of the psoas muscle [7]. Variations in the location of these structures can obstruct or modify the surgical corridor to reach the disc, thereby increasing the risk of fatal intraoperative vascular complications [8]. Therefore, anatomical research based on different imaging modalities and cadaveric studies has detailed the features of the left-sided ATP oblique corridor and the surrounding spinal retroperitoneal structures [7-17].

A critical appraisal that has not been addressed yet in the medical literature is how to plan a safer trajectory of the oblique ATP approach that reduces the risk of injuring contralateral anatomical structures or avoids breaking into the contralateral foramen due to the oblique nature of the approach.

The oblique ATP lumbar fusion technique execution includes the well-known orthogonal maneuvering, which consists of positioning the instruments as perpendicular as possible to the disc when working within the intervertebral space. However, the more dorsal retraction of the psoas muscle when instruments levering, the potential injury of the lumbar plexus is possible. The contralateral neural structures are at risk of being transgressed during the whole process of intervertebral space preparation to deliver the cage because an oblique trajectory is followed.

For these reasons, preoperative planning of a trajectory to execute the whole oblique ATP technique with the lower risk of transgressing contralateral nerve structures and simultaneously knowing the possible transverse area of the psoas muscle that will be retracted with the selected trajectory is necessary. It requires identifying an entry point to the disc and measuring the different angles to approach disc space.

This article suggests an imaging-based routine preoperative assessment of patients who will undergo an oblique ATP lumbar fusion and also analyzes and discusses the results obtained through a preclinical morphometric CT-based anatomical study in an American Hispanic population.

MATERIALS AND METHODS

The ethics committee of Hospital H+ Queretaro approved this study (no.10.21JQO). From January 2019 to January 2020, 160 computed tomography (CT) images of the lumbar spine obtained randomly from the Hospital's Radiology Department were measured. The scanner's parameters of non-enhanced CT images were: slice thickness of 5 mm, pitch of 1.15 mm, and reconstructive slice thickness of 1 mm. Lumbar CT scans were excluded from patients with a history of previous lumbar or retroperitoneal surgery, vertebral malformation, spinal deformity, infection, fractures, and spinal tumors. Also, lumbar levels with high-rising psoas (Mickey Mouse ear-like) and less than 5 mm between the left lateral border of the aorta or left iliac artery and the anterior ventral medial border of the psoas muscle were excluded. Two different researchers meticulously reviewed CT images at different times. Demographic data (i.e., sex, age, and BMI) were recorded for all included CT scans.

1. Preoperative Assessment

The following parameters were planned and measured in the axial views at the midpoint disc height of the L2-L3, L3-L4, and L4-L5 segments. 1) The disc contour was divided into thirds from anterior to posterior. The middle one was considered the ideal location to place the interbody device using an oblique trajectory (Figure 1A). 2) The entry point (EP) to the disc was planned in the upper left corner of the middle third. The distance between the EP and the anterior vertebral line was measured (Figure 1B). 3) The distance between the left lateral border of the aorta or iliac artery (anterior vessels) and the EP was measured (Figure 1C). 4) Two different oblique trajectories to approach the intervertebral disc were simulated; the α and β trajectories. The α is tangential to the anterior border of the psoas muscle (Figure 1D), and the β crosses the psoas muscle and intersects the EP and the inferior right corner of the middle third (Figure 1E). Both trajectories meet the coronal line forming an angle measured. The cross-section area of the whole psoas muscle and the psoas ventral to the β trajectory was defined. Then, the percentage of psoas retraction was calculated as follows: the cross-sectional area of the psoas ventral to the β trajectory (100)/the cross-sectional area of the whole psoas. Finally, an example of a cage inserted at L3-L4 under these parameters is shown in Figure 1F.

2. Statistical Analysis

The distances between the anterior vertebral line and anterior vessel to the EP were expressed as mean±standard deviation (SD) with minimum and maximum in mm. The α

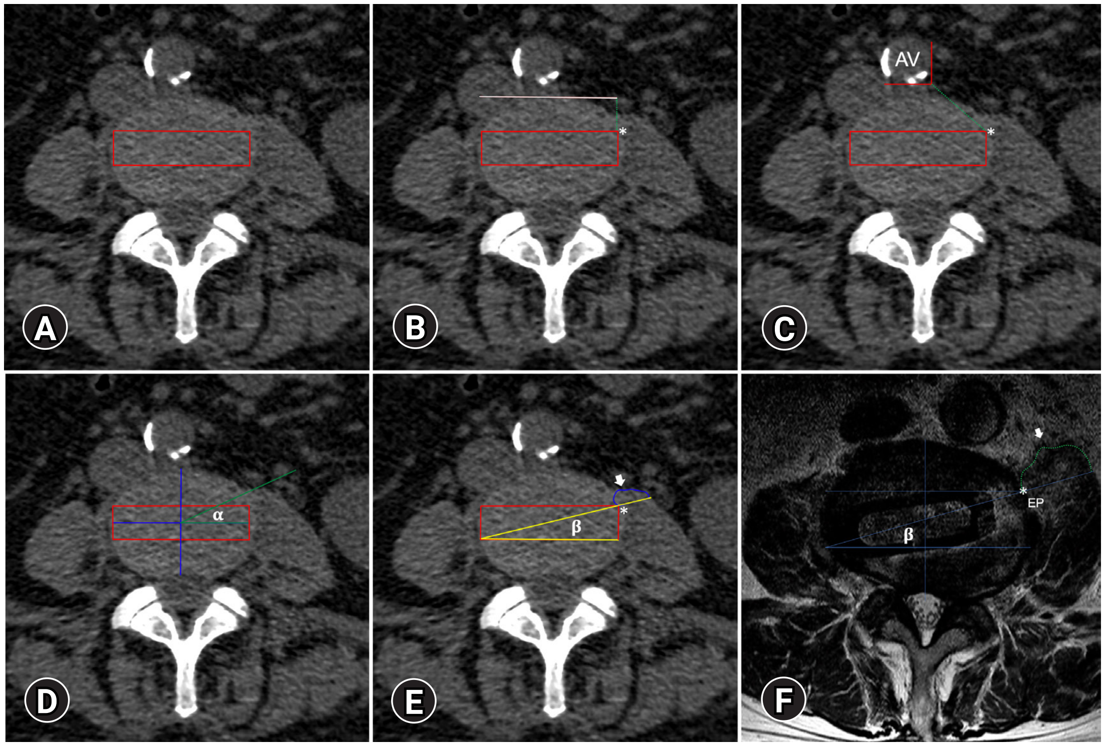

Figure 1. Proposed CT-based preoperative assessment for planning an oblique trajectory. (A) The middle third is shown in red. (B) Distance between the anterior vertebral line (white line) and the entry point. (C) Distance between the anterior vessel (AV) and the entry point (green dotted line). (D) The α and (E) β trajectories. The white arrow pointed to the psoas cross-sectional area ventral to the β trajectory potentially retracted. (F) An example showing a postoperative axial view of MRI showing the cage's final location under the β trajectory. Entry point (*).

and β trajectories were reported as mean±SD with minimum and maximum degrees. The different measures of the psoas cross-sectional area were reported in mm^2, with the percentage retracted. An unpaired t-test was used to analyze the differences in the distances with the EP between sexes, with $p \leq 0.05$ being statistically significant. One-way analysis of variance (ANOVA) followed by Bonferroni's post-hoc test was used to analyze differences in the distances mentioned and the possible retracted psoas cross-sectional area between levels with $p<0.05$ indicating statistical significance. IBM SPSS version 24 software (IBM Corp., Armonk, NY, USA) was employed for the statistical analysis.

RESULTS

A total of 160 non-enhanced lumbar CT scans were revised. Of these, 36 CTs did not meet the inclusion criteria (16.9% did not have a left-sided oblique corridor, 4.4% had high-rising psoas, and 6.2% had other exclusion criteria, e.g., deformity, retroperitoneal surgery, previous spinal surgery). In the present study, 124 CT scans met inclusion criteria. CT scans from 67 male and 57 female patients with a mean age of 47.9±15.3 (min, 18; max, 82) years and a mean BMI of 25.27±3.02 (min, 18.48; max, 34.50) were included in the study. Measurements at the L2-L3, L3-L4, and L4-L5 levels were completed for all 124 CT scans.

The distance between the EP to the anterior vertebral line was 11.49±0.89 mm at L2-L3, 11.54±0.88 mm at L3-L4, and 11.57±0.87 mm at L4-L5. A shorter distance was found in females at all levels than males (Table 1). The mean distance between the EP to the anterior vessel (AV) was 17.64±5.62 mm at L2-L3, 19.36±5.49 mm at L3-L4, and 16.48±6.47 mm at L4-L5. The only statistical difference in EP-AV distance was found at the L4-L5 compared to the other levels ($p<0.001$). A comparison of EP-AV distances by sex revealed that females had a significantly smaller mean value at both the L3-4 (17.44±5.10 vs. 20.99±5.30; $p<0.001$) and L4-5 (15.44±5.89 vs. 17.35±5.83; $p=0.007$) levels as compared to males. Women had shorter EP-AV distances than men. The most considerable EP-AV distance was observed at the L3-L4 level, while the smallest was L4-L5 (Figure 2).

At the L2-L3, L3-L4, and L4-L5 levels, the mean angle of α

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Table 1. Entry point (EP) distances measured

Level	Mean (mm)	SD	Min (mm)	Max (mm)	p-value[b]	Male (mm)	SD	Female (mm)	SD	p-value[a]
Entry point - anterior vertebral line distance										
L2-L3	11.49	±0.89	9.01	13.27	0.748	11.74	±0.86	11.24	±0.83	<0.001*
L3-L4	11.54	±0.88	9.40	13.02	0.690	11.74	±0.89	11.30	±0.80	<0.001*
L4-L5	11.57	±0.87	9.17	13.19	0.938	11.72	±0.85	11.38	±0.85	<0.001*
Average	11.53	±0.88				11.73	±0.86	11.30	±0.83	
Entry point - anterior vessel distance										
L2-L3	17.64	±5.62	7.36	33.94	0.222	18.8	±5.52	16.27	±5.46	0.012
L3-L4	19.36	±5.49	6.57	33.58	0.200	20.99	±5.30	17.44	±5.10	<0.001*
L4-L5	16.48	±6.47	5.02	32.81	<0.001*	17.35	±5.83	15.44	±5.89	0.007*
Average	17.83	±5.86				19.05	±5.55	16.38	±5.48	

mm: millimeters, SD: standard deviation, Min: minimum, Max: maximum.
[a]Unpaired t-test of males vs. females.
[b]ANOVA of L2-L3 vs. L3-L4 vs. L4-L5.
*Asterisks denote significance.

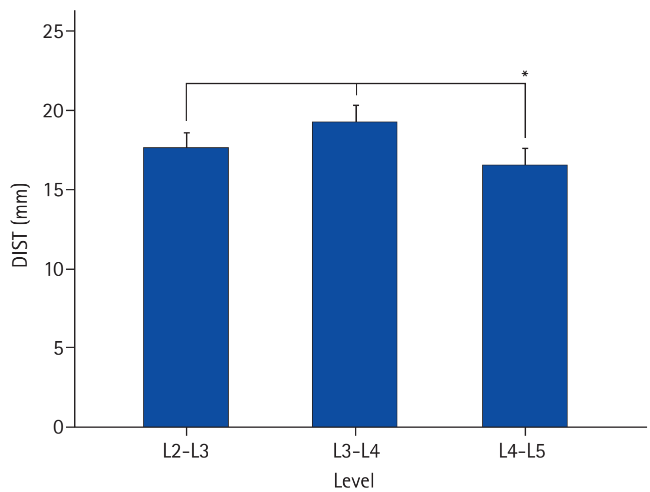

Figure 2. The bar chart demonstrates the longest entry point – anterior vessel distance at the L3-L4 level, followed by L2-L3. The narrowest space was found in L4-L5. The comparison of L4-L5 to the other levels was statistically significant (*).

trajectory was 38.16°±11.37°, 39.88°±9.66°, and 41.68°±10.15°, respectively. Men had steeper angle values than women, and the L4-L5 level had the steepest angle of the α trajectory in both sexes (Table 2). The comparison of α trajectory angles between levels showed a statistically significant difference at L4-L5 (p=0.008), but comparison by sex did not reveal any differences (p>0.05) (Table 2). The mean angle of β trajectory at L2-L3, L3-L4, and L4-L5 were 14.86°±3.55°, 14.40°±2.43°, and 14.17°±1.97°, respectively. These angles were shallower than the α trajectory angles (Table 2). A comparison of the β trajectory angles between levels revealed a significant difference at the L4-L5 compared with the other levels (p=0.004). No significant difference was observed between the sexes (Table 2). L4-L5 had the shallowest β trajectory angle in both sexes. The mean psoas cross-sectional area retracted at each level using the β trajectory was 120.32 mm^2 at L2-L3, 250.13 mm^2 at L3-L4, and 399.63 mm^2 at L4-L5 (Table 3). The comparison between levels was statistically significant (all p<0.05), and the percentage of the psoas retracted is shown in Figure 3.

DISCUSSION

Successful indirect decompression placing a larger interbody cage is one of the procedure-related advantages of lateral and anterolateral lumbar fusion techniques [18-20]. Another benefit is the approach's ability to restore lordosis compared with other fusion techniques [6,21]. In addition, other factors contribute to adequately restoring sagittal balance. Such factors include the cage type (neutral or lordotic cage), the position of the implant within the intervertebral space, the more anterior, the more lordosis, and maneuvers to release the lumbar spine. Nonetheless, with more anterior surgical corridors, there is a higher risk of vascular injury and subsidence [22]. Alternatively, while a more posterior cage diminishes sagittal balance restoration, it also lessens the risk of subsidence. It must also be noted that with a more posterior approach, a slightly higher risk of damage to the psoas and lumbar plexus due to its dorsal location can occur, especially at L4-L5 [22,23].

The surgical corridor immediately anterior to the center of the intervertebral space in the anteroposterior direction has been considered convenient for placing the interbody device in lateral techniques. However, it depends on the lumbar plexus location at levels [22,24].

The oblique ATP approach has gained popularity among

Table 2. Angle measurements of alpha and beta trajectories

Level	Mean (°)	SD	Min (°)	Max (°)	p-value[b]	Male (°)	SD	Female (°)	SD	p-value[a]
α trajectory										
L2-L3	38.16	± 11.37	10.04	59.60	0.195	39.84	± 10.30	38.19	± 12.30	0.074
L3-L4	39.88	± 9.66	20.80	60.70	0.173	41.18	± 9.11	38.35	± 10.13	0.104
L4-L5	41.68	± 10.15	21.68	63.18	0.008*	43.12	± 9.96	39.99	± 10.20	0.087
Average	39.91	± 10.39				41.38	± 9.79	38.17	± 10.87	
β trajectory										
L2-L3	14.86	± 3.55	7.10	28.70	0.189	15.02	± 3.23	14.66	± 3.90	0.572
L3-L4	14.40	± 2.43	8.94	18.40	0.512	14.49	± 2.22	14.3	± 2.67	0.674
L4-L5	14.17	± 1.97	8.65	23.21	0.004*	14.33	± 2.12	13.99	± 1.78	0.336
Average	14.48	± 2.65				14.61	± 2.52	14.31	± 2.78	

(°): grades, SD: standard deviation, Min: minimum, Max: maximum.
[a]Unpaired t-test of males vs. females.
[b]ANOVA of L2-L3 vs. L3-L4 vs. L4-L5.
*Asterisks denote significance.

Table 3. Psoas retraction based on the β trajectory

Level	Mean total area (mm^2)	Mean retracted area (mm^2)	Percentage of retraction (%)	p-value[a]
L2-L3	632.11	120.32	19.03	< 0.001*
L3-L4	1003.27	250.13	24.93	< 0.001*
L4-L5	1353.23	399.63	29.53	< 0.001*

mm^2: square millimeters.
[a]ANOVA of L2-L3 vs. L3-L4 vs. L4-L5.
*Asterisks denote significance.

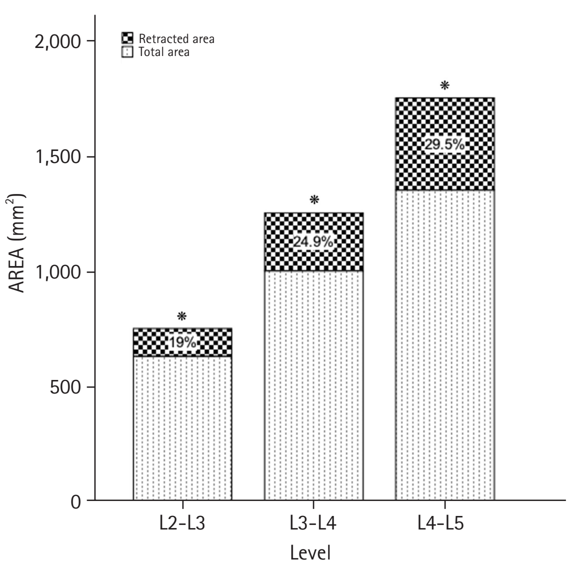

Figure 3. The bar chart shows the total psoas cross-sectional area and the percentage of possible retraction on each level based on the β trajectory. It is evident the biggest area of the psoas at L4-L5 with the most psoas retraction. *Asterisks denote significance.

spine surgeons interested in minimally invasive techniques in recent years. This procedure shares the advantages of the transpsoas approach, including reduced blood loss, improved postoperative pain, faster recovery, and preservation of posterior muscle and ligament structures. The most notable procedure-related advantage of the oblique ATP approach is the minor violation of the lumbar plexus because the surgical corridor is anterior to the psoas muscle [6]. Several authors reported an incidence of 5% to 14% for postoperative neuromuscular symptoms in the thigh after oblique lumbar interbody fusion, compared to the 19% to 33% seen in patients who underwent the transpsoas technique [25-28]. However, the primary concern among surgeons interested in oblique fusion is the risk of abdominal arterial injury. Interestingly, this technique's arterial injury rates are low and previously reported as 0.3% to 2.4% [29].

To make the procedure as safe as possible, several image-based and cadaveric dissection studies have intensively examined the surgical ATP corridor [7-17]. Most of these publications are based on Asian [8-14,16] and American [7,15,17] populations. Therefore, while the general considerations have been well described (e.g., the anatomical elements involved in the oblique surgical corridor and the elements surrounding the lumbar spine at each level), data on the North American/American Hispanic population are lacking.

The following concerns are addressed in the present article:

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1) How could a safe entry point (EP) to the intervertebral space (IVS) be planned for an oblique ATP approach? 2) How to plan a safe oblique trajectory to the IVS for the contralateral neural elements and vessels anterior to the spine? And finally, 3) How is the potential retraction of the psoas muscle calculated preoperatively using the parameters proposed?

Three points must be considered before an oblique lumbar fusion. 1) An oblique surgical corridor from 0.5 to 10 mm, limited by the left lateral border of the anterior vessel (aorta or left iliac artery) and the anterior belly of the psoas. 2) The surgeon should opt for other fusion techniques in patients with high-rising psoas due to the risk of excessive manipulation. 3) Assess the location of the anterior vessel relative to the disc space to avoid arterial injury.

Wang et al. [9] studied the anterior vessel and psoas muscle locations relative to the disc space. The authors constructed different models to specifically study the prevalence of any one scenario. The most prevalent models were to locate the vessel distal to the psoas at L2-L3 and L3-L4, enlarging the surgical corridor, and the psoas closer to the anterior vessel at L4-L5, shrinking the corridor. Similar to the oblique corridor length reported by Davis et al. [7] in a cadaveric study of Americans. They found L4-L5 to be the narrowest with a 15.00 mm distance, L2-L3 18.60 mm, and L3-L4 19.25 mm.

Here we propose an oblique ATP approach where the entry point is not based on the psoas muscle location due to its anatomical variability at each lumbar level. The patient must have a feasible surgical corridor: a distance from the proposed entry point to the anterior vessel at least more than 5 mm. In our case series, the entry point proposed was located, on average, 11.53 mm away from the anterior vertebral line (AVL) in the lumbar levels measured (L2-L5). To calculate the entry point to AVL distance as part of this preoperative assessment proposed in the present study would allow starting the oblique approach far from the at-risk zone located anterior to the spine. It would enable the surgeon to start the oblique ATP approach with a pre-planned target to place the initial needle at one particular point (entry point) on the IVS based on the AVL. The average distance between the anterior vessel and entry point was 17.83 mm and was longer in men (19.05 mm) than in women (16.38 mm). It means that the routine prior recognition of this information will provide safety to the approach since the entry point is far from the anterior vessels of the spine.

Our findings are similar to other studies based on different populations. Our results confirmed that the L4-L5 level has the narrowest entry point to anterior vessel distance in Hispanics, suggesting that ethnicity is not a determinant in the entry point to anterior vessel measure [7-17].

The oblique trajectory to the IVS could injure contralateral neural structures mainly if the angulation is not meticulously planned or if a more significant than required interbody cage is selected. The more posterior the trajectory or steeper the angled trajectory, the greater the risk of damage to the contralateral lumbar plexus, exiting nerve root, and thecal sac. The surgeon must also consider the orthogonal maneuver while tapping the cage to set it into the prepared disc space. A steeper angle means a prolonged orthogonal maneuver and a greater compression risk for the ipsilateral psoas muscle and lumbar plexus.

An MRI-based imaging study within the Asian population evaluated different scenarios using simulated trajectories from 0º to 45º [16]. They found that a 15º trajectory for placing the interbody device is associated with a lower risk of damaging contralateral neural structures [16]. In our study, the trajectory called α depended on the location of the anterior edge of the psoas; the surgeon usually chooses this to set the cage in a real-life scenario. The average of the α trajectory angle was 39.9º, which is dangerous for the reasons mentioned. Our results also indicated that the steepest trajectory was observed at L4-L5 in both sexes. This can be attributed to the most significant volume of the psoas being found in the caudal rather than lumbar cranial levels.

The angle of β trajectory we found in Hispanics was 14.48º on average. The β trajectory was determined based on setting the interbody device in the middle-third of the intervertebral space; therefore, it can be planned before the surgery. This parameter is relevant because not all medical centers are equipped with intraoperative navigation technologies. Furthermore, our study confirmed that the trajectory reported by Huang et al. [16] is safest using anatomical measurements. We inferred that there was no significant difference in the angle of β trajectory values among the lumbar levels since it depends on the size of the middle-third region and the anteroposterior lengths of the lumbar vertebral bodies were similar.

Finally, we analyzed the approximate percentage of psoas retraction during the interbody cage placement following the β trajectory. The results revealed that between 20% to 30% of the psoas cross-sectional area anterior to the β trajectory could be manipulated temporarily during cage insertion. This indicates that oblique lumbar fusion is not free of psoas manipulation, and the surgeon should keep it in mind when opting for this procedure.

Limitations

An age-based subgroup would have enabled determining the influence of age on the β trajectory. Only two experienced researchers did the measurements. An image-based study could expose differences with accurate anatomical findings. Our study used non-enhanced lumbar CT scans in a supine position, which may differ from right/left lateral decubitus position. No CT scans from patients with deformities were included, which may affect the parameters. This article is an observational retrospective morphometric preclinical research study based on a particular population at a single institution and limits its generalizability. A North American/American Hispanic population from Mexico and similarities or differences among all Hispanics (i.e., American, South American, and Iberic) should be considered in future studies.

CONCLUSION

Our study proposes an entry point that provides access to the disc space laterally in the middle-third and away from the anterior arterial lumbar vessels that depend on the anterior vertebral line. It could permit the introduction of the surgical instruments, prepare the intervertebral space and obliquely place the cage with a different trajectory proposed and termed β, with which it is possible to measure the potential psoas muscle retracted during the procedure. The parameters presented and analyzed in this research could serve as a preoperative assessment in Hispanic North American/American patients recommended for an oblique ATP lumbar fusion.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Mayer HM. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine (Phila Pa 1976) 1997 22:691–699. discussion 700
2. Silvestre C, Mac-Thiong JM, Hilmi R, Roussouly P. Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 2012;6:89–97.
3. O'Brien JR. Nerve injury in lateral lumbar interbody fusion. Spine (Phila Pa 1976) 2017;42 Suppl 7:S24.
4. Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY. An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion. J Neurosurg Spine 2011;15:11–18.
5. Li JX, Phan K, Mobbs R. Oblique lumbar interbody fusion: technical aspects, operative outcomes, and complications. World Neurosurg 2017;98:113–123.
6. Quillo-Olvera J, Lin GX, Jo HJ, Kim JS. Complications on minimally invasive oblique lumbar interbody fusion at L2-L5 levels: a review of the literature and surgical strategies. Ann Transl Med 2018;6:101.
7. Davis TT, Hynes RA, Fung DA, Spann SW, MacMillan M, Kwon B, et al. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs in the lateral position: an anatomic study. J Neurosurg Spine 2014;21:785793.
8. Liu L, Liang Y, Zhang H, Wang H, Guo C, Pu X, et al. Imaging anatomical research on the operative windows of oblique lumbar interbody fusion. PLoS One 2016;11:e0163452.
9. Wang Z, Liu L, Xu XH, Cao MD, Lu H, Zhang KB. The OLIF working corridor based on magnetic resonance imaging: a retrospective research. J Orthop Surg Res 2020;15:141.
10. Tao Y, Huang C, Li F, Chen Q. Magnetic resonance imaging study of oblique corridor and trajectory to L1-L5 intervertebral disks in lateral position. World Neurosurg 2020;134:e616–e623.
11. Zhang F, Xu H, Yin B, Tao H, Yang S, Sun C, et al. Does right lateral decubitus position change retroperitoneal oblique corridor? A radiographic evaluation from L1 to L5. Eur Spine J 2017;26:646–650.
12. Julian Li JX, Mobbs RJ, Phan K. Morphometric MRI imaging study of the corridor for the oblique lumbar interbody fusion technique at L1-L5. World Neurosurg 2018;111:e678–e685.
13. Chen X, Chen J, Zhang F. Imaging anatomic research of oblique lumbar interbody fusion in a Chinese population based on magnetic resonance. World Neurosurg 2019;128:e51–e58.
14. Ng JP, Kaliya-Perumal AK, Tandon AA, Oh JY. The oblique corridor at L4-L5: a radiographic-anatomical study into the feasibility for lateral interbody fusion. Spine (Phila Pa 1976) 2020;45:E552–E559.
15. Molinares DM, Davis TT, Fung DA. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs: an MRI study. J Neurosurg Spine 2016;24:248–255.
16. Huang C, Xu Z, Li F, Chen Q. Does the access angle change the risk of approach-related complications in minimally invasive lateral lumbar interbody fusion? An MRI study. J Korean Neurosurg Soc 2018;61:707–715.
17. Boghani Z, Steele WI, Barber SM, Lee JJ, Sokunbi O, Blacklock

 https://doi.org/10.21182/jmisst.2021.00290

JB, et al. Variability in the size of the retroperitoneal oblique corridor: a magnetic resonance imaging-based analysis. Surg Neurol Int 2020;11:54.
18. Sato J, Ohtori S, Orita S, Yamauchi K, Eguchi Y, Ochiai N, et al. Radiographic evaluation of indirect decompression of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spondylolisthesis. Eur Spine J 2017;26:671–678.
19. Lang G, Perrech M, Navarro-Ramirez R, Hussain I, Pennicooke B, Maryam F, et al. Potential and limitations of neural decompression in extreme lateral interbody fusion-a systematic review. World Neurosurg 2017;101:99–113.
20. Mahatthanatrakul A, Kim HS, Lin GX, Kim JS. Decreasing thickness and remodeling of ligamentum flavum after oblique lumbar interbody fusion. Neuroradiology 2020; 62:971–978.
21. Phan K, Thayaparan GK, Mobbs RJ. Anterior lumbar interbody fusion versus transforaminal lumbar interbody fusion--systematic review and meta-analysis. Br J Neurosurg 2015;29:705–711.
22. Shiga Y, Orita S, Inage K, Sato J, Fujimoto K, Kanamoto H, et al. Evaluation of the location of intervertebral cages during oblique lateral interbody fusion surgery to achieve sagittal correction. Spine Surg Relat Res 2017;1:197–202.
23. Moro T, Kikuchi S, Konno S, Yaginuma H. An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery. Spine (Phila Pa 1976) 2003 28:423–428. discussion 427
24. Le TV, Baaj AA, Dakwar E, Burkett CJ, Murray G, Smith DA, et al. Subsidence of polyetheretherketone intervertebral cages in minimally invasive lateral retroperitoneal transpsoas lumbar interbody fusion. Spine (Phila Pa 1976) 2012;37:1268–1273.
25. Abe K, Orita S, Mannoji C, Motegi H, Aramomi M, Ishikawa T, et al. Perioperative complications in 155 patients who underwent oblique lateral interbody fusion surgery: perspectives and indications from a retrospective, multicenter survey. Spine (Phila Pa 1976) 2017;42:55–62.
26. Jin J, Ryu KS, Hur JW, Seong JH, Kim JS, Cho HJ. Comparative study of the difference of perioperative complication and radiologic results: MIS-DLIF (minimally invasive direct lateral lumbar interbody fusion) versus MIS-OLIF (minimally invasive oblique lateral lumbar interbody fusion). Clin Spine Surg 2018;31:31–36.
27. Campbell PG, Nunley PD, Cavanaugh D, Kerr E, Utter PA, Frank K, et al. Short-term outcomes of lateral lumbar interbody fusion without decompression for the treatment of symptomatic degenerative spondylolisthesis at L4-5. Neurosurg Focus 2018;44:E6.
28. Sellin JN, Brusko GD, Levi AD. Lateral lumbar interbody fusion revisited: complication avoidance and outcomes with the mini-open approach. World Neurosurg 2019;121:e647–e653.
29. Hah R, Kang HP. Lateral and oblique lumbar interbody fusion-current concepts and a review of recent literature. Curr Rev Musculoskelet Med 2019;12:305–310.

Clinical Article

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Minimally Invasive Subaxial Cervical Pedicle Screw Placement with Routine Fluoroscopy: Cadaveric Feasibility Study and Report of 6 Clinical Cases

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Objective: Conventional cervical pedicle screw insertion necessitates extensive paraspinal muscle dissection and retraction in order to achieve the lateral to medial angulation needed to achieve the optimal screw trajectory. Minimally invasive transmuscular approach can comfortably achieve this angulation without significant injury to the midline structures and its musculo-ligamentous attachments.

Methods: Minimally invasive cervical pedicle screws were inserted in 4 fresh frozen cadaveric specimens. Pre-procedure and post-procedure CT scans were done to assess the pedicle dimensions, suitability for screw insertion and integrity of the screws. The same technique was applied in a clinical cohort of six cases – 3 cases of traumatic subluxation; one case of traumatic vertebral fracture and 2 cases of infective facet destruction (Koch's).

Results: Among the 38 screws in the cadaver specimens, a total of 11 screws (28.9%) had breached the pedicle wall(Lateral wall breach–9; Medial wall breach–2). Of the 9 screws (23.6%) that had a lateral breach into the vertebral canal, 4 (10.5%) each had Grade IIa breach and one (2.6%) had Grade III breach. Among the 22 screws inserted in the clinical cohort of 6 cases, 4 screws (18.1%) had breached the pedicle wall. All the identified breaches were in the lateral wall(Grade IIa – 3; Grade IIb–1; Grade III–nil).

Conclusion: Minimally invasive subaxial pedicle screw insertion provides robust posterior cervical fixation, either in isolation or as an adjunct to anterior surgery, in cases where a direct posterior decompression is not warranted. It is a safe and effective approach which minimizes injury to the paraspinal structures and midline attachments.

Key Words: Cervical pedicle screw, Minimally invasive, Posterior cervical fixation, Percutaneous cervical fixation

INTRODUCTION

Among the numerous techniques advocated for the stabilization of cervical spine, pedicle screws offer the greatest biomechanical stability [1-3]. However, placing cervical pedicle screws is technically demanding due to a narrow pedicle, significant variation in anatomy and hence, higher chances of pedicle wall perforation resulting in injury to adjacent important neurovascular structures [4,5].

Another concern that is less frequently raised is the exposure required to access the lateral entry point and achieve a steep medial angulation required for proper positioning of these screws [1,2]. Several reports suggest that such extensive muscle dissection and retraction causes disruption of the posterior musculo-ligamentous tension band resulting in impaired post-operative neck muscle function and may be responsible for persistent neck discomfort [6,7].

Minimally invasive muscle splitting approaches, introduced for the lumbar spine, have the potential to significantly reduce muscle injury and preserve the posterior tension band [8]. Their superiority in minimizing blood loss, reducing the duration of hospital stay, enabling earlier return to work and improving functional outcomes as compared to conventional procedures has been shown in several studies [9,10]. Recently, several reports of extension of this technique to the cervical spine have appeared in the literature and have shown promising outcomes [11-13].

The present study elaborates technique and results of placing minimally invasive cervical pedicle screws in four cadaveric specimens and subsequently in six clinical cases.

MATERIALS AND METHODS

Cadaveric Specimens

Four fresh frozen cadavers with intact cervical spine and good visualization of the bony anatomy on fluoroscopy were selected for the study. Pre-operative CT scan with axial, saggital and coronal reconstruction was done in all the cadavers to note the dimensions and integrity of C3 to C7 pedicles and their practicality to accept a standard 3.5 mm screw. Using the minimal access technique described below, bilateral C3 to C7 pedicle screws were placed in all the cadavers. Post- procedural CT scans was done in all the cadavers with axial, saggital and coronal reconstructions to assess the position and integrity of the screws. The following parameters were noted on the CT scans:

- Transverse pedicle angle (pre-procedure CT) (Figure 1): measured as the angle between the long axis of the pedicle and the vertical plane (vertical line bisecting the vertebral body)
- Transverse screw angle (post-procedure CT): measured as the angle between the long axis of the screw and the vertical plane
- Pedicle wall breach (post-procedure CT) – Pedicle screw integrity was assessed based on the percentage of perforation and involvement of neurovascular structures
- Grade I – within pedicle; No breach
- Grade IIa – <25% and no contact with neurovascular structures
- Grade IIb – <25% and contact with neurovascular structures
- Grade III – >25% of screw diameter breached the pedicle wall In addition, the direction of breach, whether lateral or medial was also noted.
- Anterior/Lateral v. body breach (post-procedure CT)

1) Surgical Technique

Cadaveric specimens were placed prone on bolsters and head fixed with a makeshift frame. Anteroposterior and lateral fluoroscopy was done to ensure clear visibility of the cervical spine for the procedure. A linear vertical incision was made on either side, 3.0 to 3.5 cm off the midline, extending vertically from C3-4 interspace lower down to C6 vertebral body on the lateral fluoroscopy image. The incision roughly corresponded to a line approximately 0.5–1 cm lateral to the lateral border of the lateral mass on an anteroposterior fluoroscopy image. The incision was deepened in layers and dissection done with

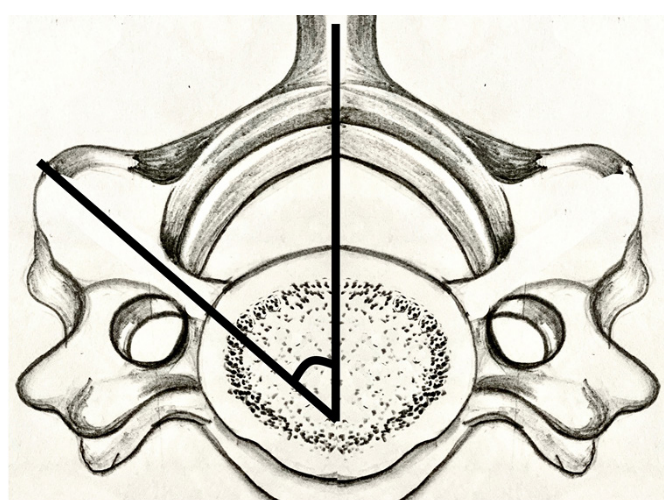

Figure 1. Criteria used to measure transverse pedicle angle.

finger and blunt instruments to create a plane all the way down to reach the dorsal surface of lateral mass. Sequential dilatation was done to finally dock an expandable 22 mm tubular retractor (Quadrant system, Medtronic Sofamor Danek, Memphis, TN, USA) roughly at the level of C4-5. The vertical blades of the retractor were expanded and further muscle dissection done to expose the dorsolateral part of lateral masses from C3 to C6, and approximate pedicle screw entry points were identified in the upper lateral quadrant of the lateral mass in line with the waist of the articular pillar. The retractor had to be angulated inferiorly in order to visualize the lateral mass of C7 and pedicle screw entry point. A high speed drill was used to drill off the cortex horizontally (as described in the key slot technique) [14], and pedicle was cannulated with a 1 mm bone curette. The direction of the curette was predominantly turned medially, observing that the medial cortex of the pedicle was thicker [15] and difficult to violate as compared to the lateral wall, which was thinner and most liable to be breached during pedicle screw placement. Once the pedicle was cannulated, the track was drilled with a 2.7 mm hand held drill. The walls of pedicle were probed for any breach and an appropriate length 3.5 mm screw was inserted into the same track. Similar steps were followed in inserting pedicle screws from C3 to C7, sequentially first on one side and then on the other (Figure 2).

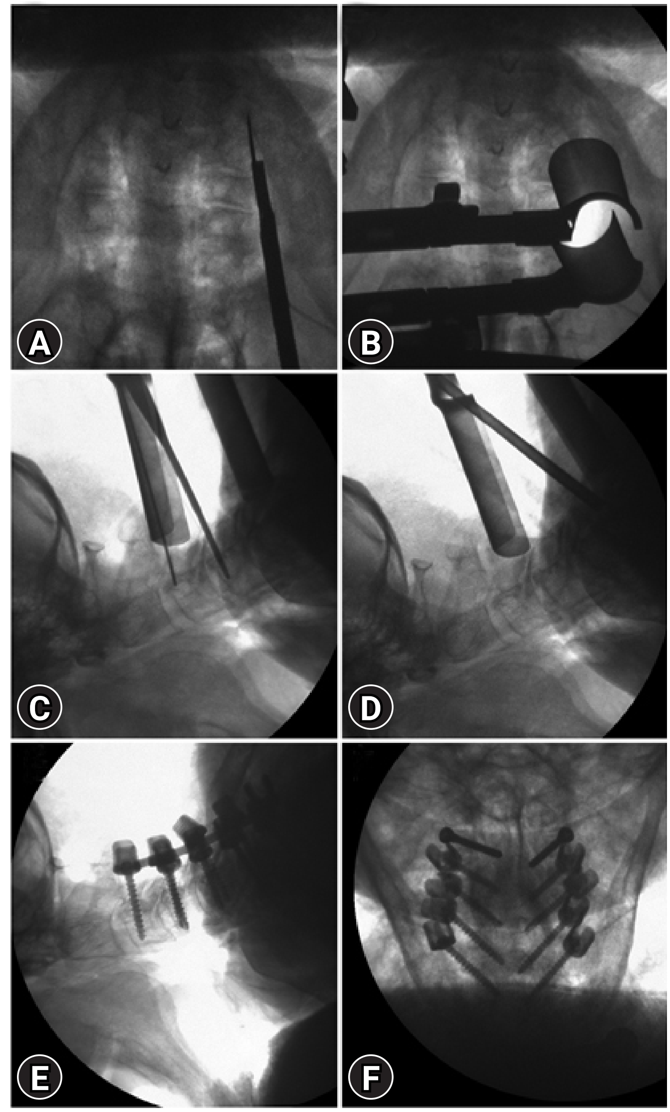

Figure 2. Representative images for pedicle screw insertion in one of the cadavers. (A) Marking the incision approximately 1 cm lateral to the lateral border of lateral mass on AP fluoroscopy. (B) Positioning the expandable tubular retractor. (C) Making drill holes with a 1 mm curette (C4), (D) angulating the tube inferiorly to access C6 and C7. (E) Lateral and (F) AP fluoroscopy after placing bilateral pedicle screws from C3 to C7.

RESULTS

1. Cadaveric Specimens

Of the 40 pedicles assessed on pre-procedural CT of 4 fresh frozen cadavers (C3-C7, Bilateral, 10 each per cadaver), 2 of the pedicels were sclerosed and very narrow with transverse diameter <2.5 mm and were not selected for screw insertion. Minimally invasive cervical pedicle screws could be successfully inserted in the remaining 38 pedicles, which were analyzed on post-procedural CT. The mean transverse pedicle angle was 45.6° at C3, 47.7° at C4, 46.1° at C5, 38.6° at C6 and 32.7° at C7.

Among the 38 screws, a total of 11 screws (28.9%) had breached the pedicle wall (Lateral wall breach – 9; Medial wall breach – 2). Of the 9 screws (23.6%) that had a lateral breach into the vertebral canal, 4 (10.5%) each had Grade IIa breach and one (2.6%) had Grade III breach (Figure 3). Three of the lateral breaches were at C3, 4 at C4 and 2 at C5. Apart from these, 2 screws had a medial breach, one Grade IIa and one grade IIb. Both of these were at C3. All the screws at C6 and C7 were intact with no pedicle wall violation in any direction.

Correlation was also observed between mean transverse screw angle and direction of pedicle breach. The mean transverse screw angle in the subset of pedicle screws with no breach was 34.1° whereas it was 22.1° in screws that had lateral breach and 43.6° in those that had medial breach.

Six screws (15.7%) had lateral vertebral body breach. Understandably, all these cases had lateral pedicle wall breach as well. None of the screws had an anterior vertebral body breach.

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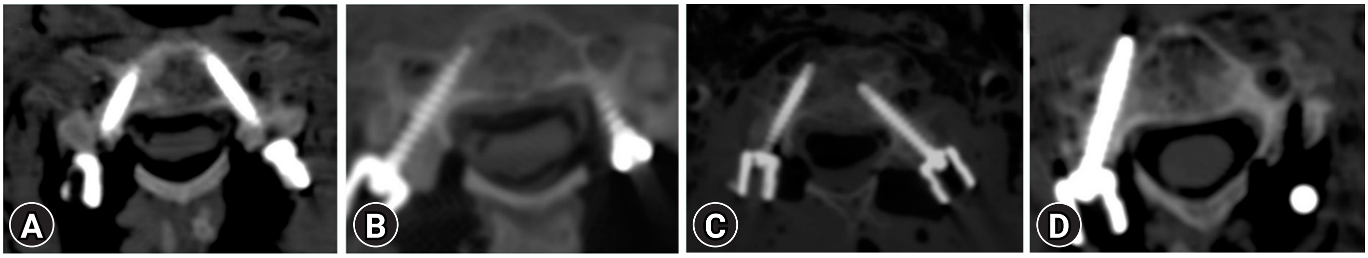

Figure 3. Representative post-procedural CT scans in cadaver specimens showing the pedicle screw integrity. (A) Bilateral pedicle screws intact. (B) Gr. IIa breach in the right pedicle screw. (C) Gr IIb breach in the right pedicle screw with correctly placed screw on left side. (D) Right screw showing Gr. III lateral wall breach as well as lateral vertebral body breach.

Table 1. Summary of clinical cases

No.	Age/sex	Final diagnosis	Clinical	Procedure	No. of screws included for study	Integrity of screw	f/u and status
1	55/F	C3 lateral mass Koch's with destruction	Severe neck pain; No FND	Tube-assisted decompression; C2-C4 MIS pedicle screw fixation	2 (b/l C4)	Gr IIa, unilateral, lateral (CT)	20 months, no FND, completed ATT
2	22/M	C5-6 subluxation	ASIA E	C5-6 MIS pedicle screw fixation	4	No breach (X-ray/ intra-op)	8 months, back to work
3	24/F	C5-6 subluxation (Fig. 4)	ASIA E	C5-6 MIS pedicle screw fixation	4	Gr IIa, unilateral, lateral (CT)	12 months, back to work
4	38/F	C3 lateral mass koch's with destruction (Fig. 5)	Severe neck pain; No FND	Tube-assisted decompression; C2-C4 MIS pedicle screw fixation	2 (b/l C4)	No breach (X-ray/ intra-op)	18 months, no FND; Completed ATT
5	47/M	C6-7 subluxation	ASIA D	C6-7 MIS pedicle screw fixation	4	No breach (CT)	4 months, no FND
6	34/M	C5, 6 fracture with PLC injury	ASIA D	C4,5-C7 MIS pedicle screw fixation	6	Gr IIb (1) Gr IIa (1) (CT)	2 years, no FND, back to work

F: female, FND: focal neurological deficits, b/l: bilateral, CT: computed tomography, Gr: grade, PLC: posterior ligamentous complex, f/u: follow-up, ATT: anti-tubercular treatment.

2. Clinical Cases

A total of 22 subaxial pedicle screws were inserted among 6 cases that underwent free hand or 2D fluoro-guided minimally invasive pedicle screw stabilization for various pathologies between 2014 to 2017. The details of the clinical cases are enumerated in Table 1 (Figure 4, 5). The senior author (US) has shifted to 3D-navigation guided minimally invasive cervical pedicle screw stabilization after 2017 (not discussed here).

None of the clinical cases had any approach/wound related complications. All patients were mobilized on first post-operative day with a hard-cervical collar, which was kept for 3 weeks. Post-operative CT scan to assess screw accuracy could be done in 4 cases (16 screws). The results in other two patients (6 screws) were tabulated solely on the basis of post-op X-ray and intra-op probing. Of the 22 screws, 4 screws (18.1%) had breached the pedicle wall. All the identified breaches were in the lateral wall (Grade IIa – 3; Grade IIb – 1; Grade III – nil). None of them had any obvious vertebral artery related complications. All the breaches were identified on CT scans. All patients had uneventful post-op recovery and were having good functional status at the time of their last follow-up.

DISCUSSION

Cervical Pedicle screw fixation, first described by Abumi et al. [1] in 1994, has been shown to be the strongest means of fixation in the subaxial cervical spine [3,16]. They have been used in the treatment of various cervical pathologies including traumatic subluxations or fracture [1,17], deformity [18,19] and tumors [20], especially in presence of co-existing severe osteoporosis [21]. In the present study, we assessed the feasibility of minimally invasive subaxial cervical pedicle screw placement on a subset of 4 cadaveric specimens (4 specimens; 38 screws) before applying the technique in the clinical setting (6 cases; 22 screws). The senior author (US) had followed a similar protocol for Minimally invasive atlanto-axial fixation as well [22]. Though cervical pedicle screw insertion using lateral stab in-

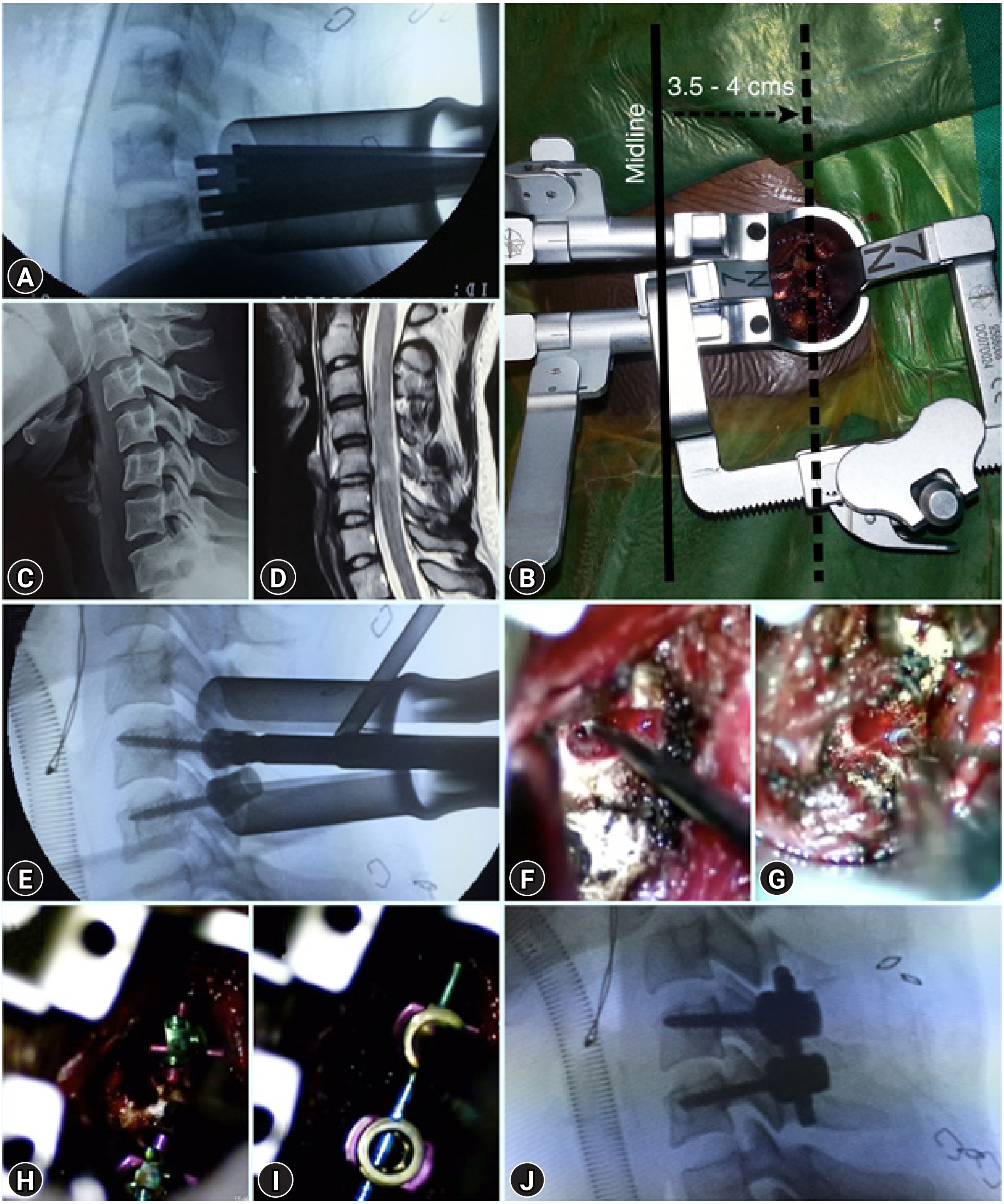

Figure 4. Illustrative images of minimally invasive pedicle screw stabilization in a case of C5-6 Gr1 subluxation. (C, D) Pre-operative lateral X-ray and T2W sagittal MRI image showing subluxation at C5-6 with intrinsic cord signal changes. (A) Intra-operative lateral fluoroscopy image showing tubular retractor in place. (B) Intra-operative image showing the tubular retractors in place and the incision of approach approximately 3.5–4.0 cm lateral to the midline. (E) Lateral Fluoroscopy image showing placement of pedicle screws. (F, G) Intra-operative microscope views showing pedicle being cannulated with a 1 mm curette (angled medially) (F) and later being probed (G) to identify any breach. (H, I) Intra-operative microscope views showing both screws after placement (H) and after rod and Innie screw insertion (I). (J) Final intra-operative image after bilateral pedicle screw stabilization.

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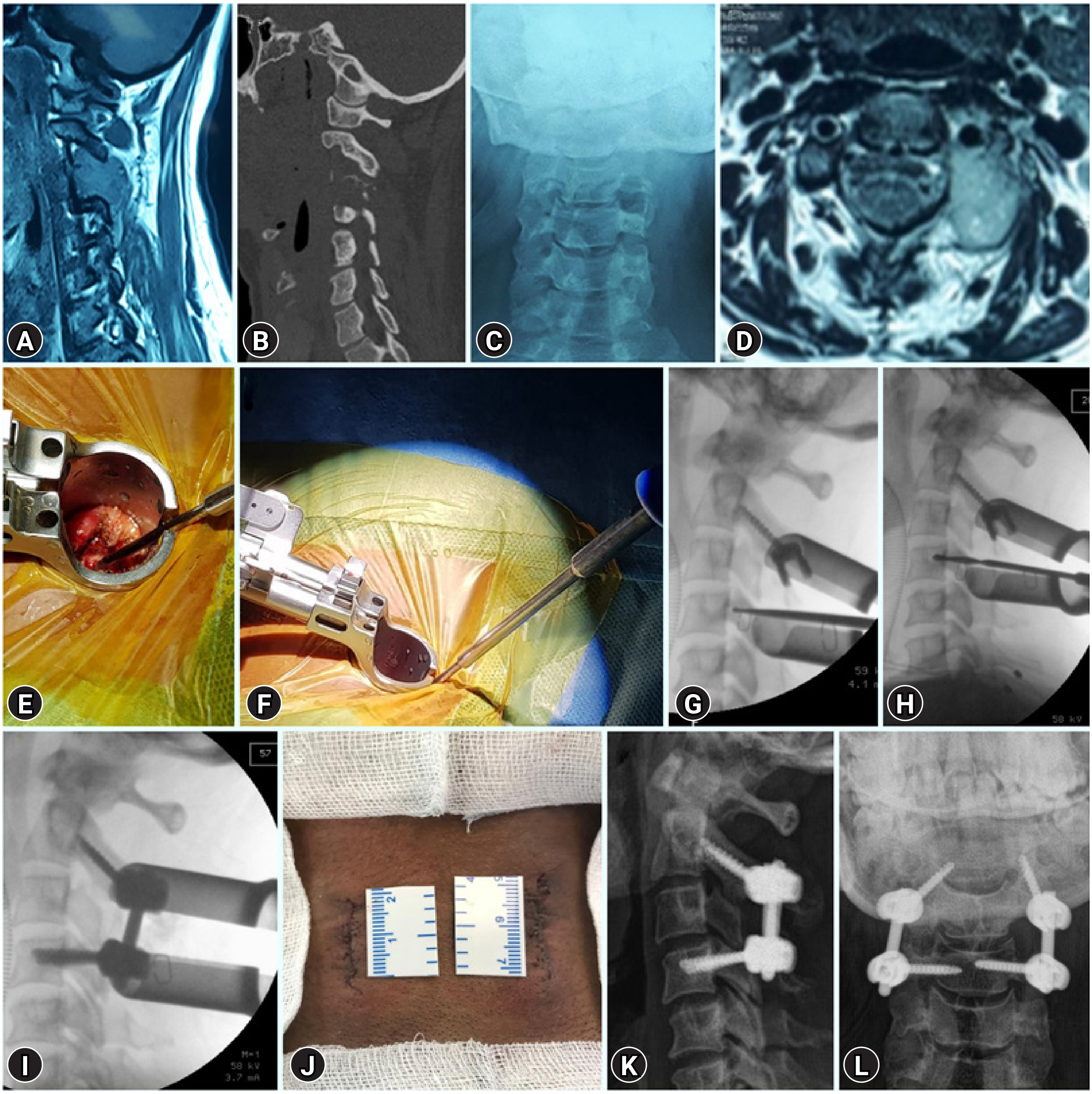

Figure 5. Illustrative images of minimally invasive pedicle screw stabilization in a case of C3 lateral mass Koch's with destruction. (A–D) Pre-operative images showing near-total destruction of the left C3 lateral mass visible both in CT (B) and AP fluoroscopy image (C) by a lesion that is isointense on T1W (A) and hyperintense on T2W (D) MRI image with no intracanalicular component. (E, F) Intra-operative photographs showing placement of tubular retractor (E) and lateral to medial angulation achieved for placing pedicle screw (F). (G, H) Intra-operative lateral fluoroscopy images showing insertion of bilateral C4 pedicle screw sequentially with a 1mm curette (G) and a 2.7mm hand held drill guide (H). (I) Final intra-operative fluoroscopy image after placing bilateral C2-C4 pedicle screws and rods. (J) Image showing bilateral 2–2.5 cm wounds after closure. (K, L) Lateral (K) and AP (L) X-rays done at 6 months follow-up.

cision was done previously, minimally invasive approach with use of a tubular retractor and free hand placement of cervical pedicle screw was first attempted by Lee and Park [23].

The reported overall rates of cervical pedicle screw breach in the literature range form 9%–30% overall with 4%–12% incidence of major (grade IIb and III) pedicle wall breaches, that can potentially injure the neurovascular structures [24-26]. The rates are similar in our cadaver study as well, with an overall pedicle breach rate of 28.9% and major (grade IIb and III) breach rate of 13.1%. In our clinical series of 22 screws, the overall breach rate was 18.1% with one screw (4.5%) having a major breach (Grade IIb). Several other series on minimally invasive cervical pedicle screw placement have shown pedicle breach rates that are similar or better to open series [27,28]. Komatsubara et al. [29] reported lesser incidence of screw perforation in the minimally invasive group, owing to a better transverse pedicle angle, which reduces the incidence of lateral pedicle wall breaches as compared to an open technique. Koakutsu et al. [30] did not have any pedicle breach in 29 screws placed by a novel minimally invasive technique. Several other isolated reports of successful minimally invasive cervical pedicle screw placement are also present [23,31].

Minimally invasive cervical pedicle screw insertion has the obvious advantages of minimizing soft tissue dissection and paraspinal injury as compared to an open approach, an extension of the principle that have yielded good results in percutaneous thoraco-lumbar pedicle screw fixation [32,33]. The significant lateral to medial angulation needed for placing cervical pedicle screws necessitates an extensive lateral paraspinal exposure and retraction. In cases where the soft tissue impedance is significantly higher, a separate lateral stab incision has also been recommended [34] to aid in achieving the lateral to medial trajectory, minimize soft tissue injury and prevent lateral pedicle wall breaches. Minimally invasive cervical pedicle screw insertion obviates the need for midline dissection, paraspinal muscle retraction and by creating a transmuscular route, comfortably achieves the lateral to medial screw angulation required [27,29,35]. In our cadaver study, the mean transverse screw angle in those with lateral pedicle wall breach was 22.1°, lower than the mean transverse angle in screws with no breach (34.1°). The more vertical angulation ideally should have been avoided with a minimally invasive approach. The incidence of lateral wall breach in our clinical series has improved, owing partially at least to the correction of the lateral to medial angulation.

Studies that compare open vs minimally invasive posterior laminoforaminotomy (comparatively a much simpler exposure in open surgeries as compared to open cervical pedicle screw insertion) have shown significant benefit and advantages for the minimally invasive approach [36,37]. It could hence be rationally hypothesized that minimally invasive cervical pedicle screw placement would yield better outcomes as compared to an open approach, as far as approach related morbidity is concerned. A Japanese study that compared outcomes in a small group of 12 open pedicle screw insertion and 6 cases of Minimally invasive pedicle screw insertion reported significantly reduced blood loss in the minimally invasive group [35]. To the best of our knowledge, there are no studies that have compared differences in approach related morbidity between open and minimally invasive subaxial pedicle screw insertion in a detailed manner, with biochemical and markers of tissue injury being assessed.

Minimally invasive cervical pedicle screw placement does have its limitations. In the absence of 3D navigation, it demands a certain degree of skill and expertise to place an already challenging subaxial cervical pedicle screw in a minimally invasive fashion. We have used this technique sparingly in simple cases with good pedicles, in patients who were neurologically well preserved. Reducible traumatic grade 1 subluxations with no disc prolapse or canal compromise are ideal for a standalone posterior stabilization and fusion. The 2 cases of lateral mass lesion (Koch's spine) without much of intra-canalicular component or cord compression presents an ideal case for a lateral approach, wherein the tubular retractor can be directly docked onto the area of pathology and achieve adequate decompression as well as fixation in the same sitting, at the same time obviating any injury to the intact midline structures and its musculo-ligamentous attachments. As expected, addressing any canalicular pathology and achieving cord decompression is difficult with this far lateral approach.

To summarize, minimally invasive subaxial pedicle screw insertion can be utilized in cases where a robust posterior fixation is required, either in isolation or as an adjunct to anterior surgery, in cases where a direct posterior canalicular or spinal cord decompression is not warranted. It is a safe and effective approach which minimizes injury to the paraspinal structures and midline attachments. A larger series and prospective comparison with conventional/open pedicle screw fixation are needed to conclusively establish its presumed clinical benefit.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Abumi K, Itoh H, Taneichi H, Kaneda K. Transpedicular screw fixation for traumatic lesions of the middle and lower cervical spine: description of the techniques and preliminary report. J Spinal Disord 1994;7:19–28.

https://doi.org/10.21182/jmisst.2021.00262

2. Karaikovic EE, Yingsakmongkol W, Gaines RW Jr. Accuracy of cervical pedicle screw placement using the funnel technique. Spine (Phila Pa 1976) 2001;26:2456–2462.
3. Jones EL, Heller JG, Silcox DH, Hutton WC. Cervical pedicle screws versus lateral mass screws. Anatomic feasibility and biomechanical comparison. Spine (Phila Pa 1976) 1997;22:977–982.
4. Karaikovic EE, Kunakornsawat S, Daubs MD, Madsen TW, Gaines RW Jr. Surgical anatomy of the cervical pedicles: landmarks for posterior cervical pedicle entrance localization. J Spinal Disord 2000;13:63–72.
5. Yukawa Y, Kato F, Ito K, Horie Y, Hida T, Nakashima H, et al. Placement and complications of cervical pedicle screws in 144 cervical trauma patients using pedicle axis view techniques by fluoroscope. Eur Spine J 2009;18:1293–1299.
6. Kotani Y, Abumi K, Ito M, Sudo H, Takahata M, Ohshima S, et al. Minimum 2-year outcome of cervical laminoplasty with deep extensor muscle-preserving approach: impact on cervical spine function and quality of life. Eur Spine J 2009;18:663–671.
7. Shiraishi T, Kato M, Yato Y, Ueda S, Aoyama R, Yamane J, et al. New techniques for exposure of posterior cervical spine through intermuscular planes and their surgical application. Spine (Phila Pa 1976) 2012;37:E286–E296.
8. Rahman M, Summers LE, Richter B, Mimran RI, Jacob RP. Comparison of techniques for decompressive lumbar laminectomy: the minimally invasive versus the "classic" open approach. Minim Invasive Neurosurg 2008;51:100–105.
9. Fan S, Hu Z, Zhao F, Zhao X, Huang Y, Fang X. Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: minimally invasive procedure versus conventional open approach. Eur Spine J 2010;19:316–324.
10. Tian NF, Wu YS, Zhang XL, Xu HZ, Chi YL, Mao FM. Minimally invasive versus open transforaminal lumbar interbody fusion: a meta-analysis based on the current evidence. Eur Spine J 2013;22:1741–1749.
11. Santiago P, Fessler RG. Minimally invasive surgery for the management of cervical spondylosis. Neurosurgery 2007;60:S160–S165.
12. Wang MY, Levi AD. Minimally invasive lateral mass screw fixation in the cervical spine: initial clinical experience with long-term follow-up. Neurosurgery 2006;58:907–912.
13. Celestre PC, Pazmiño PR, Mikhael MM, Wolf CF, Feldman LA, Lauryssen C, et al. Minimally invasive approaches to the cervical spine. Orthop Clin North Am 2012 43:137–147. x
14. Lee SH, Kim KT, Abumi K, Suk KS, Lee JH, Park KJ. Cervical pedicle screw placement using the "key slot technique": the feasibility and learning curve. J Spinal Disord Tech 2012;25:415–421.
15. Reinhold M, Bach C, Audigé L, Bale R, Attal R, Blauth M, et al. Comparison of two novel fluoroscopy-based stereotactic methods for cervical pedicle screw placement and review of the literature. Eur Spine J 2008;17:564–575.
16. Kothe R, Rüther W, Schneider E, Linke B. Biomechanical analysis of transpedicular screw fixation in the subaxial cervical spine. Spine (Phila Pa 1976) 2004;29:1869–1875.
17. Liu B, Liu X, Shen X, Wang G, Chen Y. The "slide technique"-a novel free-hand method of subaxial cervical pedicle screw placement. BMC Musculoskelet Disord 2020;21:399.
18. Abumi K, Shono Y, Taneichi H, Ito M, Kaneda K. Correction of cervical kyphosis using pedicle screw fixation systems. Spine (Phila Pa 1976) 1999;24:2389–2396.
19. Rajasekaran S, Kanna PR, Shetty TA. Intra-operative computer navigation guided cervical pedicle screw insertion in thirty-three complex cervical spine deformities. J Craniovertebr Junction Spine 2010;1:38–43.
20. Oda I, Abumi K, Ito M, Kotani Y, Oya T, Hasegawa K, et al. Palliative spinal reconstruction using cervical pedicle screws for metastatic lesions of the spine: a retrospective analysis of 32 cases. Spine (Phila Pa 1976) 2006;31:1439–1444.
21. Abumi K, Kaneda K, Shono Y, Fujiya M. One-stage posterior decompression and reconstruction of the cervical spine by using pedicle screw fixation systems. J Neurosurg 1999;90(1 Suppl):19–26.
22. Srikantha U, Khanapure KS, Jagannatha AT, Joshi KC, Varma RG, Hegde AS. Minimally invasive atlantoaxial fusion: cadaveric study and report of 5 clinical cases. J Neurosurg Spine 2016;25:675–680.
23. Lee S, Park JH. Minimally invasive cervical pedicle screw placement with a freehand technique through the posterolateral approach using a tubular retractor: a technical note. Oper Neurosurg (Hagerstown) 2019;17:E166–E172.
24. Abumi K, Shono Y, Ito M, Taneichi H, Kotani Y, Kaneda K. Complications of pedicle screw fixation in reconstructive surgery of the cervical spine. Spine (Phila Pa 1976) 2000;25:962–969.
25. Uehara M, Takahashi J, Ikegami S, Mukaiyama K, Kuraishi S, Shimizu M, et al. Screw perforation features in 129 consecutive patients performed computer-guided cervical pedicle screw insertion. Eur Spine J 2014;23:2189–2195.
26. Wang Y, Xie J, Yang Z, Zhao Z, Zhang Y, Li T, et al. Computed tomography assessment of lateral pedicle wall perforation by free-hand subaxial cervical pedicle screw placement. Arch

Orthop Trauma Surg 2013;133:901–909.
27. Coric D, Rossi VJ, Peloza J, Kim PK, Adamson TE. Percutaneous, navigated minimally invasive posterior cervical pedicle screw fixation. Int J Spine Surg 2020;14:S14–S21.
28. Lang Z, Tian W, Yuan Q, He D, Yuan N, Sun Y. [Percutaneous minimally invasive pedicle screw fixation for cervical fracture using intraoperative three-dimensional fluoroscopy-based navigation]. Zhonghua Wai Ke Za Zhi 2015 53:752–756. Chinese
29. Komatsubara T, Tokioka T, Sugimoto Y, Ozaki T. Minimally invasive cervical pedicle screw fixation by a posterolateral approach for acute cervical injury. Clin Spine Surg 2017;30:466–469.
30. Koakutsu T, Aizawa T, Itoi E. Accurate and minimally invasive cervical pedicle screw insertion procedure using the bone biopsy needle as drill guide. Spine Surg Relat Res 2020;4:358–364.
31. Tanaka M, Fujiwara Y, Uotani K, Kadiri V, Yamauchi T. C-arm-free minimally invasive cervical pedicle screw fixation (MICEPS): a technical note. Acta Med Okayama 2020;74:551–556.
32. Grass R, Biewener A, Dickopf A, Rammelt S, Heineck J, Zwipp H. Perkutane dorsale versus offene Instrumentation bei Frakturen des thorakolumbalen Ubergangs. Eine vergleichende prospektive Untersuchung [Percutaneous dorsal versus open instrumentation for fractures of the thoracolumbar border. A comparative, prospective study]. Unfallchirurg 2006 109:297–305. German
33. Lee JK, Jang JW, Kim TW, Kim TS, Kim SH, Moon SJ. Percutaneous short-segment pedicle screw placement without fusion in the treatment of thoracolumbar burst fractures: is it effective?: comparative study with open short-segment pedicle screw fixation with posterolateral fusion. Acta Neurochir (Wien) 2013 155:2305–2312. discussion 2312
34. Uehara M, Takahashi J, Hirabayashi H, Hashidate H, Ogihara N, Mukaiyama K, et al. Perforation rates of cervical pedicle screw insertion by disease and vertebral level. Open Orthop J 2010;4:142–146.
35. Sugimoto Y, Hayashi T, Tokioka T. Minimally invasive cervical pedicle screw fixation via the posterolateral approach for metastatic cervical spinal tumors. Spine Surg Relat Res 2017;1:218–221.
36. Clark JG, Abdullah KG, Steinmetz MP, Benzel EC, Mroz TE. Minimally invasive versus open cervical foraminotomy: a systematic review. Global Spine J 2011;1:9–14.
37. Subramanian N, Srikantha U, Jagannatha AT, Khanapure K, Varma RG, Hegde AS. Posterior cervical laminoforaminotomy: a comparative study between open vs minimally invasive approach. J Spinal Surg 2015;2:8–12.

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Efficiency of Spinal Anesthesia versus General Anesthesia for Minimal Invasive Single Level Transforaminal Lumbar Interbody Fusion: A Retrospective Analysis of 178 Patients

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Objective: To evaluate the efficacy of spinal anesthesia in patients undergoing minimal invasive single level transforaminal lumbar interbody fusion (MIS TLIF) surgery and to compare the results with that of general anesthesia.

Method: 178 patients were included in the study, 86 were in general anesthesia and 92 were in spinal anesthesia. Patients aged between 20 to 70 years who had undergone MIS TLIF not responding to 6 weeks of conservative treatment were included. The routine steps of anesthesia for both general and spinal anesthesia were adhered. The visual analogue scale, blood loss, duration of surgery, time from entering operation theatre to time of incision, time of bandaging to exit from operation theatre, time of stay in Post Anesthesia Care Unit (PACU), nausea/vomiting, urinary retention, duration of stay in hospital, peri-operative complications were compiled and assessed. Appropriate statistical analysis was applied.

Results: The mean time for entering the operation theatre to the incision; mean time from bandaging to the exit; mean PACU time and the mean hospital stay were significantly lower in the spinal anesthesia group ($p<0.05$). The other parameters are comparable except, urinary retention which was significantly higher in spinal anesthesia group ($p<0.05$).

Conclusion: Spinal anesthesia offers efficient operating room functioning with decreasing overall operation theatre time. It is very efficient alternative technique to general anesthesia which can be considered for elective lumbar surgeries with a lower late of adverse events especially at lower lumbar levels.

Key Words: Spinal anesthesia, General anesthesia, Lumbar surgery, Visual analog scale, Minimal invasive single level transforaminal lumbar interbody fusion

INTRODUCTION

Unstable spine is most common indication for lumbar fusion surgeries. With advent of minimal invasive techniques, minimal invasive lumbar interbody fusion is in vogue. Various anesthetic techniques are used for performing lumbar spinal surgeries. They are performed either in general or regional anesthesia. Endotracheal general anesthesia is the most commonly used technique [1]. The main advantages of general anesthesia being that longer duration surgeries can be performed with secured airway in the prone position [2,3].

The advantages in favour of spinal anesthesia being rapid onset, lesser blood loss, lesser thrombotic events, pulmonary complications and other neurological cognitive dysfunctions. Other benefits being that the patient can spontaneously breathe and can reposition themselves avoiding compression injuries during the procedure [4-6].

Few studies have been done which compare general anesthesia and spinal anesthesia in lumbar spinal surgeries and have reported much shorter surgical time, postoperative pain, less time in recovery room, lesser incidence of urinary retention, postoperative nausea vomiting and most importantly less financial implications in spinal anesthesia [7,8].

Despite encouraging results in favour of spinal anesthesia, spinal anesthesia does not come without risk, and there is (at least to date) no clear evidence to delineate the difference in morbidity and mortality between the two approaches [9]. Hence in our study we aimed to study spinal anesthesia as an alternate option to do lumbar fusion surgeries.

MATERIALS AND METHODS

The present comparative study was a retrospective study conducted at the Department of Orthopedics, Bombay Hospital & Research Centre, Mumbai during the study period from April 2018 to April 2020. We included 178 patients who underwent single-level primary minimal invasive transforaminal lumbar interbody fusion (MIS TLIF) for degenerative lumbar spine disorders (degenerative lumbar canal stenosis with instability, prolapsed intervertebral disc, degenerative/dysplastic/ isthmic spondylolisthesis) during the study period.

Patient with age between 20 and 70 years of either gender, undergoing minimal invasive single level lumbar interbody fusion at lower lumbar levels (L3-L4, L4-L5, L5-S1), not responding to 6 weeks of conservative therapy and having mechanical low back pain with radiculopathy with claudication with/ without neurodeficit with willingness to provide their verbal consent for allowing to use their data for research purpose were included in the study.

Patient who had undergone any revision spine surgery, having tumour, infection or other pathological causes, extraspinal cause of back pain/radiculopathy, patients who required multi-level surgery, patient requiring surgery at L1-L2 or L2-L3 levels and those not providing their willingness to provide consent for participation in the study were excluded. All surgeries were performed by a single surgeon in a single institute, managed by a single anesthesiologist with similar surgical and anesthetic techniques. Demographic characteristics and American Society of Anesthesiologists (ASA) physical status of the patients were all recorded.

According to the inclusion and exclusion criteria, after counselling for surgery the patients who fit the deemed criteria for study were offered both choices to choose either spinal or general anesthesia. They were thoroughly counselled and explained pros and cons associated with each technique and allowed to opt anesthesia as per their choice. Since the anesthesia was as per patient's demand, the comorbidities were not considered for evaluation. The choice of anesthesia was chosen by the patient and not observer of the study. 178 patients satisfied the selection criteria. These patients were further divided into two groups based on the anesthesia given. Of these, 92 patients underwent MIS TLIF under spinal anesthesia and 86 under general anesthesia.

Anesthesia Technique

Patients who received general anesthesia were given a combination of nitrous oxide, desflurane, propofol, sevoflurane, halothane and isoflurane. After intubating, they were positioned prone. Post completion of general anesthesia and discontinuation of anesthetic drugs, 100% oxygen was administered. Patients were then transferred to PACU after appropriate extubation. PACU nursing staff monitored patients until they were alert, responsive and stable before their transfer to ward. Intravenous analgesics was administered to the patients during their stay in PACU.

Spinal anesthesia administered patients were first given a 500 milliliters infusion of ringer lactate solution 10–15 minutes before giving spinal anesthesia. After entering operating room patient was put in seated position. Local infiltration of 3 mL of 2% lidocaine was given, SA was achieved via lumbar puncture, using a needle size of 25 gauze most commonly. After visualization of spinal fluid, bupivacaine was injected in combination with fentanyl into the intrathecal space. Bupivacaine was given as 15 mg dose of a 0.75% bupivacaine in 8.25% dextrose solution. 25 μg of fentanyl was given in combination with bupivacaine, in order to increase the of the spinal anesthesia antinociceptive effect. Once the spinal anesthesia had been given, adequate anesthesia was verified on the lower back and extremities after the patient was put into a supine position. The patient was then turned into the prone position on the operating table. Oxygen was administered via nasal cannula and propofol infusion assured sedation. Propofol was discontinued at completion of the procedure and the patient was transferred to the PACU for recovery. The patients remained in the PACU till hemodynamic stability was confirmed, followed by transfer

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to the ward.

Visual analogue score for pain, duration of surgery, blood loss, time from entering the operation theatre to incision, time from bandaging to exit, PACU time, duration of hospital stay, urinary retention and adverse events were our outcome measures.

A customized proforma designed for the purpose of the study was used for collecting the data of the patients. No personal details of the patients were disclosed. Only data needed for the purpose of the research paper was included. The present study was not funded by any company or institution and also no additional tests/procedures, etc. were conducted for the specific requirement of the study, so there was no financial burden on the patient and/or on the institution. Researcher bore all the expenses towards the conduct of the study.

The mean comparison between the two groups was done using independent samples test and comparison of proportions was done using Pearson Chi-square test. A p-value of <0.05 was taken as statistically significant.

RESULTS

178 patients were included in the study undergoing MIS TLIF under general or spinal anesthesia during the study period. Of these patients, 86 patients underwent surgery under general anesthesia and 92 under spinal anesthesia.

In both the groups, majority of the patients were in the age group more than 40 years, 95.3% in general anesthesia group and 93.5% in the spinal anesthesia group. The mean age of patients in the general anesthesia group was 58.36±9.12 years and in the spinal anesthesia group was 56.90±10.39 years. The difference was found to be statistically not significant (p=0.323), showing a comparable mean between the two groups (Table 1).

There was a female predominance in both the groups (54.7% in general anesthesia vs. 60.9% in spinal anesthesia group). The distribution of male and female was comparable between the two groups (p=0.401) (Table 1).

The indication for surgery in our study were degenerative, isthmic, lumbar canal stenosis with instability and prolapse of intervertebral disc in both the groups. And majority of the patients underwent surgery due to degeneration (45.3% in general anesthesia vs. 48.9% in spinal anesthesia) (Table 2).

The mean duration of surgery (general anesthesia 148.95±17.15 minutes vs. spinal anesthesia 147.55±17.29 minutes) and mean blood loss (general anesthesia 111.22±111.74 mL vs. spinal anesthesia 108.69±108.45 mL) were comparable between the two groups (p>0.05). The extent of spinal anesthesia was obtained

Table 1. Patient demographic profile

Parameter	General anesthesia (n = 86)	Spinal anesthesia (n = 92)	p-value
Age (± SD) years	58.36 ± 9.12	56.90 ± 10.39	0.323, NS
Gender			
Female	47 (54.7%)	56 (60.9%)	
Male	39 (45.3%)	36 (39.1%)	

NS: not significant.

Table 2. Clinical parameters

Parameter	General anesthesia (n = 86)	Spinal anesthesia (n = 92)	p-value
Level of surgery			
L3-L4	9 (10.5%)	7 (7.6%)	
L4-L5	50 (58.1%)	59 (64.1%)	
L5-S1	27 (31.4%)	26 (28.3%)	
Indication for surgery			
Degenerative	39 (45.3%)	45 (48.9%)	
Isthmic	16 (18.6%)	17 (18.5%)	
LCS with instability	20 (23.3%)	22 (23.9%)	
Prolapse of intervertebral disk	11 (12.8%)	8 (8.7%)	
Duration of surgery (± SD) min	148.95 ± 17.15	147.55 ± 12.29	0.589, NS
Blood loss (± SD) mL	111.22 ± 111.74	108.69 ± 108.45	0.879, NS
Time of entering OT to incision (min)	41.80 ± 32.39	27.55 ± 5.27	0.001*
Time from bandaging to exit	16.98 ± 4.96	6.85 ± 3.03	0.001*
Post Anaesthesia Care Unit min	57.14 ± 19.35	36.79 ± 7.32	0.001*
Hospital stay (days)	3.05 ± 0.67	1.61 ± 0.55	0.001*

NS: not significant.
*p<0.05

up to D10 in majority of the cases (Table 2).

The mean time from entering the operation theatre to the incision was significantly shorter in spinal anesthesia group (41.80±32.39 minutes general anesthesia vs. 27.55±5.27 minutes spinal anesthesia, p<0.05). Similarly, the mean time from bandaging to the exit was also significantly shorter in the spinal anesthesia group (16.98±4.96 minutes general anesthesia vs. 6.85±3.03 minutes spinal anesthesia, p<0.05) (Table 2).

The mean PACU time in the general anesthesia group was 57.14±19.35 minutes and in the spinal anesthesia group it was 36.79±7.32 minutes, which was significantly lower in the spinal anesthesia group (p<0.05) (Table 2).

The mean hospital stay was significantly shorter in the spinal anesthesia group (1.61±0.55 days vs. 3.05±0.67 days in general anesthesia), p<0.05) (Table 2).

The mean preoperative (p=0.251) and postoperative visual analogue scale (VAS) was comparable between the two groups at immediate post op (p=0.071), 3 months (p=0.068), and 12 months (p=0.064) follow-ups (p>0.05) (Table 3).

The incidence of nausea/vomiting was comparable between the two groups (p=0.113), but the incidence of urinary retention was significantly higher in the spinal anesthesia group in comparison to the general anesthesia group (20.7% spinal anesthesia vs. 5.8% general anesthesia) (p<0.05). The other complications encountered in our study were screw malposition, dural tear, screw loosening, cage slippage and implant failure seen in very less number of patients in both the groups and were comparable in both spinal as well as general anaethesia patients (Table 4).

DISCUSSION

Despite all the comparative studies on general and spinal anesthesia, there is still controversy on the influence of these two different anesthesia methods on perioperative outcome of surgery as there are not many studies done to compare spinal anesthesia advantages over general anesthesia. So considering this lacunae in the literature, we undertook the present study at our institution to evaluate the efficacy of spinal anesthesia and general anesthesia in terms of clinical and surgical outcome in patients undergoing single level minimal invasive lumbar interbody fusion surgery.

In the present study with a mean age was comparable between the two groups (p>0.05). There was a comparable distribution of males and females in our study with a female predominance in each of the two groups. Studies done by Jellish et al. [10], McLain et al. [11], Dashtbani et al. [12], and Sadrolsadat et al. [13] also found comparable demographic variables in their studies. While in the study done by Papadopoulos et al. [14] a slightly higher age was seen in patients undergoing general anesthesia, with a male preponderance in both the groups.

The mean preoperative (p=0.251) and postoperative VAS was comparable between the two groups at immediate post op (p=0.071), 3 months (p=0.068) and 12 months (p=0.064) follow-ups (p>0.05). While in Dashtbani et al. [12] study the mean preoperative VAS was significantly higher in general anesthesia group.

Mean blood loss reported in our study was also comparable, which is supported by the study done by Dashtbani et al. [12]. While Sadrolsadat et al. [13] and Jellish et al. [10] found a significantly higher blood loss in general anesthesia group, which is contradictory to our findings.

The duration of surgery in the present study was comparable between the two groups, Sadrolsadat et al. [13] and Dashtbani et al. [12] and also found a comparable mean duration of surgery in their study, while studies done by Jellish et al. [10] and McLain et al. [11] reported a significantly longer duration of surgery in general anesthesia group (p<0.05).

However in our study, there was shorter total anesthesia time in the spinal anesthesia group. Though the duration of surgery is a large component of this parameter, results remained significant when adjustment was made for operative time. This is due to the reason as we recorded two additional time points,

Table 3. Visual analogue scale score

	Visual analogue scale score		
	SA	GA	p-value
Immediate pre op	3.94	4.15	0.251
Immediate post op	1.68	1.82	0.071
3 months	1.64	1.74	0.068
12 months	0.52	0.54	0.064

SA: spinal anesthesia, GA: general anesthesia.

Table 4. Complications

Parameter	General anesthesia (n = 86)	Spinal anesthesia (n = 92)	p-value
Screw malposition	1 (1.2%)	1 (1.1%)	0.962, NS
Dural tear	6 (6.9%)	7 (7.6%)	0.871, NS
Screw loosening	3 (3.5%)	4 (4.4%)	0.767, NS
Cage slippage	3 (3.5%)	1 (1.1%)	0.287, NS
Implant failure	1 (1.2%)	1 (1.1%)	0.962, NS
Nausea/vomiting	13 (15.1%)	7 (7.6%)	0.113, NS
Urinary retention	5 (5.8%)	19 (20.7%)	0.004*

NS: not significant.
*p<0.05

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operation theatre to incision time and bandaging to exit time from the operation theatre. We found a significantly shorter operation theater to incision time and also time from bandaging to the exit in the spinal anesthesia group ($p<0.05$), which is comparable to study done by Pierce et al. [15]. This highlighted higher efficiency with quicker operation theatre turnover rates and inturn cost effectiveness. The longer duration of general anesthesia in comparison to spinal one was because of the peri-anesthesia events which included pre-anesthestic medication taking time to prepare before induction and intubation as well as post operative anesthesia reversal time which was not there in spinal anesthesia group.

The patients of the spinal anesthesia group required lesser PACU time along with a shorter hospital stay in comparison to the general anesthesia group patients in our study ($p<0.05$). Jellish et al. [10] found a longer duration of hospital stay in patients who underwent surgery under general anesthesia. Since this study was performed at lower lumbar levels i.e. below L3, the chance of neurodeficit was very less. Also, author did not experience any event of neurodeficit in his period of study. Although general anesthesia offers the advantage of observation of motor recovery soon after reversal of anesthesia, a sensible motor evaluation is difficult to obtain as patient is in drowsy state. Spinal anesthesia offered excellent control of post operative pain which gave the advantage of early shifting of patient from PACU to ward.

The mean hospital stay in our study was lesser in spinal anesthesia group as compared to general anesthesia ($p<0.05$) which is comparable to results obtained by Pierce et al. [15]. Early ambulation, early start to oral feeds with less throat irritation, early bowel function return and less neurocognitive changes favoured early discharge from hospital after spinal anesthesia.

We found a significantly higher incidence of urinary retention in spinal anesthesia group (20.4% vs. 5.7% in general anesthesia), while incidence of nausea/vomiting was comparable ($p>0.05$). In a study done by Jellish et al. [10] the incidence of nausea was significantly higher in spinal anesthesia, while urinary retention incidence was higher in general anesthesia. This finding is contradictory to our findings. McLain et al. [11] found a higher incidence of nausea in general anesthesia group, while reported a significantly lower incidence of urinary retention in spinal anesthesia induced patients.

Papadopoulos et al. [14] also reported a higher incidence of nausea in general anesthesia group. Prolonged analgesia and sensory loss after bupivacaine perhaps could be the reason of higher incidence of urinary retention in our patients after spinal anesthesia as compared to general anesthesia. All those patients who had urinary retention episode had temporary retention. None of the patient had permanent retention. The patients with retention issues were managed by inserting foley's catheter in situ and keeping it for 24 hours which was later removed. Patients were discharged comfortably after urine was passed.

Though it may seem that spinal anesthesia has certain advantages over general anesthesia but this method cannot be recommended for all patients. Loss of spinal anesthesia effect can happen although not reported in any of our patients. Another disadvantage being time constraint in spinal anesthesia group.

Our study too has some flaws. Firstly, intraoperative hemodynamic changes were not recorded; therefore, we could not compare the patients anesthetically. Also, satisfaction rate of the surgeon, anesthesiologist, and the patient was not investigated, although it is one of the important criteria for choosing a certain anesthetic type.

CONCLUSION

Spinal anesthesia offers efficient operating room functioning with decreasing overall operation theatre time with lower operation theatre entry to incision and bandaging to exit time. Lesser post anesthesia care unit time (PACU) in spinal anesthesia ensures early shift to ward for patients. Lower duration of stay in hospital in spinal anesthesia, lowers down the overall cost for the patient. Hence, spinal anesthesia is very efficient alternative technique to general anesthesia which can be considered for elective lumbar surgeries with a lower late of adverse event especially at lower lumbar levels.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Demirel CB, Kalayci M, Ozkocak I, Altunkaya H, Ozer Y, Acikgoz B. A prospective randomized study comparing perioperative outcome variables after epidural or general anesthesia for lumbar disc surgery. J Neurosurg Anesthesiol 2003;15:185–192.
2. De Rojas JO, Syre P, Welch WC. Regional anesthesia versus general anesthesia for surgery on the lumbar spine: a review of the modern literature. Clin Neurol Neurosurg 2014;119:39–43.

3. Pflug AE, Halter JB. Effect of spinal anesthesia on adrenergic tone and the neuroendocrine responses to surgical stress in humans. Anesthesiology 1981;55:120–126.
4. McLain RF, Bell GR, Kalfas I, Tetzlaff JE, Yoon HJ. Complications associated with lumbar laminectomy: a comparison of spinal versus general anesthesia. Spine (Phila Pa 1976) 2004;29:2542–2547.
5. McLain RF, Tetzlaff JE, Bell GR, Uwe-Lewandrowski K, Yoon HJ, Rana M. Microdiscectomy: spinal anesthesia offers optimal results in general patient population. J Surg Orthop Adv 2007;16:5–11.
6. Rodgers A, Walker N, Schug S, McKee A, Kehlet H, van Zundert A, et al. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. BMJ 2000;321:1493.
7. Chen HT, Tsai CH, Chao SC, Kao TH, Chen YJ, Hsu HC, et al. Endoscopic discectomy of L5-S1 disc herniation via an interlaminar approach: prospective controlled study under local and general anesthesia. Surg Neurol Int 2011;2:93.
8. Greenbarg PE, Brown MD, Pallares VS, Tompkins JS, Mann NH. Epidural anesthesia for lumbar spine surgery. J Spinal Disord 1988;1:139–143.
9. Kao FC, Tsai TT, Chen LH, Lai PL, Fu TS, Niu CC, et al. Symptomatic epidural hematoma after lumbar decompression surgery. Eur Spine J 2015;24:348–357.
10. Jellish WS, Thalji Z, Stevenson K, Shea J. A prospective randomized study comparing short- and intermediate-term perioperative outcome variables after spinal or general anesthesia for lumbar disk and laminectomy surgery. Anesth Analg 1996;83:559–564.
11. McLain RF, Kalfas I, Bell GR, Tetzlaff JE, Yoon HJ, Rana M. Comparison of spinal and general anesthesia in lumbar laminectomy surgery: a case-controlled analysis of 400 patients. J Neurosurg Spine 2005;2:17–22.
12. Dashtbani M, Dori MM, Hassani M, Omidi-Kashani F. A survey on the short-term outcome of microlumbar discectomy with general versus spinal anesthesia. Clin Orthop Surg 2019;11:422–426.
13. Sadrolsadat SH, Mahdavi AR, Moharari RS, Khajavi MR, Khashayar P, Najafi A, et al. A prospective randomized trial comparing the technique of spinal and general anesthesia for lumbar disk surgery: a study of 100 cases. Surg Neurol 2009 71:60–65. discussion 65
14. Papadopoulos EC, Girardi FP, Sama A, Pappou IP, Urban MK, Cammisa FP Jr. Lumbar microdiscectomy under epidural anesthesia: a comparison study. Spine J 2006;6:561–564.
15. Pierce JT, Kositratna G, Attiah MA, Kallan MJ, Koenigsberg R, Syre P, et al. Efficiency of spinal anesthesia versus general anesthesia for lumbar spinal surgery: a retrospective analysis of 544 patients. Local Reg Anesth 2017;10:91–98.

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Lateral Lumbar Interbody Fusion in the Outpatient Setting with Multimodal Analgesic Protocol: Clinical Case Series

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Objective: Minimally invasive techniques and multimodal analgesia protocols have made spine surgery in the outpatient setting increasingly feasible. A number of spinal procedures have been documented in the outpatient setting, though the feasibility of lateral lumbar interbody fusion (LLIF) on an ambulatory basis has not been thoroughly assessed. To present a clinical case series of patients undergoing LLIF in the outpatient setting.

Methods: A prospectively maintained surgical database was retrospectively reviewed to identify patients undergoing outpatient spine procedures with an enhanced multimodal analgesia protocol from October 2016 to February 2021. Patient demographics, medical and spinal diagnoses, procedural characteristics, operative duration, estimated blood loss (EBL), postoperative length of stay (LOS), postoperative pain scores, postoperative narcotic consumption, and incidence of any intra- or postoperative complications were collected. The state's prescription monitoring program was queried to assess rates of filling narcotic prescriptions >6 weeks following surgery.

Results: A total of 24 LLIF patients were included. Mean postoperative pain score was 5.8, and mean postoperative narcotic consumption was 26.8 oral morphine equivalents. All patients were discharged on the same day of surgery. No postoperative complications were observed. After the 6-week postoperative timepoint, 16.7% of patients filled a prescription for tramadol, 8.3% for hydrocodone, 4.2% for hydromorphone, 4.2% for cyclobenzaprine, and 4.2% for alprazolam.

Conclusion: This clinical case series demonstrates that LLIF can be both safe and feasible in the outpatient setting, with minimal narcotic medication dependence in the postoperative period.

Key Words: Lumbar vertebrae, Ambulatory care, Patient reported outcome measures

INTRODUCTION

Introduced by Pimenta et al. in 2006 as an alternative to anterior or posterior approaches for lumbar arthrodesis, the retroperitoneal transpsoas minimally invasive lateral interbody fusion (MIS LIF) or lateral lumbar interbody fusions (LLIF) provides an effective approach for surgical interbody fusion for a broad spectrum of surgical pathology [1,2]. The LLIF has become increasingly adopted by spine surgeons due to its beneficial approach (avoiding spinal canal and neural foramen dissection), biomechanics (wide interbody cage spanning the dense apophyseal ring), and minimally invasive technique. In this technique, the spine is accessed laterally via splitting fibers of the psoas muscle longitudinally to create a retroperitoneal corridor [3]. The lateral plane of access affords the surgeon wide discectomy similar to an anterior approach, with the benefit of avoiding major bowel and vessel injury anteriorly and nerve and dural damage posteriorly [4]. A testament to its utility, the indications for the technique have broadened since its inception, and recently it has started being performed in the outpatient setting [4].

With the advancement of minimally invasive spinal operative techniques coinciding with milestone developments in anesthetics along with post-operative pain management protocols, spinal fusion surgeries are becoming increasingly feasible within outpatient ambulatory settings with several studies documenting its safety, efficacy, and beneficial cost profile when compared to inpatient surgery [4-8]. Further, the renewed emphasis of value and cost containment in spine surgery has served as a further impetus to the transition of surgical cases traditionally performed in an inpatient setting to being performed increasingly in ambulatory surgery centers (ASC) [8]. Owing to the expanding role of outpatient spine surgery and inevitable growth of ASCs, understanding determinants and deterrents of outpatient spine surgical success is paramount to both surgeons and administrators.

A significant barrier in transitioning fusion surgery to the outpatient setting is optimizing postoperative patient pain, as prior studies have noted inadequate pain control as the leading factor underpinning unplanned postoperative admission [9]. While providers are afforded the flexibility to alter discharge plans in an inpatient setting, this is not feasible in the context of stand-alone ASCs. It is therefore crucial that a safe, effective, and reproducible multimodal analgesia (MMA) protocol is used in this setting. While studies have commented on such protocols for lumbar decompression, transforaminal lumbar interbody fusion, there is scarce literature documenting MMA protocols for LLIFs in an ambulatory setting [10,11].

To address this need, our study presents a clinical case series of patients undergoing LLIF with an enhanced multimodal analgesic protocol in an ambulatory setting. The goal of the protocol was to provide reproducible postoperative pain relief while reducing patient reliance on opioid medication. We believe our experience may be of use to surgical teams interested in adapting lateral fusion cases to an outpatient setting.

METHODS

1. Selection

After institutional review board approval (ORA #14051301) and patient-informed consent were obtained, a retrospective review for eligible patients who underwent LLIF between October 2016 and February 2021 was performed. Inclusion criteria consisted of primary or revision, single or multi-level LLIF procedures for degenerative pathology utilizing our MMA protocol (Appendix). Procedures indicated due to trauma, infection, or malignancy were excluded. All surgeries were performed by senior author who is fellowship trained attending spine surgeon, and all surgeries were conducted at ambulatory surgical center where observation >23 hours is not permitted.

2. Data Collection

Selected baseline characteristics were noted, including age,

Table 1. Patient demographics and baseline characteristics

Demographic	Total (n = 24)
Age (mean ± SD, yr)	57.0 ± 5.0
Gender (n)	
Female	50.0% (12)
Male	50.0% (12)
Body mass index (n)	28.3 ± 6.8
Non-obese (< 30 kg/m^2)	62.5% (15)
Obese (≥ 30 kg/m^2)	37.5% (9)
Smoking status (n)	
Non-smoker	87.5% (21)
Smoker	12.5% (3)
Charlson comorbidity index (mean ± SD)	2.0 ± 0.6
ASA score	
1	4.2% (1)
2	83.3% (20)
≥ 3	12.5% (3)
Insurance	
Medicare/medicaid	0.0% (0)
Workers' compensation	20.8% (5)
Private	79.2% (19)
Preoperative diagnoses[a]	
Hypertension	16.7% (4)
Chronic lung disease	4.2% (1)
Arthritis	16.7% (4)
Neurological disease	4.2% (1)
Cancer	4.2% (1)

[a]There were no patients in our study with a recorded medical history of diabetes mellitus, peripheral vascular disease, myocardial infarction, liver disease, renal failure, or gastrointestinal bleeding.

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sex, weight, BMI, comorbidity burden as determined by Charlson Comorbidity Index, smoking status, American Society of Anesthesiologists (ASA) score, and pre-operative spinal diagnosis (Table 1).

A range of intraoperative data was collected, including the primary or revision status, the number of operative levels, the index level, the operative duration (from the skin incision to closure), and blood loss estimates. Postoperative variables were recorded, including surgery center length of stay, patient-reported visual analog scale pain scores before discharge, and quantity of narcotic medications administered before discharge (i.e., converted into units of oral morphine equivalents and summed across all types of narcotic medications prescribed) (Table 2). Complications experienced during the immediate postoperative time period were recorded (Table 3). The state's prescription monitoring program was queried to assess rates of filling narcotic prescriptions >6 weeks following surgery (Table 4).

1) MMA Protocol

A standardized protocol is initiated for all procedures and modified on an individualized basis. Successful administration of anesthetic regimen is initiated at patient's preoperative visit, when he or she is informed of the perioperative procedure and expectations. Pre-emptive analgesia is administered before the start of surgery, consisting of cyclobenzaprine, pregabalin, and oxycodone. Intraoperatively, patients are induced using propofol and ketamine. Maintenance anesthesia consists of sevoflurane gas and a fentanyl infusion. Additional intraoperative medications include bupivacaine with epinephrine, acetaminophen, dexamethasone, ondansetron, and famotidine. Postoperatively, patients receive a detailed protocol of PO medications. Protocol can be viewed in Figure 1 and 2. The MMA protocol was indicated in patients undergoing LLIF in the outpatient ambulatory setting.

2) Surgical Technique

LLIF patients were placed in the lateral decubitus position and approach was transpsoas. The surgical procedure differed based on surgeon preference and patient needs, and consequently surgeries included LLIF with posterior fixation (rods and percutaneous screws) as well as stand-alone LLIF. The surgeries were all performed under neuromonitoring guidance. A single, transverse incision was made on the lateral aspect of the

Table 2. Perioperative characteristics

Characteristic	Total (n = 24)
Preoperative spinal diagnosis	
Degenerative spondylolisthesis	66.7% (16)
Isthmic spondylolisthesis	16.7% (4)
Recurrent herniated nucleus pulposus	12.5% (3)
Degenerative scoliosis	29.2% (7)
Surgical history	
Primary	83.3% (20)
Revision	16.7% (4)
Number of levels fused	
1 level	87.5% (21)
2 levels	12.5% (3)
Operative level (n)	
L2-L3	8.3% (2)
L2-L4	12.5% (3)
L3-L4	8.3% (2)
L3-L5	4.2% (1)
L4-L5	66.7% (16)
Operative time[a] (mean ± SD, min)	121.8 ± 43.3
Estimated blood loss (mean ± SD, mL)	44.0 ± 30.5
Postoperative length of stay (mean ± SD, hr)	4.5 ± 1.7
Postoperative VAS pain score (mean ± SD)	5.8 ± 1.5
Postoperative narcotic consumption (mean ± SD, OME)	26.8 ± 21.2

SD: standard deviation, VAS: visual analog scale, OME: oral morphine equivalents.
[a]Operative duration from incision to skin closure.

Table 3. Postoperative complications

	Total (n = 24)
Complications	
Acute renal failure	0
Altered mental status	0
Aspiration	0
Atelectasis	0
Epidural hematoma	0
Ileus	0
Nausea and vomiting	0
Postoperative anemia	0
Urinary retention	0
Urinary tract infection	0
Venous thromboembolism	0

Table 4. Narcotic prescriptions after 6-weeks postoperatively

Medication	Total (n = 24)
Tramadol	16.7% (4)
Hydrocodone	8.3% (2)[a]
Hydromorphone	4.2% (1)[a]
Cyclobenzaprine	4.2% (1)
Alprazolam	4.2% (1)

[a]One patient received both medications at different timepoints.

Multimodal Analgesic Regmen

Prior to admission

Preoperative patient counseling regarding intraoperative and postoperative analgesia at spine surgeon's office.

Day of surgery

Preoperatively:

Oral medications given preoperatively in holding area about 1 hour prior to surgery:

1. Cyclobenzaprine 10mg
2. Pregabalin 150mg
3. Oxycodone controlled-release 10mg

Intraoperatively:

- Inducation of anesthesia–propofol 2mg/kg plus ketamine 50mg
- Maintenance of anesthesia–sevoflurane qith fentanyl 1-2μg/kg titrated to clinical effect
- Additional medications administered intraoperatively:
  1. Bupivacaine 0.5% with epinephrine 1:200,000 injected at incision site
     a. 20ml per side if patient weight <70kg
     b. 30ml per side if patient weight ≥70kg
  2. Acetaminophen 1,000mg IV
  3. Dexamethasone 10mg IV
  4. Ondansetron 4mg IV
  5. Famotidine 20mg IV

Postoperatively in recovery room:

1. Trmadol 50mg
2. Cyclobenzaprine 10mg orally for spasms
3. Oxycodone immediate release
   a. 5mg q4h as needed for pain (VAS pain >3) for opioid naÏve patients
   b. 10mg q4h as need for pain (VAS pain >4) for opioid tolerant patients

Inpatient Medications:

1. Tramadol 50mg
2. Oxycodone 5mg
   a. 5mg as needed for pain (VAS 4-6)
   b. 10mg as needed for pain (VAS 7-10)
3. Cyclobemzaprine 10mg
4. Pregabalin 75mg
5. Acetaminophen 650mg q6h
6. Cold compress applied to surgical site

Figure 1. Protocol for the multimodal analgesic regimen

body in-line. The psoas muscle is palpated and blunt dissection is carried out through the psoas down to the disc space. The cannulated dilator was attached to the disc center, and a guide wire was fed through it. Before removal, a specialized retractor was placed over the last dilator. Muscle was cleared from the annulus, which was then incised. The contralateral annulus was perforated after discectomy and endplate preparation. Interbody cages were filled with allograft and then implanted. The patient was then moved from lateral decubitus to the prone position in cases requiring direct decompression. Finally, posterior decompression and bilateral pedicle screw placement were achieved via an 18-mm tubular retractor and guide wire, respectively.

RESULTS

1. Patient Demographics

Total of 24 LLIF patients were included with a mean age of 57.0 years, of whom 50.0% were female and 37.5% were obese. Hypertension was the most common preoperative diagnosis and majority (79.2%) of patients utilized private

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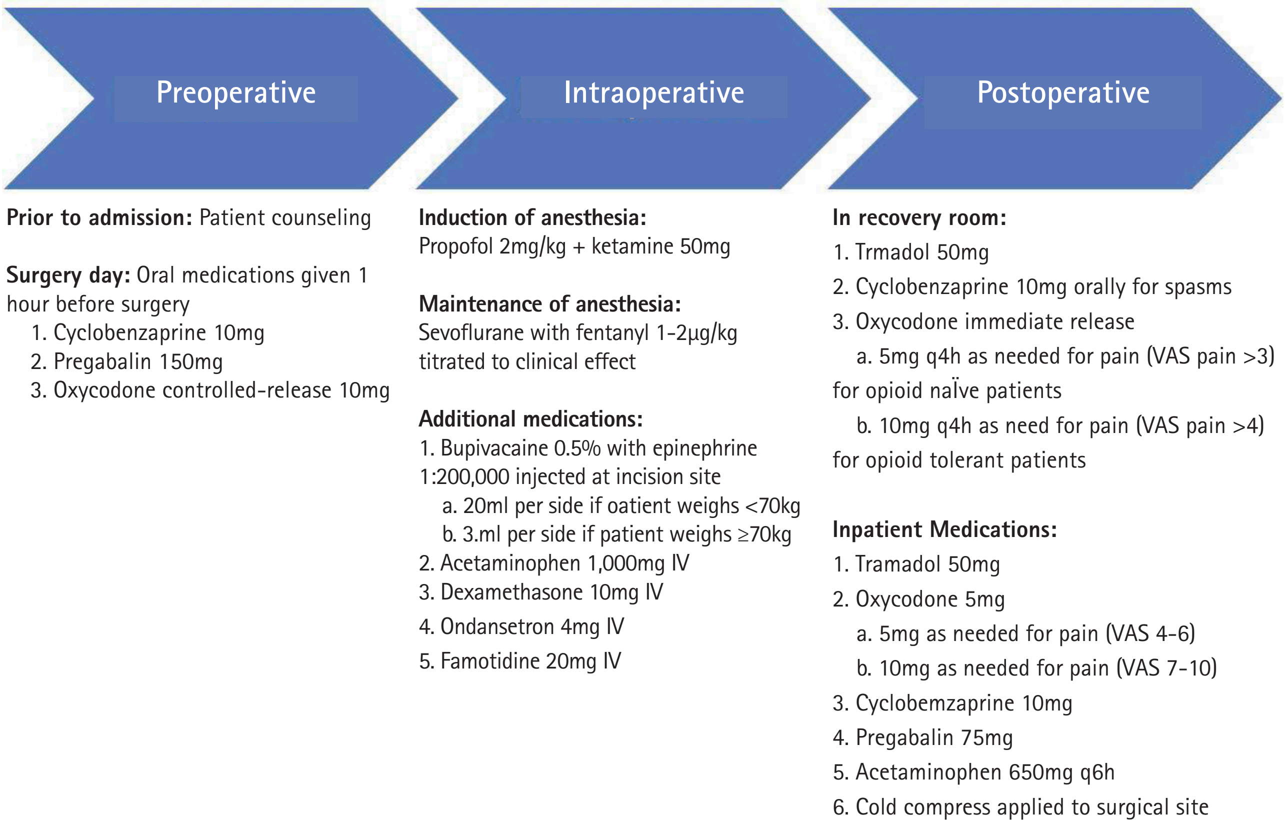

Figure 2. Diagram of the protocol for the multimodal analgesic regimen

insurance. Mean Charlson Comorbidity Index was 2.0 and most patients had an American Society of Anesthesiologists classification of 2 (83.3%) (Table 1). Most patients had a preoperative spinal diagnosis of degenerative spondylolisthesis (66.7%) and underwent primary (81.8%) single-level (87.5%) procedures.

2. Perioperative and Postoperative Outcomes

Majority (83.3%) of surgeries undertaken were primary. The most common level to be fused was L4-L5 (66.7%), and most cases were single-level surgeries (87.5%). Mean operative duration was 121.8 minutes, mean EBL was 44.0 mL, mean LOS was 4.5 hours, mean postoperative pain score was 5.8, and mean postoperative narcotic consumption was 26.8 oral morphine equivalents (Table 2). All patients were discharged on the same day of surgery. No postoperative complications were observed (Table 3). After the 6-week postoperative timepoint, 16.7% of patients filled a prescription for tramadol, 8.3% for hydrocodone, 4.2% for hydromorphone, 4.2% for cyclobenzaprine, and 4.2% for alprazolam (Table 4).

DISCUSSION

In the United States, surgical care accounts for 7% of the gross domestic product (GDP) [12]. As healthcare costs continue to increase, hospitals, patients, and insurance providers are actively working to reduce costs and patients' length of stay without compromising the quality of care and improving the value of care. As advancements in operative, analgesic, and anesthetic techniques improve, surgical treatment in outpatient ambulatory surgery centers (ASCs) appears to be more favorable than inpatient hospital settings. While implementation of such advances present potential clinical and economic gains, thorough evaluation of procedure efficacy and patient outcomes is required as the quality of care and patient safety are not to be compromised.

In this study, we present a case series of 24 patients undergoing LLIF surgical treatment in an outpatient setting utilizing our institution's novel MMA protocol. While studies have commented on similar analgesic protocols for lumbar decompression, transforaminal lumbar interbody fusion, there is scarce literature documenting analogous protocols for the lateral approach to fusion in an ambulatory setting [10,11]. Additionally, it should be noted that the protocol utilized in this surgery for LLIF technique is not specific to the lateral approach but may be generalized per surgeon discretion to other fusion surgeries performed in an ambulatory setting.

On average, patients were younger than 65 years old and had an average length of stay of 4.5 hours. Additionally, the mean narcotic consumption of postoperative day 0 (POD 0) was 26.8 oral morphine equivalents (OME). All patients did well during the surgery with none presenting any complications postoperatively and all patients were discharged home on the same day of surgery (in less than 23 hours) without further hospitalization or readmission required.

These positive results are attributed to our strict adherence to effective MMA protocol, appropriate pre-and peri-operative patient management, and effective patient selection. Prior studies have demonstrated MMA protocols following spine surgery to be instrumental in postoperative clinical improvements in pain and disability without raising patient complication profile [13,14].

1. Patient Selection

In order for successful surgery avoidant of potential complications, patients must be carefully selected for both the outpatient setting and for use under the MMA protocol. In their study, Smith et al. [15] concluded that the best predictors for early postoperative discharge and prevention of transfers to inpatient facilities from outpatient settings were decreased comorbidity burden, age, and BMI. Further, Chin et al. [16] proposed the following criteria for outpatient spine surgery based on their experience with lumbar decompression, disc replacement, and fusion in a single surgeon private practice: patients living or staying 30 minutes or less of the surgery location, a BMI≤42 kg/m2, clearance from a patient's general practitioner or cardiologist, ASA score of ≤3, and presence of a responsible adult for at least 24 hours after the surgery. Using this criteria, the authors concluded that 79% of spine surgery patients in their private practice were eligible for procedures in the ambulatory setting [16].

The results of our study align with the findings of prior literature in that the majority of patients deemed suitable for outpatient LLIF were younger than 65 years old, had a BMI less than 42 kg/m2 and had an ASA score of less than 3.

Specific criteria for LLIF in ASCs have not yet been developed to our knowledge. In combination with published literature and our patient demographics in this study we present the following exclusion criteria: patients≥65 years older [12], BMI≥40 kg/m^2 [16,17], increase risk of postoperative nausea and vomiting (PONV) [5,18], no presence of a responsible adult for at least 24 hours postoperatively or the patient cannot take care of him/herself [5,16], and an ASA score no greater than 3 [19]. In addition to these criteria, surgery in an ASC may not be possible if cases are composed of complex spinal pathologies and/or multilevel cases, more invasive procedures such as open approaches in place of MIS, and operations that must be done in parts or have duration greater than 2 hours [5,20].

Furthermore, ASCs may have limited available clinical support staff and emergency services. In case of an emergency, patients may be transferred to the hospital. As such, it is vital to acknowledge a patient's comorbidities and health. In our study, no patients with an ASA greater than 3 were included. In this way, patients that have present comorbidities that may pose life-threatening risks are not included as the operative risk is too high.

2. Multimodal Analgesia Protocol

Our team's MMA protocol aims to target multiple causes of pain following spine surgery, including neuropathic pain, inflammation, muscle spasticity, and a diminished central nervous system pain threshold [21]. With these aforementioned aims in mind, the protocol strives to optimize pain control and therefore reduce dependence on opioid medications [21]. Adequately controlling pain postoperatively has shown success in lowering risk of complications, faster recovery, superior mobility and coordination, and even patient satisfaction [22-24]. In a randomized controlled-trial by Kim et al. [14] of 80 patients undergoing lumbar spinal fusions, the authors reported that pain scores decreased and disability scores improved postoperatively without increasing complication rates. Further, in a retrospective review of postoperative clinical and perioperative outcomes following single-level transforaminal lumbar interbody fusion (TLIF) using either a MMA or patient-controlled analgesia (PCA) protocol, authors reported the MMA cohort to have reduced rates of inpatient narcotic consumption, PONV, and reduced LOS [17]. The same study noted, however, that postoperative narcotic consumption after discharge, inpatient pain scores, and Post operative urinary retention demonstrated no differences between the two cohorts [17].

In our study, the mean postoperative pain score was 5.8 on a numerical Visual Analog (VAS) scale of 0–10 (0 being no pain and 10 being as bad as it can be) (Table 2). Our team attributes our postoperative pain management primarily to the preoperative and intraoperative components of our analgesic protocol.

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Following orthopedic surgical procedures where severe pain can be experienced by the patient before the surgery and afterward, detailed preoperative analgesia is crucial to enhancing patient recovery, pain ratings, and rehabilitation [25,26].

3. Preoperative Component

Several approaches have been proposed to alleviate severe postoperative pain, such as use of preemptive analgesia, opioids, cyclooxygenase-2 inhibitors, epidural anesthesia, peripheral nerve blockade, local infiltration analgesia, patient-controlled analgesia, and multimodal analgesia [26]. Furthermore, Kashefi et al. [27] found preoperative administration of either tramadol, cyclooxygenase-2 inhibitors, nonsteroidal anti-inflammatory drugs or opioids lead to deceased patient-reported levels of pain, increased activity levels, improved mental health reporting, and generally a positive satisfaction with their procedure. Acetaminophen demonstrates the ability to enhance postoperative pain scores and analgesia predominantly through central nervous system action [28,29]. Beyond the well documented analgesic effects, acetaminophen also has antipyretic effects preventing downstream peroxidase steps involved with synthesis of prostaglandins [30]. Acetaminophen is inexpensive, is associated with few mild adverse side effects, and has demonstrated effectiveness, often as a single agent, in managing the analgesic effectiveness of surgery. Preoperative utilization of anticonvulsants, such as gabapentin and pregabalin, have demonstrated efficacy in reducing pain intensity postoperatively and improving functional outcomes for spine surgeries [31]. Turan et al. [32] specifically note in their study in which patients received 1,200 mg gabapentin 1 hour before surgery that patients reported decreased pain scores and decreased postoperative morphine use versus the placebo group following spine surgery. Further, the use of cyclobenzaprine preoperatively, often in conjunction with nonsteroidal anti-inflammatory drugs, have improved efficacy over opioids. Cyclobenzaprine has been observed to provide significant lower back pain relief justifying their utility as a multimodal analgesic approach [33].

4. Intraoperative Component

While the utility of preoperative pain management is gaining statistical and clinical significance, intraoperative pain management has long been a standard surgical approach. Medications that decrease the patient's level of consciousness, along with inhaled anesthetics, are used to keep the patient comfortable during the procedure. Specifically propofol and ketamine [30]. Ketamine, which antagonizes an NMDA receptor, has been proven to decrease opioid consumption via receptor modulation and lowering central excitability also function in conjunction with acetaminophen and nonsteroidal anti-inflammatory drugs intraoperatively. Throughout the surgical procedure, acetaminophen, dexamethasone, ondansetron, and famotidine are given [25,30]. Further, intraoperative use of bupivacaine was administered in a one-time dose typically towards the conclusion of surgery to provide significant incremental pain relief. A study by Reynolds et al. [34] demonstrated 0.25% solution of bupivacaine associated with decreased opioid use following fusion surgery for idiopathic scoliosis compared to patients receiving local anesthetic, without showing systemic side effects.

5. Postoperative Component

By providing adequate postoperative analgesia, patients would not only experience less pain and possibly less opioid consumption, but it also has implications for cost savings and improved rehabilitation by reducing the length of stay, conducting more effective postoperative therapy, and increasing patient satisfaction [26,35]. MMA protocols optimize non-opioid interventions by limiting their use to treat "breakthrough" pain postoperatively. Furthermore, the mean postoperative narcotic consumption on the day of surgery was 26.8 oral morphine equivalents (OME). After querying the state's prescription monitoring program to assess rates of fulfilled narcotic prescriptions at 6 weeks following surgery, it was shown that 16.7% of patients filled a prescription for tramadol, 8.3% for hydrocodone, 4.2% for hydromorphone, 4.2% for cyclobenzaprine, and 4.2% for alprazolam demonstrating that the majority of patients had weaned off narcotics. It should be noted that regarding opioid utilization following MMA protocol in this case series, at the 6-week timepoint 4 patients utilized tramadol, 2 patients utilized hydrocodone, 1 patient utilized hydromorphone, 1 patient utilized cyclobenzaprine, and 1 patient utilized alprazolam. 1 patient received both medications at different timepoints. Regarding opioid medication usage at 6-weeks, 5 patients or around 20% of patients in this case series utilized a narcotics at 6-weeks. When combined with opioid equivalent analgesics, about 1/3 of case series fulfilled medication prescription at 6-week. This would suggest that a non-trivial number (20%) of patients required narcotic medications at 6-weeks, and further study with greater cohort sizes will need to be conducted to understand how to drive this percentage lower. Although this case series consists of only 24 patients, the results of our study as a preliminary analysis show the promise and utility of our MMA protocol in the context of outpatient LLIF surgery as the majority of patients in this case series were weaned off narcotic medications at first follow-up. The overarching goals of an MMA protocol include using a variety of medications to reduce perioperative pain, specifically improving patient-reported postoperative pain ratings while minimizing harmful iatrogenic effects. Postoperatively, patients are given a detailed outline of PO medications. Many preoperative medications, including muscle relaxants, anticonvulsants, and opioids, are continued into the postoperative period. Additionally, a schedule including NSAIDs and/or acetaminophen is part of a comprehensive MMA [30]. While surgical interventions may be the next best step in treating a pathological state, it doesn't come without risk of pain leading to stress, anxiety, depression, and medication dependence. The development and implementation of a thorough patient-centered MMA can decrease postoperative pain-related risks and lower dependence on opioids long term. Implementation and utilization of a patient-centered MMA can adequately reduce pain and improve patient-reported outcomes.

6. Complications

Unique to the LLIF, it involves exposure to the lumbar spine through a lateral aspect by a retroperitoneal approach through the psoas muscle [36]. For successful completion of an LLIF procedure, preoperative imaging in the form of MRI or CT is necessary to visualize the disc space and ensure that intra-abdominal vessels are not vulnerable to injury [36]. Throughout the procedure, neuromonitoring and fluoroscopy are utilized to obtain anterior-posterior and lateral radiographs for the surgeon to plan and perfectly execute the incision in line with the disc space [36].

Reported complication rates are controversial across literature [37], which most likely is associated with the surgeon's surgical experience, patient demographic characteristics, and varied instruments and/or techniques utilized [38]. The most common and greatest risk from LLIF includes neurological injury to the lumbar plexus, which may result in sensory and motor problems potentially due to psoas muscle trauma or lumbar plexus stretching. It should be noted that an anterior to psoas approach not utilized in this case series may provide a more natural corridor to the disc space with decreased postoperative risk of hip weakness with such risk inherently greater in the lateral transpoas approach [39].

As the lateral approach to fusion is technically demanding and post-operative complications are more likely the longer a procedure lasts, surgeons unable to perform cases in <2 hours should not migrate lateral fusion cases to outpatient setting. In a multicenter study of prospectively treated patients fused at L3-4 and L4-5 with LLIF, 27.5% of patients reported postoperative hip flexion weakness and the systematic review by Hijji et al. [37] noted that up to 36% of patients reported temporary neurologic injury following surgery with lumbar neurapraxia occurring in up to 62.7% of patients [40]. Previous studies have attributed such complications to prolonged retractor time (>30 minutes), increased tissue edema and damage from retractor placement, and excess extension of the psoas muscle opening leading to ischemic nerve damage [37,40]. Performing an open LLIF is especially not suitable, as these procedures are generally longer and patients require longer time to recover, often requiring hospitalization [41]. In our study, the attending surgeon benefitted from 15 years of experience with MIS techniques, allowing for shortened operative times, minimized blood loss, and tissue trauma burden. Surgical experience and where a surgeon is on their learning curve is important when assessing when to make the switch from performing lateral fusions in an inpatient setting to the ASC.

Rarely, bowel perforation has been reported as a life threatening complication of the lateral approach, with literature noting that primary means of avoidance of bowel perforation to be presurgical imaging (MRI/CT) to provide information regarding sagittal vertebral length and anatomical abnormalities [2,42]. Furthermore, by examining the location of anatomic structures, such as the retroperitoneal vasculature, lumbar nerve roots, and genitofemoral nerve relative to the psoas muscle, complications related to retroperitoneal exposure may be reduced [42].

Postoperatively, the lateral approach has been associated with ileus, with independent risk factors including GERD, L1-2 operative levels, and posterior instrumentation [43]. A multimodal approach should be utilized to limit administration of narcotics and other agents that may contribute to decreased gastrointestinal motility [44].

In our study, no immediate postoperative complications were observed (no cases of acute renal failure, altered mental status, aspiration, atelectasis, Epidural hematoma, ileus, nausea and vomiting, anemia, urinary retention, urinary tract infection, or venous thromboembolism) (Table 3). This is surely attributable to surgeon experience, low study power, and patient selection. As careful attention was paid to selection of patients for outpatient spine surgery, this allowed for faster recovery and discharge from the ASCs. Patients included in this

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outpatient case series were generally younger (mean age of 57.0 years), majority were non-obese (62.5%), with low independent comorbidity burden (83.2% with ASA score<3). These modifiers of patient risk surely benefited our postoperative complication results as elevated comorbidity, age and BMI are risk factors for surgical complication postoperatively. As such conclusions of the utility of this protocol and subsequent risk of postoperative complications in older patients, obese patients, or those with severe comorbidity burden should not be made. Furthermore, a significant barrier to discharge is postoperative nausea and vomiting, which notably in our case series no patients were observed to display. While the small sample size could have played a role, the reliance of our protocol on local anesthesia that doesn't exert systemic effects potentially contributed to this observation. In our protocol, appropriate treatment for PONV includes preoperative administration of anti-emetics such as ondansetron or metoclopramide, and adequate hydration.

7. Limitations

As our study is a case series, only 24 patients were included which limits the power of the study. Additionally, not all of the patients the surgeon treated were included in the study due to refusal to consent to the study on the patient's behalf. Further, we did not follow up with the patients or analyze patient-reported outcomes, which if included would add strength to the study with insight into patient postoperative improvement across quality of life domains. Given strict selection for outpatient ambulatory spine surgery, patients included in this case series were generally younger, non-obese, with low comorbidity burden. As such conclusions of the utility of this protocol in older patients, obese patients, or those with severe comorbidity burden should not be made. Additionally, this study is based on a single surgeon at a single academic institution limiting generalizability of study findings to other clinical settings. In addition, while mention of opioid prescriptions more than 6 weeks postoperatively is reported, we did not report whether some of these patients were opioid-naive patients or patients already taking opioids.

CONCLUSION

Ambulatory surgery centers are performing a growing number of spine surgeries. With the proven benefits and improving safety profile of the lateral approach, an increasing number of LLIFs will be performed in ASCs. The ability to control pain is a crucial component of the success of these procedures. Based on a review of high-quality literature and our own clinical experience, we present a specific multimodal protocol in this study. The findings of our study may inspire similar groups to adopt aspects of their own MMA protocols.

REFERENCES

1. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 2015;1:2–18.
2. Salzmann SN, Shue J, Hughes AP. Lateral lumbar interbody fusion-outcomes and complications. Curr Rev Musculoskelet Med 2017;10:539–546.
3. Kwon B, Kim DH. Lateral lumbar interbody fusion: indications, outcomes, and complications. J Am Acad Orthop Surg 2016;24:96–105.
4. Chin KR, Pencle FJ, Coombs AV, Brown MD, Conklin KJ, O'Neill AM, et al. Lateral lumbar interbody fusion in ambulatory surgery centers: patient selection and outcome measures compared with an inhospital cohort. Spine (Phila Pa 1976) 2016;41:686–692.
5. Parrish JM, Jenkins NW, Brundage TS, Hrynewycz NM, Podnar J, Buvanendran A, et al. Outpatient minimally invasive lumbar fusion using multimodal analgesic management in the ambulatory surgery setting. Int J Spine Surg 2020;14:970–981.
6. Nolte MT, Lynch CP, Cha EDK, Geoghegan CE, Jadczak CN, Mohan S, et al. Transition to outpatient minimally invasive transforaminal lumbar interbody fusion. J Orthop Exp Innov 2020. Available at: https://journaloei.scholasticahq.com/ article/13907
7. Gologorsky Y. Outpatient spine surgery: transition to the ambulatory surgery center. World Neurosurg 2018;114:369–370.
8. Mundell BF, Gates MJ, Kerezoudis P, Alvi MA, Freedman BA, Nassr A, et al. Does patient selection account for the perceived cost savings in outpatient spine surgery? A meta-analysis of current evidence and analysis from an administrative database. J Neurosurg Spine 2018;29:687–695.
9. Lang SS, Chen HI, Koch MJ, Kurash L, McGill-Armento KR, Palella JM, et al. Development of an outpatient protocol for lumbar discectomy: our institutional experience. World Neurosurg 2014;82:897–901.
10. Nolte MT, Parrish JM, Jenkins NW, Cha EDK, Lynch CP, Jacob KC, et al. Multimodal analgesic management for lumbar decompression surgery in the ambulatory setting: clinical

case series and review of the literature. World Neurosurg 2021;154:e656–e664.
11. Emami A, Faloon M, Issa K, Shafa E, Pourtaheri S, Sinha K, et al. Minimally invasive transforaminal lumbar interbody fusion in the outpatient setting. Orthopedics 2016;39:e1218–e1222.
12. Sivaganesan A, Hirsch B, Phillips FM, McGirt MJ. Spine surgery in the ambulatory surgery center setting: value-based advancement or safety liability. Neurosurgery 2018;83:159–165.
13. Garcia RM, Cassinelli EH, Messerschmitt PJ, Furey CG, Bohlman HH. A multimodal approach for postoperative pain management after lumbar decompression surgery: a prospective, randomized study. J Spinal Disord Tech 2013;26:291–297.
14. Kim SI, Ha KY, Oh IS. Preemptive multimodal analgesia for postoperative pain management after lumbar fusion surgery: a randomized controlled trial. Eur Spine J 2016;25:1614–1619.
15. Smith WD, Wohns RN, Christian G, Rodgers EJ, Rodgers WB. Outpatient minimally invasive lumbar interbody: fusion predictive factors and clinical results. Spine (Phila Pa 1976) 2016;41 Suppl 8:S106–S122.
16. Chin KR, Pencle FJR, Coombs AV, Packer CF, Hothem EA, Seale JA. Eligibility of outpatient spine surgery candidates in a single private practice. Clin Spine Surg 2017;30:E1352–E1358.
17. Singh K, Bohl DD, Ahn J, Massel DH, Mayo BC, Narain AS, et al. Multimodal analgesia versus intravenous patient-controlled analgesia for minimally invasive transforaminal lumbar interbody fusion procedures. Spine (Phila Pa 1976) 2017;42:1145–1150.
18. Bohl DD, Louie PK, Shah N, Mayo BC, Ahn J, Kim TD, et al. Multimodal versus patient-controlled analgesia after an anterior cervical decompression and fusion. Spine (Phila Pa 1976) 2016;41:994–998.
19. Kim JC, Choi YS, Kim KN, Shim JK, Lee JY, Kwak YL. Effective dose of peri-operative oral pregabalin as an adjunct to multimodal analgesic regimen in lumbar spinal fusion surgery. Spine (Phila Pa 1976) 2011;36:428–433.
20. Ahn J, Bohl DD, Tabaraee E, Basques BA, Singh K. Current trends in outpatient spine surgery. Clin Spine Surg 2016;29:384–386.
21. Nolte MT, Elboghdady IM, Iyer S. Anesthesia and postoperative pain control following spine surgery. Semin Spine Surg 2018;30:154–159.
22. Lenart MJ, Wong K, Gupta RK, Mercaldo ND, Schildcrout JS, Michaels D, et al. The impact of peripheral nerve techniques on hospital stay following major orthopedic surgery. Pain Med 2012;13:828–834.
23. Lemos P, Pinto A, Morais G, Pereira J, Loureiro R, Teixeira S, et al. Patient satisfaction following day surgery. J Clin Anesth 2009;21:200–205.
24. Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S. Causes and risk factors for 30-day unplanned readmissions after lumbar spine surgery. Spine (Phila Pa 1976) 2014;39:761–768.
25. Pushparaj H, Bhatia A. Perioperative pain management for orthopedic and spine surgery. Anesth Analg 2019;129:e98.
26. Li JW, Ma YS, Xiao LK. Postoperative pain management in total knee arthroplasty. Orthop Surg 2019;11:755–761.
27. Kashefi P, Honarmand A, Safavi M. Effects of preemptive analgesia with celecoxib or acetaminophen on postoperative pain relief following lower extremity orthopedic surgery. Adv Biomed Res 2012;1:66.
28. Cakan T, Inan N, Culhaoglu S, Bakkal K, Başar H. Intravenous paracetamol improves the quality of postoperative analgesia but does not decrease narcotic requirements. J Neurosurg Anesthesiol 2008;20:169–173.
29. Shimia M, Parish M, Abedini N. The effect of intravenous paracetamol on postoperative pain after lumbar discectomy. Asian Spine J 2014;8:400–404.
30. Bhatia A, Buvanendran A. Anesthesia and postoperative pain control-multimodal anesthesia protocol. J Spine Surg 2019;5:S160–S165.
31. Khurana G, Jindal P, Sharma JP, Bansal KK. Postoperative pain and long-term functional outcome after administration of gabapentin and pregabalin in patients undergoing spinal surgery. Spine (Phila Pa 1976) 2014;39:E363–E368.
32. Turan A, Karamanliğ_lu B, Memiş D, Hamamcioglu MK, Tükenmez B, Pamukçu Z, et al. Analgesic effects of gabapentin after spinal surgery. Anesthesiology 2004;100:935–938.
33. van Tulder M, Becker A, Bekkering T, Breen A, del Real MT, Hutchinson A, et al. COST B13 Working Group on Guidelines for the Management of Acute Low Back Pain in Primary Care. Chapter 3. European guidelines for the management of acute nonspecific low back pain in primary care. Eur Spine J 2006;15 Suppl 2:S169–S191.
34. Reynolds RA, Legakis JE, Tweedie J, Chung Y, Ren EJ, Bevier PA, et al. Postoperative pain management after spinal fusion surgery: an analysis of the efficacy of continuous infusion of local anesthetics. Global Spine J 2013;3:7–14.
35. Dimaculangan D, Chen JF, Borzio RB, Jauregui JJ, Rasquinha VJ, Maheshwari AV. Periarticular injection and continuous femoral nerve block versus continuous femoral nerve block alone on postoperative opioid consumption and pain control

 https://doi.org/10.21182/jmisst.2021.00360

following total knee arthroplasty: Randomized controlled trial. J Clin Orthop Trauma 2019;10:81–86.
36. Xu DS, Walker CT, Godzik J, Turner JD, Smith W, Uribe JS. Minimally invasive anterior, lateral, and oblique lumbar interbody fusion: a literature review. Ann Transl Med 2018;6:104.
37. Hijji FY, Narain AS, Bohl DD, Ahn J, Long WW, DiBattista JV, et al. Lateral lumbar interbody fusion: a systematic review of complication rates. Spine J 2017;17:1412–1419.
38. Lehmen JA, Gerber EJ. MIS lateral spine surgery: a systematic literature review of complications, outcomes, and economics. Eur Spine J 2015;24 Suppl 3:287–313.
39. Gragnaniello C, Seex K. Anterior to psoas (ATP) fusion of the lumbar spine: evolution of a technique facilitated by changes in equipment. J Spine Surg 2016;2:256–265.
40. Tohmeh AG, Rodgers WB, Peterson MD. Dynamically evoked, discrete-threshold electromyography in the extreme lateral interbody fusion approach. J Neurosurg Spine 2011;14:31–37.
41. Bortz C, Alas H, Segreto F, Horn SR, Varlotta C, Brown AE, et al. Complication risk in primary and revision minimally invasive lumbar interbody fusion: a comparable alternative to conventional open techniques. Global Spine J 2020;10:619–626.
42. Wangaryattawanich P, Kale HA, Kanter AS, Agarwal V. Lateral lumbar interbody fusion: review of surgical technique and postoperative multimodality imaging findings. AJR Am J Roentgenol 2021;217:480–494.
43. Al Maaieh MA, Du JY, Aichmair A, Huang RC, Hughes AP, Cammisa FP, et al. Multivariate analysis on risk factors for postoperative ileus after lateral lumbar interbody fusion. Spine (Phila Pa 1976) 2014;39:688–694.
44. Luckey A, Livingston E, Taché Y. Mechanisms and treatment of postoperative ileus. Arch Surg 2003;138:206–214.

Appendix. Multimodal Analgesic Regimen for Outpatient Spine Surgery

Prior to admission

Preoperative patient counseling regarding intraoperative and postoperative analgesia at spine surgeon's office.

Day of surgery

Preoperatively:

Oral medications given preoperatively in holding area about 1 hour prior to surgery:

1. Cyclobenzaprine 10 mg
2. Pregabalin 150 mg
3. Oxycodone controlled release 10 mg

Intraoperatively:

- Induction of anesthesia – propofol 2 mg/kg plus ketamine 50 mg
- Maintenance of anesthesia – sevoflurane with fentanyl 1–2 μg/kg titrated to clinical effect
- Additional medications administered intraoperatively:
    1. Bupivacaine 0.5% with epinephrine 1:200,000 injected at incision site
        a. 20 mL per side if patient weight<70 kg
        b. 30 mL per side if patient weight≥70 kg
    2. Acetaminophen 1,000 mg IV
    3. Dexamethasone 10 mg IV
    4. Ondansetron 4 mg IV

Postoperatively in recovery room:

1. Tramadol 50 mg
2. Cyclobenzaprine 10 mg orally for spasms
3. Oxycodone immediate release
    a. 5 mg q4h as needed for pain (VAS Pain>3) for opioid naïve patients
    b. 10 mg q4h as need for pain (VAS Pain>4) for opioid tolerant patients

Discharge Medications:

POD# 0

1. Tramadol 50 mg
2. Oxycodone 5 mg
    a. 5 mg as needed for pain (VAS 4–6)
    b. 10 mg as needed for pain (VAS 7–10)
3. Cyclobenzaprine 10 mg
4. Pregabalin 75 mg
5. Cold compress applied to surgical site

POD #1

1. Oxycodone discontinued by 9 am
2. Hydrocodone/paracetamol 5 mg
    a. 1 tablet as needed for pain (VAS Pain 4–6)
    b. 2 tablets as needed for pain (VAS Pain 7–10)
3. Cyclobenzaprine 10 mg

VAS: Visual Analog Scale for pain (where 0 = no pain and 10 = worst possible pain)

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Do Patient Expectations Represent a More Important Clinical Difference? A Study of Surgical Outcomes in the Cervical Spine

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Objective: This study aims to compare the impact of achieving an MCID or meeting preoperative expectations on patient satisfaction following cervical spine procedures.

Methods: A surgical database was retrospectively reviewed for cervical spine surgery patients from 2016 to 2020. Inclusion criteria were primary or revision, single- or multilevel cervical disc arthroplasty or anterior cervical discectomy and fusions (ACDF). Visual analogue scale (VAS) neck and arm pain was assessed preoperatively and postoperatively (6-week, 12-weeks, 6-months, 1-year). Preoperative patient expectation and postoperative satisfaction were recorded. MCID achievement was determined using previously established values. Expectations met and MCID achievement were compared as possible predictors of satisfaction.

Results: One hundred and six cervical spine patients were included. Both meeting expectations and achieving MCID were significant predictors of satisfaction for arm pain at 6-weeks and 12-weeks (all $p \leq 0.007$). Achieving MCID significantly predicted satisfaction for neck pain at all timepoints (all $p \leq 0.007$) and meeting expectations predicted satisfaction for neck pain at 6-weeks, 12-weeks, and 1-year (all $p \leq 0.003$). Comparison of coefficients revealed no significant difference in effect size between meeting expectations and achievement of MCID as predictors of patient satisfaction (all $p > 0.050$).

Conclusion: MCID achievement and meeting expectations were significant predictors of satisfaction for neck pain and short-term arm pain. Both measures may be similarly useful for interpretation of patient outcomes and the optimal choice of metric may depend on practice-specific factors.

Key Words: Total disc replacement, Minimal clinically important difference, Patient reported outcome measures, Patient satisfaction, Cervical vertebrae

INTRODUCTION

Degenerative pathology of the cervical spine can cause significant axial, radicular, and myelopathic pain. When refractory to conservative treatments, surgical intervention in the form of anterior cervical discectomy and fusion (ACDF) or cervical disc arthroplasty (CDA) is often indicated [1]. Improvement in pain, as assessed by the Visual Analogue Scale (VAS), has proven to be one of the most important factors contributing to postoperative satisfaction in patients undergoing ACDF [2].

This empirically validated questionnaire is commonly used to assess patient reported outcomes (PROs) regarding neck and arm pain and plays an important role in understanding patient satisfaction [3]. Patients mark their pain level on a linear scale in regard to each question, with one end representing "no pain" and the opposite representing "worst pain" [4]. As healthcare adopts a more patient-centered approach to care, it is critical to identify which methods of characterizing improvements in pain are most important for predicting postoperative satisfaction in the clinical setting.

One frequently used method is minimum clinically important difference (MCID), a metric that quantifies the smallest change in score that a patient perceives as beneficial. It has been increasingly used to assess postoperative improvement because traditional measures of statistical significance may not always translate to meaningful clinical improvement [5]. Its focus on differences that are clinically relevant to the patient allows MCID to provide insight into patient satisfaction. For example, Andresen et al. [6] reported that achievement of MCID for VAS neck and SF-36 PCS was strongly correlated to patient satisfaction following ACDF.

Another way to assess outcomes is through the context of a patient's preoperative expectations, which have been reported to be predictive of patient satisfaction in the spine population [7-9]. A systematic review of patient expectations across several disciplines reported that more optimistic expectations are associated with better health outcomes [10]. While these studies have identified the importance of preoperative expectations, the impact of meeting expectations on postoperative satisfaction has not been fully explored. Additionally, many expectation studies simply ask patients postoperatively if their expectations were met. This method does not directly compare postoperative outcomes to preoperative expectations and may be susceptible to significant recall bias. This methodological limitation makes it extremely difficult to distinguish between expectations and satisfaction.

As our understanding of the relationship between expectations and satisfaction continues to develop, it is important to compare which method of assessing PROs is highly associated with satisfaction. Identifying a single measure, whether it is patient expectations or MCID, will help guide physicians in providing effective preoperative education and counseling, assist in patient selection, and improve postoperative monitoring. Additionally, determining which metric is most associated with satisfaction can inform future research and allow investigators to better quantify the perceptions and postoperative outcomes of their patients. Our study aims to provide better insight into patient expectations by quantifying these expectations preoperatively and assessing whether their expectations were met postoperatively. Through this assessment, we will compare meeting preoperative expectations to achievement of MCID and determine which is a better predictor of patient satisfaction regarding arm and neck pain following cervical spine procedures.

MATERIALS AND METHODS

1. Patient Population

Informed patient consent and Institutional Review Board approval (ORA #14051301) were obtained prior to commencement of study activities. A prospectively maintained single-surgeon database was retrospectively reviewed for patients undergoing cervical spine procedures from September 2016 to June 2020. Inclusion criteria were primary or revision, single- or multi-level, elective ACDF or CDA procedures. Exclusion criteria were patients with incomplete preoperative expectations surveys or for whom surgery was indicated due to trauma, infection, or malignancy.

2. Data Collection

Patient demographics, preoperative spinal pathology, and perioperative characteristics were collected. Demographics were characterized in terms of age, gender, body mass index (BMI), smoking status, diabetic status, American Society of Anesthesiologists physical classification (ASA), Charlson Comorbidity Index (CCI), ethnicity, and insurance type/payment received. Recorded perioperative variables were number of spinal levels operated, operative duration, estimated blood loss (EBL), and postoperative length of stay.

Arm and neck pain were assessed using VAS neck and VAS arm at preoperative and 6-week, 12-week, 6-month, and 1-year postoperative timepoints. Patient expectations for postoperative neck and arm pain were assessed at the preoperative timepoint. Patient satisfaction with neck pain and arm pain was assessed at each postoperative timepoint.

3. Statistical Analysis

All calculations and statistical tests were performed using StataIC 16.1 (StataCorp, College Station, Texas). Descriptive statistics were performed for demographics, preoperative spinal pathologies, and perioperative characteristics (Tables 1, 2).

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Table 1. Patient demographics

Characteristic	Total (n = 106)
Age (yr), mean ± SD	47.4 ± 10.1
Gender	
Female	34.0% (36)
Male	66.0% (70)
Body mass index (BMI)	
< 30 kg/m^2	56.4% (57)
≥ 30 kg/m^2	43.6% (44)
Smoking status	
Non-smoker	85.9% (91)
Smoker	14.2% (15)
Diabetic status	
Non-diabetic	91.5% (97)
Diabetic	8.5% (9)
ASA score	
≤ 2	87.8% (86)
> 2	12.2% (12)
CCI score	
< 1	39.0% (30)
≥ 1	61.0% (47)
Ethnicity	
Caucasian	80.2% (85)
African American	6.6% (7)
Hispanic	9.4% (10)
Asian	3.8% (4)
Insurance	
Medicare/medicaid	1.9% (2)
Workers' compensation	26.4% (28)
Private	71.7% (76)

ASA: American Society of Anesthesiologists, CCI: Charlson Comorbidity Index, SD: standard deviation.

Table 2. Perioperative characteristics

Characteristic	Total (n = 106)
Spinal pathology	
Degenerative disc disease	6.6% (7)
Central stenosis	60.4% (64)
Radiculopathy	5.7% (6)
Myelopathy	5.7% (6)
Myeloradiculopathy	86.8% (92)
Procedure	
Anterior cervical discectomy and fusion	57.6% (61)
Cervical disc arthroplasty	42.5% (45)
Operative levels	
1-Level	68.9% (73)
2-Levels	26.4% (28)
3-Levels	4.7% (5)
Operative time (min), mean ± SD	57.2 ± 15.0
Estimated blood loss (mL), mean ± SD	29.2 ± 10.8
Length of stay (hr), mean ± SD	10.5 ± 8.6

SD: standard deviation.

In an effort to minimize bias, only patients with preoperative pain scores equal to or greater than respective published MCID values were included in each analysis of satisfaction with arm and neck pain. "Meeting expectations" was defined as a postoperative VAS score less than or equal to the patient's preoperatively reported expectation for postoperative pain. Meeting expectations was determined separately for neck and arm pain for each postoperative timepoint. Achievement of MCID was determined by comparing postoperative improvement in VAS scores from preoperative baseline values to the following previously established threshold values: VAS neck≥2.6 [11], VAS arm≥4.1 [11]. Mean VAS scores, mean satisfaction, proportion of patients whose expectations were met and proportion of patients that achieved an MCID were reported for each relevant timepoint for both neck and arm pain (Table 3).

Simple linear regression was used to assess both meeting expectations and achieving MCID as predictors of postoperative satisfaction for neck and arm pain at each postoperative timepoint (Table 4). A post-hoc comparison of beta coefficients was used to directly assess differences in effect sizes of expectations met and MCID achievement as predictors of satisfaction for neck and arm pain at each postoperative timepoint. A p-value≤0.05 was set as the threshold for statistical significance in all tests.

RESULTS

A total of 106 patients were included in the final study cohort. The overall cohort had a mean age of 47.4 years, was 34.0% female, and 43.6% were obese (Table 1). Myeloradiculopathy was the most common preoperative spinal pathology (86.8%), 61 patients underwent ACDF (57.6%) while 45 underwent CDA (42.5%) and a majority of procedures were at a single level (68.9%) (Table 2).

After excluding those patients with preoperative pain scores less than the respective published MCID values, 64 patients were eligible for analysis regarding arm pain outcomes and 88 were eligible for analysis of neck pain outcomes. Mean preoperative VAS arm pain was 6.8±1.5 and mean preoperative VAS neck pain was 6.3±1.9 (Table 3). Mean satisfaction ranged from 6.3 at 6-weeks and 1-year to 7.4 at 6-months for arm pain and from 6.7 at 6-weeks to 7.1 at 12-weeks and 1-year for neck pain. A majority of patients met their preoperative expectations

Table 3. Patient reported outcomes

	VAS, mean ± SD	Satisfaction, mean ± SD	Met expectations	Achieved MCIDa
Arm pain (n = 64)				
Preoperative	6.8 ± 1.5	-	-	-
6-weeks	2.7 ± 3.1	6.3 ± 3.8	48.7 (19)	56.4% (22)
12-weeks	2.9 ± 3.1	6.8 ± 3.8	52.6% (20)	50.0% (19)
6-months	2.1 ± 2.7	7.4 ± 3.2	58.6% (17)	58.6% (17)
1-year	2.9 ± 3.1	6.3 ± 3.7	35.3% (6)	52.9% (9)
Neck pain (n = 88)				
Preoperative	6.3 ± 1.9	-	-	-
6-weeks	3.0 ± 2.6	6.7 ± 3.3	40.7% (22)	63.0% (34)
12-weeks	2.6 ± 2.6	7.1 ± 3.3	50.0% (27)	63.0% (34)
6-months	2.1 ± 2.1	6.8 ± 3.5	41.7% (15)	69.4% (25)
1-year	3.0 ± 3.1	7.1 ± 3.4	45.8% (11)	62.5% (15)

SD: standard deviation.
[a]MCID values based on results of Parker et al. [11].

Table 4. Predictors of satisfaction

	Meeting expectations		Achieving MCID		p-value[b]
	Coef.	p-value[a]	Coef.	p-value[a]	
Arm pain					
6-weeks	3.1	0.007	4.3	< 0.001	0.068
12-weeks	4.2	< 0.001	4.7	< 0.001	0.499
6-months	1.9	0.121	2.3	0.055	0.182
1-year	3.2	0.092	3.4	0.055	0.815
Neck pain					
6-weeks	2.6	0.003	1.9	0.039	0.444
12-weeks	3.4	< 0.001	2.4	0.008	0.235
6-months	1.9	0.103	3.5	0.004	0.228
1-year	4.3	0.001	3.8	0.006	0.419

Boldface indicates statistical significance.
[a]p-values calculated using simple linear regression to assess meeting expectations or achieving an MCID as a predictor of postoperative satisfaction.
[b]p-values calculated using comparison of coefficients to determine differences in effect size between meeting expectations and achieving MCID as predictors of satisfaction.

for arm pain at 12-weeks (52.6%) and 6-months (58.6%), but not at 6-weeks (48.7%) or 1-year (35.3%) (Table 3). A majority met expectations for neck pain at 12-weeks (50.0%), but not at 6-weeks (40.7%), 6-months (41.7%), or 1-year (45.8%). A majority of patients achieved MCID for both arm pain and neck pain at all timepoints (Table 3). A total of 17 patients included in the arm pain analysis and 24 in the neck pain analysis followed up through the full 1-year postoperative period. Meeting expectations was a significant predictor of postoperative satisfaction for both arm pain and neck pain at 6-weeks (p=0.007, p<0.003), 12-weeks (both p<0.001), and for neck pain only at 1-year (p=0.001) (Table 4). Achieving MCID for arm pain significantly predicted satisfaction at 6-weeks and 12-weeks (both p<0.001), but not at 6-months (p=0.055), or 1-year (p=0.055). Achieving MCID for neck pain significantly predicted satisfaction at all postoperative timepoints (all p≤0.039). Effect sizes for prediction of satisfaction did not significantly differ between expectations and MCID at any timepoint (all p>0.05).

DISCUSSION

As value-based assessments of medical treatment become increasingly patient-centered, patient satisfaction has been identified as an important indicator of surgical success. While a number of factors are important for patient satisfaction [12,13], improvement in neck pain has consistently been demonstrated as a key determinant of satisfaction following cervical spine surgery [6,14,15]. While VAS is a well-validated measure of neck and arm pain, there are several ways in which improvements in this metric can be quantified [3]. Both MCID and meeting preoperative expectations significantly predicted patient satisfaction with neck pain and short-term arm pain, and the choice of which metric to use may be best considered on an individual basis.

Patient satisfaction can be characterized through a variety of methods, and previous studies differ with regard to how they assess satisfaction. Asher et al. [12] utilized the North American Spine Society (NASS) satisfaction scale to determine predictors of satisfaction following ACDF. Similar to many other measures, the NASS satisfaction scale characterizes global satisfaction with the procedure and operative experience as a whole, rather than individual aspects, using the following 4 ordinal responses: "Surgery met my expectations," "I did not improve as much

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as I had hoped, but I would undergo the same operation for the same results," "Surgery helped but I would not undergo the same operation for the same results," "I am the same or worse compared to before surgery" [16]. As is the case with many similar analyses, the NASS satisfaction scale seems to conflate "expectations met" with "satisfaction", while our study treats these as separate, although related, entities. In contrast to previous studies, our analysis characterized satisfaction specifically in terms of neck and arm pain, using a 0–10 scale to describe each at every postoperative timepoint. This focused assessment may allow for more direct consideration of the surgical outcomes, compared to more global assessments of satisfaction which may be influenced by factors such as the experience with clinical staff, the hospital setting, etc.

Preoperative expectations have been a topic of interest for many previous studies, which demonstrate their importance in terms of patient-reported outcomes and postoperative satisfaction. Mancuso et al. [17] developed a survey to assess which of the 21 items patients undergoing cervical spine procedures may expect to improve postoperatively (e.g., pain, numbness, physical limitations) and the degree to which improvement is expected. Later studies by Mancuso et al. [18] reported that relieving neck and upper extremity pain, preventing worsening of spinal conditions, and removing control of spinal disease over one's life were the most common reported patient expectations for surgery. The same group also reported that patients listing higher preoperative expectations tended to be younger, had worse disability, physical function, and mental health scores. Additionally, these individuals also tended to have a lower proportion of expectations fulfilled and less postoperative improvement in disability and pain [8,18]. Alternatively, a study by Soroceanu et al. [7] demonstrated that having a greater proportion of preoperative expectations fulfilled was associated with higher postoperative satisfaction. Interestingly, these authors also demonstrated that patients with loftier preoperative expectations tended to be less satisfied postoperatively yet achieved greater functional improvement.

Although many studies have aimed to explore the fulfillment of expectations following spine surgery, a common shortcoming of such analysis is the failure to quantify these expectations at the preoperative timepoint [18,19]. For example, Mancuso et al. [18] determined patient expectations by asking them at the postoperative timepoint what their expectations were and whether they felt they had been met. However, such methodology may place these studies at increased risk for significant recall bias, which has been well-documented in studies of patient reported outcomes following spine surgery. A study by Rodrigues et al. [20] demonstrated that patients may generally have poor to moderate ability to recall their preoperative status in terms of neck and arm pain, disability, and quality of life. They noted that patients who were satisfied postoperatively recalled significantly worse preoperative scores than what they had actually reported before surgery, suggesting that relying on patient recall of preoperative status may result in overestimation of surgical efficacy. Furthermore, Aleem et al. [21] reported that recollection of neck pain, arm pain, and disability was generally more severe than the actual preoperative scores and observed that over 30% of patients shifted in regard to which symptom they stated was most predominant when asked at the postoperative timepoint to recall their preoperative condition.

To minimize the risk for recall bias, we asked patients to report what they expected their postoperative pain to be along a 10-point scale, similar to that used by VAS, and recorded these expectations before surgery. These preoperative scores were then compared with their actual postoperative scores to determine whether patients had met their expectations for neck and arm pain at each follow up time. Our analysis demonstrated that roughly half of patients met their expectations for arm pain from 6-weeks to 6-months and for neck pain through 1-year. Of note, a generally similar proportion of patients met their expectations and achieved MCID for arm pain. The exception to this trend was at the 1-year timepoint, which saw a significant drop in expectations met, but less so for MCID achievement. In contrast, a substantially greater proportion of patients achieved MCID than met expectations for neck pain at every postoperative timepoint. This may be partly explained by the substantially higher MCID threshold for clinically important improvement in VAS arm as compared to VAS neck calculated by Parker et al. [11]. In contrast, although patients were generally quite optimistic in terms of their expectations for both neck and arm pain, these values tended to be relatively similar, with mean values of 1.3 and 1.0, respectively.

Meeting preoperative expectations was a statistically significant predictor of satisfaction for both arm pain and neck pain at short-term follow up, but only at 1-year long-term follow up for neck pain. Achieving MCID similarly predicted satisfaction with arm pain only at short-term timepoints. In comparison, however, achieving MCID significantly predicted satisfaction at all postoperative timepoints for neck pain. Interestingly, the 6-month timepoint at which MCID achievement was a significant predictor of neck pain satisfaction, but meeting expectations was not, was also the period of largest discrepancy between the two rates (41.7% vs. 69.4%). In contrast, while a large difference in the proportion of patients meeting expectations vs achieving MCID for arm pain was observed at the 1-year timepoint (35.3% vs. 52.9%), neither metric proved to be a significant predictor of long-term satisfaction with arm pain.

Further analysis comparing beta coefficients revealed no significant differences between achievement of MCID and meeting preoperative expectations in terms of their ability to predict postoperative satisfaction in both arm and neck pain at both short- and long-term follow up. This may reflect the lower rates of achievement rates themselves, where prior studies reported that 71.3% of patients categorized as satisfied had achieved an MCID and 12.5%–44.7% of uncertain or unsatisfied patients achieved an MCID for VAS arm [6]. However, achieving MCID and meeting expectations may both represent a substantial improvement that is appreciated by the patient following cervical spine surgery and our results suggest that these may provide similar predictive capacity for determining patient satisfaction. While both measures appear to be effective long-term predictors of neck pain satisfaction, these outcome metrics may become less relevant to satisfaction with arm pain as the patient progresses through their postoperative recovery.

MCID has been well supported as an important metric for assessing patient-reported outcomes [22], and our results suggest that patient expectations may be a similarly useful measure of outcomes related to neck pain and short-term arm pain. Therefore, the choice of metric may be largely dependent upon physician preference and the needs of their practice. In circumstances where standardization is highly emphasized, such as large multi-provider registries or clinical trials, the more uniform MCID threshold may be preferable. However, the uniformity of MCID may present a drawback if some patients initially present with symptoms that are near or below the level of change considered an "important difference", though our analysis was specifically adjusted to minimize the effects of this potential bias. In cases where more nuanced patient-specific assessment is called for, considering patients' outcomes in terms of their preoperative expectations may be favorable. Furthermore, these findings also underline the importance of preoperative education and effectively managing patient expectations. If patient expectations are moderated in a way that allows for a more reasonable chance of achieving the desired outcome, a greater degree of long-term postoperative satisfaction may be realized by a greater number of patients. Given the importance of patient expectations documented in the current study for pain, future research should seek to similarly assess other commonly utilized quality of life measures, such as the Neck Disability Index.

Limitations

Several limitations are inherent to the current study. First, our cohort consisted of patients undergoing procedures performed by a single attending surgeon at the same academic institution, which may limit the generalizability of our results. Second, while characterization of expectations at the preoperative timepoint minimized risk for recall bias, it may have been challenging for patients to accurately report their true postoperative expectations for pain without a standardized point of reference. Third, assessment of pain through patient reported outcomes also increases the chances of reporting bias, as it is a subjective evaluation. Finally, MCID achievement was only possible for patients with a preoperative pain score greater than or equal to the respective MCID values. We attempted to control for this by only including patients with scores at or above this level in each analysis, however this strategy may have unrealistically downplayed this effect which might be present in a "real world" patient cohort.

CONCLUSION

Meeting preoperative expectations and achieving MCID both significantly predicted postoperative satisfaction arm pain at short-term timepoints and neck pain at both short- and long-term follow up. When compared directly, neither metric emerged as a significantly stronger predictor of satisfaction than the other. Therefore, assessment of postoperative outcomes may be determined in a practice-specific manner based on the needs of a given provider, patient population, or research endeavor. Nonetheless, physicians should be aware of the importance of their patients' preoperative expectations for pain improvement. Effective management of these expectations may be critical for maximizing patient satisfaction. Identifying patients that fail to either achieve an MCID or meet their preoperative expectations may highlight opportunities for closer follow up or additional postoperative support.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Todd AG. Cervical spine: degenerative conditions. Curr Rev Musculoskelet Med 2011;4:168–174.
2. Hessler C, Boysen K, Regelsberger J, Vettorazzi E, Winkler D,

https://doi.org/10.21182/jmisst.2021.00353

Westphal M. Patient satisfaction after anterior cervical discectomy and fusion is primarily driven by relieving pain. Clin J Pain 2012;28:398–403.
3. MacDowall A, Skeppholm M, Robinson Y, Olerud C. Validation of the visual analog scale in the cervical spine. J Neurosurg Spine 2018;28:227–235.
4. Delgado DA, Lambert BS, Boutris N, McCulloch PC, Robbins AB, Moreno MR, et al. Validation of digital visual analog scale pain scoring with a traditional paper-based visual analog scale in adults. J Am Acad Orthop Surg Glob Res Rev 2018;2:e088.
5. Chung AS, Copay AG, Olmscheid N, Campbell D, Walker JB, Chutkan N. Minimum clinically important difference: current trends in the spine literature. Spine (Phila Pa 1976) 2017;42:1096–1105.
6. Andresen AK, Paulsen RT, Busch F, Isenberg-Jørgensen A, Carreon LY, Andersen MØ. Patient-reported outcomes and patient-reported satisfaction after surgical treatment for cervical radiculopathy. Global Spine J 2018;8:703–708.
7. Soroceanu A, Ching A, Abdu W, McGuire K. Relationship between preoperative expectations, satisfaction, and functional outcomes in patients undergoing lumbar and cervical spine surgery: a multicenter study. Spine (Phila Pa 1976) 2012;37:E103–E108.
8. Mancuso CA, Duculan R, Cammisa FP, Sama AA, Hughes AP, Lebl DR, et al. Proportion of expectations fulfilled: a new method to report patient-centered outcomes of spine surgery. Spine (Phila Pa 1976) 2016;41:963–970.
9. Mannion AF, Junge A, Elfering A, Dvorak J, Porchet F, Grob D. Great expectations: really the novel predictor of outcome after spinal surgery. Spine (Phila Pa 1976) 2009;34:1590–1599.
10. Mondloch MV, Cole DC, Frank JW. Does how you do depend on how you think you'll do? A systematic review of the evidence for a relation between patients' recovery expectations and health outcomes. CMAJ 2001;165:174–179.
11. Parker SL, Godil SS, Shau DN, Mendenhall SK, McGirt MJ. Assessment of the minimum clinically important difference in pain, disability, and quality of life after anterior cervical discectomy and fusion: clinical article. J Neurosurg Spine 2013;18:154–160.
12. Asher AL, Devin CJ, Kerezoudis P, Nian H, Alvi MA, Khan I, et al. Predictors of patient satisfaction following 1- or 2-level anterior cervical discectomy and fusion: insights from the Quality Outcomes Database. J Neurosurg Spine 2019;31:835–843.
13. Sivaganesan A, Khan I, Pennings JS, Roth SG, Nolan ER, Oleisky ER, et al. Why are patients dissatisfied after spine surgery when improvements in disability and pain are clinically meaningful. Spine J 2020;20:1535–1543.
14. Skolasky RL, Albert TJ, Vaccaro AR, Riley LH 3rd. Patient satisfaction in the cervical spine research society outcomes study: relationship to improved clinical outcome. Spine J 2009;9:232–239.
15. Schroeder GD, Coric D, Kim HJ, Albert TJ, Radcliff KE. Are patient-reported outcomes predictive of patient satisfaction 5 years after anterior cervical spine surgery. Spine J 2017;17:943–952.
16. Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH, Liang MH. The North American Spine Society lumbar spine outcome assessment Instrument: reliability and validity tests. Spine (Phila Pa 1976) 1996;21:741–749.
17. Mancuso CA, Cammisa FP, Sama AA, Hughes AP, Girardi FP. Development of an expectations survey for patients undergoing cervical spine surgery. Spine (Phila Pa 1976) 2013;38:718–725.
18. Mancuso CA, Duculan R, Stal M, Girardi FP. Patients' expectations of cervical spine surgery. Spine (Phila Pa 1976) 2014;39:1157–1162.
19. Hamilton DK, Kong C, Hiratzka J, Contag AG, Ailon T, Line B, et al. Patient satisfaction after adult spinal deformity surgery does not strongly correlate with health-related quality of life scores, radiographic parameters, or occurrence of complications. Spine (Phila Pa 1976) 2017;42:764–769.
20. Rodrigues R, Silva PS, Cunha M, Vaz R, Pereira P. Can we assess the success of surgery for degenerative spinal diseases using patients' recall of their preoperative status. World Neurosurg 2018;115:e768–e773.
21. Aleem IS, Currier BL, Yaszemski MJ, Poppendeck H, Huddleston P, Eck J, et al. Do cervical spine surgery patients recall their preoperative status?: a cohort study of recall bias in patient-reported outcomes. Clin Spine Surg 2018;31:E481–E487.
22. Copay AG, Chung AS, Eyberg B, Olmscheid N, Chutkan N, Spangehl MJ. Minimum clinically important difference: current trends in the orthopaedic literature, part I: upper extremity: a systematic review. JBJS Rev 2018;6:e1.

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Multilevel Percutaneous Fenestrated Screw Fixation with Bone Cement Augmentation in Adult Lumbar Spinal Deformity

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Objective: Fenestrated screw fixation with bone cement augmentation has been demonstrated to increase the pullout strength. Bone cement augmentation is performed to prevent screw failure. The study aimed to investigate the safety and efficacy of multilevel percutaneous fenestrated screw fixation with bone cement augmentation in the adult lumbar spinal deformity.
Methods: We performed a retrospective study of 15 patients who underwent multilevel percutaneous fenestrated screw fixation (PFSF) with bone cement augmentation between January 2018 and December 2020. Visual analogue scale (VAS) score, Oswestry disability index (ODI), sagittal vertical axis (SVA), and lumbar lordosis (LL) were investigated in the patients.
Results: Mean BMD was -2.0. The mean percutaneous fenestrated screw fixation level was 6. The mean VAS score changed from 7.14 preoperatively to 4.57 postoperatively, to 3.71 at the last follow-up. The mean ODI changed from 45.21 preoperatively to 32.5 postoperatively, to 27.0 at the last follow-up. The mean LL changed from 23.6 preoperatively to 32.96 postoperatively, to 31.67 at the last follow-up. The mean SVA changed from 76.65 preoperatively to 46.15 postoperatively, to 48.46 at the last follow-up. The bony fusion rate was 73.3%. There were screw loosening in 4 patients and screw fracture in 3 patients. Cement leakage occurred towards the anterior body of the vertebrae in 2 patients but no symptoms were observed.
Conclusion: Our study results demonstrate that multilevel PFSF with bone cement augmentation can result in good clinical and radiological outcomes for lumbar spinal deformity. However, larger size screws or smaller through-hole screws are required to prevent screw fracture.

Key Words: Pedicle screw, Osteoporosis, Bone cement, Spinal curvatures.

INTRODUCTION

As the aging population becomes more abundant, degenerative spine diseases are also increasing. With the development of surgical techniques for degenerative spinal diseases, various surgical methods have been introduced to obtain good surgical results. However, conventional surgical procedures for adult degenerative spinal deformity have been associated with severe blood loss, instrument failure, proximal junctional failure, and other complications found in elderly patients with multiple medical comorbidities.

Minimally invasive deformity correction and fusion remains as an exciting field of spinal deformity surgery. In adult lumbar spinal deformity, percutaneous fenestrated screw fixation is a promising approach to spinal deformity surgery that can achieve correction and fusion with less tissue trauma, bleeding, and potentially fewer complications [1].

The biggest obstacle in performing spinal deformity surgery is osteoporosis [2]. As the number of osteoporotic patients increases, the related problems also increase. The anchoring effect of holding the screw in place is reduced and the probability of hardware failure becomes higher for osteoporotic patients. As a result, chances of non-union and complications such as screw loosening and pull-out also become higher.

Accordingly, various surgical fixation techniques have been introduced to address some of the problems encountered with osteoporotic patients. The use of larger and longer screws, addition of equipment such as hooks to increase screw fixation range, and injection of bone cement into the vertebral body around the screw have been some of the efforts made to overcome the weak bone integrity of osteoporotic patients. Among them, bone cement injection is mainly used to overcome osteoporosis. Bone cement augmentation is considered to be an effective method to increase the screw strength [3]. The challenge lies in the injection of bone cement while performing percutaneous pedicle screw fixation (PPF). Fenestrated screws were introduced to make the cement insertion process more convenient. A bone cement filler device is used to inject bone cement into the screw and the cement enters the vertebral body through small holes in the screw.

Injection of bone cement into percutaneous screws can inadvertently result in bone cement leakage at the screw head, which can make the rod fixation procedure difficult [4]. Screw fracture is another emerging complication for cement injecting screws, and the size of the screw hole through which the cement is injected seems like a very important factor in preventing screw fracture.

Although percutaneous transpedicular screw fixation alone may not be sufficient to correct spinal deformity, screw fixation with bone cement augmentation can reduce various complications such as loosening or pull-out screw that may commonly occur in conventional adult spinal deformity surgery [5]. This study aimed to investigate the safety and efficacy of multilevel percutaneous fenestrated screw fixation with bone cement augmentation in the adult lumbar spinal deformity.

MATERIALS AND METHODS

1. Patient Population

From January 2018 to December 2020, a total of 15 patients with lumbar spinal disease underwent multilevel PFSF with bone cement augmentation by a single experienced spine surgeon. There were 14 women and 1 man with a mean age of 71.3±7.2 years and a mean follow-up period of 19±7.5 months.

The following group of patients were included in this study.

1) Multilevel degenerative diseases such as spinal stenosis, spondylolisthesis with spinal deformity requiring PPF of at least 5 levels.
2) Spinal instability with spinal cord compression requiring PPF of at least 5 levels.
3) Osteopenic or osteoporotic patients who have poor bone quality.

Out of the 15 patients, 14 patients underwent surgery due to degenerative diseases, 1 patient due to burst fracture with instability. The mean BMD was –2.0±0.8. The Body Mass Index (BMI), past history (diabetes, hypertension, thyroid disease, renal failure and cardiac disease) were investigated in the patients (Table 1).

2. Surgical Method

The posterior lumbar interbody fusion (PLIF) and/or transforaminal lumbar interbody fusion (TLIF) with PPF via midline incision was performed in 10 patients, and direct lateral interbody fusion (DLIF) with percutaneous screw fixation in 5 patients. Multilevel PPF was performed in prone position using bone cement fenestrated screws (ZENIUS pedicle screw system distributed by Medyssey). The screws were placed percutaneously under fluoroscopic guidance. For every lumbar fenestrated screw, approximately 1.5–2.5 mL of polymethylmethacrylate (PMMA) was injected in the top and lower screws through the injection cannula. The rods were shaped according to the sagittal contour and then passed through the screw heads under fluoroscopic control. Compression or distraction was applied to the extenders as required to gain further correction.

3. Clinical and Radiologic Data

A retrospective review of clinical and radiological data was conducted. The visual analog scale (VAS) and the ODI scores were measured preoperatively, postoperatively (after 1 month of surgery) and at the last follow up. For radiological evaluation, SVA, PT, PI, SS, LL and Cobb's angle were measured through radiographs taken preoperatively, postoperatively (1–2 months after operation), and at last follow up (Figure 1).

The bony fusion rate of interbody fusion and instrument failure such as fracture or loosening were evaluated by radiographs

Table 1. Characteristics of patients

Case	Sex	Age	Diagnosis	Decompression levels	PPF levels	BMD	BMI	Past history
1	F	62	Scoliosis, stenosis and spondylolisthesis L2-5	TLIF L2-4, PLIF L45	5	−1.4	25.97	HTN, DM
2	F	76	Scoliosis, stenosis with instability L2-5	DLIF L2-5	7	−2.5	26.22	None
3	F	73	Scoliosis, stenosis with instability L3-S1	TLIF L3-5	5	−2.5	27.2	CRF
4	F	74	Stenosis and spondylolisthesis L2-S1	TLIF L2-S1	5	−0.7	26.3	HTN
5	F	80	Scoliosis, stenosis with instability L2-5	DLIF L2-5	5	−2.4	28.78	HTN
6	F	65	Scoliosis, stenosis with instability L2-S1	PLIF L2-5	6	−1.5	23.43	None
7	F	78	Scoliosis, stenosis with instability L3-S1	PLIF L34, TLIF L4-S1	5	−3.3	21.63	HTN
8	M	81	Scoliosis, stenosis with instability L1-5	TLIF L1-5	5	−1.5	23.31	None
9	F	62	Stenosis and spondylolisthesis L2-S1	DLIF L2-5, PLIF L5S1	6	−1.8	25.39	HTN
10	F	77	Stenosis and spondylolisthesis T12-S1	TLIF T12-S1	7	−2.1	24.03	HTN, DM
11	F	76	Scoliosis, stenosis with instability L1-5	TLIF L1-3, DLIF L3-5	6	−2.1	20.8	HTN, DM
12	F	72	Scoliosis, stenosis and spondylolisthesis L2-S1	TLIF L2-S1	5	−0.9	23.61	None
13	F	71	Stenosis and spondylolisthesis L1-S1	DLIF L1-4, PLIF L5S1	5	−1.9	19.29	HTN
14	F	73	Scoliosis, stenosis and spondylolisthesis L3-5	PLIF L3-5	8	−2.5	27.43	HTN
15	F	58	Old burst fracture L3, scoliosis	Corpectomy L3, DLIF L2-4	6	−3.2	20.9	None
Mean		71.3			6	−2.02	24.29	

PPF: percutaneous pedicle screw fixation, BMD: bone mineral density, BMI: body mass index, HTN: hypertension, DM: diabetes mellitus, CRF: chronic renal failure, DLIF: direct lateral interbody fusion, TLIF: transforaminal interbody fusion, PLIF: posterior lumbar interbody fusion.

and computed tomography (CT) during the follow-up period. The degree of bone fusion was based on the classification of Brantigan and Steffee (Table 2) [6]. Grade 4 or 5 was regarded to have achieved bony fusion. Screw loosening was defined as halo sign showing a radiolucent line of ≥1 mm around the screw in radiographs or CT [7].

Perioperative complications such as postoperative infection, PMMA and cerebrospinal fluid leakage, or neurologic deterioration were also recorded.

4. Statistical Analysis

For statistical analysis, ANOVA test was conducted using SPSS software (ver. 17.0; SPSS Inc, Chicago, IL, USA). A probability value of less than 0.05 was considered significant.

RESULTS

1. Clinical Outcomes

The mean VAS score decreased from 7.14 preoperatively to 4.57 postoperatively. VAS score decreased to 3.71 at the last follow up. The mean ODI score improved from 45.21 preoperatively to 32.5 postoperatively. Like the VAS score, ODI score improved to 27.0 at the last follow up. Both VAS and ODI score improved after the surgery and the improvement was maintained during the follow-up period with statistical significance ($p<0.05$).

2. Radiological Outcomes

Spinopelvic parameters were measured by three researchers (two experienced spine surgeons, one spine fellow), and the mean values were used for analysis.

The mean SVA decreased from 76.65 mm before the surgery to 46.15 postoperatively and 48.46 at the last follow-up. The mean LL increased from 23.60 before the surgery to 32.96 postoperatively however, decreased to 31.67 at the last follow-up. The mean PT decreased from 32.67 before the surgery to 28.11 postoperatively and 28.70 at the last follow-up. The mean PI-LL decreased from 35.20 before the surgery to 22.56 postoperatively and 22.76 at the last follow-up. The mean Cobbs angle decreased from 18.30 before the surgery to 6.27 postoperatively and 5.98 at the last follow-up (Table 3).

All the clinical and radiographic values were improved after the surgery and the improvement was well maintained during the follow-up period with statistical significance ($p<0.05$) (Figure 2). Figure 1 shows a 77-year-old patient that underwent PPF 6 levels with bone cement augmentation. SVA improves from 107.30 mm preoperative to 34.70 mm last follow-up, PT improves from 28.93 to 24.08, LL improves from 14.56 to 35.38, PI – LL improves from 38.13 to 14.22 and Cobb's angle improves from 28.69 to 4.12.

At the last follow-up, bony fusion was achieved in 11 patients

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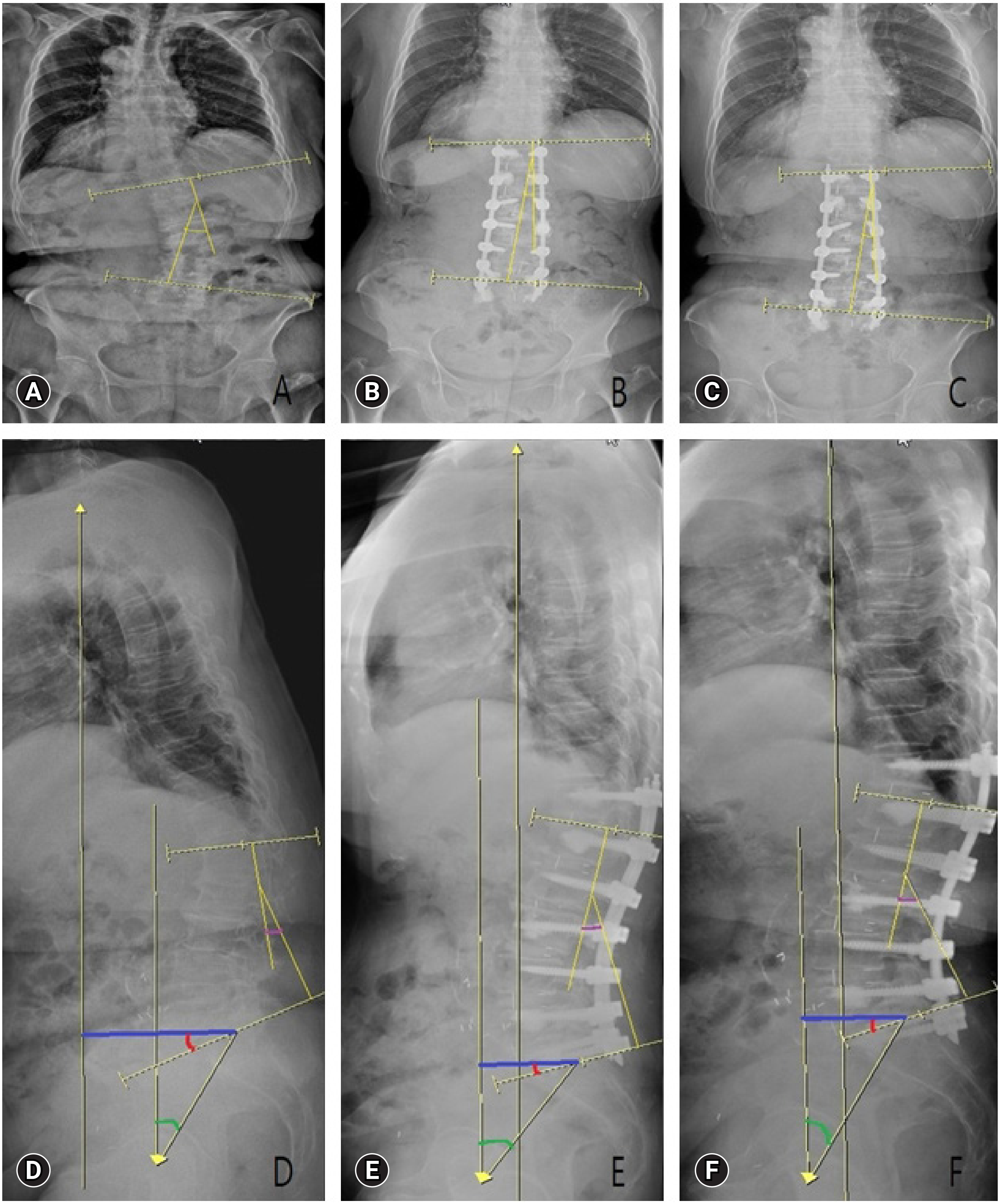

Figure 1. Female, 77-year-old, T=–2.1 SD, the patient underwent PPF with bone cement augmentation. (A) The preoperative A-P view X-ray image measured Cobb's angle; (B) Postoperative A-P view X-ray image measured Cobb's angle; (C) Last follow-up A-P view X-ray image measured Cobb's angle (yellow angle); (D) The preoperative lateral view X-ray image measured SVA (blue line), PT (green angle), SS (red angle), and LL (purple angle); (E) Postoperative lateral view X-ray image measured SVA, PT, SS, and LL; (F) Last follow-up lateral view X-ray image measured SVA, PT, SS, and LL.

Table 2. Discription of fusion result by Brantigan and Steffee [6]

Grade	Description
1	Obvious collapse of construct due to pseudoarthrosis, loss of disc height, vertebral slip, broken screws, displacement of the cage, resorption of bone graft
2	Probable significant resorption of the bone graft due to pseudoarthrosis, major lucency, or gap visible in fusion area (2 mm around the entire periphery of graft)
3	Uncertain non-union, bone graft visible in the fusion area ot approximately the density originally achieved at surgery. A small lucency of gap may be visible involving a portion of the fusion area with at least half of the graft area.
4	Probable fusion bone bridges entire fusion area with at least the density achieved at surgery. There should be no lucency between the donor and vertebral bone.
5	Fusion bone in the fusion area is radiographically more dense and mature than originally achieved by surgery. Optimally, there is no interface between the donor bone and the vertebral bone, although a sclerotic line between the fusion areas, resorption of the anterior traction spur, anterior progression of the graft within disc space, and fusion of facet joints.

Table 3. Radiological outcomes of patients

Index	Preoperative	Postoperative	Last follow-up	p-value
PT	32.67	28.11	28.70	0.003
LL	23.60	32.96	31.67	0.011
PI-LL	35.20	22.56	22.76	0.001
Cobb's angle	18.30	6.27	5.98	0.002
SVA (mm)	76.65	46.15	48.46	0.009

PT: pelvic tilt, LL: lumbar lordosis, PI-LL: pelvic incidence minus lumbar lordosis, SVA: sagittal vertical axis.

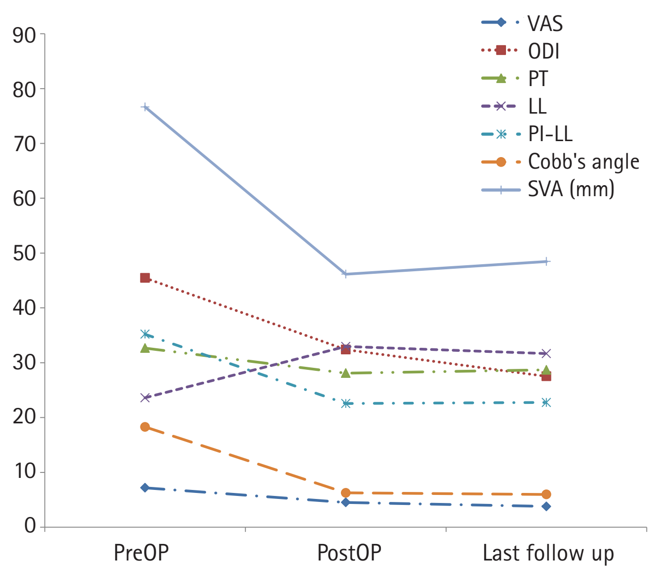

Figure 2. Graph showing Visual Analog Scale (VAS), Oswestry Disaability Index (ODI), Pelvic Tilt (PT), Lumbar Lordosis (LL), Pelvic incidence minus Lumbar Lordosis (PI-LL), Cobb's angle, and Sagittal Vertical Axis (SVA) before the surgery, 1–2 months after the surgery (postoperative period), and last follow-up period. The mean improvement of VAS from pre-operation to the last follow-up was 3.43 points (from 7.14 to 3.71) ($p<0.05$). The mean improvement of ODI from the pre-operation to the last follow-up was 18.21 points (from 45.21 to 27.0) ($p<0.05$). All the last follow-up radiologic outcomes improves than before the surgery ($p<0.05$). X axis represents preoperative, postoperative, and last follow-up period. The Y axis represents the score.

out of 15 patients and thus the fusion rate was 73.3%. Screw loosening was observed in 4 patients, rod fracture in 1 patient and screw fracture in 3 patients. Among the 3 patients of screw fracture, 1 patient underwent screw pull-out at the top screw and required reoperation. Cement leakaged occurred in 2 patients through the anterior body of vertebrae but no symptoms were observed. There were no cases of postoperative surgical site infection (Table 4).

DISCUSSION

Multilevel PFSF in adult spinal deformity is becoming a popular option among surgeons for the aging population. PPF decreases muscle crush injures during retraction, avoids detachment of tendons to the posterior bony elements, maintains the integrity of the dorsolumbar fascia, limits bony resection, and decreases the size of the surgical corridor. But technical limits of PPF also exists. Facet hypertrophy, high iliac crest when screwing S1 segment, severe spondylolisthesis, osteopenia or osteoporosis, and scoliosis [8].

Therefore, perioperative complications such as screw loosening or fracture are commonly encountered. Studies have demonstrated that 17% of revision surgeries are associated with fenestrated screw failure [4,9]. Longer, thicker sized screws, bone cement augmentation along with teriparatide injections have been applied to overcome such instrument failure. This study was aimed to evaluate safety and efficacy of percutaneous fenestrated screw with bone cement augmentation in adult lumbosacral degenerative spine diseases with low bone quality.

There are two main methods of screw augmentation currently in practice. One method is using a fenestrated screw, through which bone cement is injected via injection cannula after screw insertion. The other conventional augmentation method involves tapping over the guidewire, bone cement injection through a injection cannula, followed by screw insertion. A pre-

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Table 4. Complications related to procedure

	Number
Screw fracture	3
Screw loosening	4
Screw pull-out	1
Rod fracture	1
Leakage of cement	2
Postoperative surgical site infection	0

vious study demonstrated that fenestrated screw augmentation is more effective than vertebroplasty augmentation [5].

Many problems can occur during the bone cement augmentation process. Cement leakage into the spinal canal or intervertebral foramen causing neural obstructions and neurologic damage to the nearby nerve root as a result of the chemical reaction of the PMMA are some of the common complications [10,11]. More serious complications such as pulmonary embolism, paraplegia, or death can also occur [12]. In our patients at least 1.5 mL of bone cement was injected at each fenestrated screw based on the study that 1.5 mL is an effectiveness dose that increases the pullout strength and minimizes the risks associated with higher volume [13].

In this study, all sagittal parameters improved post-operatively compared to the pre-operative state. The correction rate of the sagittal imbalances was not ideal according to SRS-Schwab Classification, but all patients showed clinical improvements postoperatively and at the last follow up. Sagittal corrections needed to be tailored to each patient characteristic based on bone quality and patient comorbities. Increased post-surgical infection and dural tear, massive blood loss during surgery, proximal junctional kyphosis, and rod fracture or haloing around screw can occur when excessive correction is performed [14].

In this study bony fusion rate was 73.3%, which is somewhat lower than the previously reported 93.47% [4]. This may be due to the fact that ideal sagittal correction values could not be achieved based on the limitations of the PPF technique, which in turn leads to spinal instability and unbalanced load baring on the screws and rods. Screw fractures occurred in three patients. In all of the screw fracture cases, large holed screws were used. While large holed screws allow much easier cement injection, screw integrity may be compromised and the chances of inadvertent cement leakage become more abundant. Consistent with previous study of cement leakage rate of 9.3%, cement leakage occurred in two of fifteen patients (13.3%) [5]. Cement leakage occurred through the anterior body of vertebrae but no symptoms were triggered. Bone cement injection can also occur at the screw head to which the injection cannula is attached. Such leakage can make the rod fixation procedure difficult and operation time longer. Removal of excess bone cement at the screw heads is a crucial process before rod application to ensure appropriate capping. Screw pull-out occurred in one patient at the uppermost screw fixation level (L2). Female, 73-year-old, T=–2.5 SD, the patient has history of chronic renal failure (CRF) that operation of TLIF L3-5 PPF L2,3,4,5,S1. But screw pull-out occurred at the L2 level that removal of instrument L2-S1 bilateral and allobone chips was applied at the reoperation surgery (Figure 3). Screw loosening occurred in four cases. Screw loosening occurred due to insufficient bone cement injection on the loosening site in one patient, but all screw loosening cases did not result in spinal instability. In this study, the mean BMD was –2.02. The mean BMD of the screw loosening group was –2.87, and the mean BMD of the those without instrument failure was –1.73. Mean BMD values of screw loosening cases was significantly lower than those of without instrument failure. The rate of instrument related complications was quite high compared to other studies about multilevel fusion. We believe that the use of large holed fenestrated screws and lengthy fusion levels (mean fusion level of 6) can be attributed to these results. Previous studies have shown that age, more than 5 fusion levels, scoliosis, PI/LL mismatch and osteoporosis to be associated with high risk of instrument failure [15].

In light of the results, it is important to improve the bone quality to decrease the rate of instrument failure. Using teriparatide injection after the surgery has proven to be an effective adjunctive treatment [16]. In this study a daily injection of 20 μg of teriparatide for 6 months was prescribed to all osteoporosis patients. But based on our experience, teriparatide injections should be recommended to osteopenia patients when multilevel fusion is being considered in order to reduce screw loosening.

There are many limitations to the study. Selection bias may have occurred due to the retrospective nature of the study. The sample size is also very small and the follow-up period is not long enough to discuss long term outcomes. This study does not have a control group to which we can compare the results of using fenestrated cement screws. Thus, a randomized control study with more patients and longer follow-up duration is needed to reinforce our results. This study is significant in that PPF with bone cement augmentation can conveniently and safely be performed using fenestrated screws in adult deformity surgery.

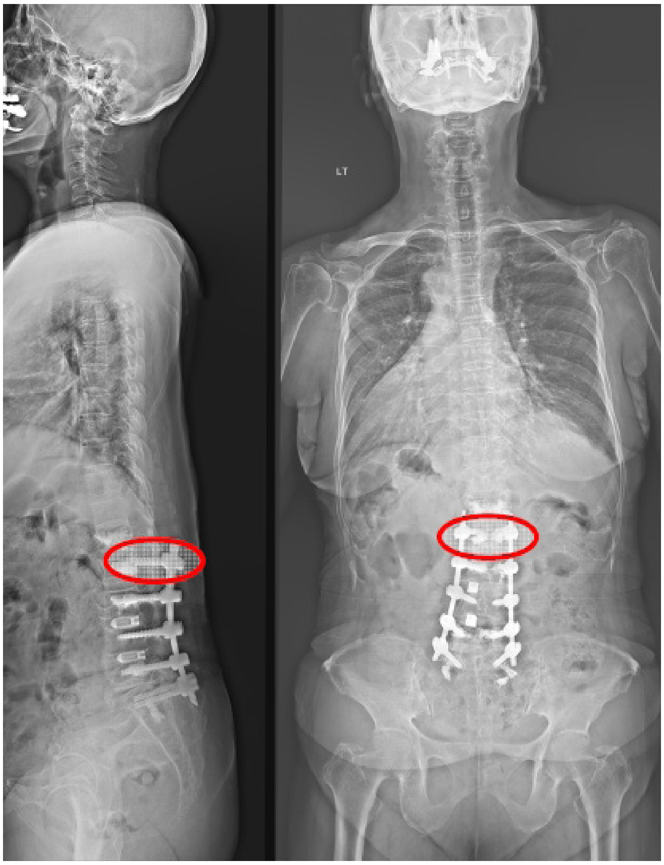

Figure 3. Female, 73-year-old, T=–2.5 SD, the patient has history of CRF that operation of TLIF L3-5 PPF L2, 3, 4, 5, S1. Screw pull-out occurred at the uppermost screw fixation level (L2).

CONCLUSION

Although the current study examined a small sample with a relatively short term follow up period, our study results demonstrate that multilevel percutaneous fenestrated screw fixation with bone cement augmentation can result in good clinical and radiological outcomes for lumbar spinal deformity. Based on our experience, we believe that bone cement augmentation should be performed at all levels for severely osteoporotic patients and at least at the uppermost and lowermost level in osteopenia patients or those undergoing more than four level fusion to minimize instrument failure. Large holed screws used for bone cement augmentation may be vulnerable to screw fracture and increase the risk of screw fracture. Larger size screws or smaller through-holed screws are necessary to prevent screw fracture. Teriparatide injection for at least 6 months is recommended after percutaneous screw fixation in low bone quality patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Son S, Lee SG, Park CW, Kim WK. Minimally invasive multilevel percutaneous pedicle screw fixation for lumbar spinal diseases. Korean J Spine 2012;9:352–357.
2. Gupta A, Cha T, Schwab J, Fogel H, Tobert DG, Razi AE, et al. Osteoporosis is under recognized and undertreated in adult spinal deformity patients. J Spine Surg 2021;7:1–7.
3. Seo JH, Ju CI, Kim SW, Kim JK, Shin H. Clinical efficacy of bone cement augmented screw fixation for the severe osteoporotic spine. Korean J Spine 2012;9:79–84.
4. Tang YC, Guo HZ, Guo DQ, Luo PJ, Li YX, Mo GY, et al. Effect and potential risks of using multilevel cement-augmented pedicle screw fixation in osteoporotic spine with lumbar degenerative disease. BMC Musculoskelet Disord 2020;21:274.
5. Kim JH, Ahn DK, Shin WS, Kim MJ, Lee HY, Go YR. Clinical effects and complications of pedicle screw augmentation with bone cement: comparison of fenestrated screw augmentation and vertebroplasty augmentation. Clin Orthop Surg 2020;12:194–199.
6. Brantigan JW, Steffee AD. A carbon fiber implant to aid interbody lumbar fusion. Two-year clinical results in the first 26 patients. Spine (Phila Pa 1976) 1993;18:2106–2107.
7. Moon BJ, Cho BY, Choi EY, Zhang HY. Polymethylmethacrylate-augmented screw fixation for stabilization of the osteoporotic spine : a three-year follow-up of 37 patients. J Korean Neurosurg Soc 2009;46:305–311.
8. Yuan L, Zhang X, Zeng Y, Chen Z, Li W. Incidence, risk, and outcome of pedicle screw loosening in degenerative lumbar scoliosis patients undergoing long-segment fusion. Global Spine J 2021 doi: 10.1177/21925682211017477
9. Bostelmann R, Keiler A, Steiger HJ, Scholz A, Cornelius JF, Schmoelz W. Effect of augmentation techniques on the failure of pedicle screws under cranio-caudal cyclic loading. Eur Spine J 2017;26:181–188.
10. Sawakami K, Yamazaki A, Ishikawa S, Ito T, Watanabe K, Endo N. Polymethylmethacrylate augmentation of pedicle screws increases the initial fixation in osteoporotic spine patients. J Spinal Disord Tech 2012;25:E28–E35.
11. Fan HT, Zhang RJ, Shen CL, Dong FL, Li Y, Song PW, et al. The biomechanical properties of pedicle screw fixation combined with trajectory bone cement augmentation in osteoporotic vertebrae. Clin Spine Surg 2016;29:78–85.

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12. Lee BJ, Lee SR, Yoo TY. Paraplegia as a complication of percutaneous vertebroplasty with polymethylmethacrylate: a case report. Spine (Phila Pa 1976) 2002;27:E419–E422.
13. Paré PE, Chappuis JL, Rampersaud R, Agarwala AO, Perra JH, Erkan S, et al. Biomechanical evaluation of a novel fenestrated pedicle screw augmented with bone cement in osteoporotic spines. Spine (Phila Pa 1976) 2011;36:E1210–E1214.
14. Hyun SJ, Rhim SC. Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients : a long-term follow-up data. J Korean Neurosurg Soc 2010;47:95–101.
15. Marie-Hardy L, Pascal-Moussellard H, Barnaba A, Bonaccorsi R, Scemama C. Screw loosening in posterior spine fusion: prevalence and risk factors. Global Spine J 2020;10:598–602.
16. Kim JW, Park SW, Kim YB, Ko MJ. The effect of postoperative use of teriparatide reducing screw loosening in osteoporotic patients. J Korean Neurosurg Soc 2018;61:494–502.

Clinical Article

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Using Swallowing Quality of Life to Compare Oropharyngeal Dysphagia Following Cervical Disc Arthroplasty or Anterior Cervical Discectomy and Fusion

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Objective: To evaluate dysphagia outcomes using the swallowing quality of life (SWAL-QOL) questionnaire between patients undergoing cervical disk arthroplasty (CDA) or anterior cervical discectomy and fusion (ACDF).

Methods: Patient-reported outcome measures (PROMs) were collected using SWAL-QOL, VAS, NDI, and SF-12 PCS. All measures were recorded preoperatively to 6-month postoperatively. Patients were grouped according to cervical procedure and instrumentation used. Differences in PROMs and SWAL-QOL domains were evaluated by t-test and one-way ANOVA with post-hoc testing, respectively. Simple linear regression was employed to evaluate the relationship between number of levels operated on and postoperative outcomes.

Results: 161 patients were included. CDA patients had significantly worse SWAL-QOL scores at 6-months. Preoperative VAS neck was significantly worse for patients who underwent either an ACDF procedure with a stand-alone cage or CDA as compared to patients who underwent an ACDF with anterior plating. At 6-months postoperatively, CDA patients reported a significantly worse “fatigue” score compared to ACDF patients. At 6-months postoperatively, ACDF patients reported a significantly better “sleep” scores compared to CDA patients with both recipients of an anterior plate and stand-alone cage reporting significantly better scores compared to the CDA cohort ($p = 0.024$; $p < 0.001$). The SWAL-QOL domain of symptom frequency at 6-weeks postoperatively was significantly associated with number of levels operated ($p = 0.032$).

Conclusion: Patients undergoing either an ACDF or CDA procedure largely did not demonstrate differences in pain, disability, and dysphagia scores. However, at more longitudinal timepoints CDA patients reported worse fatigue and sleep scores compared to ACDF patients.

Key Words: Anterior cervical discectomy and fusion, Arthroplasty, Dysphagia, Swallowing

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is commonly performed for cervical degenerative spine pathology and is considered an effective form of treatment [1,2]. Cervical disc arthroplasty (CDA) is a comparable procedure to ACDF and its increased use for treatment of cervical spine pathologies can be tied to its reported favorable outcomes [3-5]. However, use of either procedure still places patients at risk for complications such as oropharyngeal dysphagia, tracheoesophageal hematomas, increased radiculopathy, respiratory insufficiency, and esophageal perforation [1], with dysphagia being one of the more common complications [6,7]. In fact, its occurrence rate has been reported to be as high as 8.5% [8], with one study reporting an incidence of 71% within several weeks postoperatively [9]. Although dysphagia is a prevalent postoperative complication, a limited number of studies have explored its effects on a patient's recovery course [10-12].

Dysphagia often occurs during the more immediate postoperative time period; however, instances of delayed onset are possible and can range from a few weeks, several months, or even as long as 5 years postoperatively [13,14]. Currently, methods for assessing dysphagia are primarily performed clinically and involve the use of videofluoroscopic swallow studies and upper endoscopies [15,16]; Beyond the immediate postoperative timepoint, the psychosocial effects of dysphagia should also be evaluated, which can be accomplished using dysphagia specific patient reported outcomes measures (PROMs). One such PROM used across different patient populations is the swallowing quality of life (SWAL-QOL) questionnaire, which is a validated psychometric with several scales that evaluate the impact of dysphagia on quality of life [17]. The majority of the survey's scales assess dysphagia-specific quality of life measures, including: burden, eating duration, eating desire, symptom frequency, food selection, communication, fear, mental health, and social. Meanwhile, sleep and fatigue scales of SWAL-QOL assess general quality-of-life. As the questionnaire has demonstrated favorable internal-consistency reliability and short-term reproducibility, with proven sensitivity to clinically defined dysphagia severity, SWAL-QOL is an effective means to evaluate the presence and severity of dysphagia [17]. Other similar PROMs have also been developed, including the HSS Dysphagia-Dysphonia (HSS-DDI) score [18], the M.D. Anderson Dysphagia Inventory (MDADI) [19], the Bazaz Score [20], and the Dysphagia Symptom Questionnaire (DSQ) score [21]. Although useful in their own right, these tools have been reported to have several limitations with being too simplistic [8], not formally validated [22], lacking a preoperative assessment [23], or designed for patients undergoing treatment for malignancy [22].

Yet, even with a number of different dysphagia PROMs to choose from, the literature surrounding the impact of swallowing difficulties on patient quality of life remains underreported within the ACDF and CDA patient population. While a number of investigators have studied the validity of SWAL-QOL within the ACDF population [22,24], others have detailed the ability of dysphagia to severely affect quality of life and act as a risk factor for depression and anxiety [25,26]. As profound as these results are, these studies were conducted primarily on cancer patients and individuals with gastroesophageal reflux disease. Other studies have alluded to the effect swallowing difficulties have on pain and disability and overall quality of life but were either restricted to clinical diagnosis of dysphagia [10], were restricted to deformity patients [11], or utilized a metric other than the SWAL-QOL survey [12]. Therefore, our study aims to address this gap in knowledge by establishing differences in the impact of dysphagia on quality of life between ACDF and CDA patients. Based on substantial previous literature, we hypothesize there will be comparable results regarding incidence of dysphagia but will differ on its impact on patient quality of life.

MATERIALS AND METHODS

1. Inclusion and Exclusion Criteria

In accordance with institutional ethical guidelines, both Institutional Review Board approval (IRB Approval No. ORA #14051301) and written patient informed consent were obtained prior to commencing the study. Eligible participants were identified through a retrospective review of a prospectively maintained surgical database for cervical spine procedures performed between November 2014 and September 2020. Patient inclusion criteria was set as individuals undergoing a primary, elective, single or multilevel ACDF or CDA. Individuals were excluded for undergoing a revision procedure or for a surgery indicated for traumatic, malignant, or infectious etiologies. The purpose of our exclusion criteria was to eliminate potential confounding variables that may significantly bias our final results. Additionally, patients who did not complete a preoperative SWAL-QOL survey were removed from the study. All patients were treated at the same academic tertiary medical institution by a single spine surgeon.

2. Patient Health Information

Demographic information (Table 1) regarding a patient's age, gender, body mass index (BMI), tobacco use, diabetic status, and insurance collected were recorded prior to surgery. Additionally, patient fitness for surgery and comorbidity burden were recorded as the American Society of Anesthesiologists physical classification and Charlson Comorbidity Index.

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Perioperative characteristics were also recorded (Table 2), which included preoperative spinal pathology, number of operative levels, operative level, use of an anterior cervical plate or stand alone interbody cage, operative duration (from first skin incision to final closure), estimated intraoperative blood loss (EBL), length of postoperative stay (LOS), and day of discharge. Each incidence of a postoperative complication was recorded, reviewed, and summarized (Table 3).

3. Patient Reported Outcomes

The primary outcome of interest of this study was dysphagia scores as evaluated by the SWAL-QOL survey, which is a 44-item questionnaire separated into 11 separate domains that assess the impact of swallowing difficulty on a patient's quality of life [17]. The individual domains include: dysphagia burden, eating duration, eating desire, symptom frequency, food selection, communication, fear, mental health, social, fatigue, and sleep. Each domain has a variable number of questions, which assess the severity of dysphagia's impact. All 11 domains are equally weighted to produce a total SWAL-QOL score (out of 100) where a lower score indicates worse symptoms of dysphagia and a higher score implies more favorable symptoms.

In addition to the SWAL-QOL questionnaire, patient neck and arm pain as well as neck disability due to pain were also evaluated using the Visual Analogue Scale (VAS) and Neck Disability Index (NDI). VAS is a continuous pain rating scale with higher values indicating worse pain. NDI is a survey adapted from Oswestry's Disability Index and evaluates severity of dysfunction due to pain across 10 different domains. Like SWAL-QOL, each domain equally contributes to an overall score (NDI=Total Score/Total Potential Score). A higher NDI score indicates worse disability. All PROMs were administered at preoperative and postoperative (6 weeks, 12-weeks, 6-months) timepoints using an Outcomes Based Electronic Research Database (OBERD, Columbia, MO) through a private patient portal.

4. Statistical Analysis

Prior to statistical analysis, patients were separated into groups according to which cervical procedure they underwent (ACDF vs. CDA). Differences in demographics and perioperative characteristics were evaluated using either a Student's t-test for continuous values or a chi-square test for categorical variables. Prevalence of postoperative complications were

Table 1. Patient demographics

Characteristic	Total (n = 161)	ACDF (n = 108)	CDA (n = 53)	p-value[a]
Age (mean ± SD, yr)	47.5 ± 10.3	48.5 ± 10.1	45.3 ± 10.5	0.067
BMI (mean ± SD, kg/m^2)	29.5 ± 5.4	29.6 ± 5.7	29.1 ± 4.5	0.576
Gender				0.931
Female	37.3% (60)	37.0% (40)	37.7% (20)	
Male	62.7% (101)	63.0% (68)	62.3% (33)	
Diabetic status				**0.009**
Non-diabetic	88.8% (143)	84.3% (91)	98.1% (52)	
Diabetic	11.2% (18)	15.7% (17)	1.9% (1)	
Smoking status				0.305
Non-smoker	88.8% (143)	87.0% (94)	92.5% (49)	
Smoker	11.2% (18)	13.0% (14)	7.5% (4)	
ASA classification				0.427
≤ 2	89.2% (124)	87.6% (78)	92.0% (46)	
> 2	10.8% (15)	12.4% (11)	8.0% (4)	
CCI score (mean ± SD)	1.1 ± 1.2	1.2 ± 1.3	0.5 ± 0.9	**0.012**
Insurance				0.251
Medicare/medicaid	3.1% (5)	1.9% (2)	5.7% (3)	
Workers' compensation	22.4% (36)	25.0% (27)	16.9% (9)	
Private/other	74.5% (120)	73.1% (79)	77.4% (41)	

Boldface indicates statistical significance.
ASA: American Society of Anesthesiologists, CCI: Charlson Comorbidity Index, SD: standard deviation.
[a]p-value of 0.05.

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Table 2. Perioperative characteristics

Characteristic	Total (n = 161)	ACDF (n = 108)	CDA (n = 53)	p-value[a]
Spinal pathology				
HNP	91.3% (147)	88.8% (95)	98.1% (52)	0.098
Central stenosis	55.3% (89)	52.8% (57)	60.4% (32)	0.362
Myeloradiculopathy	86.2% (137)	82.4% (89)	94.1% (48)	0.073
Number of levels				0.472
1-level	62.1% (100)	60.2% (65)	66.0% (35)	
2-levels	37.9% (61)	39.8% (43)	34.0% (18)	
Operative level(s)				0.771
C3-5	1.9% (3)	1.8% (2)	1.9% (1)	
C4-5	6.2% (10)	6.5% (7)	5.7% (3)	
C4-6	6.8% (11)	6.5% (7)	7.5% (4)	
C5-6	28.6% (46)	25.0% (27)	35.9% (19)	
C5-7	29.2% (47)	29.6% (32)	28.3% (15)	
C6-7	24.8% (40)	26.9% (29)	20.7% (11)	
C6-T1	1.2% (2)	1.9% (2)	0.0% (0)	
C7-T1	1.2% (2)	1.9% (2)	0.0% (0)	
Cervical plating				-
Stand alone cage	-	33.3% (36)	-	
Anterior plate	-	66.7% (72)	-	
Operative time (mean ± SD; min)	53.8 ± 17.0	55.9 ± 15.2	49.5 ± 19.7	**0.025**
Estimated blood loss (mean ± SD; mL)	27.9 ± 10.4	27.8 ± 11.0	28.4 ± 8.7	0.738
Length of stay (mean ± SD; hr)	10.5 ± 8.8	11.0 ± 9.0	9.1 ± 8.2	0.222
Discharge date				0.500
POD0	80.5% (120)	78.3% (83)	86.1% (37)	
POD1	18.8% (28)	20.7% (22)	14.0% (6)	
POD2	0.7% (1)	0.94% (1)	0.0% (0)	

Boldface indicates statistical significance.
HNP: herniated nucleus pulposus, SD: standard deviation.
[a]p-value of 0.05.

Table 3. Postoperative complications

Complication	Total (n = 161)	ACDF (n = 108)	CDA (n = 53)	p-value[a]
Urinary retention	0.6% (1)	0.0% (0)	1.9% (1)	0.579
Seizure	0.6% (1)	0.0% (0)	1.9% (1)	0.315
Tracheoesophageal hematoma	0.6% (1)	0.9% (1)	0.0% (0)	0.999
Atrial fibrillation	0.6% (1)	0.9% (1)	0.0% (0)	0.999
Total	2.5% (4)	1.8% (2)	3.8% (2)	0.598

[a]p-value was calculated using Fisher's exact test.

evaluated for differences between the two groups using a chi-square test. Differences in mean PROM scores between groups were evaluated using an unpaired Student's t-test. An unpaired Student's t-test was also used to evaluate intergroup differences at each timepoint for individual SWAL-QOL domain scores. A sub-analysis was also performed whereby the ACDF group was further sub-categorized according to use of an anterior cervical plate. Differences in mean overall PROM scores as well as the individual domains at each timepoint was then evaluated using an analysis of variance (ANOVA) and post-hoc Tukey test. Simple regression analysis was utilized to evaluate whether the number of fusion levels operated on were significantly associated with postoperative outcomes. All statistical tests were performed using StataIC (StataCorp LLC, College Station, TX) and had the α value set to 0.050 to reject the null hypothesis.

RESULTS

1. Study Cohort

An initial 312 patients were identified as eligible for this study and after inclusion and exclusion criteria were applied the final study cohort was 161 patients. Patients had a mean age of 47.5 years and mean BMI of 29.5 kg/m^2 with a majority being male (62.7%). A higher proportion of diabetics was observed in the ACDF group (p=0.009) and also had a higher mean CCI (1.2 vs. 0.5; p=0.012) (Table 1). The most prevalent preoperative spinal pathology was herniated nucleus pulposus (91.3%) and 86.2% of patients reported clinical symptoms in line with myeloradiculopathy. Majority of procedures were performed at a single level (62.1%) with the most common 1-level procedure performed at C5-6 (28.6%) and 2-level procedures at C5-7 (29.2%). The ACDF group had a significantly longer operative duration (p=0.025) (Table 2). A total of 4 postoperative complications were recorded: 1 patient had urinary retention, 1 patient has a seizure, 1 patient had a tracheoesophageal hematoma, and 1 patient with a history of paroxysmal atrial fibrillation experienced atrial fibrillation (Table 3).

2. Patient Reported Outcomes

At the preoperative timepoint, patients who underwent an ACDF procedure with use of a stand alone cage reported a SWAL-QOL score of 91.3±5.4. Patients who underwent an ACDF with use of an anterior cervical plate recorded a preoperative score of 90.3±7.2 and those who underwent a CDA had a score of 89.7±6.7. No significant differences in SWAL-QOL between all groups were demonstrated (p=0.362; p=0.534) (Table 4). Group and subgroup analysis also demonstrated no significant differences in preoperative VAS arm and NDI scores (p≥0.071, all); however, testing of subgroups revealed significant differences for VAS neck (p=0.011) (Table 4). Post-hoc testing demonstrated significant differences in mean preoperative VAS neck between ACDF-No plate and ACDF-Plate individuals (6.7±1.9 vs. 5.5±2.6) and ACDF-Plate and CDA (6.6±2.2 vs. 5.5±2.6). Postoperatively, no significant differenc-

Table 4. Patient reported outcomes by procedure type

PROM	ACDF-no plate (mean ± SD)	ACDF-plate (mean ± SD)	CDA (mean ± SD)	p-value[a]	p-value[b]	ACDF p-value[c]	CDA p-value[d]
SWAL-QOL							
Preoperative	91.3 ± 5.4 (36)	90.3 ± 7.2 (72)	89.7 ± 6.7 (53)	0.362	0.534	0.345	0.965
6-wk	90.4 ± 7.6 (27)	86.7 ± 12.0 (56)	88.9 ± 7.8 (35)	0.663	0.279	0.211	0.544
12-wk	92.9 ± 5.4 (20)	89.9 ± 8.8 (42)	91.7 ± 7.5 (42)	0.628	0.322	0.699	0.573
6-mo	94.5 ± 7.1 (14)	93.6 ± 5.7 (33)	89.7 ± 9.1 (24)	**0.022**	0.07	0.643	0.211
VAS neck							
Preoperative	**6.7 ± 1.9 (35)**	**5.5 ± 2.6 (55)**	**6.6 ± 2.2 (49)**	0.073	**0.011**	**0.022**	0.885
6-wk	3.1 ± 2.4 (31)	3.3 ± 2.6 (69)	3.0 ± 2.6 (34)	0.683	0.892	0.377	0.469
12-wk	2.5 ± 2.3 (30)	2.7 ± 2.5 (58)	2.4 ± 2.2 (37)	0.636	0.84	0.438	0.584
6-mo	2.9 ± 2.5 (27)	2.3 ± 2.3 (50)	2.7 ± 2.1 (21)	0.762	0.465	0.343	0.665
VAS arm							
Preoperative	6.5 ± 2.4 (35)	5.6 ± 2.3 (70)	5.6 ± 2.7 (49)	0.546	0.194	**0.046**	0.717
6-wk	2.3 ± 2.2 (31)	2.7 ± 2.6 (68)	2.9 ± 3.3 (34)	0.579	0.662	0.888	0.365
12-wk	2.2 ± 2.6 (30)	3.4 ± 3.3 (58)	2.7 ± 3.1 (37)	0.635	0.223	0.555	0.904
6-mo	2.2 ± 2.3 (26)	2.9 ± 2.9 (49)	2.7 ± 2.7 (21)	0.863	0.59	0.594	0.359
NDI							
Preoperative	40.1 ± 18.0 (35)	34.5 ± 19.5 (69)	42.1 ± 16.8 (49)	0.075	0.071	0.398	0.167
6-wk	29.7 ± 16.9 (31)	30.6 ± 19.7 (69)	26.2 ± 18.4 (34)	0.261	0.519	0.662	0.325
12-wk	24.0 ± 18.1 (30)	26.2 ± 20.5 (58)	21.4 ± 16.4 (37)	0.275	0.485	0.919	0.740
6-mo	20.3 ± 17.0 (26)	19.2 ± 19.1 (49)	23.6 ± 14.5 (21)	0.355	0.631	0.737	0.304

Boldface indicates statistical significance.
[a]p-values calculated using Student's t-test to evaluate differences between CDA and ACDF groups.
[b]p-values calculated using ANOVA to determine differences between all groups.
[c]p-values calculated using simple regression analysis of PROMs by number of ACDF fusion levels.
[d]p-values calculated using simple regression analysis of PROMs by number of CDA fusion levels.

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es in dysphagia scores between groups were demonstrated except for at 6-months where CDA patients had a worse score compared to ACDF patients (p=0.022). No significant associations were found by linear regression analysis between the number of levels operated on and postoperative PROMs (Table 4).

3. SWAL-QOL Domains

Evaluation of score for each domain demonstrated no significant differences at the preoperative timepoint both when comparing groups and subgroups (p≥0.073, all) (Table 5). At 6 weeks follow-up, ACDF and CDA patients again did not demonstrate any significant differences in any of the SWAL-QOL domains. However, at the 12 week timepoint ACDF patients demonstrated a significant difference in scores for the "food selection" domain with patients receiving an anterior cervical plate reporting a worse value (p=0.036) (Table 6). At the 6-month timepoint, ACDF patients reported a significantly better score for both "Fatigue" and "Sleep" domains. Further subgroup analysis demonstrated that both ACDF subgroups (plate and stand alone cage) demonstrated significantly better "Fatigue" scores compared to the CDA group (p≤0.038). A similar observation was noted for the "Sleep" domain with again both group and subgroup analysis demonstrating a better score with ACDF patients compared to CDA patients (p<0.001; p≤0.003) (Table 6). None of the SWAL-QOL domains were significantly associated with number of fusion levels, other than symptom frequency at 6-weeks following ACDF (p=0.032) (Table 6).

DISCUSSION

Anterior cervical spine surgery is a highly effective treatment for intractable neck pain and disability [27]. One of the most common complications linked to these operations is oropharyngeal dysphagia [28], which has been previously assessed in ACDF and CDA populations subjectively using the Bazaz Scale, MD Anderson Dysphagia Inventory, the Hospital for Special Surgery Dysphagia and Dysphonia Inventory, and the Dysphagia Short Questionnaire [7,18,20]. However, few studies have evaluated swallowing difficulty using the SWAL-QOL questionnaire, and even fewer have longitudinally compared this outcome measure in cervical fusion versus arthroplasty patients [17,22,29-31]. Thus, after assessing SWAL-QOL in CDA and ACDF patients, this study reports similar overall outcome scores between groups with longitudinal differences in fatigue and sleep in relation to dysphagia.

After initial analysis of patient demographics and perioperative characteristics, significant differences were found in diabetes status, CCI score, and operative time between procedure groups. However, these variances likely did not affect long term postoperative dysphagia occurrence, as previous literature does not report CCI score or diabetes as risk factors [32,33]. In the present study, a significantly shorter operative time was seen for CDA than ACDF procedures, which is in contrast to

Table 5. Preoperative SWAL-QOL domains by procedure type

SWAL-QOL	ACDF-no plate (mean±SD)	ACDF-plate (mean±SD)	CDA (mean±SD)	p-value[a]	p-value[b]	ACDF p-value[c]	CDA p-value[d]
Preoperative							
Burden	97.2±8.1	95.6±12.7	95.4±13.3	0.718	0.775	0.774	0.693
Eating duration	98.8±4.6	95.5±12.9	97.9±5.9	0.439	0.177	0.123	0.407
Eating desire	97.9±5.5	95.8±10.4	96.7±5.8	0.891	0.438	0.067	0.204
Frequency	95.1±7.5	93.4±9.8	92.6±9.6	0.409	0.467	0.713	0.886
Food selection	96.7±9.3	94.3±11.2	96.6±7.3	0.353	0.319	0.368	0.729
Communication	98.8±3.9	98.4±4.6	96.9±6.9	0.073	0.187	0.990	0.519
Fear	98.7±3.8	98.4±4.9	97.4±6.0	0.215	0.439	0.561	0.500
Mental health	98.7±4.2	97.9±8.5	97.2±7.9	0.427	0.632	0.114	0.435
Social	97.6±6.4	97.4±8.5	97.9±5.9	0.694	0.923	0.374	0.586
Fatigue	65.5±17.5	67.6±20.1	61.5±21.7	0.106	0.239	0.946	0.720
Sleep	58.6±25.2	59.4±26.1	55.6±27.9	0.431	0.725	0.854	0.552

[a]p-values calculated using Student's t-test to evaluate differences between CDA and ACDF groups.
[b]p-values calculated using ANOVA to determine differences between all groups.
[c]p-values calculated using simple regression analysis of PROMs by number of ACDF fusion levels.
[d]p-values calculated using simple regression analysis of PROMs by number of CDA fusion levels.

Table 6. Postoperative SWAL-QOL domains by procedure type

SWAL-QOL	ACDF-no plate (mean ± SD)	ACDF-plate (mean ± SD)	CDA (mean ± SD)	p-value[a]	p-value[b]	ACDF p-value[c]	CDA p-value[d]
6-wk postop							
Burden	89.2 ± 17.3	85.5 ± 19.7	85.7 ± 15.7	0.777	0.654	0.441	0.466
Eating duration	96.2 ± 10.0	90.0 ± 19.6	93.4 ± 13.9	0.676	0.237	0.432	0.052
Eating desire	98.2 ± 7.7	94.1 ± 13.9	96.9 ± 7.6	0.509	0.219	0.302	0.803
Frequency	92.0 ± 7.9	89.1 ± 9.9	89.3 ± 7.6	0.696	0.335	**0.032**	0.957
Food selection	93.7 ± 11.1	90.3 ± 16.9	92.2 ± 11.4	0.771	0.582	0.382	0.291
Communication	96.7 ± 8.3	93.2 ± 15.0	98.0 ± 6.3	0.122	0.137	0.717	0.287
Fear	97.2 ± 5.3	94.1 ± 11.2	93.7 ± 11.1	0.475	0.346	0.131	0.217
Mental health	92.4 ± 13.9	91.7 ± 15.3	91.4 ± 14.2	0.859	0.963	0.110	0.789
Social	95.3 ± 9.2	90.4 ± 18.3	95.8 ± 9.9	0.173	0.135	0.493	0.730
Fatigue	70.8 ± 33.3	69.9 ± 18.9	71.2 ± 17.5	0.779	0.937	0.965	0.928
Sleep	72.5 ± 15.5	66.0 ± 26.8	69.4 ± 20.5	0.790	0.464	0.371	0.196
12-wk postop							
Burden	98.0 ± 5.2	92.6 ± 11.6	94.3 ± 10.3	0.973	0.158	0.156	0.896
Eating duration	99.0 ± 3.1	95.0 ± 11.5	97.1 ± 8.6	0.649	0.259	0.440	0.401
Eating desire	98.0 ± 6.5	95.7 ± 11.7	95.7 ± 8.3	0.600	0.595	0.583	0.745
Frequency	93.5 ± 8.1	90.6 ± 10.5	93.1 ± 8.9	0.437	0.406	0.630	0.303
Food selection	**99.0 ± 3.1**	**91.9 ± 13.6**	95.9 ± 9.1	0.417	**0.036**	0.619	0.503
Communication	95.5 ± 8.3	96.7 ± 7.2	97.3 ± 7.6	0.473	0.660	0.308	0.201
Fear	97.5 ± 7.1	94.6 ± 8.9	95.4 ± 9.0	0.959	0.481	0.875	0.547
Mental health	98.2 ± 4.6	93.5 ± 12.0	96.2 ± 9.3	0.563	0.191	0.467	0.615
Social	98.0 ± 6.1	94.0 ± 10.6	96.2 ± 8.3	0.586	0.234	0.657	0.539
Fatigue	73.0 ± 19.6	73.9 ± 18.5	75.1 ± 17.4	0.696	0.909	0.608	0.911
Sleep	73.0 ± 21.5	70.9 ± 21.7	70.9 ± 22.8	0.881	0.933	0.608	0.737
6-mo postop							
Burden	97.8 ± 5.7	95.7 ± 10.3	95.0 ± 14.7	0.628	0.754	0.576	0.349
Eating duration	98.5 ± 5.3	95.4 ± 10.3	97.0 ± 8.6	0.757	0.530	0.697	0.505
Eating desire	99.0 ± 3.5	98.6 ± 5.2	97.2 ± 6.5	0.271	0.528	0.454	0.091
Frequency	96.5 ± 5.4	95.1 ± 6.2	92.8 ± 10.1	0.171	0.328	0.946	0.847
Food selection	98.5 ± 5.3	97.2 ± 7.6	92.9 ± 14.2	0.064	0.167	0.333	0.376
Communication	97.1 ± 10.7	98.4 ± 5.1	97.9 ± 7.2	0.925	0.839	0.245	0.262
Fear	99.6 ± 1.3	97.4 ± 6.7	95.6 ± 10.0	0.190	0.275	0.391	0.274
Mental health	97.7 ± 7.4	96.6 ± 8.8	95.6 ± 11.3	0.595	0.813	0.816	0.218
Social	97.1 ± 7.3	98.1 ± 5.8	95.6 ± 12.3	0.337	0.599	0.843	0.199
Fatigue	**79.0 ± 18.8**	**78.7 ± 16.8**	**66.6 ± 20.7**	**0.011**	**0.038**	0.197	0.769
Sleep	**79.3 ± 22.0**	**79.0 ± 18.1**	**60.4 ± 23.6**	**< 0.001**	**0.003**	0.573	0.306

Boldface indicates statistical significance.
[a]p-values calculated using Student's t-test to evaluate differences between CDA and ACDF groups.
[b]p-values calculated using ANOVA to determine differences between all groups.
[c]p-values calculated using simple regression analysis of PROMs by number of ACDF fusion levels.
[d]p-values calculated using simple regression analysis of PROMs by number of CDA fusion levels.

previous literature reporting either longer operative time for CDA as compared to ACDF or no differences in duration of surgery [4,34]. This may be explained by the fact that our ACDF cohort included a larger proportion of patients who underwent plate placement, which has been previously shown to induce longer operative times than the stand alone cage method [35]. Additionally, procedure duration in orthopaedic surgeries is itself dependent on factors such as physician experience and hospital workflow as well [36]. Regardless, it is unlikely that this difference in operative time solely influenced dysphagia scores in the long-term periods evaluated in this study, as any potential effects have previously been shown only in the immediate

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postoperative days 1 and 2 [37].

In addition to these baseline characteristics, this study also considered improvement of clinical outcomes such as pain and disability. Preoperatively, VAS neck pain scores were significantly poorer for the CDA group than ACDF patients. This is possibly related to the fact that a greater percentage of CDA patients had an initial pathology of myeloradiculopathy, which may induce more severe pain in the afflicted due to compression of both the nerve roots and spinal canal [38]. However, this cannot be concluded with certainty as severity of symptoms and its relationship with radiographic findings was not assessed. Postoperatively, no significant differences between groups for the VAS neck, VAS arm, and NDI scores were found at any time points. Many investigations comparing ACDF and CDA have reported similar quality of life outcomes through long term follow ups of 2 years [39-41]. A few studies do report, though, that NDI and neck pain scores may be statistically better in those undergoing CDA rather than ACDF [42,43]. These differences may arise as a result of an inherent advantage of the CDA surgery, in that it allows patients to have a better postoperative range of motion than what is experienced after cervical fusion [34]. With range of motion preserved, these patients may be able to experience improvements in disability and neck pain to a greater extent.

Along with analysis of the former postoperative outcomes, dysphagia was quantified through SWAL-QOL scores at all timepoints. Overall, there were no differences between the ACDF and CDA groups in dysphagia outcomes, other than at the 6 month time point where CDA patients reported significantly poorer scores than ACDF patients. Interestingly, prior studies using other dysphagia assessment tools have reported lower incidences of postoperative dysphagia over the 1 to 2 years following CDA versus ACDF [44,45]. Although, our findings may be supported by McAfee et al. [46] who reported an increase in dysphagia in 42% of arthroplasty patients at the 3 month time point before eventual resolution at 1 year. Perhaps these fluctuating incidences are due to the transient nature of the condition itself, as dysphagia may newly arise at any point in the postoperative period. For example, swallowing difficulty may occur immediately after operation or even more than a month following anterior cervical spine surgery [28]. Future studies may provide further clarification of this complication's progression by continuing to track SWAL-QOL scores further out to 1 or 2 years postoperatively. Another factor that may have influenced this finding is the low number of patients in the CDA group who completed the SWAL-QOL questionnaire up to 6 months. As such, patients with extremely low scores may have a greater effect on the overall score for the group at this time point, which is reflected by the high standard deviation as well.

Dysphagia incidence was analyzed further through specific domains in the SWAL-QOL survey, which represents various aspects of daily life, and significant differences were observed at 12 weeks and 6 months. In the Food Selection domain, the ACDF no plate group had higher scores than the anterior plate group at 12 weeks. As previously reported in literature, this may be a result of the reports that suggest ACDF performed with a stand alone cage is superior in reducing dysphagia related complications at earlier time points than the ACDF with an anterior plate method [47,48]. With less difficulty in swallowing, patients may be able to be more liberal in selecting which foods to intake. However, other studies have conversely demonstrated that dysphagia was not significantly different between ACDF with and without plate groups [24,35,49]. Though, due to the fact that only one of these studies utilized SWAL-QOL as an assessment tool, further evaluation with larger ACDF cohorts using this psychometric tool are required for greater elucidation of differences within this domain. Better comprehension of the effects on this attribute of a patient's quality of life can help enhance the guidance provided to individuals during their recovery period.

Cervical spine patients also presented with different mean values for fatigue and sleep domains, both with lower scores in the CDA group, at the 6 month follow up. Additionally, these patients also had poorer baseline scores in those two domains as well and, as a result, may have required a greater magnitude of dysphagia improvement to ameliorate their fatigue and sleep. It is possible that this trend is related to overall swallowing difficulty as CDA patients also reported worse overall SWAL-QOL scores at 6 months. A previous study also indicated that patients who underwent CDA had higher rates of persistent postoperative neck pain than ACDF patients at 9 months post op [50]. It is plausible that given the CDA group also reported initially higher VAS neck pain scores, some residual neck pain may have had adverse implications on sleep and fatigue. Further investigations must specifically consider the interplay of dysphagia or pain with sleep and fatigue in CDA versus ACDF patient populations.

ACDF and CDA are both generally effective surgical treatments in terms of overall improvements in postoperative quality of life outcomes including dysphagia. However, specific aspects of life such as sleep and fatigue related to swallowing issues may be experienced differently by those undergoing CDA procedures at long term timepoints. The present study adds to the existing literature on the safety and efficacy of utilizing CDA as a result of comparable clinical outcomes to ACDF. To the author's knowledge, this study is among the first to provide greater information on the utility of the SWAL-QOL questionnaire for evaluation of not only dysphagia but also of particular aspects of quality of life related to this complication for two types of cervical spine surgeries. Physicians may then have greater information to consider incorporating SWAL-QOL, in whole or abridged [22], into their preoperative and postoperative assessment of cervical spine candidates for either arthroplasty or fusion surgery. Through evaluations with this survey, clinicians can provide more detailed preoperative patient education on possible dysphagia occurrence and any repercussions on patients' daily lives.

Limitations

There are a few limitations to the present study that must be considered. The study's design itself lends to possible observer and selection bias, as is the case with any retrospective investigation. Additionally, a level of responder or recall bias for long term timepoints may be present, as self reported surveys were utilized to assess postoperative outcomes. Given the lengthy nature of the questionnaire, this study was also limited by diminishing patient compliance further into the postoperative period. This in turn may restrict our ability to determine the longitudinal impact of dysphagia within the two surgical populations. Potentially the implementation of an abridge yet valid SWAL-QOL may adequately serve the same purpose while not jeopardize the quality of information collected [22]. Though dysphagia was not clinically assessed and diagnosed, subjective measures such as patient surveys may be more amenable to accurately evaluating sensations of swallowing difficulty. Furthermore, since sleep and fatigue SWAL-QOL scales measure general quality of health and are not dysphagia-specific, confounding variables such as patient comorbidities may have provided significant bias. It is worthwhile mentioning that patients with single- and double-level procedures were included, which may introduce clinical heterogeneity and data bias. We addressed this limitation by performing simple regression analysis, which demonstrated no significant relationship between postoperative outcomes and number of levels operated on, other than for symptom frequency at 6-weeks following ACDF. Moreover, all patients in our cohort underwent surgery at a single institution with one surgeon, which may limit the applicability of our results to larger, general populations. Future comparative studies should include multiple surgeons in multicentered settings to strengthen the results of this study.

CONCLUSION

Postoperative outcomes of pain, disability, and dysphagia were generally similar between patients undergoing ACDF or CDA procedures. At long term follow ups, poorer fatigue and sleep as measured by the SWAL-QOL questionnaire domains were reported by CDA patients in comparison to those undergoing ACDF. Although quality of life outcomes are generally comparable between CDA and ACDF patients, those who undergo cervical disc arthroplasty may experience worse fatigue and sleep possibly in relation to dysphagia at longitudinal timepoints.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Epstein NE. A review of complication rates for anterior cervical diskectomy and fusion (ACDF). Surg Neurol Int 2019;10:100.
2. Buttermann GR. Anterior cervical discectomy and fusion outcomes over 10 years: a prospective study. Spine (Phila Pa 1976) 2018;43:207–214.
3. Gao F, Mao T, Sun W, Guo W, Wang Y, Li Z, et al. An updated meta-analysis comparing artificial cervical disc arthroplasty (CDA) versus anterior cervical discectomy and fusion (ACDF) for the treatment of cervical degenerative disc disease (CDDD). Spine (Phila Pa 1976) 2015;40:1816–1823.
4. Xie L, Liu M, Ding F, Li P, Ma D. Cervical disc arthroplasty (CDA) versus anterior cervical discectomy and fusion (ACDF) in symptomatic cervical degenerative disc diseases (CDDDs): an updated meta-analysis of prospective randomized controlled trials (RCTs). Springerplus 2016;5:1188.
5. Saifi C, Fein AW, Cazzulino A, Lehman RA, Phillips FM, An HS, et al. Trends in resource utilization and rate of cervical disc arthroplasty and anterior cervical discectomy and fusion throughout the United States from 2006 to 2013. Spine J 2018;18:1022–1029.
6. Campbell PG, Yadla S, Malone J, Zussman B, Maltenfort MG, Sharan AD, et al. Early complications related to approach in cervical spine surgery: single-center prospective study. World Neurosurg 2010;74:363–368.

 https://doi.org/10.21182/jmisst.2021.00367

7. Skeppholm M, Ingebro C, Engström T, Olerud C. The Dysphagia Short Questionnaire: an instrument for evaluation of dysphagia: a validation study with 12 months, follow-up after anterior cervical spine surgery. Spine (Phila Pa 1976) 2012;37:996–1002.
8. Shriver MF, Lewis DJ, Kshettry VR, Rosenbaum BP, Benzel EC, Mroz TE. Dysphagia rates after anterior cervical diskectomy and fusion: a systematic review and meta-analysis. Global Spine J 2017;7:95–103.
9. Cho SK, Lu Y, Lee DH. Dysphagia following anterior cervical spinal surgery: a systematic review. Bone Joint J 2013;95:868–873.
10. Riley LH 3rd, Skolasky RL, Albert TJ, Vaccaro AR, Heller JG. Dysphagia after anterior cervical decompression and fusion: prevalence and risk factors from a longitudinal cohort study. Spine (Phila Pa 1976) 2005;30:2564–2569.
11. Iyer S, Kim HJ, Bao H, Smith JS, Protopsaltis TS, Mundis GM, et al., International Spine Study Group (ISSG). Cervical deformity patients have baseline swallowing dysfunction but surgery does not increase dysphagia at 3 months: results from a prospective cohort study. Global Spine J 2019;9:532–539.
12. Rosenthal BD, McCarthy MH, Bhatt S, Savage JW, Singh K, Hsu WK, et al. A comparison of patient-centered outcome measures to evaluate dysphagia and dysphonia after anterior cervical discectomy and fusion. J Am Acad Orthop Surg 2019;27:848–853.
13. Lee MJ, Bazaz R, Furey CG, Yoo J. Risk factors for dysphagia after anterior cervical spine surgery: a two-year prospective cohort study. Spine J 2007;7:141–147.
14. Yue WM, Brodner W, Highland TR. Persistent swallowing and voice problems after anterior cervical discectomy and fusion with allograft and plating: a 5- to 11-year follow-up study. Eur Spine J 2005;14:677–682.
15. Ramsey DJ, Smithard DG, Kalra L. Early assessments of dysphagia and aspiration risk in acute stroke patients. Stroke 2003;34:1252–1257.
16. O'Horo JC, Rogus-Pulia N, Garcia-Arguello L, Robbins J, Safdar N. Bedside diagnosis of dysphagia: a systematic review. J Hosp Med 2015;10:256–265.
17. McHorney CA, Robbins J, Lomax K, Rosenbek JC, Chignell K, Kramer AE, et al. The SWAL-QOL and SWAL-CARE outcomes tool for oropharyngeal dysphagia in adults: III. Documentation of reliability and validity. Dysphagia 2002;17:97–114.
18. Hughes AP, Salzmann SN, Aguwa OK, Miller CO, Duculan R, Shue J, et al. HSS dysphagia and dysphonia inventory (HSS-DDI) following anterior cervical fusion: patient-derived, validated, condition-specific patient-reported outcome measure outperforms existing indices. J Bone Joint Surg Am 2018;100:e66.
19. Chen AY, Frankowski R, Bishop-Leone J, Hebert T, Leyk S, Lewin J, et al. The development and validation of a dysphagia-specific quality-of-life questionnaire for patients with head and neck cancer: the M. D. Anderson dysphagia inventory. Arch Otolaryngol Head Neck Surg 2001;127:870–876.
20. Bazaz R, Lee MJ, Yoo JU. Incidence of dysphagia after anterior cervical spine surgery: a prospective study. Spine (Phila Pa 1976) 2002;27:2453–2458.
21. Dellon ES, Irani AM, Hill MR, Hirano I. Development and field testing of a novel patient-reported outcome measure of dysphagia in patients with eosinophilic esophagitis. Aliment Pharmacol Ther 2013;38:634–642.
22. Mayo BC, Massel DH, Bohl DD, Patel DV, Khechen B, Haws BE, et al. Dysphagia following anterior cervical spine surgery: assessment using an abridged SWAL-QOL. Int J Spine Surg 2019;13:102–109.
23. Okano I, Salzmann SN, Ortiz Miller C, Hoshino Y, Oezel L, Shue J, et al. Risk factors for postoperative dysphagia and dysphonia following anterior cervical spine surgery: a comprehensive study utilizing the hospital for special surgery dysphagia and dysphonia inventory (HSS-DDI). Spine J 2021;21:1080–1088.
24. Haws BE, Khechen B, Patel DV, Yoo JS, Guntin JA, Cardinal KL, et al. Swallowing function following anterior cervical discectomy and fusion with and without anterior plating: a SWAL-QOL (swallowing-quality of life) and radiographic assessment. Neurospine 2019;16:601–607.
25. Eslick GD, Talley NJ. Dysphagia: epidemiology, risk factors and impact on quality of life--a population-based study. Aliment Pharmacol Ther 2008;27:971–979.
26. Finizia C, Rudberg I, Bergqvist H, Rydén A. A cross-sectional validation study of the Swedish version of SWAL-QOL. Dysphagia 2012;27:325–335.
27. Sugawara T. Anterior cervical spine surgery for degenerative disease: a review. Neurol Med Chir (Tokyo) 2015;55:540–546.
28. Anderson KK, Arnold PM. Oropharyngeal dysphagia after anterior cervical spine surgery: a review. Global Spine J 2013;3:273–286.
29. Siska PA, Ponnappan RK, Hohl JB, Lee JY, Kang JD, Donaldson WF 3rd. Dysphagia after anterior cervical spine surgery: a prospective study using the swallowing-quality of life questionnaire and analysis of patient comorbidities. Spine (Phila Pa 1976) 2011;36:1387–1391.
30. Kukreja S, Ahmed OI, Haydel J, Nanda A, Sin AH. Complica-

tions of anterior cervical fusion using a low-dose recombinant human bone morphogenetic protein-2. Korean J Spine 2015;12:68–74.
31. Shi S, Li XF, Zhao QT, Yang LL, Liu ZD, Yuan W. Risk factors for dysphagia after single-level anterior cervical decompression with arthroplasty or fusion: a prospective study comparing 2 zero-profile implants. World Neurosurg 2016;95:148–155.
32. Singh K, Marquez-Lara A, Nandyala SV, Patel AA, Fineberg SJ. Incidence and risk factors for dysphagia after anterior cervical fusion. Spine (Phila Pa 1976) 2013;38:1820–1825.
33. Smith-Hammond CA, New KC, Pietrobon R, Curtis DJ, Scharver CH, Turner DA. Prospective analysis of incidence and risk factors of dysphagia in spine surgery patients: comparison of anterior cervical, posterior cervical, and lumbar procedures. Spine (Phila Pa 1976) 2004;29:1441–1446.
34. Zou S, Gao J, Xu B, Lu X, Han Y, Meng H. Anterior cervical discectomy and fusion (ACDF) versus cervical disc arthroplasty (CDA) for two contiguous levels cervical disc degenerative disease: a meta-analysis of randomized controlled trials. Eur Spine J 2017;26:985–997.
35. Nemoto O, Kitada A, Naitou S, Tachibana A, Ito Y, Fujikawa A. Stand-alone anchored cage versus cage with plating for single-level anterior cervical discectomy and fusion: a prospective, randomized, controlled study with a 2-year follow-up. Eur J Orthop Surg Traumatol 2015;25 Suppl 1:S127–S134.
36. Badawy M, Espehaug B, Fenstad AM, Indrekvam K, Dale H, Havelin LI, et al. Patient and surgical factors affecting procedure duration and revision risk due to deep infection in primary total knee arthroplasty. BMC Musculoskelet Disord 2017;18:544.
37. Liu JM, Tong WL, Chen XY, Zhou Y, Chen WZ, Huang SH, et al. The incidences and risk factors related to early dysphagia after anterior cervical spine surgery: a prospective study. PLoS One 2017;12:e0173364.
38. McCartney S, Baskerville R, Blagg S, McCartney D. Cervical radiculopathy and cervical myelopathy: diagnosis and management in primary care. Br J Gen Pract 2018;68:44–46.
39. Skeppholm M, Lindgren L, Henriques T, Vavruch L, Löfgren H, Olerud C. The Discover artificial disc replacement versus fusion in cervical radiculopathy--a randomized controlled outcome trial with 2-year follow-up. Spine J 2015;15:1284–1294.
40. Donk RD, Verbeek ALM, Verhagen WIM, Groenewoud H, Hosman AJF, Bartels RHMA. What's the best surgical treatment for patients with cervical radiculopathy due to single-level degenerative disease? A randomized controlled trial. PLoS One 2017;12:e0183603.
41. Hou Y, Liu Y, Yuan W, Wang X, Chen H, Yang L, et al. Cervical kinematics and radiological changes after Discover artificial disc replacement versus fusion. Spine J 2014;14:867–877.
42. Gornet MF, Lanman TH, Burkus JK, Dryer RF, McConnell JR, Hodges SD, et al. Two-level cervical disc arthroplasty versus anterior cervical discectomy and fusion: 10-year outcomes of a prospective, randomized investigational device exemption clinical trial. J Neurosurg Spine 2019;31:508–518.
43. Davis RJ, Nunley PD, Kim KD, Hisey MS, Jackson RJ, Bae HW, et al. Two-level total disc replacement with Mobi-C cervical artificial disc versus anterior discectomy and fusion: a prospective, randomized, controlled multicenter clinical trial with 4-year follow-up results. J Neurosurg Spine 2015;22:15–25.
44. Segebarth B, Datta JC, Darden B, Janssen ME, Murrey DB, Rhyne A, et al. Incidence of dysphagia comparing cervical arthroplasty and ACDF. SAS J 2010;4:3–8.
45. Skeppholm M, Olerud C. Comparison of dysphagia between cervical artificial disc replacement and fusion: data from a randomized controlled study with two years of follow-up. Spine (Phila Pa 1976) 2013;38:E1507–E1510.
46. McAfee PC, Cappuccino A, Cunningham BW, Devine JG, Phillips FM, Regan JJ, et al. Lower incidence of dysphagia with cervical arthroplasty compared with ACDF in a prospective randomized clinical trial. J Spinal Disord Tech 2010;23:1–8.
47. Hofstetter CP, Kesavabhotla K, Boockvar JA. Zero-profile anchored spacer reduces rate of dysphagia compared with ACDF with anterior plating. J Spinal Disord Tech 2015;28:E284–E290.
48. Shin JS, Oh SH, Cho PG. Surgical outcome of a zero-profile device comparing with stand-alone cage and anterior cervical plate with iliac bone graft in the anterior cervical discectomy and fusion. Korean J Spine 2014;11:169–177.
49. O'Donohoe TJ, Mililli L, Magee A, Thien C, Wang YY. Effect of the presence and type of plate augmentation on postoperative dysphagia among adult patients undergoing elective anterior cervical discectomy and fusion for spondylosis: a randomized trial. Neurospine 2020;17:174–183.
50. Tracey RW, Kang DG, Cody JP, Wagner SC, Rosner MK, Lehman RA Jr. Outcomes of single-level cervical disc arthroplasty versus anterior cervical discectomy and fusion. J Clin Neurosci 2014;21:1905–1908.

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Unilateral Biportal Endoscopic Translaminar Keyhole Approach to Treat High-grade Up-migrated Lumbar Disc Herniation: Technical Note

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The incidence of lumbar disc fragment migration is approximately 35%–72% of which 34% are high-grade up-migrated discs. Translaminar keyhole approach is a minimally invasive and true tissue sparing technique which has been applied to approach migrated disc herniation. The unilateral biportal endoscopic approach is an emerging technique among endoscopic spine surgery that combines the advantages of microscopic surgery with endoscopic surgery. In this technical report we demonstrate the surgical technique of performing the translaminar keyhole approach with unilateral biportal endoscopic spine surgery to treat high-grade up-migrated discs. As far as we know, this is the first technical report of unilateral biportal endoscopy with translaminar keyhole approach to treat high-grade up migrated lumbar disc herniation.

Key Words: Disc herniation, Intervertebral disc, Lumbar disc disease, Minimally invasive surgical procedures

INTRODUCTION

The incidence of lumbar disc fragment migration is approximately 35%–72%, of which, 34% are high-grade migrated discs [1]. The treatment of migrated disc herniation requires laminotomies, interlaminectomies or partial or total facetectomies [2]. However, these surgical procedures may alter normal spinal segment biomechanics, leading to an iatrogenic instability, worsening patients' back pain symptoms and requiring fusion surgery [2,3]. Translaminar approach is a minimally invasive and true tissue-sparing technique which has been applied to approach migrated disc herniation [4]. Unilateral biportal endoscopy (UBE) is an emerging technique among minimally invasive spinal surgery. By using 2 portals, high resolution and magnified visualization is possible with simultaneous free handling and angulation of surgical instruments without crowding of the instruments [1]. Minimal anatomical disruption by UBE with the benefit of translaminar approach to treat the up-migrated lumbar disc herniations allows access to the surgeon to difficult areas, without compromising segmental spinal stability. As far as we know, there are few journals of uniportal endoscopic spine surgery by translaminar keyhole approach, but this is the first technical report of UBE utilizing translaminar keyhole approach for high-grade up migrated lumbar disc herniation.

Surgical Technique

The exact location of migrated disc fragment and the ideal keyhole trajectory are planned with preoperative images, such as anteroposterior and lateral radiographs, computed tomography (CT) and three-dimensional (3D) CT scans, magnetic resonance imaging (MRI), and MRI with myelogram (Figure 1). The target point was located under fluoroscopy. Two skin incisions were made above and below the target point, slightly separated from the midline (Figure 2); a 6–8-mm incision was made for the endoscope portal and an 8–10-mm incision for the working portal. The average distance between the portals was 2 cm. After introducing the 0° endoscope, a saline irrigation pump was connected to the viewing portal and set to a pressure of 30 mmHg. Continuous irrigation was essential to prevent excessive elevation of epidural pressure. Working space was created through working portal using forceps and radiofrequency (RF) ablation probes (RF® Ablation system, Stryker Kalamazoo, MI, USA) to contract the connective tissue until the bony surface of the lamina was exposed. The first landmark that was localized was the isthmus followed by the exact target point to drill. Before drilling the keyhole, it is very important to spare at least 3 mm of the lateral border of the isthmus to avoid unwanted fracture of the pars interarticularis causing iatrogenic instability [5]. The 5–7-mm translaminar keyhole was drilled using high-speed diamond burr on the lamina. The drilling in this area was performed with caution since there is no ligament flavum in this area, and the drill could enter directly to the epidural space. After removal of the thin shell of inner cortical bone, epidural fat, and a small portion of the ligament flavum was seen in the caudal margin of the keyhole. This point was considered as the second landmark and was cautiously drilled to approach the axillary portion to prevent injury of the thecal sac or the nerve root. Migrated discs are usually identified at this point,

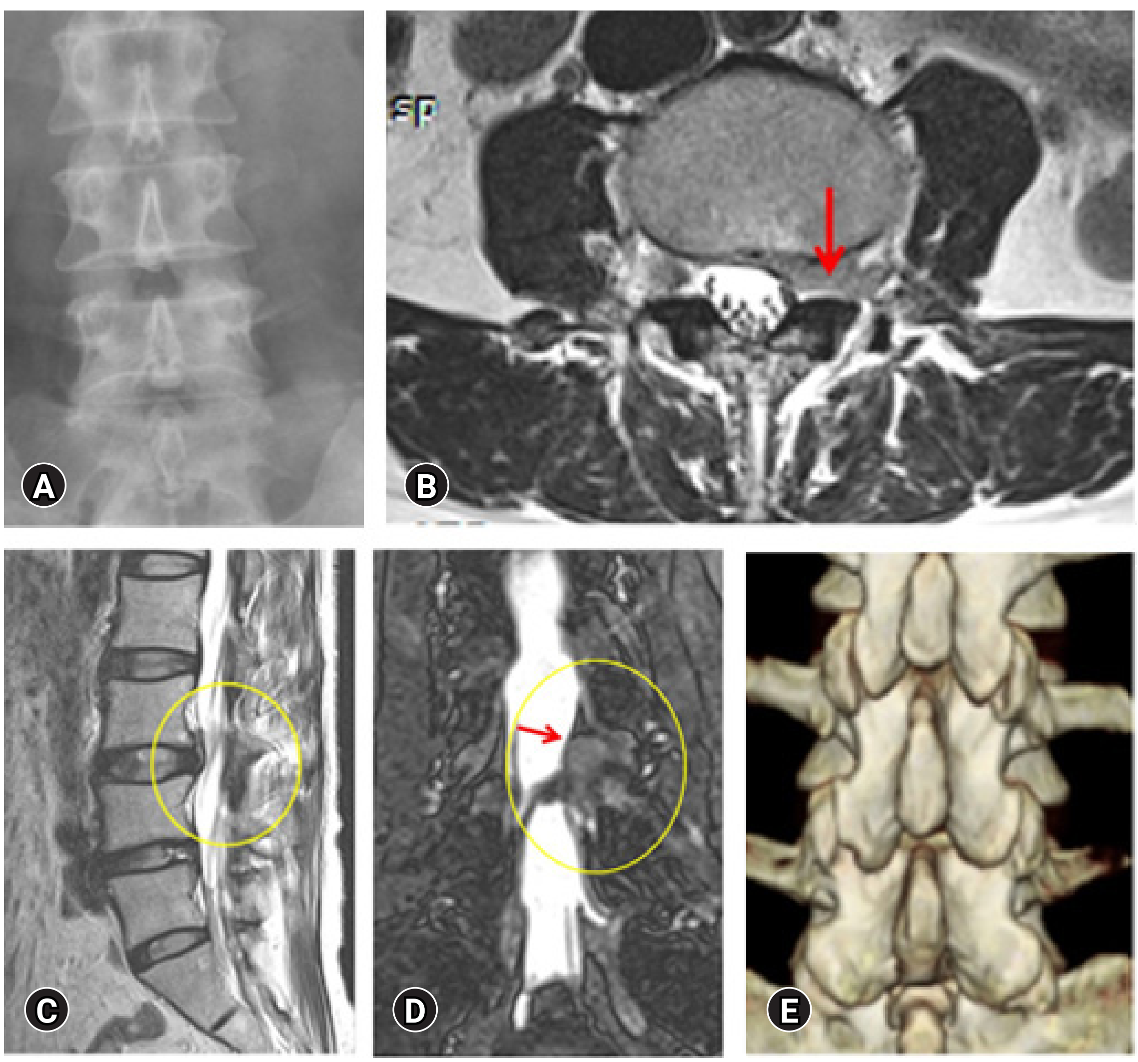

Figure 1. Different preoperative images that helps to localize the exact position of up-migrated disc and plan the exact target point of keyhole. (A) X-Ray, (B) MRI Axial, Red arrow showing migrated disc fragment. (C) MRI Saggital, Yellow circle showing migrated disc fragment (D) Myelogram, Yellow circle and red arrow showing migrated disc fragment (E) 3D CT.

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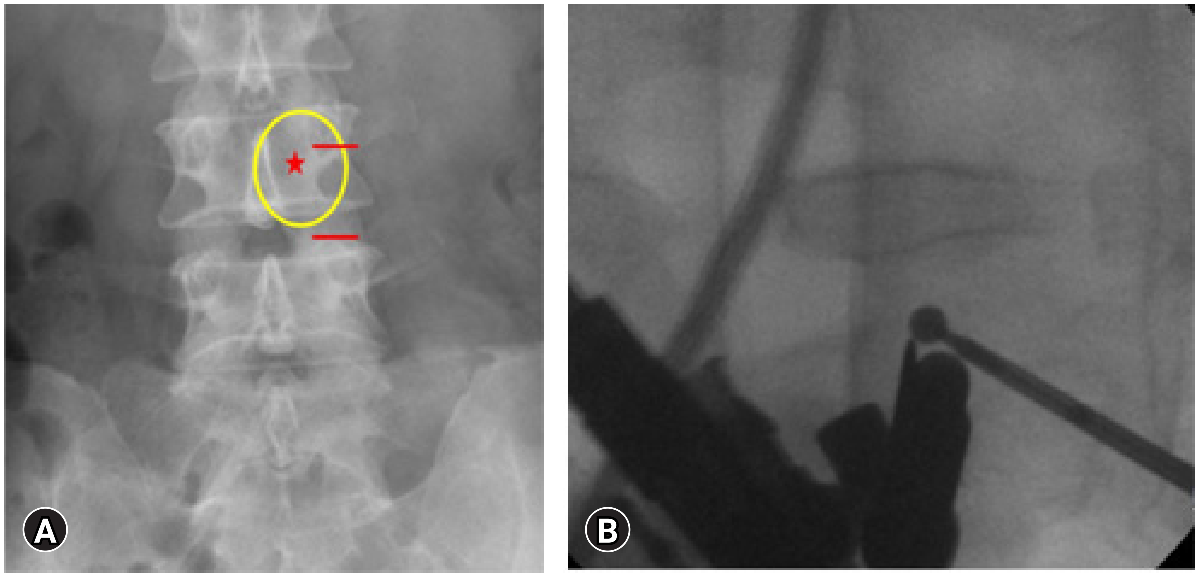

Figure 2. Skin incision point (A) Two skin incisions (two red horizontal lines) were made above and below the target point (red star), slightly separated from the midline, yellow circle showing working zone (B) C-Arm intraoperative image of the scope and diamond burr drilling the keyhole.

compressing the nerve root. The pedicle was identified to verify the exiting root. Subsequently, endoscopic forceps, probes, RF and holmium:yttrium-aluminum-garnet (Ho:YAG) laser are used to remove the migrated or sequestrated disks. Complete decompression and elimination of fragment was verified using the probe. Floseal® (Baxter biosurgery, Vienna, Austria) was used to control any residual bleeding. Drainage was collocated under endoscope guidance. The incision was closed with 3-0 nylon suture. The average operative time was 30 minutes.

CASE REPORT

1. Case 1

A 77-year-old woman complained of progressive low back pain irradiating to the right leg. MRI showed a right paracentral extrusion with high-grade up-migrated disc from L2-3 (Figure 3A–C). We decided to use translaminar keyhole discectomy by UBE to remove the migrated disc (Figure 3D–G). One-day postoperative MRI revealed successful removal of the very high-grade up-migrated disc from L2-3. Patient was discharged 8 days after surgery.

2. Case 2

A 55-year-old man came to emergency room complaining of acute low back pain which started at the same day of his visit trying to wear his pants. At the examination the SLRT was positive and no signs of motor weakness or sensitive alteration. The patient had history of L3-4-5 neurolysis 8 months before his visit. Preoperative MRI showed mild listhesis and high-grade up-migrated disc herniation at L3-4 (right). Translaminar Keyhole UBE was performed to remove the migrated disc (Figure 4). One-day postoperative MRI showed complete removal of migrated disc.

DISCUSSION

Disc fragment migration is a common condition. In 35%–72% of cases, the fragment enters the anterior epidural spaces through the posterior longitudinal ligament and migrates. Cranially extruded disc fragments can migrate to different zones; they can be localized in central, subarticular, foraminal, extraforaminal, and preforaminal zones (Figure 5A) [2,4]. Macnab referred preforaminal or foraminal zone as hidden zone because of their unusual and hard-to-reach feature [4]. Generally, removal of migrated disc fragments requires extensive bone resection, including lamina, pars interarticularis, and facet joints, which can cause iatrogenic instability [3].

Translaminar keyhole approach was introduced recently to treat patients with high-grade up-migrated lumbar disc herniation. It is a minimally-invasive technique where small (6–8 mm) translaminar fenestration is made to directly access the foraminal space and migrated disc fragments [2]. One of the greatest advantages of this approach is that it offers minimal disruption of the soft tissues and posterior bone elements avoiding iat-

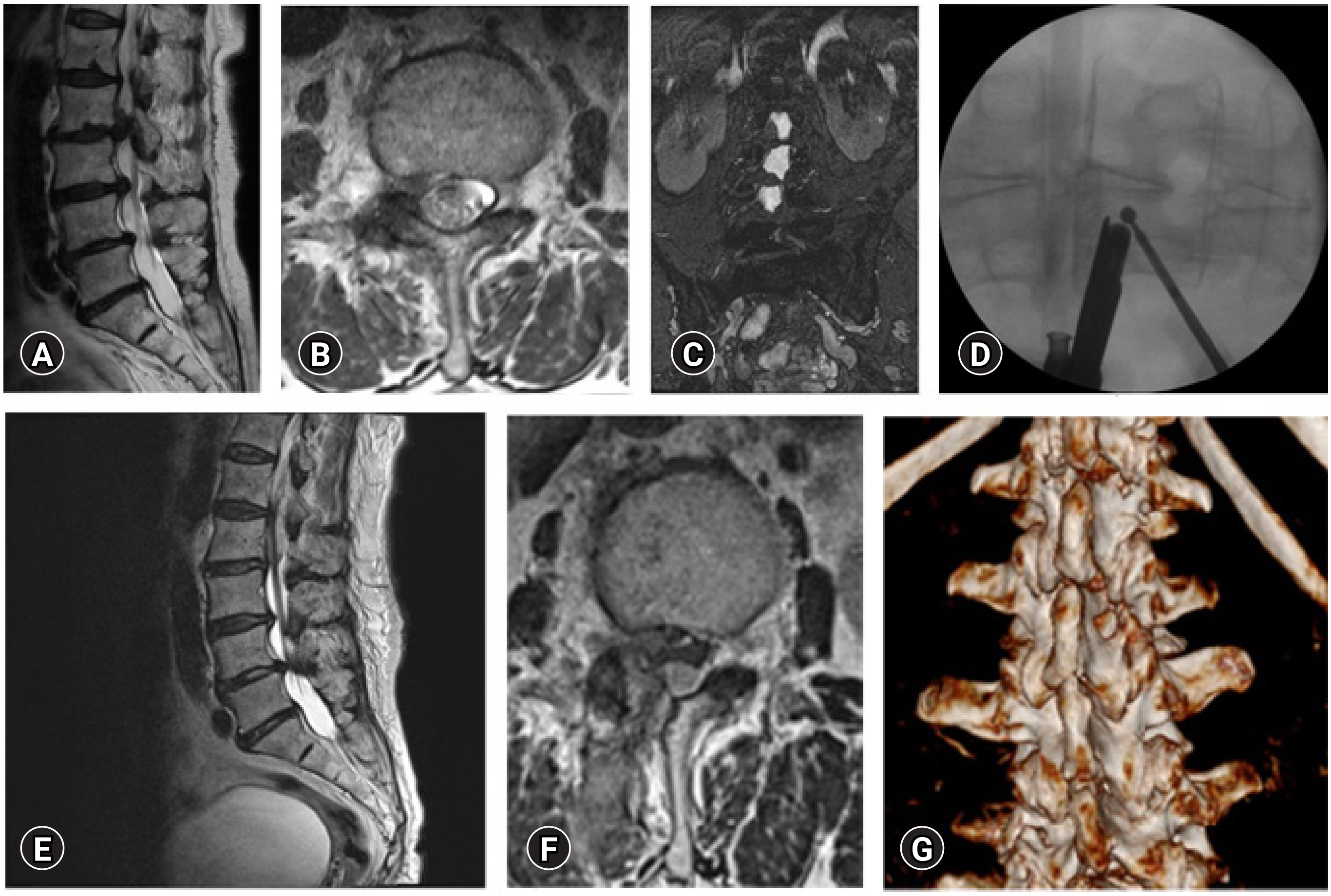

Figure 3. Preoperative sagittal MRI showing right paracentral extrusion with high-grade up-migrated disc from L2-3. (A) Sagittal MRI, (B) axial MRI, (C) myelogram. Images during and after translaminar keyhole discectomy by UBE. (D) C-arm intraoperative image of the scope and diamond burr drilling the keyhole. (E) Postoperative sagittal MRI, (F) postoperative axial MRI, (G) postoperative 3D-CT.

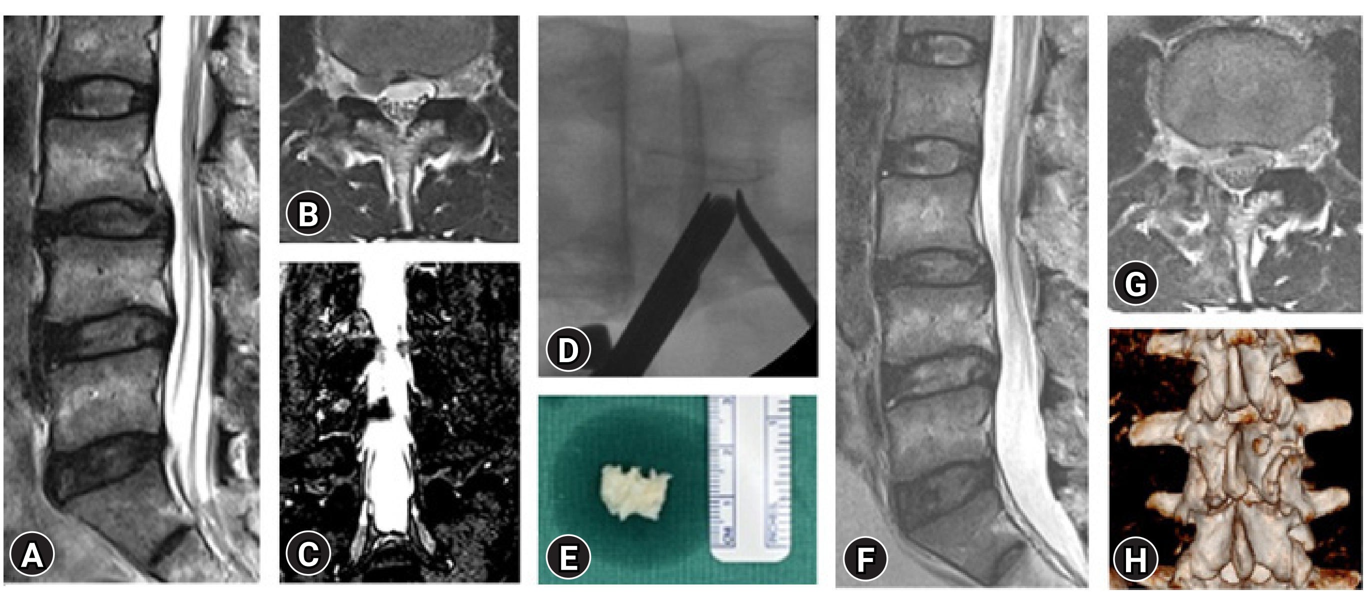

Figure 4. Preoperative sagittal MRI showing mild listhesis and high-grade up-migrated disc herniation at L3-4 (right). (A) Sagittal MRI, (B) axial MRI, (C) myelogram. Images during and after translaminar keyhole discectomy by UBE. (D) C-arm intraoperative image of the scope and diamond burr drilling the keyhole. (E) Fragment of disc herniation. (F) Postoperative sagittal MRI, (G) postoperative axial MRI, (H) postoperative 3D-CT.

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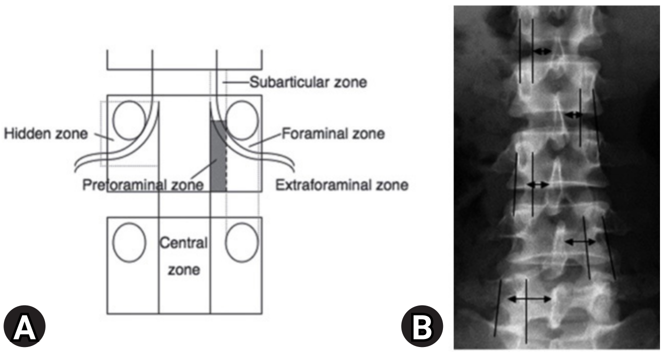

Figure 5. (A) Different zones of cranially extruded disc fragments. (B) The gradual decrease of width of the lamina in a cranial-caudal direction as width of isthmus increases.

rogenic instability. As a ligament flavum-sparing approach, it offers several advantages. Ligament flavum is known as the essential stabilizer of the lumbar spine as it offers translational control of the angular and segmental motion of the spine [4]. It also provides proprioception by high threshold dynamic mechanoreceptors, and protects spinal cord from damage especially during flexion-extension movements [4]. Without the need of flavectomy, which is an essential step in other approaches such as interlaminar approach, the risk of epidural bleeding reduces which is known to cause acute compressions of the roots or spinal cord due to epidural hematoma and iatrogenic stenosis because of the fibrosis [4]. Another point to consider in translaminar approach is the width of the lamina and the isthmus, which vary depending on the lumbar intervertebral space. The width of the lamina gradually decreases in a cranial-caudal direction as width of isthmus increases (Figure 5B). Because of these anatomical characteristics, breakage of the isthmus or excessive facet joint violation is common [2]. It is important to consider the caudo-cranial direction and oval shape of the keyhole [4]. The preoperative images such as AP and lateral radiographs, CT and 3D CT scans, MRI, and MRI with myelogram help us to pre-check the interlaminar and isthmus width to consider the viability of translaminar keyhole approach. Coronal scans of MRI with myelogram are useful in characterizing the migrated fragment and identifying the compression site of the roots [4]. CT scans are helpful to exclude any bony abnormalities causing lateral recess stenosis or foraminal spondylosis that contraindicates this approach [4]. Vogelsang was the first to describe translaminar approach in combination with a tubular retractor system in 15 patients with good results according to Macnab Criteria [6]. Dezawa et al. [7] described percutaneous endoscopic translaminar approach to treat nine cranially migrated disc herniation in 2012, and in 2020, Lin et al. [8] described 13 high-grade up-migrated lumbar disc herniation full endoscopic procedures using a translaminar approach with great results.

UBE is an emerging minimally invasive technique that offers several advantages with minimal limitations [3]. Under a microscope, the translaminar procedure of removing a herniated disk by laminar fenestration requires a traumatic muscle approach with a larger opening of the spine due to the limited surgical vision [8]. This is when the use of an endoscope is clearly advantageous compared to the microscope assisted surgery [8]. There are several advantages of translaminar discectomy using UBE. Unlike uniportal endoscopy, the extra working portal in UBE permits free movement, handling, and angulation of the instruments; therefore, the keyhole laminotomy is performed precisely over the migrated fragment. Further, high-definition (HD) endoscopic vision is allowed without crowding of instruments [3]. The endoscopy facilitates a close view of the lesion, easier disc dissection, ruptured fragment removal, and better and safer manipulation than the conventional microscopic technique. The extra incision in comparison to uniportal endoscopy, offers these advantages to undertake a minimally invasive and precision-requiring surgery. Compared to conventional microscopic technique, the intraoperative c-arm fluoroscopy enables the surgeon to continuously check the exact position of keyhole laminotomy in comparison to the site in the surgery plan. Ordinary arthroscopic and spine instruments can be used through the working portal, and the endoscopic trajectory is the same as that in conventional surgery, for which an experienced microscopic spine surgeon can attain the necessary surgical skills without a steep learning curve [9]. Continuous saline perfusion can control bleeding and reduce the risk of infection [3]. Other advantages over conventional surgery are that UBE allows minimized skin incision with muscle-preserving and minimized injury to the posterior musculoligamentous structures reducing postoperative back pain, shorter hospital stays, and faster return to work [9].

Numerous microscopes assisted translaminar keyhole discectomy procedures were undertaken by the author before realizing translaminar keyhole approach by UBE technique. In our experience, translaminar discectomy using UBE is the true minimally invasive surgery that sums up the advantages of both techniques to treat up-migrated disc herniations. Minimal anatomical disruption by UBE with the benefit of translaminar approach to treat the up-migrated lumbar disc herniations allows access to the surgeon to difficult areas, without compromising segmental spinal stability. Further studies will be essential to accurately establish the efficiency and safety of UBE translaminar keyhole approach. But to our knowledge, this is the first technical report of UBE utilizing translaminar approach for high-grade up migrated lumbar disc herniation and our intention with this technical report is to share our own experience to colleagues.

CONCLUSION

The UBE translaminar keyhole approach is the combination of the minimally invasive endoscopic technique that permits the free movement of the dominant hand of the surgeon to realize precise and exact control of the instruments with the most segmental spinal stability-preserving and “straightforward” approach, to treat up-migrated lumbar disc herniations. The minimal anatomical disruption claimed by UBE, adding the benefit of translaminar approach to treat the up-migrated lumbar disc herniations allows access to the surgeon to difficult areas, without compromising segmental spinal stability.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Wu C, Lee CY, Chen SC, Hsu SK, Wu MH. Functional outcomes of full-endoscopic spine surgery for high-grade migrated lumbar disc herniation: a prospective registry-based cohort study with more than 5 years of follow-up. BMC Musculoskelet Disord 2021;22:58.
2. Son S, Lee SG, Kim WK, Ahn Y. Advantages of a microsurgical translaminar approach (keyhole laminotomy) for upper lumbar disc herniation. World Neurosurg 2018;119:e16–e22.
3. Kang T, Park SY, Park GW, Lee SH, Park JH, Suh SW. Biportal endoscopic discectomy for high-grade migrated lumbar disc herniation. J Neurosurg Spine 2020;33:360–365.
4. Vanni D, Sirabella FS, Guelfi M, Pantalone A, Galzio R, Salini V, et al. Microdiskectomy and translaminar approach: minimal invasiveness and flavum ligament preservation. Global Spine J 2015;5:84–92.
5. Kulkarni AG, Kantharajanna SB, Dhruv AN. The use of tubular retractors for translaminar discectomy for cranially and caudally extruded discs. Indian J Orthop 2018;52:328–333.
6. Vogelsang JP. The translaminar approach in combination with a tubular retractor system for the treatment of far cranio-laterally and foraminally extruded lumbar disc herniations. Zentralbl Neurochir 2007;68:24–28.
7. Dezawa A, Mikami H, Sairyo K. Percutaneous endoscopic translaminar approach for herniated nucleus pulposus in the hidden zone of the lumbar spine. Asian J Endosc Surg 2012;5:200–203.
8. Lin GX, Park CW, Suen TK, Kotheeranurak V, Jun SG, Kim JS. Full endoscopic technique for high-grade up-migrated lumbar disk herniation via a translaminar keyhole approach: preliminary series and technical note. J Neurol Surg A Cent Eur Neurosurg 2020;81:379–386.
9. Kim SK, Kang SS, Hong YH, Park SW, Lee SC. Clinical comparison of unilateral biportal endoscopic technique versus open microdiscectomy for single-level lumbar discectomy: a multicenter, retrospective analysis. J Orthop Surg Res 2018;13:22.

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A Novel Technique of the Full Endoscopic Interlaminar Contralateral Approach for Symptomatic Extraforaminal Juxtafacet Cysts

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Extraforaminal juxtafacet cyst is rare and present a surgical challenge due to its anatomical location. This study aimed to introduce the surgical technique of interlaminar contralateral endoscopic lumbar foraminotomy (ICELF) for extraforaminal juxtafacet cyst removal and reveal its approach-related benefits. The endoscope was docked on the ipsilateral spinolaminar junction and access the contralateral foraminal area through the contralateral sublaminar space created by the fine drilling. As the foraminal was enlarged by bony drilling, the endoscope was introduced deeper to the extraforaminal area without violation of the foraminal disc. Combined foraminal stenosis was also resolved while exploring the foraminal space. Subsequently, the extraforaminal cyst was safely and entirely removed while exposing the cyst-nerve root adhesion site with an endoscopic view looking up obliquely. Radiating pain in the right leg, back pain, leg hypesthesia, and ankle weakness improved. ICELF for the treatment of extraforaminal JFC can be an alternative surgical method to resolve symptomatic foraminal stenosis and the cyst simultaneously. The entire cyst contour and the site of cyst-nerve root adhesion can be detected without nerve root retraction, and meticulous dissection is possible without violating the cystic wall using the full endoscopic contralateral approach.

Key Words: Endoscopy, Synovial cyst, Lumbar vertebrae, 1

INTRODUCTION

Lumbar juxtafacet cysts (JFCs) include both synovial and ganglion cysts located adjacent to the facet joint or arising from the ligamentum flavum [1,2]. Lumbar JFCs may cause symptomatic nerve root and thecal sac compression, leading to radiculopathy, neurogenic claudication, and back pain [1,3]. Surgical treatment should be considered if refractory pain persists despite conservative management. The surgical approaches for these lesions have evolved from open surgery to minimally invasive methods, such as the Wiltse approach using a tubular retractor and uniportal or biportal endoscopic approach [4-7]. Moreover, interlaminar contralateral approaches using a microsurgical tubular retractor system or endoscopic systems can preserve the facet joint during the resection of lumbar JFC [4,8,9]. These advanced surgical approaches are usually used to treat lumbar intraspinal JFC and lumbar foraminal JFC.

Extraforaminal JFCs are rare and present a surgical challenge due to its anatomical location. In previously reported cases, a microscopic paraspinal approach was mainly used to resect the extraforaminal cysts at the L5-S1 level with total or partial facet joint removal [10,11]. Recently, Telfeian et al. [12] described a full endoscopic transforaminal approach to resect a lumbar extraforaminal JFC.

Uniportal interlaminar contralateral endoscopic lumbar foraminotomy (ICELF) has the optimized benefits of using a small-diameter endoscopic system that can pass through the foraminal space, nearly parallel to the exiting nerve root, making foraminal and extraforaminal nerve root decompression without retraction [13-15]. However, the interlaminar contralateral approach for extraforaminal cysts has not been reported.

This study aimed to introduce the surgical technique of ICELF for extraforaminal juxtafacet cyst removal and reveal its approach-related benefits with operating cases treated by the ICELF technique.

CASE REPORT

Case 1.

An 83-year-old man presented with a 12-month history of progressively increasing pain in the right lower back, buttock, and right leg. The pain radiated through the right L5 dermatome. The pain increased while standing, walking, and bending to the right. On physical examination, the patient showed hypesthesia of the L5 nerve root distribution in the right leg, however no motor weakness was detected. The straight-leg-raising test and bilateral knee and ankle reflexes were normal. Magnetic resonance imaging (MRI) showed a cyst in the extraforaminal region and foraminal stenosis at the right L5-S1 level. The cyst was in the cranial-dorsal part of the extraforaminal space compressing the exiting nerve root in the caudal direction (Figure 1A, B). Another cyst, which was smaller than the previous one, was observed in the extraforaminal space at the right S1-S2 level on a sagittal MRI scan, and two adjacent cysts at the L5-S1 and S1-S2 levels were connected to the L5-S1 facet joint (Figure 1B,). We performed the ICELF surgery to treat the extraforaminal JFC. Postoperative MRI revealed well decompressed foraminal stenosis and complete resection of the extraforaminal cysts (Figure 1C, D).

Case 2.

A 62-year-old woman presented with an 8-month history of intractable pain in the right lower buttock and both legs despite conservative treatment at another clinic. The pain radiated through the right L5 dermatome and the S1 dermatome on both the legs, and was aggravated while walking and sitting. On physical examination, the patient showed motor weakness of the right ankle, great toe extension of grade 4 (out of 5), and decreased sensory function of the L5 nerve root distribution in the right leg. The straight-leg-raising test was positive for the right

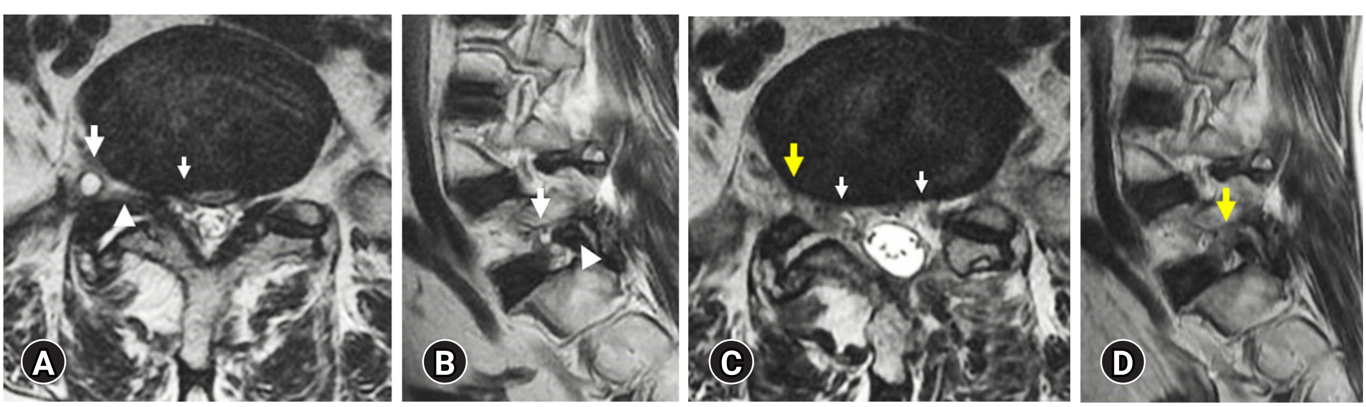

Figure 1. Left contralateral interlaminar endoscopic approach for the symptomatic extraforaminal juxtafacet cyst and foraminal and lateral recess stenosis in a 62-year-old woman presented with pain in the right buttock and radiating pain in both legs. (A, B) Preoperative magnetic resonance imaging (MRI) scans showing a juxtafacet cyst (bold white arrows) located in the cranial-ventral part of the extraforaminal space between the compressed exiting nerve root and the hypertrophied tip of the superior articular facet (SAP, white arrowheads) at the right side of the L5-S1 level. The S1 nerve root was also compressed by the coexisting lateral recess stenosis (thin white arrow). (C, D) Postoperative MRI scans revealing the successful removal of the contralateral (right) extraforaminal cyst (bold yellow arrows) and adequate decompression of coexisting contralateral foraminal stenosis including hypertrophied SAP and lateral recess stenosis (thin white arrows).

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side at 50°. Knee and ankle reflexes were normal. MRI showed a right-sided extraforaminal cyst, facet joint osteoarthritis, foraminal stenosis, and bilateral lateral recess stenosis at the L5-S1 level. The cyst was in the cranial-ventral part of the extraforaminal space compressing the exiting nerve root in the caudal-dorsal direction (Figure 2A, B). Preoperative MRI did not show the connection between the cyst and adjacent facet joint. Conservative treatment with painkillers and physiotherapy was performed for more than 6 months without improvement. Progressive deterioration of the symptoms was the indication for surgery. After ICELF surgery, postoperative MRI showed the entire removal of the extraforaminal cysts (Figure 2C, D). Coexisting foraminal and lateral recess stenosis in the female patient was also adequately decompressed (Figure 2C, D). Pathologic examination of surgical specimen revealed a synovial cyst. Both the patients did not experience any perioperative complications. Radiating pain in the right leg, back pain, leg hypesthesia, and ankle weakness improved. At the 12-month follow-up, both the patients were satisfied with the surgical result without any relapse of symptoms.

SURGICAL PROCEDURES (Video 1)

Meticulous dissection between the cyst and nerve root and visualization of the entire cyst contour are critical for safe and complete removal of the cyst adhered to the nerve root. Therefore, we used ICELF to remove the extraforaminal cystic lesion according to the method described by Kim et al. [13,14] and Wu et al. [15]. The endoscopic system used in this technique passes through the foramen along the exiting nerve root offering a direct endoscopic view of the area from the caudal-dorsal part of the foramen to cranial-ventrally located cyst and the site of cyst-nerve root adhesion (Figure 3A).

We used an endoscope with a viewing angle of 30°, outer diameter of 7.3 mm, 4.7-mm working channel, and a total length of 251 mm. The endoscope was docked on the spinolaminar junction of the ipsilateral side, and contralateral sublaminar drilling was performed to create a sublaminar space up to the contralateral medial part of the foramen (Figure 3B, C). The thickened ligamentum flavum in the medial foraminal region was removed using endoscopic forceps. The foramen was explored with the scope after drilling the overriding superior articular facet and removing the foraminal ligamentum flavum, and the exiting nerve root was then observed. As the foramen was enlarged, the endoscope was introduced deeper through the caudal-ventral part of the foramen to explore the extraforaminal cyst. The endoscope was carefully advanced into the extraforaminal space to avoid violation of the foraminal disc by the beveled working cannula. The cyst was observed between the exiting nerve root and foraminal ligament in the lateral aspect of the neural foramen; it was located cranial-ventrally to the L5 nerve root, embedded in the foraminal ligament, and severely adhered to the exiting nerve root (Figure 4A, B). The site of cyst-nerve root adhesion was confirmed under direct endoscopic vision, and meticulous dissection was performed using the flexible tip of the radiofrequency-ablation catheter

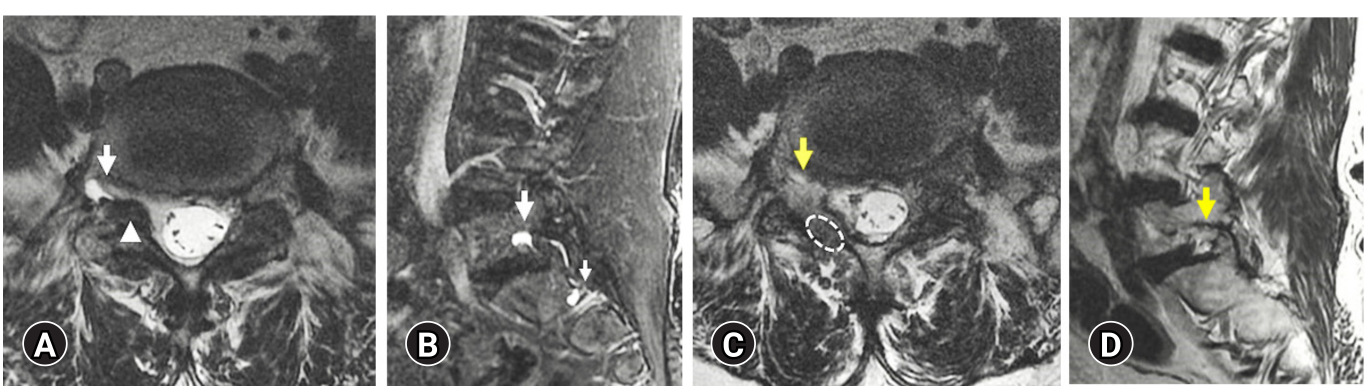

Figure 2. Left contralateral interlaminar endoscopic approach for the symptomatic extraforaminal juxtafacet cyst and foraminal stenosis in an 83-year-old man presented with radiating pain in the right buttock and leg. (A, B) Preoperative magnetic resonance imaging (MRI) scans showing a juxtafacet cyst located in the cranial-dorsal part of the extraforaminal space compressing the exiting nerve root at the right side of the L5-S1 level (bold white arrows). The L5 nerve root was also compressed by the foraminal stenosis (white arrowhead). Another cyst, which was smaller than the previous one, was detected in the extraforaminal space at the S1-S2 level (thin white arrow). Two adjacent cysts were connected to the L5-S1 facet joint. (C, D) Postoperative MRI scans revealing adequate decompression of foraminal stenosis and the complete removal of the extraforaminal cyst (bold yellow arrows). Axial MRI scan showing the contralateral (lesion side) sublaminar tract (C, white dotted circle).

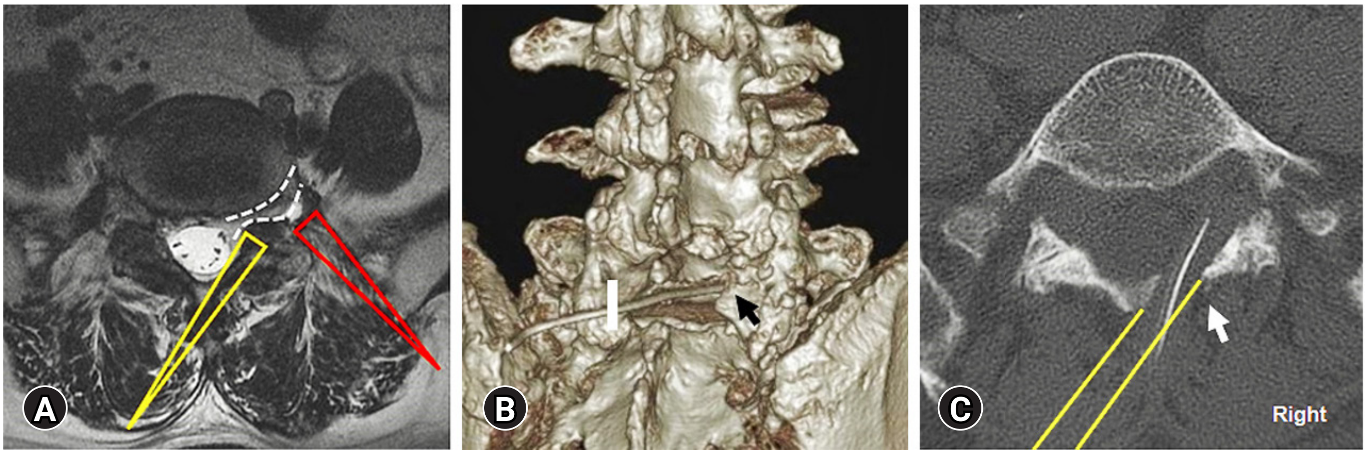

Figure 3. Interlaminar contralateral endoscopic lumbar foraminotomy for the removal of the symptomatic extraforaminal juxtafacet cyst at the L5-S1 level. (A) The endoscopic system moves nearly parallel to the exiting nerve root and accesses the foraminal and extraforaminal region. The view of the entire nerve root in the foraminal to the extraforaminal region obtained using a 30° endoscope without nerve root retraction (long yellow triangle). Endoscopic transforaminal approach for the extraforaminal cyst (long red triangle). (B) Postoperative 3D reconstructed computed tomography (CT) showing the contralateral (right) partial laminotomy (black arrow), and endoscopic approach was started from the left side skin entry point at the medial facet joint line (white bold line). (C) Axial CT image showing the right contralateral partial laminotomy site (white arrow) and a tract used for endoscopic approach (yellow double lines).

(Figure 4B). The entire cystic wall was safely removed in piecemeal fashion from the attached site on the foraminal ligament and L5 exiting nerve root using the endoscopic forceps. (Figure 4C, D). After complete cyst removal, the nerve root was fully decompressed, and the suspected connection site between the cyst and adjacent facet joint was confirmed in the first case (Figure 4E; however, the connecting site was not found in the second case. Complete decompression was confirmed by an intraoperative X-ray (Figure 4F).

DISCUSSION

Extraforaminal JFCs are rare. In previously reported extraforaminal JFC cases, a microscopic paraspinal approach was mainly used to resect the cysts at the L5-S1 level with total or partial facet joint removal [10,11] because anatomical obstacles, such as narrow surgical corridor due to the large facet joint, prominent L5 transverse process, and iliac bone, limit the approach to reach the extraforaminal cyst. The Wiltse approach is a minimally invasive procedure proposed to remove extraforaminal JFCs, but the tubular retractor docked onto the facet joint may obstruct the visualization of the facet itself [16]. Recently, a transforaminal endoscopic approach with optimized oblique access to obscure pathology was performed to successfully remove lumbar extraforaminal JFCs at the L5-S1 level [12].

Extraforaminal cysts are usually located in the cranial-dorsal aspect of the exiting nerve root [2], and they obscure the exiting nerve root and nerve root adhesion site during the paraspinal Wiltse approach or transforaminal endoscopic approach. In this situation, partial cyst removal may be required to expose the nerve root adhesion site, and meticulous dissection may be difficult due to disruption of the original structure.

The cyst and nerve root adhesion site can be exposed without partial cystectomy during the endoscopic transforaminal approach. However, nerve root retraction using a working cannula may be necessary because the endoscopic system approaches the cyst and nerve root with a steep angle (Figure 1A). Nerve root retraction while the root is in a compressed state may induce neural injury such as postoperative dysesthesia.

In the present report, both the patients had extraforaminal JFC located in an obscured area in the cranial-dorsal and cranial-ventral part of the nerve root, accompanied by symptomatic foraminal stenosis. Nerve root retraction was inevitable during cyst removal with an endoscopic transforaminal approach, and the decompression of symptomatic foraminal stenosis was necessary to resolve the L5 radiculopathy. Under these circumstances, we performed ICELF and obtained successful outcomes due to the several approach-related benefits.

The fine endoscopic system with 7.3 mm outer diameter was advanced from the opening of the medial foramen to the extra-

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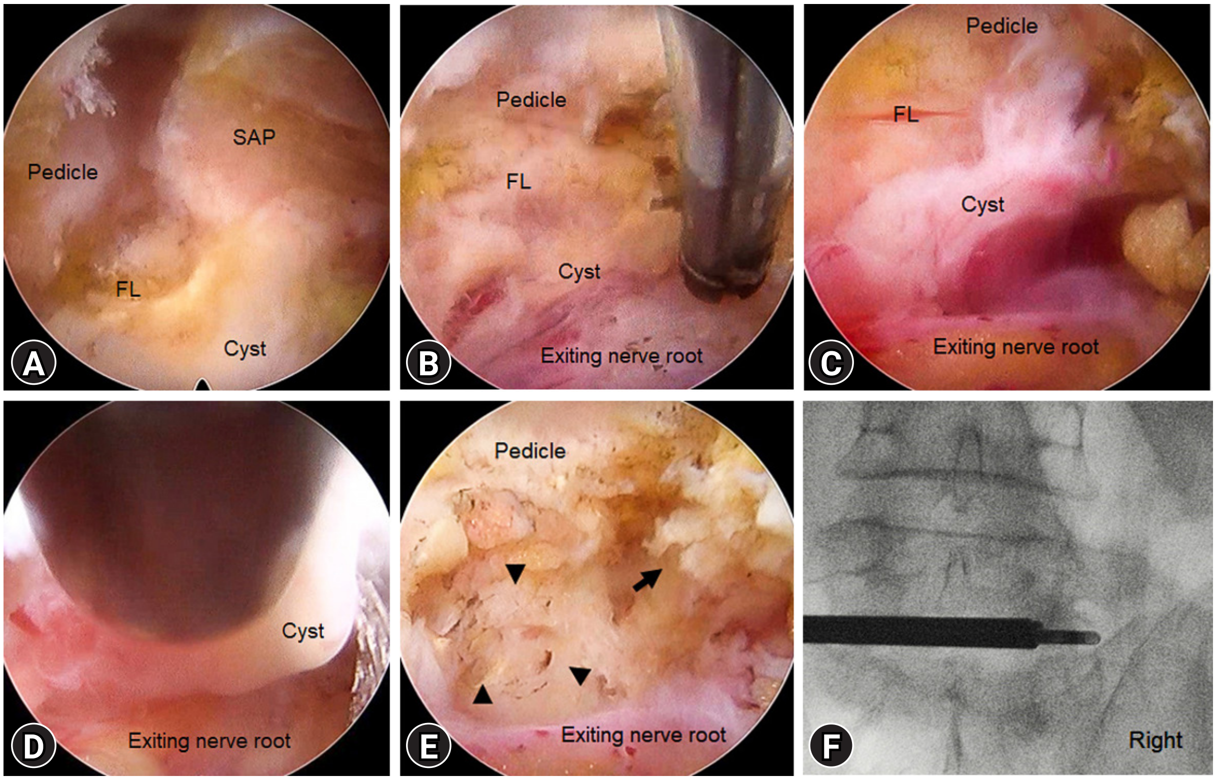

Figure 4. Endoscopic images and radiograph obtained during left interlaminar contralateral endoscopic approach for symptomatic extraforaminal juxtafacet cyst at the L5-S1 level. The endoscopic system accessed the extraforaminal space through the expanded foraminal area by endoscopic drilling. (A) The hypertrophied SAP was drilled out, and the cranial end of the foramen was confirmed by the presence of the upper-level pedicle. The cyst and thickened foraminal ligament covering the cyst were detected at the entrance of the extraforaminal space. (B) The entire adhesion site between the cyst and exiting nerve root could be confirmed without nerve root retraction, and meticulous dissection was performed using the flexible tip of the radiofrequency-ablation catheter. (C) Partial cystectomy opened the free space and allowed the safe dissection up to the cranial part of the extraforaminal space. (D) After complete dissection, a large residual part of the cyst was removed using endoscopic forceps without nerve root retraction. (E) The decompressed exiting nerve root and the extraforaminal space (black arrowheads) were found after complete cyst removal. The connection site between the cyst and adjacent facet joint was suspected to be the superior-lateral pole of the facet joint (black arrow). (F) Intraoperative X-ray confirming the location of the removed cyst. FL: foraminal ligament, SAP: superior articular process.

foraminal region in parallel with the exiting nerve root without retraction. A 30° oblique surgical view of the exiting nerve root was obtained from the endoscope located at the caudal part of the foramen. Therefore, the cranial-ventrally and cranial-dorsally located JFCs and the site of cyst-nerve root adhesion could be clearly visualized. Then, the meticulous dissection between the cyst and nerve root could be performed, and the entire cyst capsule was removed; these minimally invasive procedures might prevent neural injury and cyst recurrence.

The origin of the cyst was explored from the medial foraminal part to the extraforaminal part of the facet joint along the exiting nerve root; the facet joint connection was found in one patient, whereas it was not observed in the other patient under an endoscopic view. However, on pathologic examination, surgical specimens from both the patients were confirmed to be synovial cysts. These findings support the hypothesis that all JFCs, located in both usual and unusual locations, are derived from the facet joint [2].

The present case report may have significant scholarly information and operative technical importance for the following reasons. First, this is the first report of a cyst severely adhered to the nerve root, and the structure of its origin was confirmed without partial cystectomy under a direct endoscopic view. Second, this is the first case in which the entire cysts were successfully removed using ICELF. Third, the entire cyst was safely removed without nerve root retraction, even in the presence of foraminal stenosis. Finally, symptomatic foraminal stenosis was also resolved with minimal drilling of the medial facet joint and without violating the intervertebral disc.

There are several points to consider before performing ICELF for extraforaminal JFC. ICELF requires skillful instrument handling in the narrowed lumbar foraminal space; therefore, surgeons accustomed to endoscopic intraspinal and transforaminal surgery may successfully perform this procedure. ICELF is suitable for resolving double-exiting nerve compressions due to the extraforaminal cyst with coexisting symptomatic foraminal stenosis with one surgical approach. The full endoscopic transforaminal or biportal endoscopic paraspinal approach may be more efficient for extraforaminal cyst removal and not for resolving double crushed lesions. Furthermore, if the extraforaminal cyst is suspected to originate from the medial facet joint on MRI, ICELF is recommended because the entire cystic contour and the site of cyst's origin can be detected efficiently in this procedure, enabling the complete removal of cystic wall.

CONCLUSION

ICELF for the treatment of extraforaminal JFC can be an alternative surgical method to resolve symptomatic foraminal stenosis and the cyst simultaneously. The endoscopic system moves parallel to the exiting nerve root during ICELF, facilitating clear visualization of the cranial-dorsally or cranial-ventrally located extraforaminal JFCs. The entire cyst contour and the site of cyst-nerve root adhesion can be detected without nerve root retraction, and meticulous dissection is possible without violating the cystic wall.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

Supplementary Material

Video 1. A video of the full endoscopic interlaminar contralateral approach for lumbar foraminotomy and extraforaminal juxtafacet cyst removal. We performed a left-sided approach for right contralateral foraminal stenosis and extraforaminal cyst at the L5-S1 level. SAP: superior articular process (https://doi.org/10.21182/jmisst.2022.00010.v001).

REFERENCES

1. Bruder M, Cattani A, Gessler F, Droste C, Setzer M, Seifert V, et al. Synovial cysts of the spine: long-term follow-up after surgical treatment of 141 cases in a single-center series and comprehensive literature review of 2900 degenerative spinal cysts. J Neurosurg Spine 2017;27:256–267.
2. Spinner RJ, Hébert-Blouin MN, Maus TP, Atkinson JL, Desy NM, Amrami KK. Evidence that atypical juxtafacet cysts are joint derived. J Neurosurg Spine 2010;12:96–102.
3. Campbell R, Phan K, Mobbs R. Classification of lumbar facet joint cysts using the NeuroSpine Surgery Research Group (NSURG) grading score and correlation with recurrence and clinical outcomes. World Neurosurg 2018;119:e502–e512.
4. Heo DH, Kim JS, Park CW, Quillo-Olvera J, Park CK. Contralateral sublaminar endoscopic approach for removal of lumbar juxtafacet cysts using percutaneous biportal endoscopic surgery: technical report and preliminary results. World Neurosurg 2019;122:474–479.
5. Scholz C, Hubbe U, Kogias E, Roelz R, Klingler JH. Microsurgical resection of juxtafacet cysts without concomitant fusion-long-term follow-up of 74 patients. Clin Neurol Neurosurg 2017;153:35–40.
6. Tacconi L, Spinelli R, Serra G, Signorelli F, Giordan E. Full-endoscopic removal of lumbar juxtafacet cysts: a prospective multicentric study. World Neurosurg 2020;141:e414–e422.
7. Wu HH, Wang GC, Sun LW, Chang KS, Yang JS, Chu L, et al. Symptomatic lumbar juxtafacet cyst treated by full endoscopic surgery. World Neurosurg 2019;130:e598–e604.
8. Hwang JH, Park WM, Park CW. Contralateral interlaminar keyhole percutaneous endoscopic lumbar surgery in patients with unilateral radiculopathy. World Neurosurg 2017;101:33–41.
9. Sukkarieh HG, Hitchon PW, Awe O, Noeller J. Minimally invasive resection of lumbar intraspinal synovial cysts via a contralateral approach: review of 13 cases. J Neurosurg Spine 2015;23:444–450.
10. Phuong LK, Atkinson JL, Thielen KR. Far lateral extraforaminal lumbar synovial cyst: report of two cases. Neurosurgery 2002 51:505–507. discussion 507
11. Salmon BL, Deprez MP, Stevenaert AE, Martin DH. The extraforaminal juxtafacet cyst as a rare cause of L5 radiculopathy: a case report. Spine (Phila Pa 1976) 2003;28:E405–E407.
12. Telfeian AE, Oyelese A, Fridley J, Moldovan K, Gokaslan ZL. Transforaminal endoscopic approach for lumbar extraforaminal synovial cysts: technical note. World Neurosurg 2020;134:415–419.
13. Kim HS, Patel R, Paudel B, Jang JS, Jang IT, Oh SH, et al. Early outcomes of endoscopic contralateral foraminal and lateral recess decompression via an interlaminar approach in patients with unilateral radiculopathy from unilateral foraminal stenosis. World Neurosurg 2017;108:763–773.
14. Kim HS, Singh R, Adsul NM, Oh SW, Noh JH, Jang IT. Man-

agement of root-level double crush: case report with technical notes on contralateral interlaminar foraminotomy with full endoscopic uniportal approach. World Neurosurg 2019;122:505–507.

15. Wu PH, Kim HS, Jang IT. How I do it? Uniportal full endoscopic contralateral approach for lumbar foraminal stenosis with double crush syndrome. Acta Neurochir (Wien) 2020;162:305–310.

16. Torres Campa-Santamarina J, Towne S, Alimi M, Navarro-Ramirez R, Härtl R. Minimally invasive approach for extraforaminal synovial cyst L5-S1. Cureus 2015;7:e362.

Case Report

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Traumatic Bilateral Pars Fracture with Grade-I Spondylolisthesis Treated by Transforaminal (Trans Kambian) Endo Fusion under Epidural Analgesia: A Special Case Report

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Traumatic spine injuries are common in young and adult population with worlds incidence estimated annual rate in 10.4–130.6 cases per million. We are presenting a case of traumatic bilateral pars fracture with Grade-I spondylolisthesis treated by Endoscopic Transforaminal (Trans Kambian) spine fusion, under epidural analgesia and neuromonitoring. To the best of our knowledge this is a unique scenario reported for the first time in literature. Lumbar fusion although considered as the gold standard for the degenerative spine disease and Spondylolisthesis, Endoscopic Transforaminal (Trans Kambian) lumbar fusion popularly known as Endofusion/Endo-TLIF (Transforaminal lumbar interbody fusion) is a recent and effective minimally invasive option for certain cases. A 30-year male presented with severe low back pain and decreased sensations over dorsum of right foot after a fall of heavy metal pipe on his lower back. (VAS score 9/10). After thorough preop evaluation patient underwent Endoscopic Transforaminal (Trans Kambian) lumbar discectomy and fusion under epidural analgesia, with visualized endplate preparation. Specially designed Titanium Endo-bullet cage was inserted after percutaneous pedicle screw placement under neuromonitoring. Complete reduction of listhesis was achieved with near total relief in pain. Endoscopic TLIF ensures minimal tissue retraction and minimal alteration of the normal anatomy aiding in faster recovery and minimal blood loss. Patient was mobilized and discharged within 24 hours of surgery. We suggest Endo fusion is a safe and effective day care procedure for cases with traumatic bilateral pars fractures.

Key Words: Endoscopic transforaminal lumbar fusion, Pars fracture, Listhesis, Epidural analgesia, Neuromonitoring

INTRODUCTION

Transforaminal lumbar interbody fusion (TLIF) has been regarded as gold standard for lumbar fusion providing effective decompression of neural tissue while avoiding neural injury. Open spine procedures though address the pathology, is known for prolonged duration of anesthesia, blood loss, delayed recovery of the paraspinal muscle injury, prolong hospital stay leading to increased costs. With advancement in technology, more efficient techniques such as minimally invasive TLIF have become popular. However, mis TLIF still requires considerable length of incision and damage to musculature due to long tubular retractors also causing difficulty to work in depth with limited working space [1]. Advancement in endoscopic techniques have further revolutionized minimally invasive spine surgery resulting in minimal blood loss, decreased soft tissue destruction, minimal post-operative pain and faster recovery [2]. Transforaminal (Trans Kambian) endoscopic approach has the advantage of reaching intervertebral foramina and the disc directly, achieving decompression and fusion without excision of lamina, inferior and superior articular process, and ligamentum flavum [3]. However, foramen and lateral recess can be decompressed thoroughly, endoscopically if required. Visualized endplate preparation done as in our technique ensures improved fusion rates.

CASE REPORT

History

A 30-year male, came with history of fall of heavy metal pipe on his lower back while working. He presented with severe lower back pain (VAS score 9/10), right lower limb radiculopathy (VAS 8/10) with numbness in calf and dorsum of foot.

Examination

Clinical examination revealed a palpable step off at L5-S1 with severe touch and pressure tenderness. Straight leg raising test was positive on right side (20°). Further examination revealed decreased sensation over right dorsum of foot with no motor deficits. Magnetic resonance imaging of lumbo-sacral spine was suggestive of L5-S1 Grade 1 spondylolisthesis with bilateral pars fracture with disc herniation compressing right S1 nerve root (Figure 1).

CT lumbosacral spine confirmed L5-S1 Grade I spondylolisthesis with bilateral pars interarticularis fracture with intact pedicles (Figure 2).

With written and informed consent patient underwent Transforaminal (Trans Kambian) Endofusion with removal of disc fragment under epidural analgesia and continuous intraoperative nerve root monitoring.

Surgical method

Patient was placed on comfortable bolsters in prone position

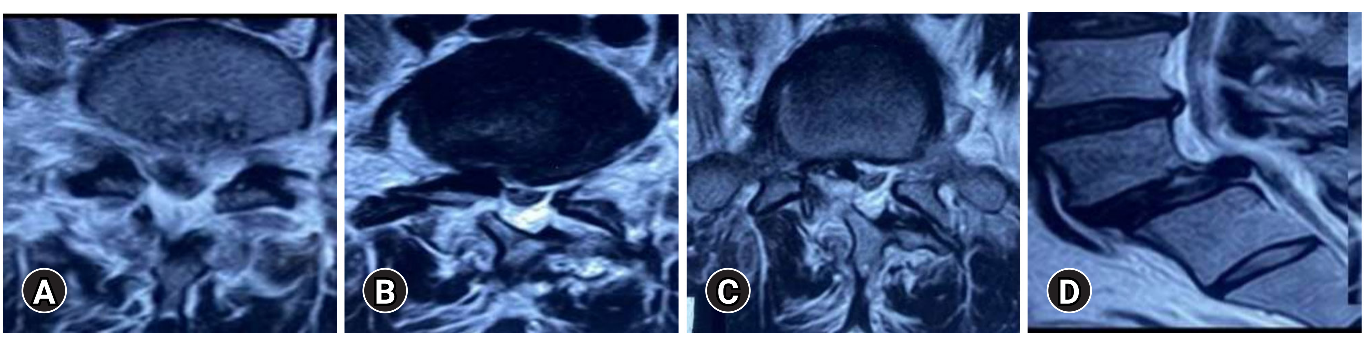

Figure 1. Preoperative MRI T2 sequence. (A) Axial T2 sequence showing bilateral pars fractures. (B) Disc protrusion and lateral recess stenosis with pars fractures. (C) Pars fracture noted at the upper L5 pedicle level. (D) Sagittal view showing Grade I- spondylolisthesis with disc rupture.

Figure 2. Preop CT LS spine. (A) Right sagittal pars defect. (B) Left sagittal pars defect. (C) Axial sections showing bilateral pars fractures.

after Epidural catheter was placed in L1-L2 space and analgesic dose of ropivacaine was given. Nerve monitoring using raw EMG'S and triggered EMG'S were applied in both lower limbs. After cleaning and draping L5-S1 pedicles were entered percutanously using Jamshidi needles under fluoroscopic guidance bilaterally (Figure 3).

Guidewires were secured bilaterally and position confirmed both in AP and Lateral views. Using C-arm AP/Lateral entry point was marked at L5-S1 level, 10 cm from midline. Local anesthetic infiltration (Lignocaine) was given. 18-gauge, 20 cm spinal needle guided under antero-posterior and lateral fluoroscopy, to access the disc space transforaminally via Kambin's triangle at L5-S1 level. Care was taken to ensure the trajectory of the needle was such that the eventual placement of the interbody device was central in antero-posterior view, and anterior in the lateral projection. A guide wire was introduced through the needle, into the disc space, after the removal of stylet. Tapered dilator was advanced over the guide wire and docked into the disc. A bevel-ended working cannula was introduced over the dilator. The guidewire and dilator were withdrawn, and a 4.1mm working channel endoscope was inserted through the cannula. Discectomy and endplate preparation for interbody fusion were performed using a combination of Disc forceps, specially designed articulating curettes and 4MHz RF through the endoscopic channel visualizing throughout while preparing the endplates with removal of disc and endplate cartilage (Figure 4).

Endoscopic visualization ensured the adequacy of end plate preparation, which was confirmed by visualization of the subchondral bone and petechial bleeding. Care was taken to preserve the subchondral bone to minimize the risk of subsidence of interbody cage. Following endplate preparation, ChronOs (Depuy synthes) mixed with bone marrow aspirate, which was obtained from the iliac crest (Figure 5), was packed anteriorly in the disc space through the working cannula. Once the fusion site preparation was done, endoscopic system was withdrawn with guidewire in situ and the specially designed (11×30 mm Titanium) Interbody fusion cage was inserted over the guidewire under fluoroscopic guidance, with neuromonitoring confirmation. Guidewire was removed after position of cage was confirmed on C-arm. Percutaneous Pedicle screws were then inserted bilaterally and connecting rods were placed (Figure 6).

Outcome

In the immediate post-operative period patient had significant relief in both back and leg pain (VAS 2/10). Patient was mobilized as per pain tolerance and was discharged within 24

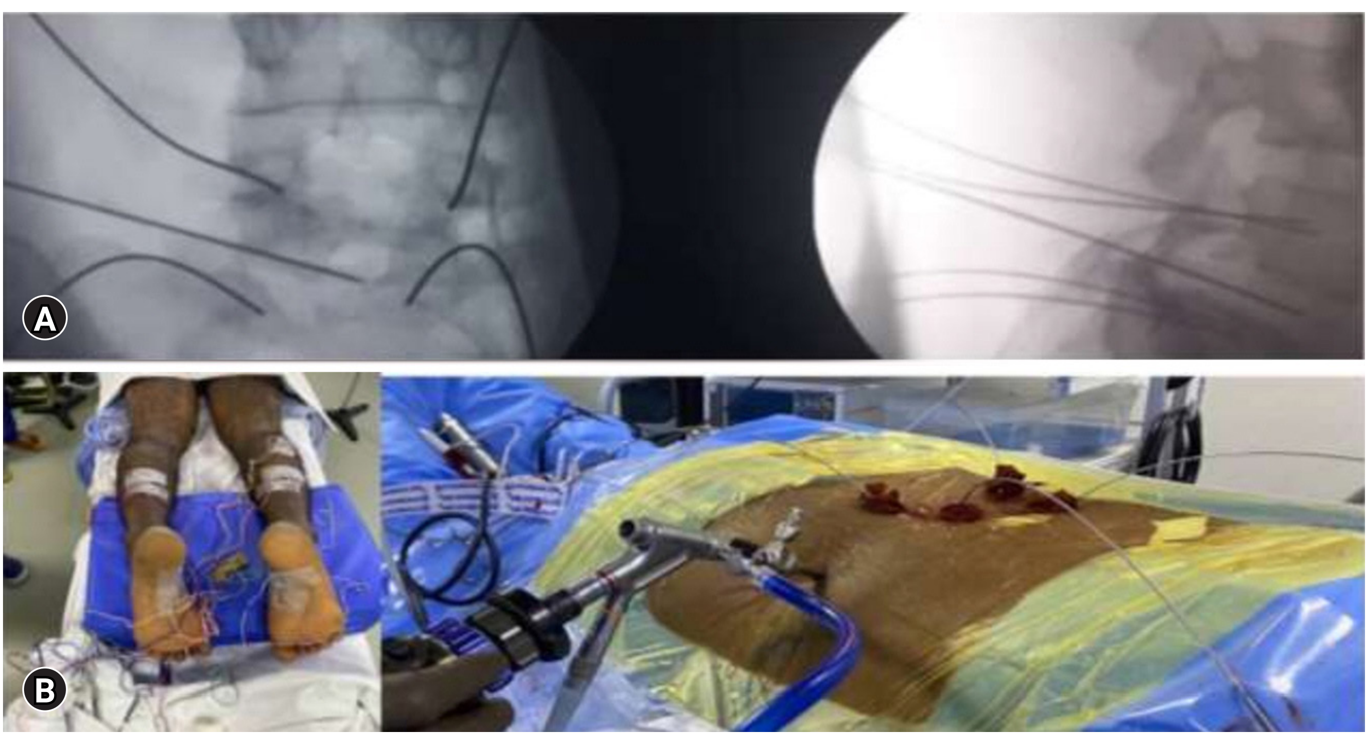

Figure 3. (A) Flouroscopic C-arm guided guide wire placement in antero-posterior and lateral view. (B) Patient in prone with neuromonitoring placed and adjacent image showing entry for the transforaminal endoscopic visualised endplate preparation.

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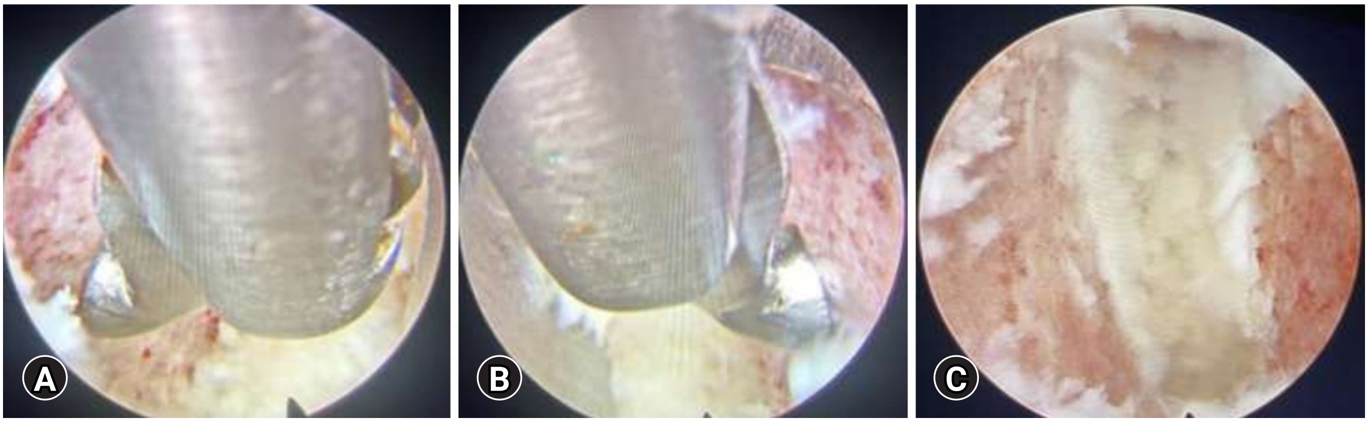

Figure 4. Visualised endplate preparation. (A) Upper endplate preparation. (B) Lower endplate preparation. (C) Final endplate preparation with petechial haemorrhages.

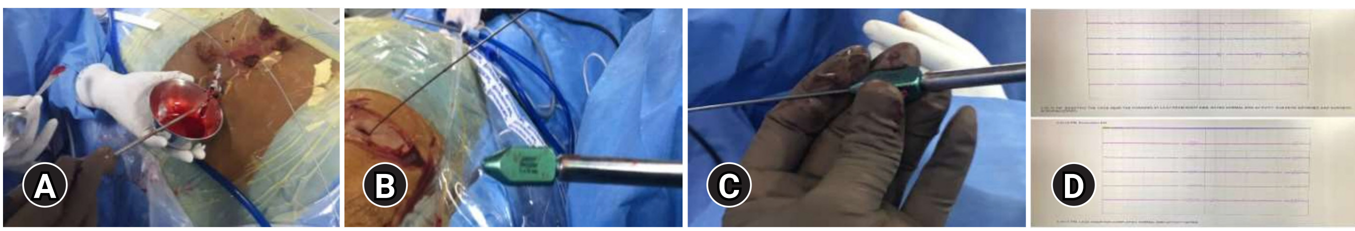

Figure 5. (A) Bone marrow aspiration from the iliac crest and mixing with ChronOs granules. (B) Specially designed endobullet cage of size 11×30 mm. (C) Cage passed over the guide wire placed. (D) Waveforms while inserting cage showing no neural structure stimulated.

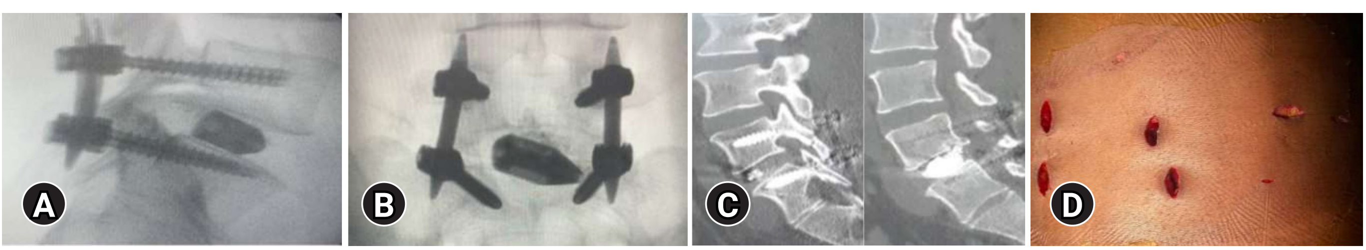

Figure 6. (A) Intra-op C arm image lateral view. (B) intra-op C arm image AP view. (C) Post-op CT sagittal view showing pedicle screws and inter body cage. (D) Post-op skin incisions.

hours of the procedure with minimal analgesics. Immediate postoperative CT Lumbo Sacral spine scan confirmed complete reduction of listhesis with satisfactory position of cage and pedicle screws in situ.

DISCUSSION

Lumbar spine fusion has come a long way since Cloward had described Posterior Lumbar Interbody Fusion (PLIF) in 1943 [4]. Although PLIF is still performed, many surgeons prefer Transforaminal Lumbar interbody Fusion (TLIF) pioneered by Harms and Rolinger in 1982 which has significant advantages over PLIF [5]. Open spine procedures though address the pathology, is known for prolonged duration of anesthesia, blood loss, delayed recovery of the paraspinal muscle injury, prolong hospital stay leading to increased costs, Persistent back pain due to para spinal muscle damage. Use of minimal invasive lumbar interbody fusion has been increasingly popular method of lumbar arthrodesis, in an attempt to decrease operative morbidity, ever since minimally invasive TLIF has been described by Foley et al. [2]. Enhanced recovery after surgery has been attempted in field of spine surgery ever since Wang et al. [6] introduced emphasizing importance of endoscopic lumbar interbody fusion. They aimed at reduction in operative scars and traumatization of posterior musculoligamentous structures.

Endo-TLIF provides significant advantages over minimally invasive and open TLIF. Endo-TLIF provides a better alternative technique than conventional procedures for the case discussed above (traumatic lumbar listhesis) minimizing muscle trauma in an already injured patient.

Following advantages were noticed in our case over conventional surgery.

Endoscopic TLIF was done under epidural analgesia giving it an advantage over general anesthesia [7] such as fewer parental narcotics, lower incidence of urinary retention, accessibility of verbal interaction between the surgeon and patient helping in intraoperative assessment by facilitating real-time neurological feedback from the patient, fewer episodes of hypertension intraoperatively and is much more feasible for patients having comorbidities. In our case ropivacaine was used for epidural analgesia in the present case.

Although studies have suggested end plate preparation to be equivalent in minimally invasive TLIF and open TLIF [8], endplate preparation is better in Endo TLIF as it is done under direct vision removing the disc material and endplate cartilage without injuring the subchondral bone.

Smaller surgical scar, minimal blood loss, no muscle retraction are other advantages seen in endo TLIF technique. Use of nerve monitoring helps in avoiding any neurological deficit intraoperatively.

Osman [9] concluded in their Endofusion series, that the endoscopic transforaminal lumbar decompression, interbody fusion consistently produced satisfactory results and it performed better than the alternative surgical options studied.

Overall hospitalization time for Endo TLIF is significantly less resulting lesser cost of treatment. Decrease in surgical time and tissue disruption, minimal postoperative pain and nausea significantly aid in reducing patients' recovery period and analgesia [10]. In present case patient was mobilized and discharged on the same day of surgery.

CONCLUSION

Endo-TLIF is an effective and safe, least invasive surgical option for interbody lumbar fusion when chosen wisely. To our knowledge ours is the first case to be reported in the literature of traumatic bilateral pars fracture treated with Endo-TLIF. Indication of Endo-TLIF can also be extended to cases of traumatic pars fractures with or without spondylolisthesis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Kim JE, Choi DJ. Biportal endoscopic transforaminal lumbar interbody fusion with arthroscopy. Clin Orthop Surg 2018;10:248–252.
2. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. Spine (Phila Pa 1976) 2003;28:S26–S35.
3. Ao S, Zheng W, Wu J, Tang Y, Zhang C, Zhou Y, et al. Comparison of preliminary clinical outcomes between percutaneous endoscopic and minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative diseases in a tertiary hospital: is percutaneous endoscopic procedure superior to MIS-TLIF? A prospective cohort study. Int J Surg 2020;76:136–143.
4. CLoward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion. I. Indications, operative technique, after care. J Neurosurg 1953;10:154–168.
5. Harms JG, Jeszenszky D. Die posteriore, lumbale, interkorporelle Fusion in unilateraler transforaminaler Technik. Oper Orthop Traumatol 1998 10:90–102. German
6. Wang MY, Chang P, Grossman J. Development of an enhanced recovery after surgery (ERAS) approach for lumbar spinal fusion. J Neurosurg Spine 2017;26:411–418.
7. Papadopoulos EC, Girardi FP, Sama A, Pappou IP, Urban MK, Cammisa FP Jr. Lumbar microdiscectomy under epidural anesthesia: a comparison study. Spine J 2006;6:561–564.
8. Ahn Y, Youn MS, Heo DH. Endoscopic transforaminal lumbar interbody fusion: a comprehensive review. Expert Rev Med Devices 2019;16:373–380.
9. Osman SG. Endoscopic transforaminal decompression, interbody fusion, and percutaneous pedicle screw implantation of the lumbar spine: a case series report. Int J Spine Surg 2012;6:157–166.
10. Kolcun JPG, Brusko GD, Basil GW, Epstein R, Wang MY. Endoscopic transforaminal lumbar interbody fusion without general anesthesia: operative and clinical outcomes in 100 consecutive patients with a minimum 1-year follow-up. Neurosurg Focus 2019;46:E14.

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The Significance of Lumbar Probing Combined with Continuous Irrigation and Undercutting Posterior Vertebral Body for Highly Upward Migrated Disc Herniation in ACDF: Case Reports and technical notes

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The purpose of this report was to present successful cases and technical notes of the patients with up migrated cervical disc herniation to the upper level who were successfully treated using anterior cervical discectomy and fusion (ACDF), describing the evaluation of treatment outcomes and perioperative complications. The cases of two patients who had ACDF in symptomatic up migrated cervical disc herniation to the upper level in February 2021 and November 2021 were reviewed. Two patients presented with a six-week history of posterior neck pain and radiating pain. Preoperative magnetic resonance imaging (MRI) confirmed a diagnosis of up migrated cervical disc extrusion. The patients were admitted to Daegu Wooridul Spine Hospital in Daegu, Korea. ACDF was performed under general anesthesia. Treatment outcomes were examined by comparing pre and postoperative Numeric Rating Scale (NRS), and MRI. Treatment outcomes were favorable: posterior neck pain and radiating pain showed a significant reduction in NRS. Postoperative MRI showed that the up migrated discs were successfully removed in both cases. Neither patient developed perioperative complications. Anterior cervical discectomy can be feasible in patients with symptomatic up migrated cervical disc herniation to the upper level.

Key Words: Intervertebral disc displacement, Minimally invasive surgical procedures, Surgical instruments

INTRODUCTION

Highly migrated cervical disc extrusion is rare [1]. Disc fragments can migrate upward or downward. Migrated disc fragments in the cervical spine are classified into four types according to their locations on the anterior, lateral, and posterior surface of the dural tube [2]. Most of the migrated disc fragments are located on the anterior or lateral surface of the dural sac, which can lead to myelopathy or radiculopathy.

Symptomatic up migrated cervical disc herniation necessitates surgery. If disc sequestrations are located on the anterior or lateral surface of the dural tube, the anterior approach is considered an effective way to decompress the cervical cord and nerve root [2]. The use of corpectomy rather than discectomy for up migrated cervical disc herniation to the upper level was advocated [1,2]. However, compared to anterior cervical corpectomy and fusion (ACCF), anterior cervical discectomy and fusion (ACDF) may lessen the scarification of normal disc level and cervical motion, as well as the rate of adjacent segment disease (ASD) [3]. Therefore, if ACDF is feasible and successful in up migrated cervical disc herniation to the upper level, ACDF will be more beneficial to the patients compared with ACCF.

In this report, we present two cases of patients with up migrated cervical disc herniation to the upper level behind the vertebral body. ACDF was performed using exploration of up migrated disc combined with continuous irrigation and undercutting posterior vertebral body. Treatment outcomes were favorable, with no perioperative complications.

CASE REPORT

1. Case 1

In February 2021, a 45-year-old man complained of severe posterior neck pain and right radiating pain six weeks ago, for which he was admitted to the Daegu Wooridul Spine Hospital in Daegu, Korea. The patient's Numeric Rating Scale (NRS) was 8 [4]. He had difficulty moving his neck posteriorly. Preoperative magnetic resonance imaging (MRI) and computed tomography (CT) showed non-calcified cervical disc extrusion with up migration on C3-4, C4-5 (Figure 1).

After informed consent was obtained from the patient, ACDF was performed in February 2021. 5 mm high PEEK cages on C3-4, C4-5 and an anterior plate were inserted. On postoperative MRI, the up migrated disc was removed clearly, and the cervical cord and nerve roots were released well (Figure 2). The operative time was about 185 minutes. Blood loss was 110 cc. The patient reported improved posterior neck pain and right radiating pain with a reduction in NRS from 8 to 3, and improved posterior neck movement compared to the preoperative state.

2. Case 2

In November 2021, a 56-year-old man presented with a six-week history of left posterior neck pain and bilateral radiating pain. The pain as evaluated by NRS was 8. Weakness of left elbow flexion and extension, as well as left hand grip as assessed by Manual muscle test (MMT), was Grade 3. Preoperative MRI and CT showed non-calcified left central and foraminal disc

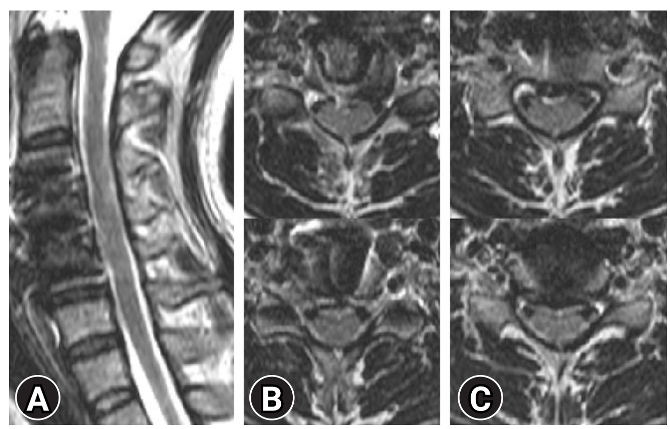

Figure 2. Postoperative images of the up migrated cervical disc herniation at C3-4, C4-5 level on MRI. (A) A mid-sagittal image on T2 weighted MRI. (B) Axial images at C3-4 level on T2 weighted MRI. (C) Axial images at C4-5 level on T2 weighted MRI.

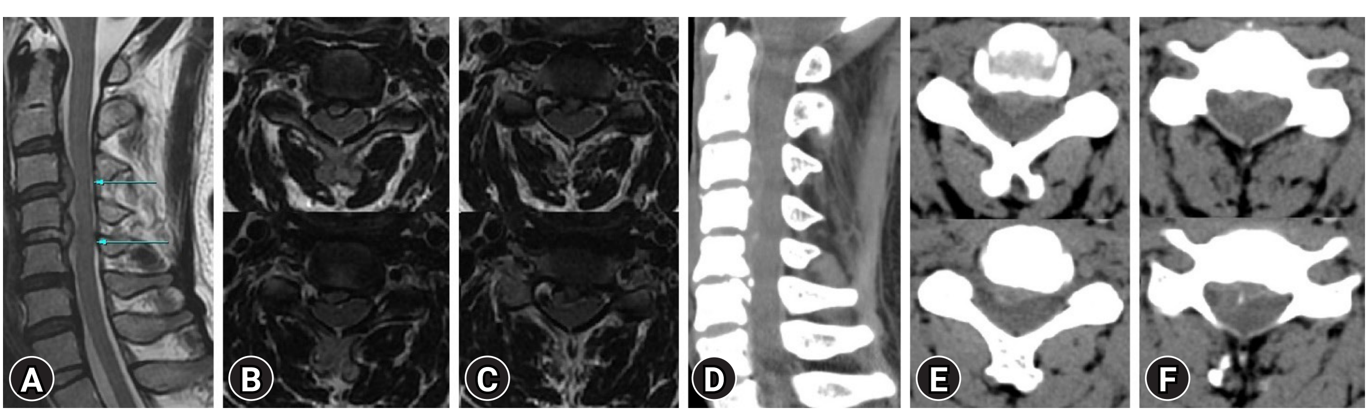

Figure 1. Preoperative images of the up migrated cervical disc herniation at C3-4, C4-5 level on MRI and CT. (A) A mid-sagittal image on T2 weighted MRI. (B) Axial images at C3-4 level on T2 weighted MRI. (C) Axial images at C4-5 level on T2 weighted MRI. (D) Mid-sagittal images on CT. (E) Axial images at C3-4 level on CT. (F) Axial images at C4-5 level on CT.

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extrusion with up migration to the upper level on C6-7, and non-calcified right central disc extrusion with segmental type ossified posterior longitudinal ligament (OPLL) on C5-6 (Figure 3). Electromyography (EMG) showed myelopathy on C5-6.

After informed consent was obtained from the patient, ACDF on the C5-6, C6-7 level was performed. Because of posterior bony spurs, C5-6 level showed dural adhesion, and the disc extrusion was cautiously removed. No injuries to the dura, cord, or nerve root were observed. We inserted 6mm high PEEK cages on C5-6, C6-7 and an anterior plate. Postoperative MRI showed that the cervical cord and nerve roots were decompressed sufficiently (Figure 4). The operative time was approximately 225 minutes. Blood loss was 230 cc. Following the procedure, the patient reported an improvement in left posterior neck pain and bilateral radiating pain (postoperative NRS=2).

3. Technical notes

Under general anesthesia, the Smith-Robinson approach to

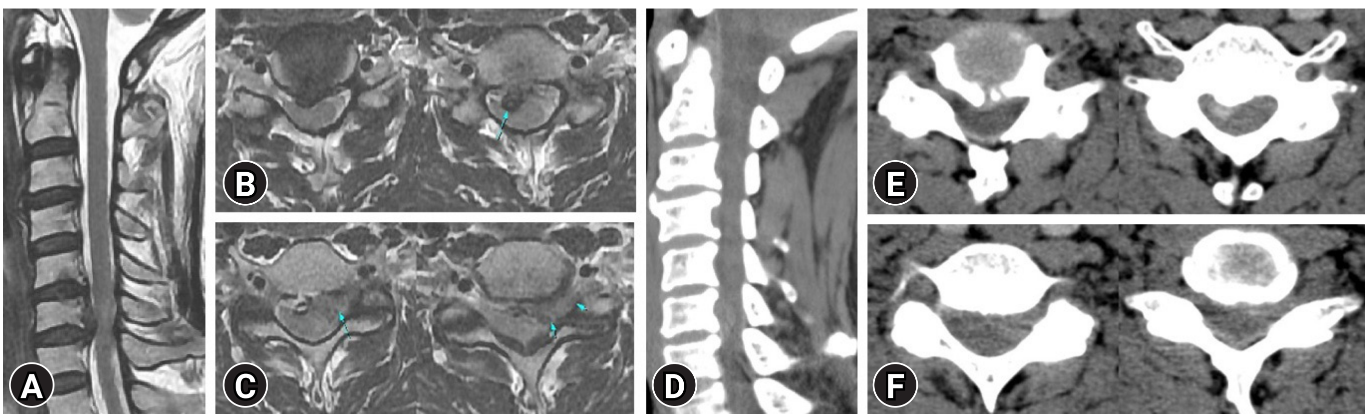

Figure 3. Preoperative images of the up migrated cervical disc herniation at C5-6, C6-7 level on MRI and CT. (A) A mid-sagittal image on T2 weighted MRI. (B) Axial images at C5-6 level on T2 weighted MRI. (C) Axial images at C6-7 level on T2 weighted MRI. (D) Mid-sagittal images on CT. (E) Axial images at C5-6 level on CT. (F) Axial images at C6-7 level on CT.

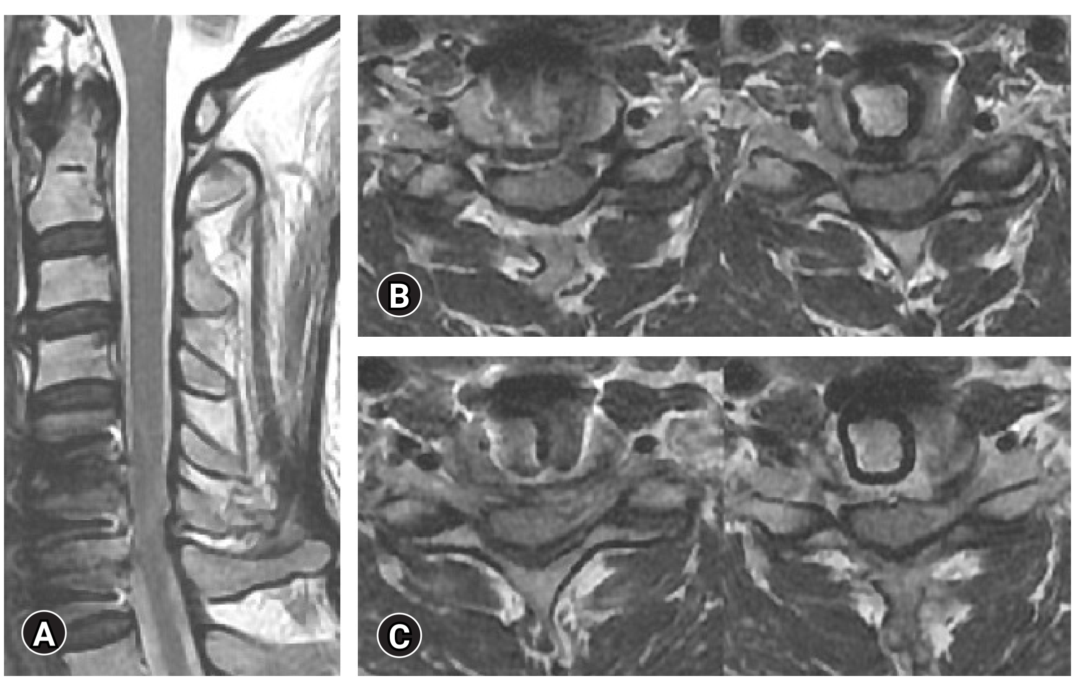

Figure 4. Postoperative images of the up migrated cervical disc herniation at C5-6, C6-7 level on MRI. (A) a mid-sagittal image on T2 weighted MRI. (B) Axial images at C5-6 level on T2 weighted MRI. (C) Axial images at C6-7 level on T2 weighted MRI.

the relevant level, discectomy, and endplate preparation are the same as the process of ACDF. The posterior annulus fibrosus and posterior longitudinal ligament (PLL) were removed. The posterior margins of the vertebral body between the center of PLL and foramen were removed within 5 mm using Kerrison punches. With continual disc irrigation, the highly up migrated disc was removed using 5 mm and 10 mm McCulloch angled ball-tipped probe. Bilateral neural foramens were decompressed sufficiently using a high speed drill. After surgical decompression, the cervical cord was pulsated, and the exiting nerve roots were freed. No injuries to the dura, spinal cord, and nerve roots were reported. Cages and an anterior plate were inserted on the target level.

DISCUSSION

ACDF is a widely accepted surgical treatment option for degenerative cervical disc diseases. However, if there is significant up migration of the disc, use of the anterior discectomy approach may be limited due to hidden discs being located behind the vertebral bodies. Most authors advocate treatment with corpectomy instead of anterior discectomy for up migrated cervical disc to the upper level, which allows for the hidden fragments to be fully exposed and clearly removed [3].

ACCF is associated with a relative high rate of implant-related failure. Although these failures could be lessened by implementing additional posterior fixation, the supplemental surgery can increase morbidity, hospital stay and costs [5,6]. Indeed, a recent large-scale cohort study concluded that patients treated with ACCF were more likely to require surgical revision compared to patients treated with ACDF [7]. For elderly patients and those with comorbidities, ACCF is associated with a higher rate of complications, thus more extensive perioperative evaluation and planning are necessary [8]. Due to the drawbacks of ACCF, ACDF can be considered for mild to moderate migrated disc herniation [3].

The major concerns for anterior discectomy are missing migrated fragments behind the vertebral body and more traumatic to the cervical cord than ACCF [1,2]. Several studies reported the “transcorporeal” or “transvertebral” approach, which enable treatment for cervical disc herniation without fusion [9-11]. To remove highly up migrated cervical disc completely, the transcorporeal herniotomy was combined with ACDF. Choi et al. [12] reported a favorable outcome without missing fragments and cord injury. However, this combined approach was applied to the only one level.

To prevent these two problems, some technical notes were combined with ACDF in our study: 1. The posterior margins of the vertebral body between the center of PLL and foramen are removed within 5 mm using Kerrison punches. 5 mm McCulloch angled ball-tipped probe is used to measure 5 mm. Extruded disc fragments are migrated upward beside the center of PLL, because the center of PLL is tightly attached to the vertebral body. 2. The hidden space should be explored carefully to remove highly sequestrated disc using 5 mm and 10 mm McCulloch angled ball-tipped probe. McCulloch angled ball-tipped probe is round, the ball-tipped probe is safer than other probes (Figure 5). The exploration must be done not only upward and downward but also laterally. 3. During the exploration disc saline irrigation should be performed continually to avoid trauma to the cord and remove the remnant fragment efficiently. 4. Sufficient decompression of the cord can be confirmed by the pulsation of the cord. Raynor [13] reported utilizing intraoperative ultrasonography to immediately assess the decompression of cervical cord during ACDF. That might be also used to verify enough decompression. We documented that favorable outcomes without these problems, and Wang et al. [3] supported these lumbar probing techniques with successful results of removing highly up migrated cervical disc herniation.

In the cases of one or two level highly up migrated cervical disc herniation to the upper level, this lumbar probing technique without partial corpectomy can be applied the first. If severe dural adhesion, including OPLL, is encountered, combined anterior approach with transcorporeal herniotomy will be recommended. In the cases of up migrated cervical disc herniation, the transcorporeal approach without fusion will be considered.

ACDF is utilized in these two methods. They have merits and demerits of ACDF. In the lumbar probing technique, there are difficulties in confirmation of remnant disc fragments and

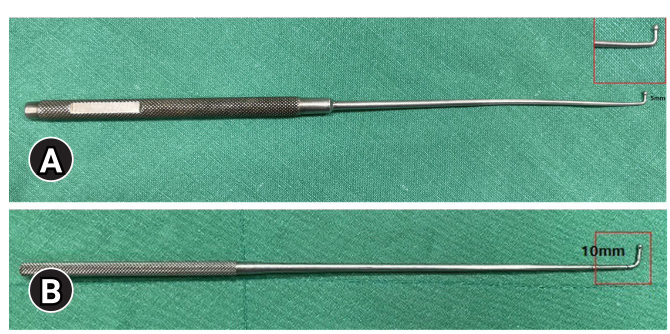

Figure 5. Images of McCulloch angled ball-tipped probes. (A) Images of 5 mm McCulloch angled ball-tipped probe. (B) An image of 10 mm McCulloch angled ball-tipped probe.

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epidural bleeding control. In the combined approach, the vertebral passage facilitates check for the remnant fragments and control of epidural bleeding [12]. Size, location, and trajectory of the passage will be considered carefully due to the risk of vertebral fracture and complete removal of the migrated disc [14].

CONCLUSION

In conclusion, ACDF can be feasible in patients with symptomatic up migrated cervical disc herniation to the upper level behind the vertebral body, providing favorable treatment outcomes without perioperative complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Srinivasan US, Kumar GS, Mahesha KB. Posterior epidural migration of sequestrated cervical disc fragment: case series. Asian Spine J 2011;5:220–227.
2. Manabe S, Tateishi A. Epidural migration of extruded cervical disc and its surgical treatment. Spine (Phila Pa 1976) 1986;11:873–878.
3. Wang Y, Qian Y, Wang J, Zhu M, Wang J, Teng H. Anterior discectomy could still be an alternative to corpectomy in highly migrated cervical disc herniation. Br J Neurosurg 2017;31:709–713.
4. Mjåset C, Zwart JA, Goedmakers CMW, Smith TR, Solberg TK, Grotle M. Criteria for success after surgery for cervical radiculopathy-estimates for a substantial amount of improvement in core outcome measures. Spine J 2020;20:1413–1421.
5. Shamji MF, Cook C, Pietrobon R, Tackett S, Brown C, Isaacs RE. Impact of surgical approach on complications and resource utilization of cervical spine fusion: a nationwide perspective to the surgical treatment of diffuse cervical spondylosis. Spine J 2009;9:31–38.
6. Koller H, Schmoelz W, Zenner J, Auffarth A, Resch H, Hitzl W, et al. Construct stability of an instrumented 2-level cervical corpectomy model following fatigue testing: biomechanical comparison of circumferential antero-posterior instrumentation versus a novel anterior-only transpedicular screw-plate fixation technique. Eur Spine J 2015;24:2848–2856.
7. Puvanesarajah V, Jain A, Cancienne JM, Shimer AL, Singla A, Shen F, et al. Complication and reoperation rates following surgical management of cervical spondylotic myelopathy in medicare beneficiaries. Spine (Phila Pa 1976) 2017;42:1–7.
8. Boakye M, Patil CG, Ho C, Lad SP. Cervical corpectomy: complications and outcomes. Neurosurgery 2008 63:295–301. discussion 301-302
9. Choi G, Lee SH, Bhanot A, Chae YS, Jung B, Lee S. Modified transcorporeal anterior cervical microforaminotomy for cervical radiculopathy: a technical note and early results. Eur Spine J 2007;16:1387–1393.
10. Nakai S, Yoshizawa H, Kobayashi S, Hayakawa K. Anterior transvertebral herniotomy for cervical disk herniation. J Spinal Disord 2000;13:16–21.
11. Shim CS, Jung TG, Lee SH. Transcorporeal approach for disc herniation at the C2-C3 level: a technical case report. J Spinal Disord Tech 2009;22:459–462.
12. Choi KC, Ahn Y, Lee CD, Lee SH. Combined anterior approach with transcorporeal herniotomy for a huge migrated cervical disc herniation. Korean J Spine 2011;8:292–294.
13. Raynor RB. Intraoperative ultrasound for immediate evaluation of anterior cervical decompression and discectomy. Spine (Phila Pa 1976) 1997;22:389–395.
14. Qiao Y, Liao WB, Du Q, Ao J, Cai YQ, Kong WJ, et al. Percutaneous full-endoscopic anterior transcorporeal diskectomy for massive migrated cervical disk herniation treatment: case report and review of the literature. World Neurosurg 2019;132:47–52.

Case Report

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Only Surgical Decompression Is Sufficient for Multilevel Lumbar Spinal Stenosis with Calcified Disc Protrusion and Vacuum Disc: Case Reports

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This report was aimed to share our successful cases of only surgical decompression for multilevel lumbar spinal stenosis, by assessing treatment outcomes. Two patients who had only surgical decompression for multilevel lumbar spinal stenosis were investigated. They were diagnosed with the calcified disc protrusion and vacuum disc in the intervertebral space by magnetic resonance imaging (MRI) and computed tomography (CT). The chief complaints were severe low back pain and bilateral sciatica 2 or 3 months ago. The patients also reported difficulty walking due to sciatica. Unilateral laminotomy for bilateral decompression was performed and discectomy was not done on the stenosis levels. Treatment outcomes were analyzed by visual analog scale for low back pain and sciatica (Back VAS, Leg VAS), improvement in walking, and postoperative MRI. Treatment outcomes were favorable: Low back pain and bilateral sciatica showed a VAS score improvement (Back VAS =3, Leg VAS=3), the patient's walking was improved, and on a postoperative MRI of the two patients, the thecal sac was released sufficiently. The patients developed no perioperative complications. Only surgical decompression is an effective method for multilevel lumbar spinal stenosis with calcified disc protrusion and vacuum disc in the intervertebral space.

Key Words: Spinal stenosis, Intervertebral disc displacement, Intervertebral disc degeneration

INTRODUCTION

Lumbar spinal stenosis is one of the most prevalent symptomatic spinal diseases in older patients, many of whom present with multilevel lumbar stenosis accompanied by disc herniation. Conservative treatment is not effective, causing many patients to require surgical treatment to relieve their symptoms [1-3].

Some authors favored decompression alone in multilevel lumbar stenosis. Orpen et al. [4] reported unilateral laminotomy for bilateral decompression (ULBD) can be applied to multilevel lumbar stenosis. Haba et al. [5] reported favorable outcomes after ULBD for multilevel lumbar stenosis. Son et al. [6] suggested decompression alone in elderly patients with two-level or more lumbar spinal stenosis without overt instability.

During surgical decompression for multilevel lumbar spinal stenosis, discectomy for disc herniation is taken into consideration. However, calcified disc is challenging to be removed because of severe adhesion between the nerve and the floor of the spinal canal. Excessive retraction is needed for ventral dissection, and dural tear or nerve root injury can be developed [7]. Resection of the protruded annulus fibrosus calcification can also increase the risk of recurrent disc herniation afterward. The vacuum disc in intervertebral space is the instability sign and related to the low back pain [8]. That is not clinical significance [9].

Here, successful cases for only surgical decompression for multiple stenosis with calcified disc protrusion and vacuum disc in the intervertebral space are presented, depicting favorable treatment outcomes and no perioperative complications.

CASE REPORT

1. Case 1

In May 2021, a 60-year-old man complained of severe low back pain and bilateral sciatica which began three months ago, and visited Daegu Wooridul Spine Hospital in Daegu, Korea. The sciatica followed a S1 dermatomal distribution. Several block procedures were performed in other hospitals; however, the symptoms prevailed. The patient's pain score was assessed by the visual analog scale (VAS). Back VAS was 5, and Leg VAS was 8. He had difficulty walking due to sciatica. Preoperative MRI and CT demonstrated multilevel lumbar spinal stenosis with the protrusion of calcified discs and the vacuum disc in not the spinal canal but the intervertebral space, and preoperative myelogram showed a total signal block on L3-4, 4-5 level (Figure 1). Following a left hip and ankle fracture surgery in 1976, the patient developed motor weakness of the ankle and great toe, which scored Grade 4 on the manual muscle testing.

After informed consent was obtained from the patient, surgical decompression was performed. Under general anesthesia, the patient was placed in a prone position. A 90-mm long skin incision was made to target the L3-4, 4-5, 5-S1 disc space level. A Caspar retractor and Counter were inserted through the incision. After microscopic right ULBD on L3-4, 4-5 level, right laminectomy on L5-S1 level, and flavectomy on L3-4. 4-5, 5-S1 level without discectomy, the compressed thecal sac was released sufficiently and severe adhesion between the dura and the bottom of the spinal canal was observed. Ventral dissection was not tried. No injury of the dura and nerve root was reported. On postoperative MRI, the dural sac was released well (Figure 2). The operative time was about 160 minutes. Blood loss was 380 cc. The motor weakness of the ankle and great toe was not improved. However, the patient reported improved low back pain and bilateral sciatica with a reduction in VAS score for back and sciatica (Back VAS=3, Leg VAS=3), and dramatically improved walking ability compared with the preoperative state.

2. Case 2

In March 2021, a 77-year-old man presented with severe low back pain and bilateral sciatica which began two months ago.

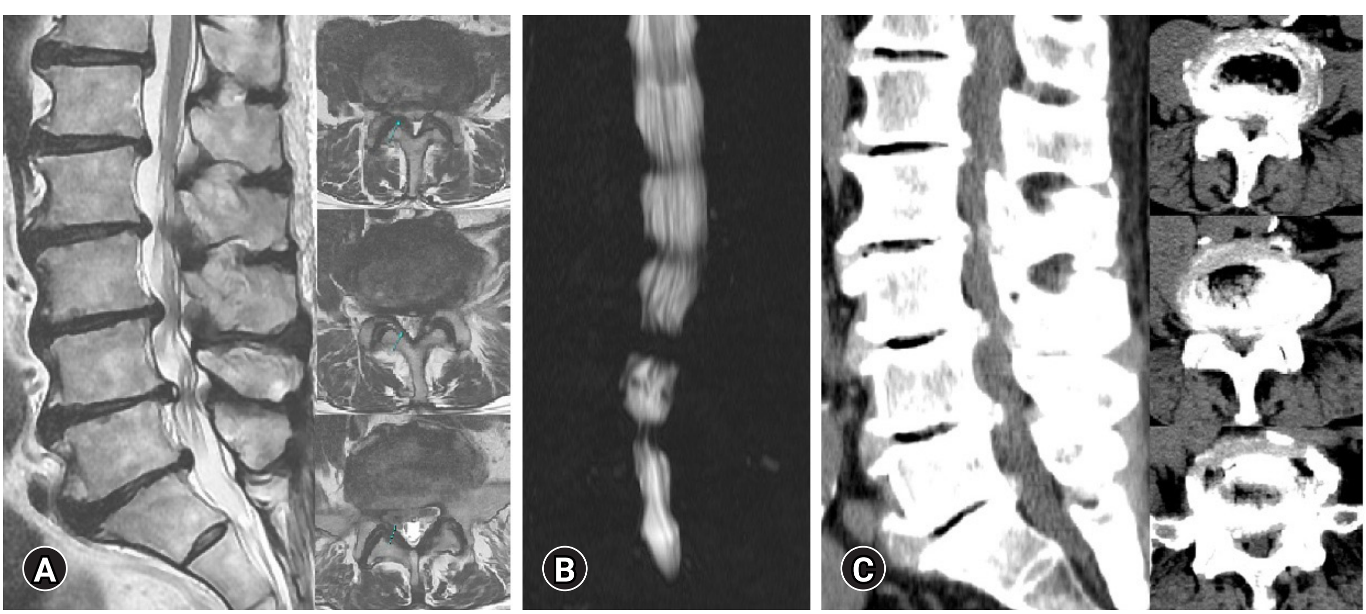

Figure 1. Preoperative images of lumbar spinal stenosis at L3-4, 4-5, 5-S1 level on MRI, MR myelography, and CT. (A) Sagittal and axial images on T2 weighted MRI. (B) An image on MR myelography. (C) Sagittal and axial images on CT.

Several block procedures were conducted in other hospitals; however, the symptoms were not relieved. The pain was evaluated by Back and Leg VAS. Back VAS was 5, and Leg VAS was 8. He had ambulation difficulty due to sciatica. Multilevel lumbar spinal stenosis with the calcified disc protrusion accompanied by the vacuum disc in not the spinal canal but the intervertebral space was demonstrated on preoperative MRI and CT, and a complete block on L2-3, 3-4 level was shown on preoperative myelogram (Figure 3).

Figure 2. Postoperative images of lumbar spinal stenosis at L3-4, 4-5, 5-S1 level on MRI.

After informed consent was obtained from the patient, a right ULBD microscopic surgery without discectomy on L2-3, 3-4 level was applied under general anesthesia. After surgical decompression, the dural sac was released well and serious adhesion between the sac and the floor of the spinal canal appeared. Ventral dissection was not tried. No injury of the dura and nerve root was observed. The thecal sac was decompressed sufficiently on postoperative MRI (Figure 4). The operative time was about 120 minutes. Blood loss was 100 cc. Following the procedure, the patient reported dramatically improved ambulation compared to the preoperative state and improved low back pain and bilateral sciatica with a reduction in VAS score for back and sciatica (Back VAS=3, Leg VAS=3).

DISCUSSION

Lumbar spinal stenoses are often multilevel, but scarcely affect the whole lumbar spine, and can be accompanied by disc herniations, calcified discs, and vacuum discs. When deciding which level to be decompressed, magnetic resonance (MR) myelography using with MRI can be helpful in the exclusion and inclusion of the target levels [10]. In our study, two cases are multilevel lumbar stenosis accompanied by calcified disc

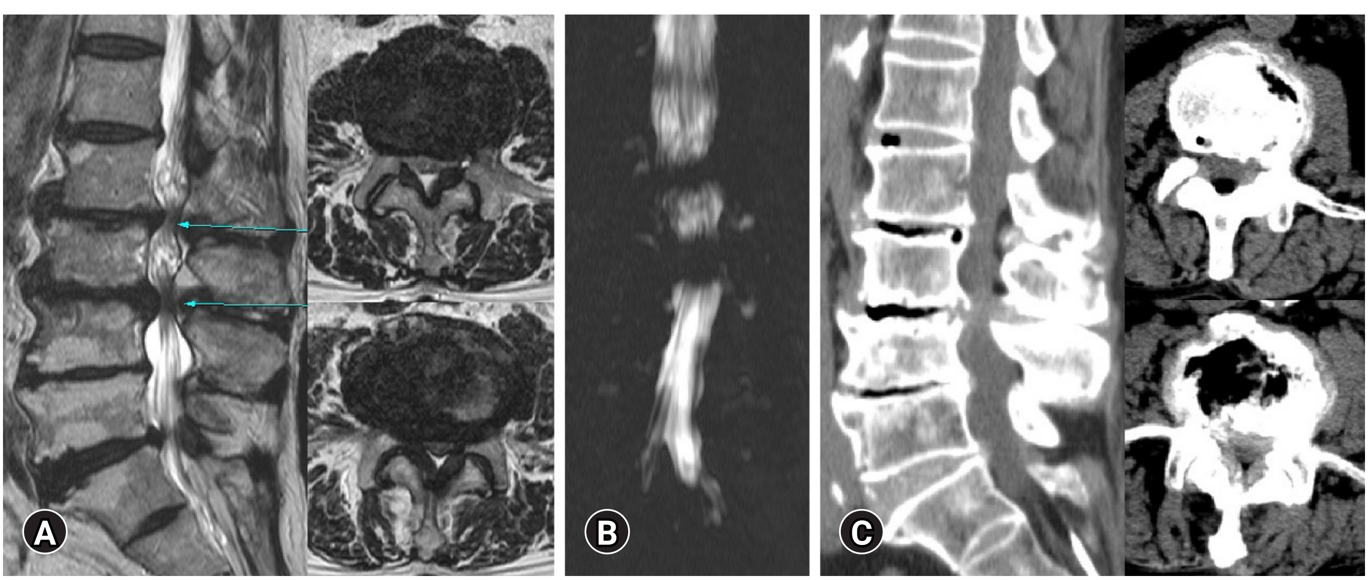

Figure 3. Preoperative images of lumbar spinal stenosis at L2-3, 3-4 level on MRI, MR myelography, and CT. (A) Sagittal and axial images on T2 weighted MRI. (B) An image on MR myelography. (C) Sagittal and axial images on CT.

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Figure 4. Postoperative images of lumbar spinal stenosis at L2-3, 3-4 level on MRI.

protrusion and vacuum disc in the intervertebral space, not in the spinal canal.

Calcification of the disc or the presence of calcium pyrophosphate dehydrate and/or hydroxyapatite in the nucleus pulposus or annulus fibrosus is more common in the elderly population with chronic disc herniation [11,12]. When a chronic and degenerative lesion such as a calcified disc exists, severe adhesion between the dural sac and the bottom of the spinal canal, especially the ventral side of the dura and surrounding soft tissues, is usually observed. Ventral dissection is needed for excessive retraction, can induce complications, including injuries of the dura and nerve root. Discectomy is rarely performed in calcified disc protrusion. In the previous experience of calcified disc, ventral dissection was tried to check the floor of the spinal canal and injury of the ventral dura was developed. If severe dural adhesion is observed in the case of calcified disc protrusion, we will advise against ventral dissection.

A vacuum disc phenomenon on radiologic images frequently appears in lumbar degenerative disease and is regarded as the last stage of disc degeneration. The vacuum consists of about 90% nitrogen and small amounts of oxygen and carbon dioxide [13-15]. The vacuum in intervertebral space is the instability sign and related to the low back pain [8]. That is not clinical significance. However, dynamic foraminal or lateral recess stenosis is induced, or after annulus fibrosus tears, the gas accumulation occurs within spinal canal. Surgical treatment is needed [9,16].

The surgical methods for treating lumbar spinal stenosis are decompression with fusion and decompression alone. However, the choice of appropriated technique remains controversial. Ahmed et al. [17] and Saleh [18] concluded that decompression with fusion had better outcomes than decompression alone, in terms of Oswestry disability index (ODI), VAS, and the Japanese Orthopedic Association score. In contrast to their findings, Shen et al. [19] supported that there were no significant differences in clinical outcomes, considering ODI. Aihara et al. [20] reported that significantly shorter operation time and hospitalization, and significantly less blood loss were observed in the decompression group.

There are numerous factors in the selection between decompression with fusion and decompression alone, including instability, age, general condition, osteoporosis, the number of involved segments, and surgeon's preference. Overt instability is the most important factor, because fusion is the treatment of choice. However, mild instability can be worrisome in the selection. Longer operation time and more blood loss can be attributed to perioperative morbidities in elderly patients or those with a poor general condition. Also, in patients with osteoporosis, instrument-related complications can be developed, such as cage subsidence, screw failure, and non-union. So, decompression alone can be a better choice for multiple lumbar stenosis in the elderly patients or those with a poor general condition or osteoporosis.

In our study, only surgical decompression was applied to cases of multilevel lumbar stenosis with calcified disc protrusion and vacuum disc in not the spinal canal but the intervertebral space. This method provided favorable treatment outcomes.

CONCLUSION

Only surgical decompression is an effective method for symptomatic multilevel lumbar spinal stenosis with calcified disc protrusion and vacuum disc in not the spinal canal but the intervertebral space, and provided favorable treatment outcomes with no perioperative complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA 2010;303:1259–1265.
2. Joaquim AF, Milano JB, Ghizoni E, Patel AA. Is there a role for decompression alone for treating symptomatic degenerative lumbar spondylolisthesis?: a systematic review. Clin Spine Surg 2016;29:191–202.
3. Joaquim AF, Sansur CA, Hamilton DK, Shaffrey CI. Degenerative lumbar stenosis: update. Arq Neuropsiquiatr 2009;67:553–558.
4. Orpen NM, Corner JA, Shetty RR, Marshall R. Micro-decompression for lumbar spinal stenosis: the early outcome using a modified surgical technique. J Bone Joint Surg Br 2010;92:550–554.
5. Haba K, Ikeda M, Soma M, Yamashima T. Bilateral decompression of multilevel lumbar spinal stenosis through a unilateral approach. J Clin Neurosci 2005;12:169–171.
6. Son S, Kim WK, Lee SG, Park CW, Lee K. A comparison of the clinical outcomes of decompression alone and fusion in elderly patients with two-level or more lumbar spinal stenosis. J Korean Neurosurg Soc 2013;53:19–25.
7. Kang MS, Choi KC, Lee CD, Shin YH, Hur SM, Lee SH. Effective cervical decompression by the posterior cervical foraminotomy without discectomy. J Spinal Disord Tech 2014;27:271–276.
8. Morishita K, Kasai Y, Uchida A. Clinical symptoms of patients with intervertebral vacuum phenomenon. Neurologist 2008;14:37–39.
9. Ayberk G, Özveren MF, Yıldırım T. Spinal gas accumulation causing lumbar discogenic disease: a case report. Acta Orthop Traumatol Turc 2015;49:103–105.
10. Hergan K, Amann T, Vonbank H, Hefel C. MR-myelography: a comparison with conventional myelography. Eur J Radiol 1996;21:196–200.
11. Bagatur AE, Zorer G, Centel T. Natural history of paediatric intervertebral disc calcification. Arch Orthop Trauma Surg 2001;121:601–603.
12. Oitment C, Kwok D, Steyn C. Calcified thoracic disc herniations in the elderly: revisiting the laminectomy for single level disease. Global Spine J 2019;9:527–531.
13. An KC, Kong GM, Park DH, Baik JM, Youn JH, Lee WS. Comparison of posterior lumbar interbody fusion and posterolateral lumbar fusion in monosegmental vacuum phenomenon within an intervertebral disc. Asian Spine J 2016;10:93–98.
14. Ford LT, Gilula LA, Murphy WA, Gado M. Analysis of gas in vacuum lumbar disc. AJR Am J Roentgenol 1977;128:1056–1057.
15. Kasai Y, Takegami K, Uchida A. Change of barometric pressure influences low back pain in patients with vacuum phenomenon within lumbar intervertebral disc. J Spinal Disord Tech 2002;15:290–293.
16. Lewandrowski KU, Zhang X, Ramírez León JF, de Carvalho PST, Hellinger S, Yeung A. Lumbar vacuum disc, vertical instability, standalone endoscopic interbody fusion, and other treatments: an opinion based survey among minimally invasive spinal surgeons. J Spine Surg 2020;6:S165–S178.
17. Ahmed SI, Javed G, Bareeqa SB, Shah A, Zubair M, Avedia RF, et al. Comparison of decompression alone versus decompression with fusion for stenotic lumbar spine: a systematic review and meta-analysis. Cureus 2018;10:e3135.
18. Saleh SM. Evaluation of posterior decompressive lumbar surgery for multilevel lumbar spinal canal stenosis with and without fusion. J Med Sci Res 2021;4:82–86.
19. Shen J, Wang Q, Wang Y, Min N, Wang L, Wang F, et al. Comparison between fusion and non-fusion surgery for lumbar spinal stenosis: a meta-analysis. Adv Ther 2021;38:1404–1414.
20. Aihara T, Toyone T, Aoki Y, Ozawa T, Inoue G, Hatakeyama K, et al. Surgical management of degenerative lumbar spondylolisthesis: a comparative study of outcomes following decompression with fusion and microendoscopic decompression. J Musculoskelet Res 2012;15:1250020.

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Case Report

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Single-stage C6-7 ACDF with T1-2 Oblique Keyhole Transcorporeal Disectomy to Treat Cervico-thoracic Tandem Disc Herniation: A Case Report

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Symptomatic cervico-thoracic tandem disc herniation occurs very rarely. On the other hand, cervical disc herniations are common and may be treated via a variety of surgical procedures. Symptomatic upper thoracic disc herniations are extremely rare, and use of a surgical approach in their treatment is controversial due to the narrow operative space within which surgical procedures must be performed. We report an extremely rare case of symptomatic tandem C6-7 and T1-2 disc herniation successfully treated via single-stage, single-incision, C6-7 anterior cervical decompression and fusion, and T1-2 oblique keyhole transcorporeal discectomy. This is the first symptomatic cervico-thoracic tandem disc herniation with its treatment.

Key Words: Disc herniation, Thoracic vertebrae, Cervical vertebrae

INTRODUCTION

Symptomatic cervico-thoracic tandem disc herniation occurs very rarely. Cervical disc herniation is a common pathology, which can be treated via several different surgical procedures [1]. Anterior cervical decompression and fusion (ACDF) remains the gold standard for treatment of symptomatic cervical disc herniation resistant to conservative treatment [1,2]. Symptomatic thoracic disc herniation (TDH) is very rare compared to disc herniation at cervical and lumbar regions, and occurs in 1 of 1,000,000 patients annually, comprising up to 4% of all surgical procedures [3,4]. Further, 75% of TDHs occur between the T8 and T12 levels [3].

The first case of T1-2 disc herniation was reported in 1954 by Sivien and Karavitis [4]. The optimal surgical approach for upper TDH treatment remains controversial [4]. Both anterior and posterior approaches have associated risks. When performing T1-2 surgery, use of the anterior approach is very challenging due to the narrow operative space available. Particularly, accessing the T1-2 level without manubriectomy, sternotomy or claviculectomy remains an issue [3,4]. On the other hand, use of the posterior approach in T1-2 surgery is associated with a high rate of neurological injury [5]. Here, we present an extremely rare case of symptomatic, tandem C6-7 and T1-2 disc herniation that was successfully treated using single-stage, single-incision C6-7 ACDF and T1-2 oblique keyhole transcorporeal discectomy.

CASE REPORT

1. Initial Findings

A 78-year-old-man without history of degenerative diseases and previous surgeries presented with a 1-year history of cervico-thoracic back pain who recently developed progressive motor weakness of both hands and both legs. A neurological examination revealed that the patient experienced numbness in both hands, and hand intrinsic muscle weakness. Hyperactive brachioradialis deep tendon reflexes and positive Hoffmann's sign was observed. Paresthesia and weakness of the lower extremities with gait instability were also observed. Magnetic resonance imaging (MRI) showed a C6-7 and T1-2 disc extrusion with signs of spinal cord compression including cord signal change a levels corresponding to the extrusions (Figure 1).

2. Operative Technique

The patient was placed in a supine position under nerve integrity monitor (NIM). After localizing the C6-7 disc space with fluoroscope, a Smith-Robinson approach was used. A 5-cm transverse incision was made at the C7 level. The sternocleidomastoid (SCM) and the carotid artery were localized and moved laterally. Subsequently, the trachea and esophagus were localized and moved medially. Then, when the longus colli muscle, an anatomic landmark, was visible they were dissected unilaterally in the medial to lateral direction. The C6-7 vertebral body (VB) was localized, and its identity was verified using a fluoroscope. The C6-7 disc was localized, and complete discectomy was performed using a microscope.

After the C6-7 discectomy performed successfully, we removed the retractor and attempted to localize the T1 VB. Achieving a true lateral view of T1-2 was very difficult due to the shoulder anatomy of the patient. Therefore, oblique views to confirm the location of the T1 VB were needed. After confirming the location of the T1 VB, we identified the precise keyhole drill point that was located during preoperative planning (Figure 2). Using a fluoroscope and microscope for assistance, high-speed diamond burr drilling was performed in oblique, lateral to central and cephalad to caudal directions, making a keyhole that allowed us to precisely reach the central, T1-2 disc space. After confirming the position of the tip of the burr in the T1-2 disc space with fluoroscope, the discectomy was performed without any complications.

Once the decompression with discectomy at the T1-2 level was completed, we proceeded to place the cage and anterior plate was placed at the C6-7 level. Cage placement was performed at the end of the procedure since we wanted to check for bleeding at the C6-7 level. The correct position of the cage and plate was confirmed, each layer was sutured, and drainage

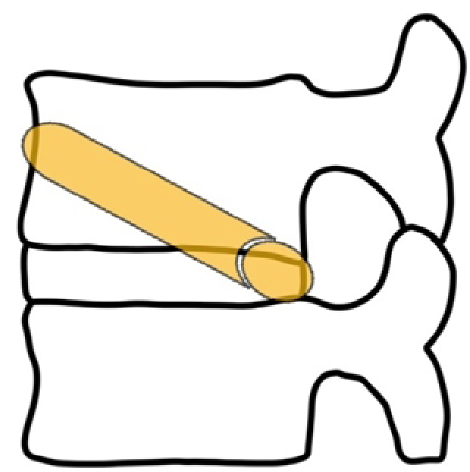

Figure 2. A schematic image of the oblique keyhole transcorporeal approach is shown.

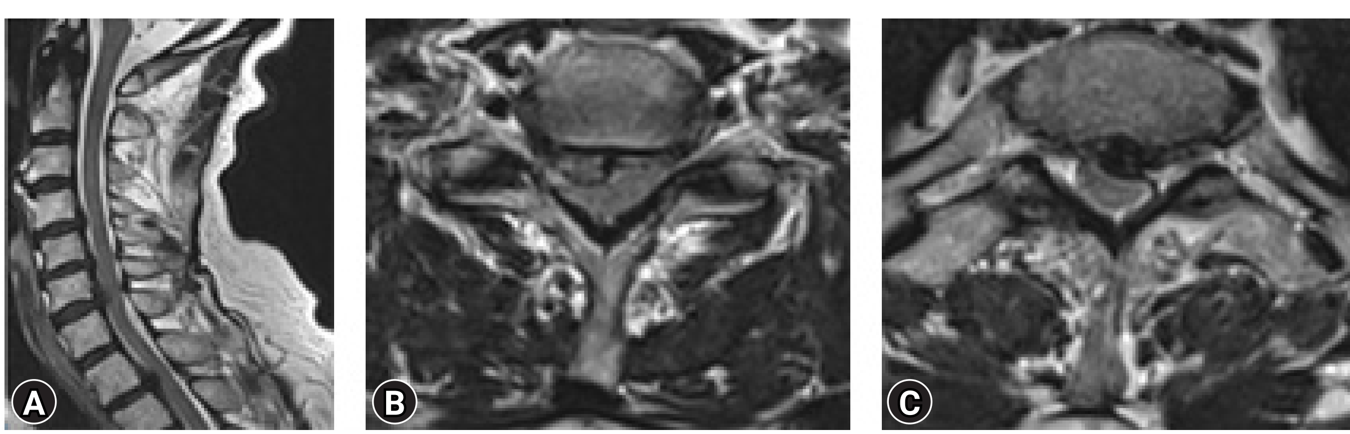

Figure 1. (A) Preoperative, sagittal T2 magnetic resonance imaging (MRI) of C6-7 and T1-2 disc herniation with signs of cord compression. (B) A preoperative, axial T2 MRI shows right disc herniation at C6-7. (C) A preoperative axial T2 MRI revealing central disc herniation at T1-2 is shown.

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was placed. The total duration of surgery was 2.5 hours.

3. Postoperative Course

Immediate cervico-thoracic back pain improvement was observed. Upper and lower extremity weakness, symptoms of myelopathy, as well as gait instability also improved significantly. The patient was discharged 14 days after surgery without any complications. Postoperative MRI scans showed complete removal of disc fragments from C6-7 and T1-2 regions (Figure 3). The diameter of keyhole entry at the vertebral body was approximately 5 mm.

DISCUSSION

Symptomatic tandem disc herniation of the cervical and thoracic spine occurs only in extremely rare cases. Several cases of tandem disc herniation of the cervical and lumbar, but not thoracic spine have been reported. The reason for this is likely because intervertebral disc herniation rarely occurs at the T1-2 level. This area is generally obstructed by the shoulder of the patient when examined via X-ray, and is located at the distal end of computed tomography (CT) or MRI examination findings [6]. Surgical treatment for thoracic disc herniation is indicated in patients with symptoms of spinal cord compression that are confirmed via MRI, and for those with radicular symptoms for whom conservative management has failed [7].

Nonetheless, surgical treatment of thoracic disc herniation remains a challenge due to its anatomy [7]. The spinal cord at the thoracic level fills most of the spinal canal, making it vulnerable to disc and intraoperative traction injuries [7]. Until the 1990s, T1-2 herniation was treated via the posterior approach with laminectomy exclusively. However, these surgeries were characterized by very high death rates (up to 50%) and an even higher morbidity levels of up to 70% [7]. Hence, use of the posterior approach for treating centrally located pathologies remains challenging. The presence of a narrow space makes it hard to retract the spinal cord without causing additional cord compression and cerebrospinal fluid leakage [8].

Anterior approaches were introduced as an alternative to laminectomy. Moreover, modern minimally invasive techniques were introduced such as thoracoscopic and endoscopic discectomy [7]. It remains obvious that the sternum, thoracic kyphosis, and clavicle restrict access to the pathology [8], and accessing the T1-2 disc space remains an issue, particularly with respect to whether it is possible for a surgeon to access the level without manubriectomy, sternotomy or claviculectomy [8]. Both posterior and anterior approaches are associated with high rates of complications.

Costotransversectomy and transthoracic approaches have high risk of pleural injury, hemothorax, subclavian vein injury and laryngeal nerve dysfunction, with complication rates of 54% and the potential for massive blood loss (1,500–200 mL) and prolonged hospitalization [7,8].

We discussed the use of numerous approaches throughout the treatment of our patient. We wanted to take advantage of the fact that the anterior approach could be used to simultaneously treat C6-7 and T1-2 regions. Posterior approaches were ruled out due to the anterior pathologies of our patient. The multiple oblique corpectomy (MOC) approach is an interesting technique since it provides wide anterior decompression of the spinal canal and limited bone resection, which preserves spinal

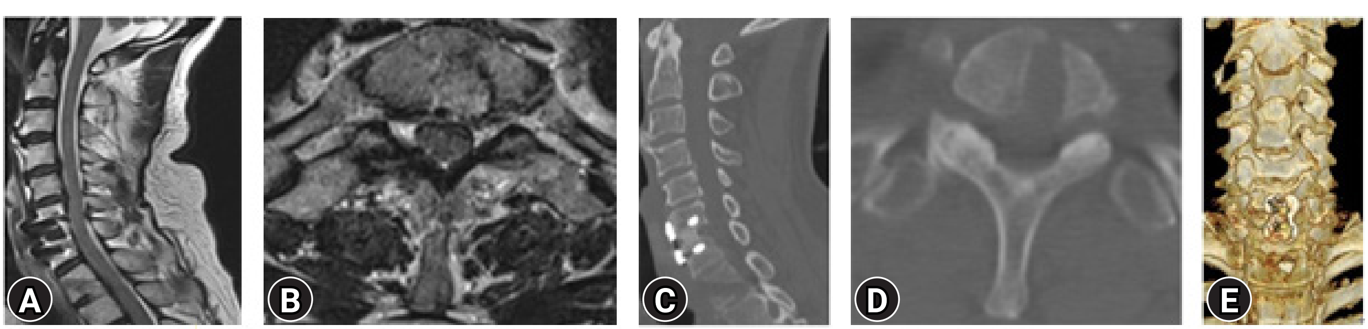

Figure 3. (A). Postoperative T2 sagittal magnetic resonance image (MRI) revealing the disappearance of herniated discs at C6-7 and T1-2, with no signs of cord compression. At the T1 body, the keyhole trajectory is shown. (B) A postoperative T2 axial MRI showing the T1 keyhole trajectory and disappearance of the T1-2 herniated disc, without signs of cord compression. (C) A sagittal computed tomography (CT) image showing adequate C6-7 anterior cervical decompression and fusion and a T1 keyhole trajectory. (D) Axial CT of the T1 keyhole trajectory is shown. (E) A three-dimensional CT of the anterior plate at C6-7 and the keyhole in the antero-superior part of the T1 vertebral body is shown.

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motion without causing instability [9]. The oblique approach would have been an ideal option for approaching C6-7 and T1-2; however, it was not selected because of its use may have required us to sacrifice the C7-T1 vertebral body or disc. Another interesting approach is keyhole transuncal foraminotomy. The technique involves direct drilling of the base of the uncinated process toward the intervertebral foramen, without destroying disc tissue. The technique also allows the functional anatomy of the uncovertebral joint to be retained post-surgery, since the joint is allowed to remain largely intact [10]. When selecting an ideal surgical method, advantages of MOC and keyhole transuncal foraminotomy were combined. A single Smith-Robinson incision of 5 cm was sufficient for ACDF realization at the C6-7 level, and T1-2 discectomy was accomplished using the oblique keyhole transcorporeal approach. With its oblique and caudal trajectory, there was no need to expose the T1-2 body nor was there a need for sternotomy, manubriectomy or claviculectomy. The oblique direction of keyhole entry (lateral to central and cephalad to caudal), the transition from lordosis to kyphosis at the C7-T1 level, and adequate positioning of the surgical bed made the perpendicular positioning of the drill possible, providing the surgeon with sufficient control and anatomic cues needed to reach the target point. Also, the keyhole approach does not cause instability because drilling of only a small portion of the vertebral body and endplate are required when performing a discectomy.

Detailed preoperative planning is needed to treat cases similar to the one described in this report. Decisions made were supported by fluoroscopic images obtained intraoperatively, which allowed the surgeon to continually check the disc level and the trajectory of the tunnel. This prevented unnecessary vertebral body resection while the surgeon attempted to reach the herniated disc at T1-2. Since the T1-2 level is hidden by the shoulder and other structures, c-arm oblique views to confirm the exact location of the drill when starting the tunnel were needed. An advanced intraoperative imaging system such as an O-arm or navigation system would have made the procedure easier. However, these types of systems are not commonly available. Also, not all of T1-2 disc herniations can be treated by transcorporeal approach. Neck length varies on each patient and therefore preoperative planning is very important. We think that a good clinical diagnosis, meticulous preoperative planning, basic preoperative images such as MRI and CT, intraoperative fluoroscopic assistance, and an experienced surgeon are sufficient for overcoming most problems associated with the procedure. With adequate preoperative planning and ideal anatomic characteristics (patients with a long neck, those within whom it is possible to visualize the upper portion of the T2 body) we think that the oblique keyhole transcorporeal approach may be used to treat different disk levels, even at lower levels including T2-T3.

CONCLUSION

We report an extremely rare case of C6-7 cervical, and T1-2 thoracic tandem disc herniation successfully treated with C6-7 ACDF and T1-2 transcorporeal oblique keyhole discectomy using single-incision, single-stage surgery. With extensive preoperative planning, transcorporeal oblique keyhole discectomy is an attractive alternative to the anterior approach to treat T1-2 disc herniation. The procedure can be performed without sternotomy or manubriectomy, which are considered principal limitations of the anterior approach. We are concerned that all of T1-2 disc herniations can be treated by transcorporeal approach. There are anatomic variance within each patient such as neck length that may limit the transcorporeal approach. However, to our knowledge, this is the first case of cervico-thoracic tandem disc herniation treated with single-incision, single-stage surgery via an anterior approach with great result which might help other colleagues facing similar scenarios.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Mazas S, Benzakour A, Castelain JE, Damade C, Ghailane S, Gille O. Cervical disc herniation: which surgery? Int Orthop 2019;43:761–766.
2. Choi KC, Ahn Y, Lee CD, Lee SH. Combined anterior approach with transcorporeal herniotomy for a huge migrated cervical disc herniation. Korean J Spine 2011;8:292–294.
3. Gokcen HB, Erdogan S, Gumussuyu G, Ozturk S, Ozturk C. A rare case of T1-2 thoracic disc herniation mimicking cervical radiculopathy. Int J Spine Surg 2017;11:30.
4. Hurley ET, Maye AB, Timlin M, Lyons FG. Anterior versus posterior thoracic discectomy: a systematic review. Spine (Phila Pa 1976) 2017;42:E1437–E1445.
5. Oltulu I, Cil H, Berven S, Chou D, Clark A, Ulu MO, et al. Surgical management of thoracic disc herniation: anterior vs posterior approach. Turk Neurosurg 2019;29:584–593.
6. Son ES, Lee SH, Park SY, Kim KT, Kang CH, Cho SW. Surgical treatment of T1-2 disc herniation with T1 radiculopathy:

 https://doi.org/10.21182/jmisst.2021.00318

a case report with review of the literature. Asian Spine J 2012;6:199–202.

7. Baranowska J, Baranowska A, Baranowski P, Rybarczyk M. Surgical treatment of thoracic disc herniation. Pol Merkur Lekarski 2020;49:267–270.
8. Choi BK, Han IH, Cho WH, Cha SH. Inferiorly migrated disc fragment at T1 body treated by T1 transcorporeal approach. J Korean Neurosurg Soc 2011;49:61–64.
9. Bruneau M, Cornelius JF, George B. Multilevel oblique corpectomies: surgical indications and technique. Neurosurgery 2007 61:106–112. discussion 112
10. Lee JY, Löhr M, Impekoven P, Koebke J, Ernestus RI, Ebel H, et al. Small keyhole transuncal foraminotomy for unilateral cervical radiculopathy. Acta Neurochir (Wien) 2006;148:951–958.

Case Report

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Minimally Invasive en bloc Excision of Rare Hemorrhagic Discal Cysts Using Unilateral Biportal Endoscopic Technique: A Report of Two Cases

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Hemorrhagic discal cyst (HDC) is a rare cause for low back pain and radiculopathy. Although there is no treatment guideline in the literature, it is believed that the surgi-cal excision showed better treatment results than the conservative treatment. In this report, we described two patients with HDC who were treated using the minimally invasive unilateral biportal endoscopic (UBE) technique. Two patients with the rare HDC in their lumbosacral spines came to our clinic due to low back pain and severe sciatica after failure of conservative treatment. Both patients' MRI revealed a cystic mass mimic a ruptured lumbar disc herniation with compression of the nerve root. The cysts were excised using UBE technique. The features of UBE technique are two small surgical wounds, minimal muscle dissection, continuous normal saline irrigation, excellent hemostasis, and a crystal clear and magnified endoscopic surgical field. These features enable meticulous dissection, en bloc excision of the cyst, and reduce the risks of dural tears or nerve root injuries. Both patients had very good symptoms relief and quick recovery after the surgery with no complications. The UBE technique is a safe, effective, and excellent surgical treatment option for patients with HDC in the lumbosacral spine.

Key Words: Hemorrhagic discal cyst, Unilateral biportal endoscopic technique, Endoscopic spine surgery, Minimally invasive surgery

INTRODUCTION

The hemorrhagic discal cyst (HDC) is a rare intraspinal extradural cystic lesion that connects with the lumbar intervertebral discs [1]. The pathophysiology of the HDC is unclear. Most of the reported cases are relatively young and active males possibly associated with trauma histories [2].

The clinical presentations of HDC are very much like the lumbar disc herniation. The differential diagnosis between them was not difficult under the magnetic resonance images (MRI). In the reported cases, the surgical excision of the cyst seemed to be a better option than the conservative treatment [3]. While the traditional open surgery was effective, the major drawbacks were massive soft tissue dissection and excessive destruction of the bony structures. Furthermore, the incidental dural tears and nerve root injuries with traditional open surgery were also reported due to severe adhesion between the cysts and the neural structures [4,5].

Unilateral biportal endoscopic surgery (UBE) has been performed for more than 10 years [6]. This minimally invasive endoscopic technique has been successfully applied in various treatments with conditions including lumbar disc herniation and degenerative lumbar spinal stenosis [7,8]. However, UBE has not been used in the treatment of lumbar HDC in the past. In this case report, we shared two successful treatment cases of HDC using the UBE technique.

CASE REPORT

1. Case 1

The first case was a 41-year-old man with no systematic disease. He was referred to our hospital due to his low back pain, intolerable sciatica in his right leg, and difficulty in walking after lifting a heavy object 2 months ago. He had severe radicular leg pain originated from his right buttock, along the posterior thigh down to posterior calf and foot sole with severe muscle cramps. He also had mild numbness distributed along the S1 dermatome in his right leg. Conservative treatments including NSAIDs and physical therapy did not improve his symptoms at all. The straight leg raising test was positive at 20 degrees in the right leg, and the contralateral straight leg raising test was also positive. Plain radiographs of his lumbar spine showed mild degeneration with no significant disc space narrowing and no segmental instability. The MRI revealed an epidural cystic mass located posteriorly to the L5-S disc space, mimicking a ruptured disc. However, the L5-S disc was essentially normal with only mild degeneration. The right S1 nerve root was displaced posteriorly in the lateral recess. The cyst had low signal intensity on T1-weighted images and high signal intensity on T2-weighted images (Figure 1A).

We planned to remove the cystic mass via right side posterior interlaminar approach using unilateral biportal endoscopic (UBE) technique. Under general anesthesia, the patient was placed prone on the radiolucent Relton-Hall frame. The skin and the surgical field were prepared in the usual manners. The surgical procedure was essentially the same as the UBE discectomy. The spinal level of concerns was localized using the biplanar fluoroscope and marked on the skin. There were two skin incisions through the deep fascia: one smaller about 5–6 mm for insertion of a 30-degree arthroscope and continuous normal saline irrigation; one larger about 8–10 mm for the outflow of normal saline and served as the instrumental portal .

The target of the initial laminotomy was the junction of the spinous process and the lower laminar margin of superior vertebra. The two skin incisions located along the medial pedicle line, separated by 2–3 cm. We used serial dilators up to 10 mm to split the fascia and the paraspinal muscles, enlarge the instrument portal, and gently detach the soft tissues off the interlaminar space. After the inflow of normal saline, a small space was created as the initial surgical field. The whole surgical procedure was performed in a crystal clear and magnified surgical field. The hemostasis was controlled by balancing hydrostatic pressure and using radiofrequency wands to coagulate the bleeders (ArthroCare, Austin, TX, USA); hence, the whole surgical procedure was performed in a crystal clear and magnified surgical field.

This laminotomy was performed using an electric high-speed diamond bur of 4 mm in diameter (Primado 2; NSK, Fukushima, Japan). Following the laminotomy and the removal of the ligamentum flavum, the dura and the traversing nerve root were identified. The cystic mass was found beneath the shoulder area of the S1 traversing nerve root with severe adhesion between the cyst and the dura. The cyst was well encapsulated, brownish blue in color with severe adhesion to the dura and the nerve root (Figure 1B). There was a fibrotic stalk connecting to the posterior annulus fibrosis of the L5-S disc. The cyst was meticulously dissected and isolated using the blunt dural dissectors and nerve hooks. Then the cyst was removed en bloc by dividing the connecting stalk. A tiny annular defect was identified and closed by thermal annuloplasty using the radiofrequency wand. Histopathological examination of the cyst showed fibrosis and hemosiderin deposition within the cyst wall with no disc materials inside the cyst. Within hours after the operation, the patient noticed great improvements in his symptoms. He was discharged from the hospital on the next day. Four weeks later, free from any pain, the patient had returned to work and resumed his daily activities.

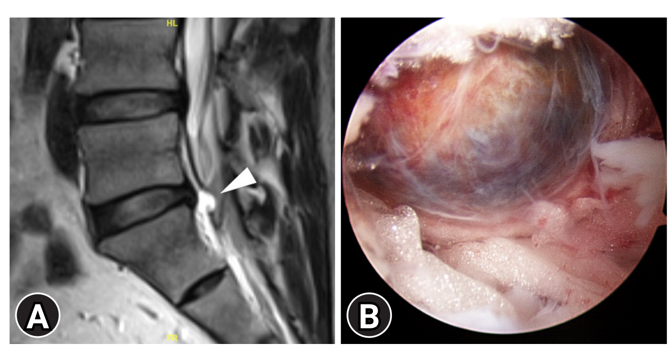

Figure 1. (A) MRI of the lumbar spine showed a cystic mass (white arrow head) mimicking a ruptured disc herniation at L5-S disc level with posterior displacement of the S1 traversing nerve root. (B) Intra-operative photo showed a well-capsulated brownish blue cyst beneath the traversing nerve root.

2. Case 2

The second case was a 25-year-old man who had been suffering from low back pain, radicular pain in his left leg, walking difficulty for 1 year with progressive worsening in the recent 4 months. He had no neurological deficits. The MRI obtained from another hospital revealed an epidural cystic lesion, measured 17 mm by 11 mm, located at the left side and posterior to the L5 vertebral body at the L5-S disc level. His cystic lesion had high signal intensity on T2-weighted images and low signal intensity on T1 weighted images (Figure 2A). He had been treated conservatively with NSAIDs, physical therapy, and epidural steroid injections with no improvement at all. Therefore, he was referred to us for further treatment with UBE surgery. The surgical procedures were the same as described for the first case, via left side posterior interlaminar approach. The plane between the cystic lesion and dura was very difficult to get identified because of severe adhesion (Figure 2B, C). However, the surgical field in UBE surgeries was so clear and magnified that we could do delicate dissection without any injury to the dura and the nerve root. The cyst was elastic firm, in dark blue color with no pulsation. Unlike the first case, there was no connecting stalk with the underlying disc. The cyst had a broad base connection with the posterior annulus fibrosis of the L5-S disc but no annular defect could be identified after en bloc excision of the cyst. Histopathological examination reported as a mass with fibrotic cyst wall composed of hemorrhagic deposit with no disc materials inside.

The patient's low back pain and lower leg pain improved immediately after the surgery. He walked very well and was discharged from the hospital on the next day. One week after the surgery, the patient returned to his work as a heavy labor with only mild soreness in his left buttock during the initial weeks. Follow-up MRI study after months showed the cyst was excised with a small cyst remnant but no neural compression.

DISCUSSION

Hemorrhagic discal cyst (HDC) in the lumbar spine is extremely rare that its importance is often overlooked. The clinical presentation and symptoms of HDC are similar to the lumbar disc herniation because of its mass effect and compression to the neural structures. There are three hypotheses regarding its pathogenesis: I. reaction to spinal epidural hematoma; II. a pseudomembrane formation that follows the focal annular tear and disc degeneration; and III. an inflammatory reaction to the herniated disc fragment [1,9]. The hemorrhagic content suggested a trauma related mechanism. Computed Tomography (CT) discography and MRI are the most accurate image modalities to detect the HDC. CT discography is able to demonstrate the connecting channel between the cyst and the corresponding intervertebral disc, but it is an invasive procedure. The lesion is not difficult to get detected in the MRI because it shows low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. However, the signal intensity may vary with evolution of the hemorrhage inside the cyst [10].

There was no guideline suggesting the optimal treatment for HDC in the past. Most of the evidences were in the form of case reports or small series [3,11,12]. Several studies with conservative treatment showed low satisfaction rate with a low rate of

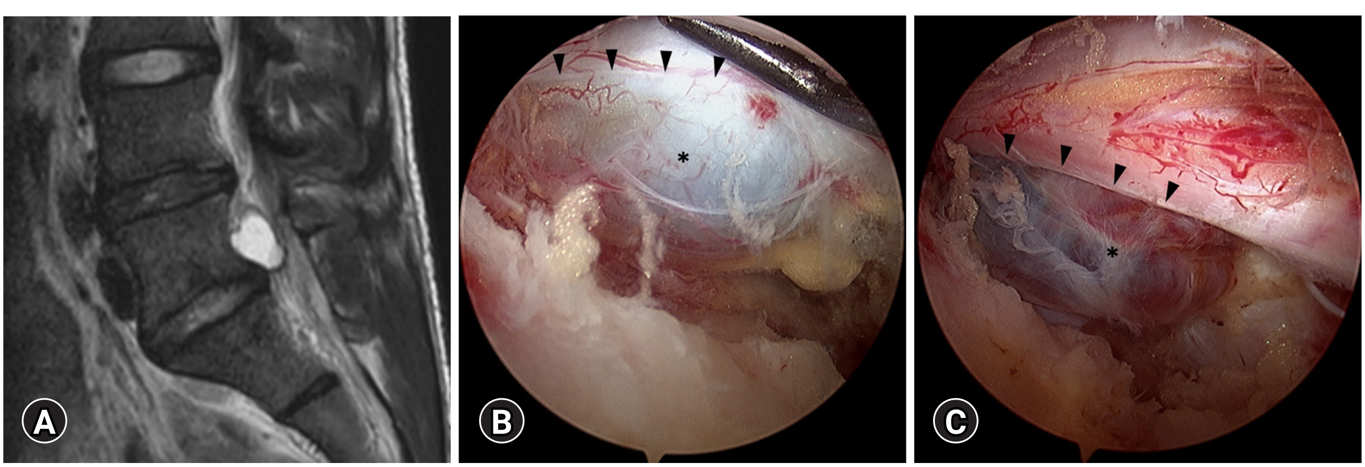

Figure 2. (A) Pre-operative MRI: the broad base cystic mass with posterior displacement of the S1 traversing nerve root. (B) The intra-operative photo: severe adhesion (black arrowheads) with a vague plane between the cyst (asterisk) and the dura. (C) The dark blue hemorrhagic cyst (asterisk) was isolated after meticulous dissection to release the adhesion from the dura and the S1 nerve root.

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spontaneous regression of the cysts. Many conservatively treated cases were ultimately shifted to surgical treatment [13,14]. A variety of invasive procedures for the HDC have been suggested, including CT-guided aspiration, laser ablation, and microscopic excision [15,16]. The CT-guided aspiration could achieve good clinical results but there still were concerns for recurrence of the cyst. Moreover, it required accurate techniques to avoid injuries to the neural structures [17]. Therefore, the surgical excision of the HDC seemed to be the most reliable way to relieve pain and decompress the neural structures.

Traditional surgical excision of the HDC is generally effective for symptom relief. However, it usually involves a big surgical wound, extensive soft tissue dissection, and excessive bony destruction. All of these issues could lead to atrophy of the paraspinal muscles, chronic post-operative low back pain, and segmental instability. In order to avoid the untoward side effects of the traditional surgery, various minimally invasive surgical techniques were developed. These techniques included the microendoscopic techniques using the tubular retractor system and the percutaneous endoscopic techniques using the uniportal endoscopic system [18]. These minimally invasive techniques shared common advantages including minimal blood loss, minimal postoperative pain, shorter hospitalization, rapid recovery, comparable treatment results with traditional open techniques, preservation of the soft tissues and the paraspinal muscles, and less destruction of the posterior stabilizing structures.

In this report, we used the UBE techniques to en bloc excise the HDC. The follow-up MRI in our cases demonstrated that there was almost no paraspinal muscles damage and very good preservation of the facet joint. Clinical presentations of both patients also showed excellent symptoms relief, quick functional recovery, and no low back pain.

Different from the uniportal endoscopic technique, the UBE technique uses two independent surgical portals: one for the endoscope and the other for the instruments. Handling of the surgical instruments in the UBE technique is not restricted in the endoscopic channel. With high resolution endoscope, continuous normal saline irrigation, and meticulously controlled hemostasis, there is almost no bleeding in the surgical filed. In both of our cases, there were severe adhesion between the cysts and the surrounding dura and nerve roots, possibly due to the inflammatory reaction induced by the cyst. The adhesion increased the risks for incidental dural tear or nerve root injury. However, with the UBE technique, we could perform delicate dissection to release the adhesion and gently manipulate around the neural structures. These unique features made the surgical procedure possible for en bloc excision of the cyst in a crystal clear and magnified surgical field with less complications.

For HDC, recurrence is a potential late complication. Although the origin of the cyst was believed to be the intervertebral disc, the concomitant discectomy was not recommended to prevent the recurrences [13]. HDC usually occurred in relatively young active people and discectomy might have negative impact on spinal biomechanics as well as to accelerate the degeneration process. Thermal annuloplasty using the radiofrequency wand might be an alternative technique to reduce the risks of recurrence and avoid the discectomy [19].

In our second case, we noted a residual cyst remnant in the follow-up MRI. The remnant located in the blind spot deep underneath the dura and was difficult to reach due to the broad base structure of the cyst. Fortunately, the remnant was asymptomatic; therefore, the secondary surgery was not necessary.

CONCLUSION

In conclusions, biportal endoscopic surgery is a safe, effective minimally invasive surgical treatment for HDC. En bloc excision of the cyst along with thermal annuloplasty could be considered as a choice for the surgical treatment.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Kobayashi S, Takeno K, Uchida K, Yayama T, Nakajima H, Miyazaki T, et al. Pathogenesis of the discal cysts communicating with an adjacent herniated disc. Histological and ultrastructual studies of two cases. Joint Bone Spine 2010; 77:184–186.
2. Sanjeevan R, Prabu S, Azizul A, Abdul-Halim Y. Discal cyst of the lumbar spine: case report of a rare clinical entity. Malays Orthop J 2018;12:56–58.
3. Bansil R, Hirano Y, Sakuma H, Watanabe K. Transition of a herniated lumbar disc to lumbar discal cyst: a case report. Surg Neurol Int 2016;7:S701–S704.
4. Hsu KY, Zucherman JF, Shea WJ, Jeffrey RA. Lumbar intraspinal synovial and ganglion cysts (facet cysts). Ten-year experience in evaluation and treatment. Spine (Phila Pa 1976) 1995;20:80–89.
5. Artico M, Cervoni L, Carloia S, Stevanato G, Mastantuono

M, Nucci F. Synovial cysts: clinical and neuroradiological aspects. Acta Neurochir (Wien) 1997;139:176–181.

6. Hwa Eum J, Hwa Heo D, Son SK, Park CK. Percutaneous biportal endoscopic decompression for lumbar spinal stenosis: a technical note and preliminary clinical results. J Neurosurg Spine 2016;24:602–607.
7. Kim JE, Choi DJ, Park EJJ, Lee HJ, Hwang JH, Kim MC, et al. Biportal endoscopic spinal surgery for lumbar spinal stenosis. Asian Spine J 2019;13:334–342.
8. Pao JL, Lin SM, Chen WC, Chang CH. Unilateral biportal endoscopic decompression for degenerative lumbar canal stenosis. J Spine Surg 2020;6:438–446.
9. Kono K, Nakamura H, Inoue Y, Okamura T, Shakudo M, Yamada R. Intraspinal extradural cysts communicating with adjacent herniated disks: imaging characteristics and possible pathogenesis. AJNR Am J Neuroradiol 1999;20:1373– 1377.
10. Lee HK, Lee DH, Choi CG, Kim SJ, Suh DC, Kahng SK, et al. Discal cyst of the lumbar spine: MR imaging features. Clin Imaging 2006;30:326–330.
11. Kim SH, Ahn SS, Choi GH, Kim DH. Discal cyst of the lumbar spine: a case report. Korean J Spine 2012;9:114–117.
12. Jha SC, Higashino K, Sakai T, Takata Y, Abe M, Nagamachi A, et al. Percutaneous endoscopic discectomy via transforaminal route for discal cyst. Case Rep Orthop 2015;2015:273151.
13. Park JW, Lee BJ, Jeon SR, Rhim SC, Park JH, Roh SW. Surgical treatment of lumbar spinal discal cyst: is it enough to remove the cyst only without following discectomy? Neurol Med Chir (Tokyo) 2019;59:204–212.
14. Aydin S, Abuzayed B, Yildirim H, Bozkus H, Vural M. Discal cysts of the lumbar spine: report of five cases and review of the literature. Eur Spine J 2010;19:1621–1626.
15. Yu HJ, Park CJ, Yim KH. Successful treatment of a symptomatic discal cyst by percutaneous C-arm guided aspiration. Korean J Pain 2016;29:129–135.
16. Kim JS, Choi G, Lee CD, Lee SH. Removal of discal cyst using percutaneous working channel endoscope via transforaminal route. Eur Spine J 2009;18 Suppl 2:201–205.
17. Kang H, Liu WC, Lee SH, Paeng SS. Midterm results of percutaneous CT-guided aspiration of symptomatic lumbar discal cysts. AJR Am J Roentgenol 2008;190:W310–W314.
18. Chen S, Suo S, Li C, Wang Y, Li J, Zhang F, et al. Clinical application of percutaneous transforaminal endoscopic surgery in lumbar discal cyst. World Neurosurg 2020;138:e665–e673.
19. Sairyo K, Kitagawa Y, Dezawa A. Percutaneous endoscopic discectomy and thermal annuloplasty for professional athletes. Asian J Endosc Surg 2013;6:292–297.

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Case Report

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Peri-operative Management and the Role of Minimally Invasive Spine Surgery in a Case of Hemophilia B

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Hemophilia A and B are rare X-chromosome-linked recessive bleeding disorders caused by mutations in the genes causing abnormalities of blood clotting factors VIII and IX, respectively. Surgery in these patients will require additional planning and interaction among the surgeon, anesthetist, and a hematologist because they inevitably result in bleeding, excessive blood loss, and other life-threatening complications. The authors present a case 62-year-old male with haemophilia B and progressive neurological claudication. On plain radiographs and MRI the patient had grade 1 spondylolisthesis with lumbar canal stenosis at L4-L5 with a VAS score of 8 and ODI score of 45 and was operated with MIS-TLIF with 22 mm diameter tubular retractor (METRx, Medtronics) and an operating microscope. Pre-operatively, the hematologist opinion was taken and the patient was optimised by maintaining the plasma factor peak level activity according to the WFH guidelines. The patient had uneventful peri-operative period. The total hospital stay is 16 days and a VAS score of 3 and ODI score of 12 after one-year follow-up and without any notable complications. Minimally invasive surgical techniques are a better option in hemophilia patients as these techniques provide the surgeon with an excellent magnification of the operative field, which enables the use of a smaller incision, better hemostasis, and facilitates less traumatic procedures.

Key Words: Hemophilia B, Factor IX, Minimally invasive surgery, spinal fusion, Spine, Surgical blood loss

INTRODUCTION

Spine surgery in the hemophilia patient is not a well documented entity in the literature. As per the author's knowledge, there is no literature related to minimally invasive spine surgery in hemophilia. We report our experience with a patient of hemophilia B treated with minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF).

CASE REPORT

After taking patient consent for purpose of the study with due care to maintain his privacy, the authors present a known case of 62-year-old male with haemophilia B and progressive neurological claudication. On plain radiographs, the patient had grade 1 spondylolisthesis according to mayerdings classification at L4-L5 with a visual analogue scale (VAS) score of 8 and Oswestry disability index (ODI) score of 45 and no symptomatic improvement with conservative management. On MRI, the patient had L4-L5 lumbar canal stenosis and the patient was operated on with MIS-TLIF (Figure 1). Pre-operatively, the hematologist opinion was taken and the patient was optimised by maintaining the plasma factor peak level activity at 60–80 IU/DL according to the world federation of hemophilia (WFH)

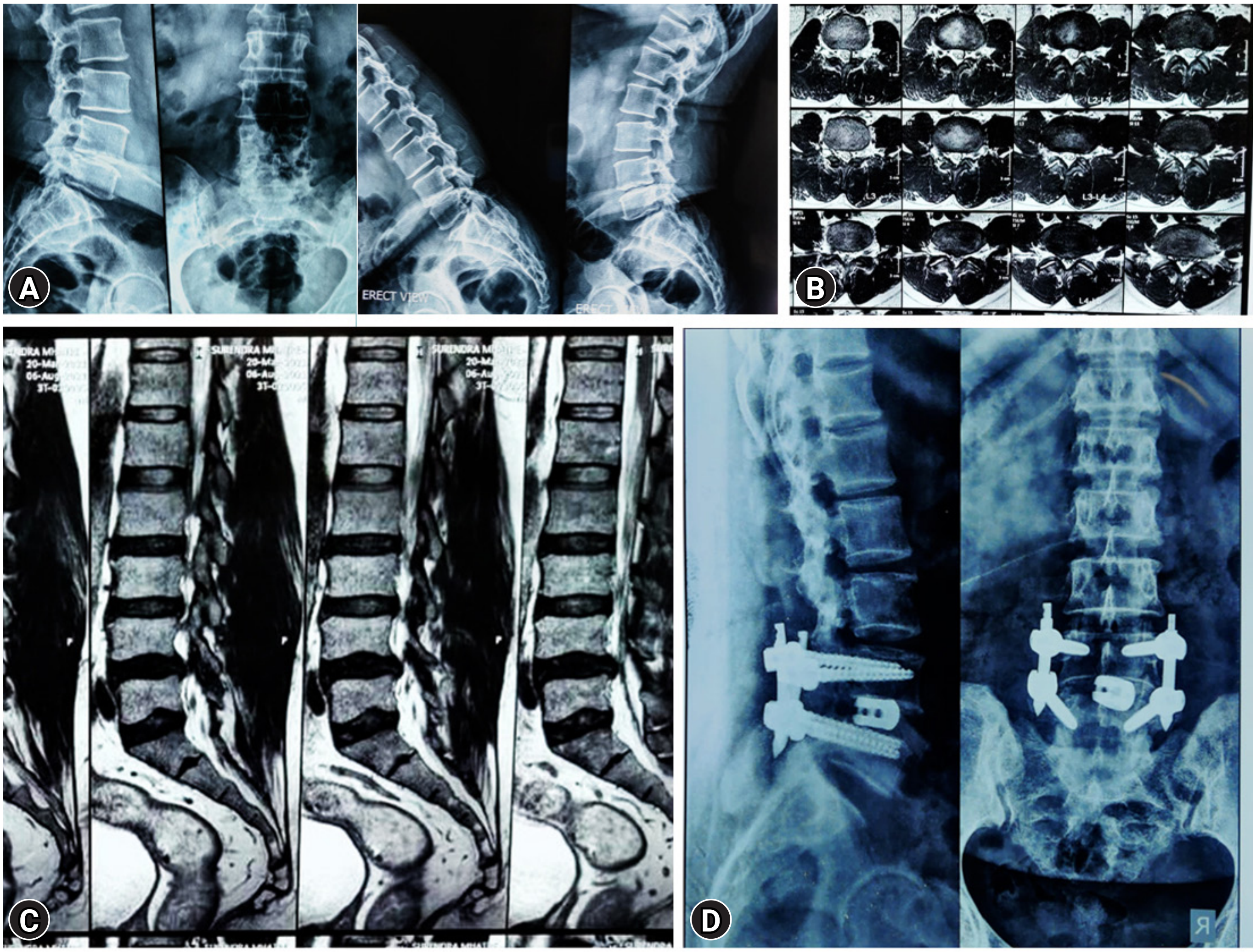

Figure 1. Index case. (A) Pre-operative plain radiographs. (B) Axial MR images. (C) Sagittal MR images. (D) Post-operative plain radiographs.

guidelines [1] after checking with activated partial thromboplastin time (APTT), and All factor allogeneic antibodies (inhibitors) levels (Table 1). Intra-operatively, hypotensive anesthesia was given, the operative time is 139 minutes and the total blood loss is 130 mL. Postoperatively, the drain output was 20 mL, and the plasma factor peak level activity was maintained according to the WFH guidelines and nonsteroidal anti-inflammatory (NSAIDs) medication was avoided for the risk of gastrointestinal bleeding. The total hospital stay is 16 days and the patient had symptomatic improvement with a VAS score of 3 and ODI score of 12 after one-year follow-up and without any notable complications. This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with the IRB of Bombay hospital and medical research centre who determined that our study did not need ethical approval. An IRB official waiver of ethical approval was granted from the IRB of Bombay hospital and medical research centre. Informed consent was obtained from all individual par-

Table 1. Summary of the patient

Age	62 years
Procedure	L4-5 MIS-TLIF
Operative time	139 minutes
Blood loss	130 mL
Drain output	20 mL
Hospital stay	16 days
Pre-op factors (IU/DL)	60–80
Post-operative factors (IU/DL)	
1–3	40–60
4–6	30–50
7–14	20–40
Blood transfusion	Not done
Complications	None

MIS-TLIF: minimally invasive transforaminal lumbar interbody fusion.

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ticipants included in the study and patients signed informed consent regarding publishing their data and photographs.

Surgical Technique

Under anesthesia, the patient was prone positioned on a radiolucent operating table. Under fluoroscopic guidance, the level was confirmed and a 3 cm long paraspinal incision 3–5 cm away from midline was given on the more symptomatic side for decompression utilizing the same for pedicle screw insertion on that side. Sequential dilatation was done and a tubular retractor with 22 mm diameter (METRx, Medtronics) was docked over the facet and spino-laminar line. Ipsilateral facetectomy and laminotomy, along with the removal of ligamentum flavum were performed under a microscope to accomplish adequate neural decompression. Utmost care is taken at every step to achieve meticulous hemostasis. Following discectomy and preparation of endplates, an appropriate size interbody cage filled with autologous bone was inserted. The pedicles were cannulated with a cook's needle under fluoroscopic guidance and guidewires were inserted on both sides. The serial dilators were used to dilate over the guidewires and the pedicles were tapped using a cannulated tap. Screws were placed with corresponding screw extenders and the rod was introduced with a device through a proximal stab incision. After placement of locking-cap screws through the screw extenders and application of compression, the screws were torqued and the screw extenders were removed. Closure in layers was performed following wound hemostasis and unlike routine protocol, negative suction drain was kept for one day.

DISCUSSION

Hemophilia A and B are rare X-chromosome-linked recessive bleeding disorders caused by mutations in the genes causing qualitative and quantitative abnormalities of blood clotting factors VIII and IX, respectively [2]. The prevalence of hemophilia A is 1 in 5,000, and B is 1 in 30,000 male live births [2,3]. The diseased can be grouped as severe, moderate, and mild forms of the diseases, defined by factor plasma levels of 1% or less, 2% to 5%, and 6% to 40%, respectively [3]. They usually present as bleeding after minor trauma or as a spontaneous bleed. Bleeding symptoms often correlate with the degree of residual factor level and the severity of the disease.

It has been described in the descent of Queen Victoria of England and is often called "the disease of the kings" [4]. The earliest description dates back to the second century AD in the Babylonian Tribe and the modern history by Dr. John Conrad Otto, where he described an inheritable bleeding disorder. The word "Hemophilia", was first documented by Johann Lukas Schönlein [4].

Surgery in these patients will require additional planning and interaction among the surgeon, anesthetist, and a hematologist because they inevitably result in bleeding, excessive blood loss, and other life-threatening complications. There are some previous studies showing that hemophilia patients can be operated with good results [5,6] following the WFH guidelines. So, optimization of peak plasma factor levels according to the world federation of hemophilia guidelines that is 60–80 IU/DL pre-operatively, 40–60 IU/DL for the first three days post-operatively, 30–50 at four to six post-operative days, 20–40 IU/DL at seven to fourteen post-operative days, is of supreme importance for uneventful surgery [1]. Administration of repeated doses of coagulation factors can lead to the appearance of inhibitors which can cause massive bleeding despite the infusion of coagulation factors. So, checking with the blood inhibitor levels before surgery can save from massive bleeding. Apart from plasma-derived and recombinant coagulation factor concentrates, other agents like desmopressin, tranexamic acid, and epsilon aminocaproic acid also are useful in hemophilia patients [7]. However, they are not used in this case because of the absence of inhibitory factors, normal aPTT values. There is a paradigm shift towards minimally invasive spine surgeries in recent times because of lesser muscle dissection, operative time, blood loss, and other favorable peri-operative factors. These factors can be an added benefit especially in patients with hemophilia to minimize the feared peri-operative complications. The case in our study has total blood loss and operative time similar to previous MIST-TLIF studies [8]. This is comparatively low as compared to the case series done by Kobayashi et al. [9] in hemophilia patients. The hospital stay is longer as compared to other studies for intravenous infusion of factors until the 14th postoperative day [8].

Although we had good results in this case report, further studies with a large study group are required. However, this case helps in understanding the protocols of peri-operative management in a hemophilia patient.

CONCLUSION

Surgeries are safe in hemophilia patients with good planning and a holistic team approach including surgeon, hematologist and anaesthetist with dose adjustment of the coagulation factor to maintain a desirable factor level and having a smooth post-operative recovery. Minimally invasive surgical techniques will further help in these patients, as these techniques provide the surgeon with an excellent magnification of the operative field, which enables the use of a smaller incision, less muscle trauma and better hemostasis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article.

REFERENCES

1. Srivastava A, Santagostino E, Dougall A, Kitchen S, Sutherland M, Pipe SW, et al. WFH Guidelines for the Management of Hemophilia panelists and co-authors. WFH guidelines for the management of hemophilia, 3rd edition. Haemophilia 2020;26 Suppl 6:1–158.
2. Mannucci PM, Tuddenham EG. The hemophilias--from royal genes to gene therapy. N Engl J Med 2001;344:1773–1779.
3. Bolton-Maggs PH, Pasi KJ. Haemophilias A and B. Lancet 2003;361:1801–1809.
4. Schramm W. The history of haemophilia - a short review. Thromb Res 2014;134 Suppl 1:S4–S9.
5. Bastounis E, Pikoulis E, Leppäniemi A, Alexiou D, Tsigris C, Tsetis A. General surgery in haemophiliac patients. Postgrad Med J 2000;76:494–495.
6. Kasper CK, Boylen AL, Ewing NP, Luck JV Jr, Dietrich SL. Hematologic management of hemophilia A for surgery. JAMA 1985;253:1279–1283.
7. Franchini M, Mannucci PM. Past, present and future of hemophilia: a narrative review. Orphanet J Rare Dis 2012;7:24.
8. Hammad A, Wirries A, Ardeshiri A, Nikiforov O, Geiger F. Open versus minimally invasive TLIF: literature review and meta-analysis. J Orthop Surg Res 2019;14:229.
9. Kobayashi K, Imagama S, Ando K, Ito K, Tsushima M, Morozumi M, et al. Perioperative management of patients with hemophilia during spinal surgery. Asian Spine J 2018;12:442–445.

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