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Systematic Review

Does Routine Post-Operative Use of Drainage in Minimally Invasive Lumbar Spine Surgery Offer Better Results?

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Objective

The advantages of minimally invasive spine surgery (MISS) in lumbar degenerative diseases have been well described (less tissue damage, shorter hospital stay, better results in pain assessment). One aspect that has not yet been studied enough is the usage of a post-operative drain in MISS. The aim of this study was to determine whether drainage in MISS is necessary or not and what advantages or disadvantages its use offers.

Materials - Methods

We conducted a systematic review of the published literature, searching articles published on Pubmed and Embasse until December 1st 2022, regarding MISS in the lumbar region and post-operative drain usage. Our inclusion criteria were original articles written in English and articles using minimally invasive techniques (usage of tubular retractors along with an endoscope or microscope, paramedian incision, percutaneous screw placement). 42 articles were assessed, and after careful examination and duplication exclusion, 26 research papers were included. Usage, type and duration of postoperative drainage, length of hospital stay, ambulation time and complications were extracted, and relevant results were pooled.

Results

The majority of the included articles (80.7 %) reported using a negative-pressure post-operative drain tube. Drains were removed either 48 hours after surgery or when the drainage volume was less than 50ml/24h. Hospital stays and time to ambulation were shorter in cases where drainage was not used. There was no difference in complications between cases where drainage was used and those that it was not.

Conclusion

The rationale behind post-operative drainage in MISS is to protect from surgical site infections and hematoma creation. Based on our study there is no evidence to support this hypothesis. On the contrary, our results suggest that the drawbacks of using a drain (pain, discomfort, anxiety, inconvenience of mobilisation, prolongation of hospitalisation) outweigh the advantages, thus making the routine use of postoperative drainage in MISS unnecessary.

Keywords: *minimally invasive, spine surgery, drains, complications*

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Knowledge E
enriching | engaging | empowering

1. Introduction

Lumbar degenerative disease is a broad medical term which encompasses conditions like spondylolisthesis, disc degeneration, and lumbar spinal stenosis. Associated with a variety of clinical symptoms, including lower extremity pain, weakness, and low back pain of varying levels of severity, lumbar degenerative spine disease can lead to a reduction in quality of life. It is estimated that annually, 266 million individuals (3.63%) worldwide suffer from lumbar degenerative disease [1], emphasising the need to improve and make more cost-effective the various techniques used in its treatment.

Over the past few decades, interest in minimally invasive spine surgery (MISS) has increased tremendously due to it minimising approach-related injury while providing outcomes similar to traditional open spine procedures. The advantages of MISS have been well described[2], including shorter hospital stays, better pain assessment results, less blood loss during surgery, reduced risk of infection, and shorter recovery times. As a result, minimally invasive techniques have become the main surgical procedures performed in most neurosurgical centres in the US[3] for treating lumbar degenerative disorders.

Unfortunately, due to their increasing popularity and their labelling as 'state-of-the-art' techniques, many procedures are presented as minimally invasive, while in reality, they do not meet the criteria of MISS. According to our research, the most reported MISS procedure for lumbar degenerative disease performed by most surgeons in the published literature is the minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF). We employed certain criteria in order to exclude studies that reported procedures that were not minimally invasive[4]. The essence of MIS-TLIF lies in the use of non-expandable or expandable tubular retractors, a paramedian or lateral incision, and the use of a microscope or endoscope for visualization. We used the same criteria to include or exclude other minimally invasive procedures as well. A significant percentage of the published literature was characterised as MISS but did not meet our criteria and was subsequently removed from our results.

Although most aspects of MISS have been widely studied, the question of whether to use post-operative drainage in such procedures has not yet been addressed. The advantages of postoperative drain placement include minimising hematoma formation and surgical site infections (SSI) while the list of drawbacks contains worse pain assessment results, patient anxiety, inconvenience of mobilisation and prolongation of hospitalisation [5]. The use of drains remains a controversial topic [6], and lately, their effectiveness has been questioned [7]. In this study, we sought to determine whether drainage in MISS was necessary or not. To our knowledge, this is the first and most extensive systematic review focused on drainage use in truly minimally invasive procedures in the treatment of lumbar degenerative disease.

2. Methods

Pubmed, Medline and Embase databases were searched until December 1st 2022 regarding MISS in the lumbar region and post-operative drain usage. The following keywords were used for the Pubmed-Medline search : (((minimally invasive spine surgery) AND (drainage)) AND (lumbar)) and for the Embase search: minimally AND invasive AND ('spine'/exp OR spine) AND ('surgery'/exp OR surgery) AND ('drain'/exp OR drain) AND lumbar AND ([embase]/lim NOT ([embase]/lim AND [medline]/lim) OR [preprint]/lim). A total of 187 articles were included in the initial screening and were reviewed by 2 researchers (Figure 1). Our inclusion criteria were original articles written in English, articles using minimally invasive techniques [4] for the treatment of lumbar degenerative disease and articles reporting or not reporting the use of postoperative drainage. After the initial removal of duplicate studies and studies marked as ineligible by automation tools, a total of 145 papers were excluded by reading titles and abstracts. Of the remaining 42 studies, 16 were excluded after full-text evaluation, leaving a total of 26 studies included in our systematic review. The majority of the articles excluded in the last part of our screening (11/16, 68%) were studies listed as minimally invasive that did not meet our inclusion criteria, as described above.

The majority of the included articles originated from China (15/26, 58%), as can be seen in Table 1. The features reported for each study were the total number of patients, their mean age, their sex, the usage of the drain, their mean hospital stay and time to ambulation where it was available, complications (post-operative hematoma formation and surgical site infections) and the MISS technique that was used. The type of postoperative drain that was used in studies that reported its use was negative pressure drains. They were either removed 48 hours after surgery or when the drainage volume was less than 50ml/24h.

3. Results

The detailed data gathered from each study can be seen in Table 1. The studies were separated into two groups based on whether they reported the use of a post-operative drain or not. The total number of patients that did not have a post-operative drain was 316 compared to 1190 patients where the use of a post-operative drain was reported. The prevalence of the reported complications was very low in both groups. No hematoma was reported in cases where a drain was not used while the range of hematoma creation in studies where a drain was used ranged from 0% to 4.8% [25]. Since the frequency of this complication was significantly low in both groups, we decided to conduct a meta-analysis of proportions and a subgroup analysis between the two groups. The results we found can be seen in Figure 2. There was no significant difference between the two groups regarding postoperative hematoma creation ($p = 0.18$). In the non-drain group, surgical site infection prevalence ranged from 0% to 0.7% [12], while in the drain group, it ranged from 0% to 3% [18]. By implementing the same type of analysis as the one mentioned above, we found that again, there is no significant difference between the two groups ($p=0.66$), as can be seen in Figure 3.

Regarding the mobilisation of the patients, the mean time to ambulation after surgery in the non-drain group ranged from 1.2 to 1.5 days, while the same time for the drain group ranged from 1.5 to 3.5 days. Moreover, the mean hospital stay in the non-drain group ranged from 2.7 to 7.7 days, while the same range for the drain group was from 0.93 to 15.07 days.

4. Discussion

Minimally invasive techniques have radically changed the way neurosurgery is performed in recent years, and this transformative trend may not have yet reached its zenith. To further advance and refine these techniques, it is imperative to scrutinize and address every facet of their implementation. The initial stride in this direction involves collectively defining and establishing the fundamental stages of minimally invasive techniques. Notably, our research reveals an intriguing observation: many studies report the use of minimally invasive techniques, but this assertion does not hold true in every instance. As previously noted by other authors [4], significant heterogeneity exists not only in how MISS operations are performed among surgeons but also in their definition. A clear definition of the MISS techniques that MISS surgeons agree upon is therefore needed. Such a definition would not only enhance clinical research but also facilitate patient education by distinguishing genuine MISS procedures from other approaches.

It has already been demonstrated [9,10,11] that in minimally invasive spine surgery, the volume

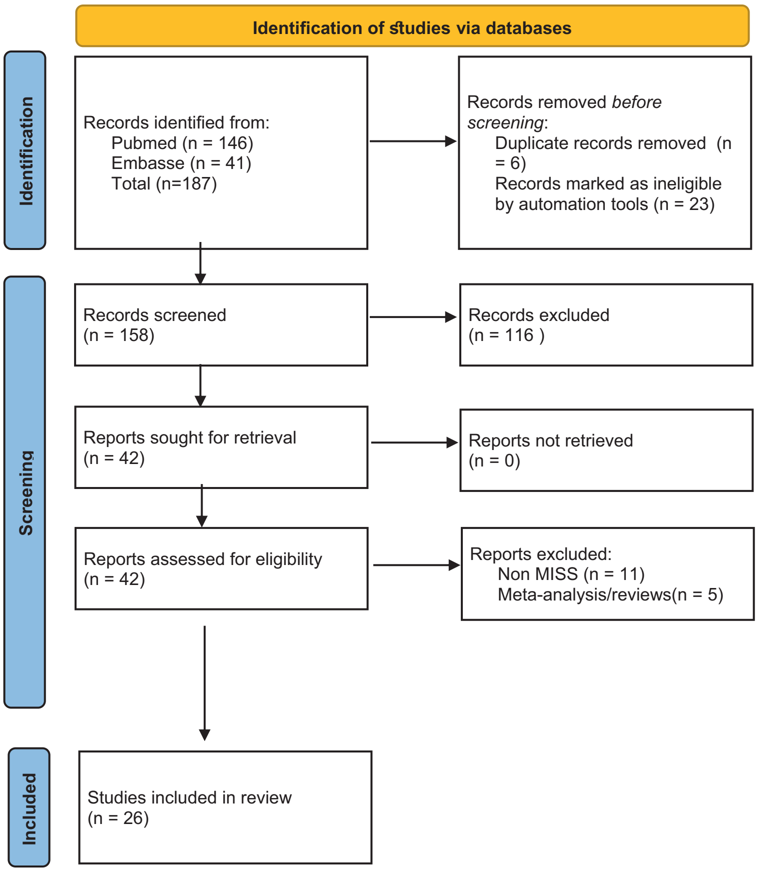

Figure 1. Methodology of our research.

of postoperative drainage is significantly lower compared to open approaches. Based on this observation, many spine surgeons instinctively might respond negatively to the question of whether a post-operative drain should be placed after MISS. However, as our study shows, the majority of the published literature reported the use of drains.

According to our findings, there is no clinical benefit in mitigating the aforementioned complications through the use of a post-operative drain. In both groups, the reported ranges of hematoma formation and surgical site infection were very low. Moreover, no increase in complication rates was observed in the non-drain group. As a result, we can conclude that the main advantage of utilizing a post-operative drain does not apply to MISS.

Furthermore, in the non-drain group, patients were mobilised earlier, and their hospital stays were substantially shorter. Minimally invasive techniques are renowned for leading to earlier hospital discharge [8]. In our study, we demonstrate that by forgoing the use of drains, we can enhance the benefits of MISS - such as earlier mobilisation and shorter hospital stays- even further, without having to deal with any unexpected complications. This simple modification not only allows us to offer higher treatment quality to our patients but also affords the opportunity to reduce the overall cost of the surgery.

Undoubtedly, minimally invasive procedures represent the future, not only in neurosurgery but in surgery at large. By making small but important changes to the way they are performed, we can make them more efficient and cost-effective, thus expanding access to a broader spectrum of patients.

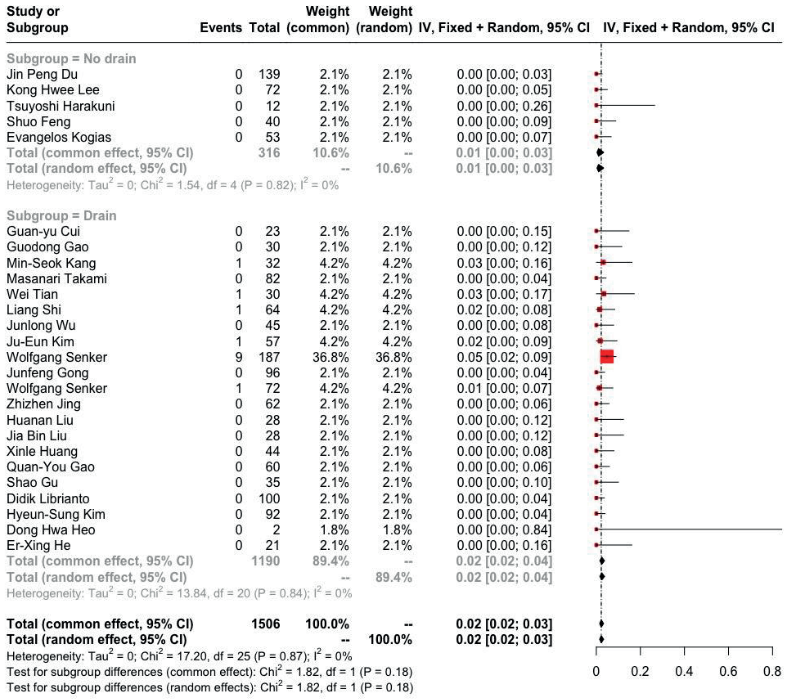

Figure 2. Forest plot results of the meta-analysis and subgroup analysis for hematoma creation. No significant difference in the frequency of post-op hematoma creation is found in the subgroup analysis between the two groups (p=0.18).

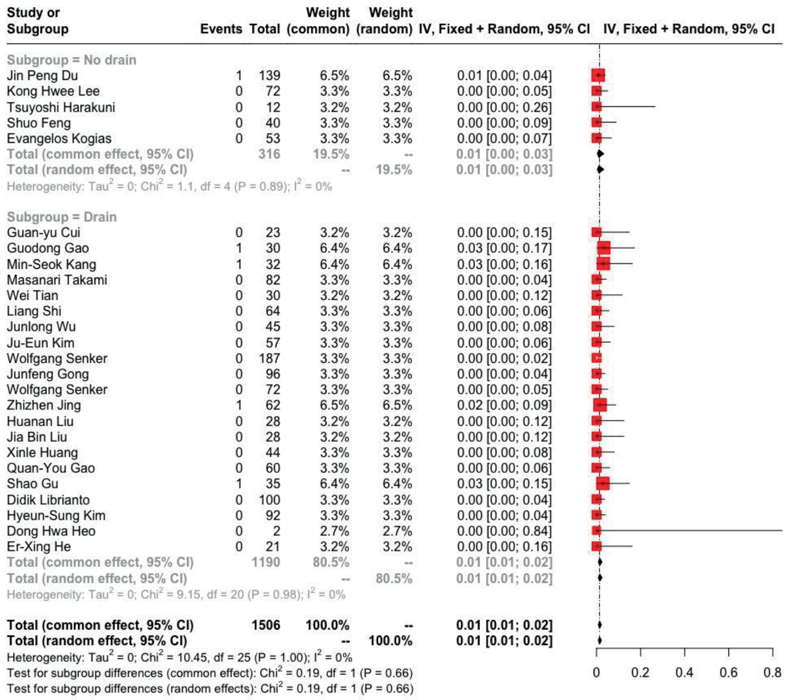

Figure 3. Forest plot results for the meta-analysis and subgroup analysis for surgical site infection.No significant difference in the frequency of surgical site infection is found in the subgroup analysis between the two groups (p=0.66).

Table I. List of studies included. [12-37].

Author	Year	Age	Sex (f)	Country	Total	Use of drain	Hospital stay	Time to ambulation	Hematoma	SSI	Technique
Jin Peng Du [12]	2020	52.8 ± 4.6	79	China	139	N	2.7 ± 0.9	1.5 ± 0.4	0	1	MIS TLIF
Kong Hwee Lee [13]	2012	52.2 ± 13.8	52	Singapore	72	N	3.2 ± 2.9	1.2 ±0.6	0	0	MIS TLIF
Tsuyoshi Harakuni [14]	2020	68.3	N/A	Japan	12	N	7.7	N/A	0	0	MIS endo LIF
Shuo Feng [15]	2019	63.45 ± 4.56	24	China	40	N	N/A	N/A	0	0	MIS pedicle screw placement
Evangelos Kogias [16]	2017	48±15	17	Germany	53	N	N/A	N/A	0	0	MIS discectomy
Guan-yu Cui [17]	2021	51.3 ± 9.8	19	China	23	Y	7.3 ± 1.8	1.5 ± 0.8	0	0	robot MIS TLIF
Guodong Gao [18]	2022	65.7	19	China	30	Y	8.2	3.5	0	1	MIS TLIF
Min-Seok Kang [19]	2021	66.38 ± 9.45	15	Rep. Korea	32	Y	12.59 ± 4.54	N/A	1	1	MIS TLIF
Masanari Takami [20]	2020	71.1±9.0	37	Japan	82	Y	N/A	N/A	0	0	Microendoscopic laminotomy
Wei Tian [21]	2017	48.21 ± 9.10	16	China	30	Y	4.53 ± 1.50	1.57 ± 0.90	1	0	MIS TLIF
Liang Shi [22]	2022	59.3 ± 6.2	32	China	64	Y	5.3 ± 1.1	N/A	1	0	MIS TLIF
Junlong Wu [23]	2019	55.98 ± 10.41	32	China	45	Y	6.38 ± 1.48	2.04 ± 0.77	0	0	MIS TLIF
Ju-Eun Kim [24]	2020	68.5 ± 9.4	29	Rep. Korea	57	Y	7.1 ± 3.3	0.5 ± 0.15	1	0	BE LIF
Wolfgang Senker [25]	2017	64.27	115	Austria	187	Y	N/A	N/A	9	0	MIS TLIF
Junfeng Gong [26]	2021	55.85 ± 11.03	59	China	96	Y	3.51 ± 0.89	N/A	0	0	endo TLIF
Wolfgang Senker [27]	2011	61.8 years ± 13.1	42	Austria	72	Y	10.2 ± 5.7	N/A	1	0	MIS TLIF
Zhizhen Jing [28]	2021	51.32±8.99	31	China	62	Y	7.03 ± 2.27	N/A	0	1	MIS discectomy
Huanan Liu [29]	2022	49.54 ± 10.78	16	China	28	Y	N/A	2.68 ±0.71	0	0	MIS TLIF
Jia Bin Liu [30]	2022	52.1 ± 12.1	16	China	28	Y	6.1 ± 2.8	2.1 ±0.3	0	0	MIS TLIF
Xinle Huang [31]	2022	57.71 ± 8.78	31	China	44	Y	4.72 ± 0.96	N/A	0	0	BE LIF
Quan-You Gao [32]	2022	59.23 ± 11.66	32	China	60	Y	15.07 ±7.38	N/A	0	0	MIS TLIF
Shao Gu [33]	2022	51.54±10.24	16	China	35	Y	3.2 ± 0.6	2.5 ± 0.3	0	1	MIS TLIF
Didik Librianto [34]	2022	46.33 ± 16.04	39	Indonesia	100	Y	0.93 ± 0.45	N/A	0	0	MIS decompression
Hyeun-Sung Kim [35]	2020	64.7	67	Rep. Korea	92	Y	N/A	N/A	0	0	endoscopic laminotomy
Dong Hwa Heo [36]	2020	55.5	2	Rep. Korea	2	Y	N/A	N/A	0	0	BE LIF
Er-Xing He [37]	2014	55.62	N/A	China	21	Y	9.5 ± 2.6	3	0	0	MIS PLIF

5. Conclusion

The rationale behind post-operative drainage in MISS is the protection from surgical site infections and hematoma creation. Based on our analysis, there is no evidence supporting this hypothesis, since there was no statistically significant difference in these complications between the two groups. On the contrary, our results suggest that the drawbacks of using a drain (pain, discomfort, anxiety, inconvenience of mobilisation, prolongation of hospitalisation) outweigh the advantages, thus making the routine use of postoperative drainage in MISS unnecessary.

Conflicts of Interest

The authors have no conflict of interest to declare.

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References

[1] Ravindra VM, Senglaub SS, Rattani A, Dewan MC, Härtl R, Bisson E, et al. Degenerative Lumbar Spine Disease: Estimating Global Incidence and Worldwide Volume. Global Spine J. 2018 Dec;8(8):784–94.

[2] Starkweather AR, Witek-Janusek L, Nockels RP, Peterson J, Mathews HL. The multiple benefits of minimally invasive spinal surgery: results comparing transforaminal lumbar interbody fusion and posterior lumbar fusion. J Neurosci Nurs. 2008 Feb;40(1):32–9.

[3] Phillips FM, Cheng I, Rampersaud YR, Akbarnia BA, Pimenta L, Rodgers WB, et al. Breaking Through the "Glass Ceiling" of Minimally Invasive Spine Surgery. Spine. 2016 Apr;41 Suppl 8:S39–43.

[4] Lener S, Wipplinger C, Hernandez RN, Hussain I, Kirnaz S, Navarro-Ramirez R, et al. Defining the MIS-TLIF: A Systematic Review of Techniques and Technologies Used by Surgeons Worldwide. Global Spine J. 2020 Apr;10(2 Suppl):151S–67S.

[5] Adogwa O, Elsamadicy AA, Sergesketter AR, Shammas RL, Vatsia S, Vuong VD, et al. Post-operative drain use in patients undergoing decompression and fusion: incidence of complications and symptomatic hematoma. J Spine Surg. 2018 Jun;4(2):220–6.

[6] von Eckardstein KL, Dohmes JE, Rohde V. Use of closed suction devices and other drains in spinal surgery: results of an online, Germany-wide questionnaire. Eur Spine J. 2016 Mar;25(3):708–15.

[7] Andrew Glennie R, Dea N, Street JT. Dressings and drains in posterior spine surgery and their effect on wound complications. J Clin Neurosci. 2015 Jul;22(7):1081–7.

[8] Kim CH, Easley K, Lee JS, Hong JY, Virk M, Hsieh PC, et al. Comparison of Minimally Invasive Versus Open Transforaminal Interbody Lumbar Fusion. Global Spine J. 2020 Apr;10(2 Suppl):143S–50S.

[9] Gao G, Cao L, Du X, Xu B, Zhang P, Zhang X, et al. Comparison of Minimally Invasive Surgery Transforaminal Lumbar Interbody Fusion and TLIF for Treatment of Lumbar Spine Stenosis. J Healthc Eng. 2022 Jan;2022:9389239.

[10] Tian W, Xu YF, Liu B, Liu YJ, He D, Yuan Q, et al. Computer-assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion May Be Better Than Open Surgery for Treating Degenerative Lumbar Disease. Clin Spine Surg. 2017 Jul;30(6):237–42.

[11] Liu H, Li J, Sun Y, Wang X, Wang W, Guo L, et al. A Comparative Study of a New Retractor-Assisted WILTSE TLIF, MIS-TLIF, and Traditional PLIF for Treatment of Single-Level Lumbar Degenerative Diseases. Orthop Surg. 2022 Jul;14(7):1317–30.

[12] Du JP, Wang XH, Shan LQ, Wang WT, Li HK, Huang DG, et al. Safety and Efficacy of Minimally Invasive Transforaminal Lumbar Interbody Fusion Combined with Gelatin Sponge Impregnated with Dexamethasone and No Drainage Tube after Surgery in the Treatment of Lumbar Degenerative Disease. Orthop Surg. 2021 May;13(3):1077–85.

[13] 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 Nov;21(11):2265–70.

[14] Harakuni T, Iwai H, Oshima Y, Inoue H, Kitagawa T, Inanami H, et al. Full-Endoscopic Lumbar Interbody Fusion for Treating Lumbar Disc Degeneration Involving Disc Height Loss: technical Report. Medicina (Kaunas). 2020 Sep;56(9):478.

[15] Feng S, Tian W, Wei Y. Clinical Effects of Oblique Lateral Interbody Fusion by Conventional Open versus Percutaneous Robot-Assisted Minimally Invasive Pedicle Screw Placement in Elderly Patients. Orthop Surg. 2020 Feb;12(1):86–93.

[16] Kogias E, Klingler JH, Franco Jimenez P, Vasilikos I, Sircar R, Scholz C, et al. Incidental Durotomy in Open Versus Tubular Revision Microdiscectomy: A Retrospective Controlled Study on Incidence, Management, and Outcome. Clin Spine Surg. 2017 Dec;30(10):E1333–7.

[17] Cui GY, Han XG, Wei Y, Liu YJ, He D, Sun YQ, et al. Robot-Assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion in the Treatment of Lumbar Spondylolisthesis. Orthop Surg. 2021 Oct;13(7):1960–8.

[18] Gao G, Cao L, Du X, Xu B, Zhang P, Zhang X, et al. Comparison of Minimally Invasive Surgery Transforaminal Lumbar Interbody Fusion and TLIF for Treatment of Lumbar Spine Stenosis. J Healthc Eng. 2022 Jan;2022:9389239.

[19] Kang MS, You KH, Choi JY, Heo DH, Chung HJ, Park HJ. Minimally invasive transforaminal lumbar interbody fusion using the biportal endoscopic techniques versus microscopic tubular technique. Spine J. 2021 Dec;21(12):2066–77.

[20] Takami M, Yoshida M, Minamide A, Hashizume H, Yukawa Y, Nakagawa Y, et al. Does prophylactic use of topical gelatin-thrombin matrix sealant affect postoperative drainage volume and hematoma formation following microendoscopic spine surgery? A randomized controlled trial. Spine J. 2021 Mar;21(3):446–54.

[21] Tian W, Xu YF, Liu B, Liu YJ, He D, Yuan Q, et al. Computer-assisted Minimally Invasive Transforaminal Lumbar Interbody Fusion May Be Better Than Open Surgery for Treating Degenerative Lumbar Disease. Clin Spine Surg. 2017 Jul;30(6):237–42.

[22] Shi L, Ding T, Shi Y, Wang F, Wu C. Comparison of the Outcomes of Minimally Invasive Transforaminal Lumbar Interbody Fusion and Endoscopic Transforaminal Lumbar Interbody Fusion for Lumbar Degenerative Diseases: A Retrospective Matched Case-Control Study. World Neurosurg. 2022 Nov;167:e1231–40.

[23] 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 Apr;76:136–43.

[24] Kim JE, Yoo HS, Choi DJ, Park EJ, Jee SM. Comparison of Minimal Invasive Versus Biportal Endoscopic Transforaminal Lumbar Interbody Fusion for Single-level Lumbar Disease. Clin Spine Surg. 2021 Mar;34(2):E64–71.

[25] Senker W, Stefanits H, Gmeiner M, Trutschnig W, Weinfurter I, Gruber A. Does Obesity Affect Perioperative and Postoperative Morbidity and Complication Rates After Minimal Access Spinal Technologies in Surgery for Lumbar Degenerative Disc Disease. World Neurosurg. 2018 Mar;111:e374–85.

[26] Gong J, Huang Z, Liu H, Zhang C, Zheng W, Li C, et al. A Modified Endoscopic Transforaminal Lumbar Interbody Fusion Technique: Preliminary Clinical Results of 96 Cases. Front Surg. 2021 Oct;8:676847.

[27] Senker W, Meznik C, Avian A, Berghold A. Perioperative morbidity and complications in minimal access surgery techniques in obese patients with degenerative lumbar disease. Eur Spine J. 2011 Jul;20(7):1182–7.

[28] Jing Z, Li L, Song J. Percutaneous transforaminal endoscopic discectomy versus microendoscopic discectomy for upper lumbar disc herniation: a retrospective comparative study. Am J Transl Res. 2021 Apr;13(4):3111–9.

[29] Liu H, Li J, Sun Y, Wang X, Wang W, Guo L, et al. A Comparative Study of a New Retractor-Assisted WILTSE TLIF, MIS-TLIF, and Traditional PLIF for Treatment of Single-Level Lumbar Degenerative Diseases. Orthop Surg. 2022 Jul;14(7):1317–30.

[30] Liu JB, Wu JL, Zuo R, Li CQ, Zhang C, Zhou Y. Does MIS-TLIF or TLIF result in better pedicle screw placement accuracy and clinical outcomes with navigation guidance? BMC Musculoskelet Disord. 2022 Feb;23(1):153.

[31] Huang X, Wang W, Chen G, Guan X, Zhou Y, Tang Y. Comparison of surgical invasiveness, hidden blood

loss, and clinical outcome between unilateral biportal endoscopic and minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative disease: a retrospective cohort study. BMC Musculoskelet Disord. 2023 Apr;24(1):274.

[32] Gao QY, Wei FL, Li T, Zhu KL, Du MR, Heng W, et al. Oblique Lateral Interbody Fusion vs. Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Spinal Stenosis: A Retrospective Cohort Study. Front Med (Lausanne). 2022 May;9:829426.

[33] Gu S, Li H, Wang D, Dai X, Liu C. Application and thinking of minimally invasive transforaminal lumbar interbody fusion in degenerative lumbar diseases. Ann Transl Med. 2022 Mar;10(6):272.

[34] Librianto D, Ipang F, Saleh I, Srie Utami W, Aprilya D, Nurhayati R, et al. (2022) Comparison of Microscopic Decompression and Biportal Endoscopic Spinal Surgery in the Treatment of Lumbar Canal Stenosis and Herniated Disc: A One-year Follow-up. Open Access Macedonian Journal of Medical Sciences. 2022;10(B):1188–1194. https://doi.org/10.3889/oamjms.2022.9043..

[35] Kim HS, Wu PH, Jang IT. Lumbar Endoscopic Unilateral Laminotomy for Bilateral Decompression Outside-In Approach: A Proctorship Guideline With 12 Steps of Effectiveness and Safety. Neurospine. 2020 Jul;17 Suppl 1:S99–109.

[36] Heo DH, Hong YH, Lee DC, Chung HJ, Park CK. Technique of Biportal Endoscopic Transforaminal Lumbar Interbody Fusion. Neurospine. 2020 Jul;17 Suppl 1:S129–37.

[37] He EX, Cui JH, Yin ZX, Li C, Tang C, He YQ, et al. A minimally invasive posterior lumbar interbody fusion using percutaneous long arm pedicle screw system for degenerative lumbar disease. Int J Clin Exp Med. 2014 Nov;7(11):3964–73.