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Clinical Study

Influence of incidental dural tears and their primary microendoscopic repairs on surgical outcomes in patients undergoing microendoscopic lumbar surgery

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Abstract

BACKGROUND CONTEXT: Dural tear represents a common complication of microendoscopic spine surgery that may lead to postoperative sequelae including insufficient decompression, cerebrospinal fluid fistula, intracranial hypotension, and subdural/intraparenchymal bleeding. The gold standard to manage intraoperative dural tears is primary repair. However, the downside of conversion to open surgery can be detrimental. Therefore, understanding the most appropriate strategy for microendoscopic dural repair and its impact on postoperative outcomes is of importance.

PURPOSE: The purpose of this study was to investigate the incidence of dural tears in patients undergoing microendoscopic lumbar surgery and to elucidate their influence on surgical outcomes whenever proper repair is accomplished microendoscopically without conversion to open surgery.

STUDY DESIGN/SETTING: A retrospective multicenter cohort study of prospectively enrolled patients using a propensity-matched analysis.

FDA device/drug status: Not applicable.

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PATIENT SAMPLE: A total of 922 consecutive patients underwent microendoscopic surgery of the lumbar spine between February and December 2012 in the three institutions belonging to our study group.

OUTCOME MEASURES: Outcome measures included the Numeric Rating Scale for back and leg pain, Oswestry Disability Index, Japanese Orthopaedic Association score, Short Form-36, and a patients' satisfaction scale.

METHODS: All incidental dural tears were repaired by microendoscopic suture of the dura mater from inside to outside using double-arm needles and/or by fibrin glue coverage without being converted to open surgery. Surgical outcomes were compared between patients with and without dural tears using a propensity-matched analysis.

RESULTS: Microendoscopic discectomy for lumbar disc herniation was performed on 474 patients, whereas microendoscopic laminectomy and posterior lumbar interbody fusion for lumbar canal stenosis were performed on 271 and 177 patients, respectively. Dural tears occurred in 49 (5.3%) patients. Of these, 23 (2.5%) patients required suture repair, whereas the rest received a fibrin patch for a pinhole tear, all of which were successfully performed under microendoscopy. Six hundred (65.1%) patients responded pre- and postoperatively to the questionnaire. Of them, the responses of 38 patients with dural tears were compared with those of 38 matched patients. No significant differences in any outcome measures were observed between the two groups.

CONCLUSIONS: In conclusion, all dural tears in our cases were managed without conversion to open surgery and did not influence surgical outcomes.

Keywords: Microendoscopic discectomy; Microendoscopic laminectomy; Microendoscopic posterior lumbar interbody fusion; Minimally invasive surgery; Lumbar spine; Dural tear; Durotomy; Surgical outcome; Patient satisfaction; Propensity-matched analysis

Introduction

Microendoscopic spine surgery originates from lumbar discectomy, which is widely performed as a minimally invasive surgery for spinal diseases [1,2]. Patients with lumbar disc herniation are usually treated with microendoscopic discectomy (MED), whereas a more extensive decompression through microendoscopic laminectomy (MEL) is considered for lumbar canal stenosis. For those with segmental instability and/or foraminal stenosis, fusion surgery is also feasible by percutaneous insertion of pedicle screws in conjunction with MEL. These techniques are considered less invasive compared with open methods as are associated with decreased blood loss, muscle trauma, and shorter hospital stays [3]. Several studies have demonstrated the efficacy of microendoscopic procedures in treating lumbar spinal canal stenosis and cervical radiculopathy or myelopathy [4−7].

A long learning curve and surgery-related complications have been posited as limitations of this technique [8]. In particular, dural tear represents a common complication of microendoscopic spine surgery [9−14]. The reported incidence of dural tears during microendoscopic lumbar surgery varies among the literature, but the rate has been reported to be between 0% to 8.7% [3,15−18], which is comparable to its reported incidence in open surgery [19]. Intraoperatively, dural tears may lead to insufficient decompression, increased blood loss caused by loss of epidural venous tamponade, and incomplete decompression [3,15]. Postoperative sequelae of dural tears include delayed wound healing, increased risk of surgical site infection, meningitis, cerebrospinal fluid (CSF) fistula, and intracranial hypotension. Moreover, clinical series and health-economics studies have described the costs of treating a CSF fistula, highlighting the detrimental impact that a failure to obtain primary intraoperative repair may have on hospital budgets [20].

The primary repair has been considered as the gold standard of dura tear treatment [17]. However, its detailed techniques varied across the literature, ranging from meticulous sutures, patches, fibrin glue and their combinations. For example, sutures can be made by silk, nylon, or polypropylene, and stiches can be interrupted, running or locking. Even patches can range from fat, fascia, or muscle grafts, with or without application of fibrin glue. Among these variations, one of the most relevant choices is the conversion of surgical approach. Some surgeons have chosen to convert to open surgery based on the simplicity of repair under direct visualization [21]. However, the advantage of microendoscopic surgery obviously lies in minimization of the tissue damage, and in the context of dural tears, minimized dead space can be beneficial to prevent protracted CSF leakage. Therefore, we believe that conversion to open surgery should be avoided as much as possible, and that simple microendoscopic approach is of absolute importance to address dural tears, regardless of its detailed technique. On this ground, at our institutions since 2012, all dural tears encountered during microendoscopic lumbar surgery have been treated microendoscopically without conversion to open surgery.

Knowledge regarding the most appropriate treatment for dural tears is an important aspect of microendoscopic spine surgery. The purpose of the present study was to assess the effectiveness of microendoscopic repair of dural tears without conversion to open surgery, and its impact on surgical outcomes by comparing them with the outcomes of the patients without dural tears, using a propensity-matched analysis.

Materials and methods

Patient selection and surgical procedure

This is a retrospective multicenter cohort study of prospectively enrolled patients, with institutional review board approval obtained from all participating institutions. A total of 922 consecutive patients underwent microendoscopic surgery of the lumbar spine at three institutions belonging to our study group between February and December 2012. The METRx endoscopic system (Medtronic Sofamor Danek, Memphis, TN, USA) was used for microendoscopic procedure. In patients with lumbar disc herniation, MED was performed on the ipsilateral side only. In patients with lumbar canal stenosis, MEL was performed on both sides via a unilateral approach, that is, ipsilateral laminectomy and contralateral laminotomy. The patients who needed a fusion surgery underwent posterior lumbar interbody fusion (PLIF). Decompression and cage insertion were performed in a similar manner to MEL, with percutaneous insertion of pedicle screws with separated skin incisions.

All dural tears were repaired under microendoscopy without conversion to open surgery. In patients with sizable tears associated with obvious CSF leakage and herniated cauda equina rootlets, suture repair was performed (Figure). Our technique of repairing dural tears using microendoscopic procedure was as follows: first, a double-arm needle with 6-0 polypropylene suture was used to stitch the dura mater inside-out to prevent nerve damage. Herniated cauda equina

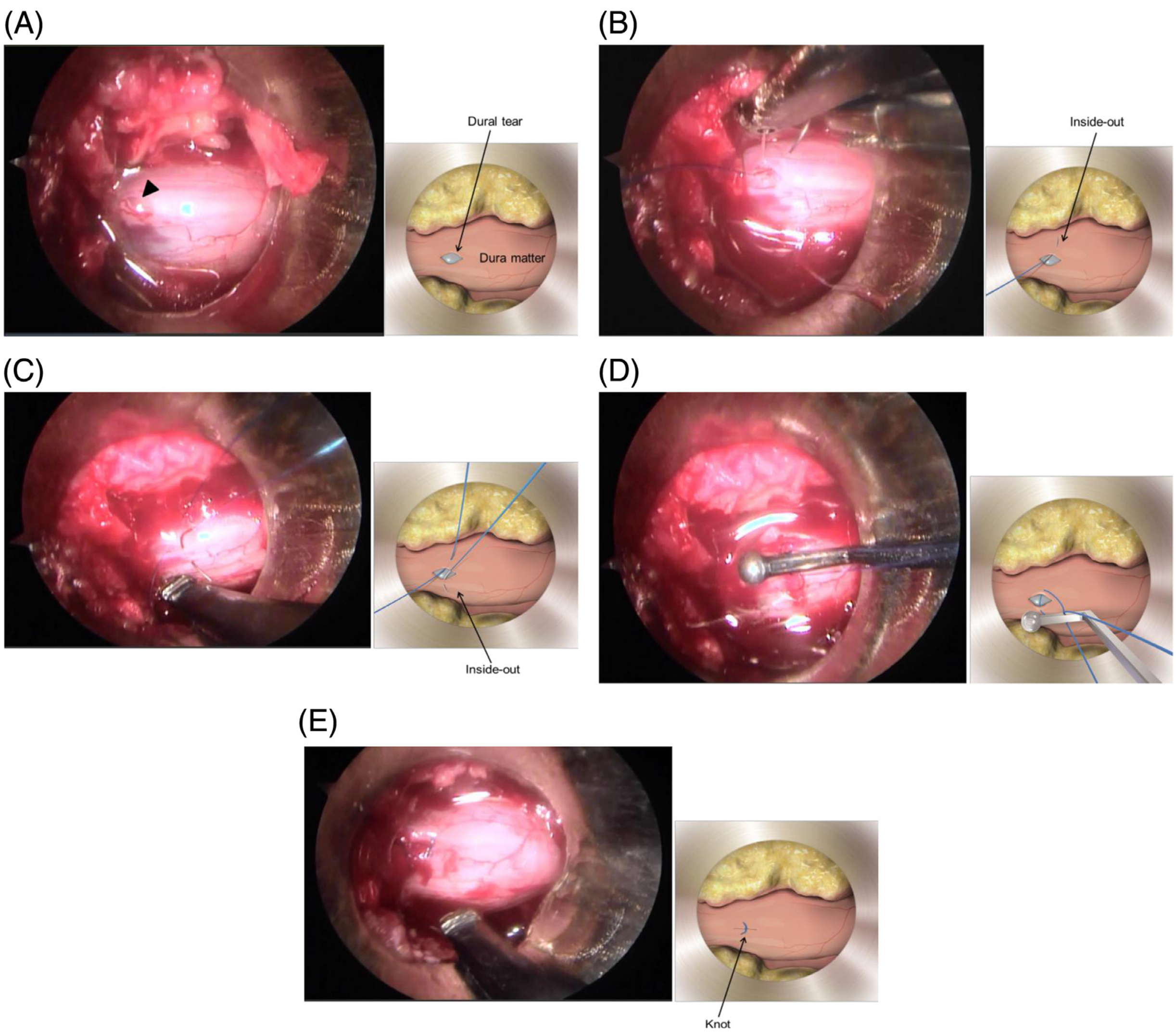

Fig. Intraoperative pictures showing our technique of repairing dural tears using microendoscopic procedure (A) black arrow indicates the tear site. (B,C) A double-arm needle with 6-0 polypropylene suture was introduced to stitch the dura mater inside-out to prevent nerve damage. (D,E) A knot was made outside the tubular retractor and pushed in by a probe.

rootlets were gently reduced within the dural cavity. In case of difficulty in reducing the cauda equina rootlets, the tear was intentionally expanded cranially and caudally. Then, a knot was made outside the tubular retractor and pushed by a probe into the retractor. After the knot was tightened, the tear was covered using fibrin glue. In case of a pinhole tear without continuous CSF leakage, fibrin glue was used without the need for suture. A subfascial drain was placed without suction and removed on postoperative day 1 or 2. All patients were allowed to ambulate on the day after surgery unless they reported nausea or severe headache.

Outcome measurements and statistical analyses

Patients' demographic data were recorded, including age and sex. Surgical data included type of operation, duration of operation, location of dural tears, whether or not suture repair was performed, length of hospital stay, and postoperative complications. Patient-reported outcomes were measured using questionnaires both preoperatively and at 12 months postoperatively. Surgeons were blinded to the answers of the questionnaire. Outcome measures included the Numeric Rating Scale for back and leg pain, dysesthesia intensity, Oswestry Disability Index (ODI), [22] Japanese Orthopedic Association (JOA) score, the Medical Outcomes Study Short Form-36 (36-Item Short Form Health Survey) [23], and a 4-point Likert scale of postoperative patients' satisfaction with possible answers of "very satisfied," "somewhat satisfied," "somewhat dissatisfied," and "very dissatisfied".

The incidence of dural tears was investigated from the patient's record. The influence of dural tears on surgical outcomes was compared between patients with and without dural tears, using a propensity score-matched analysis. A control group was formed with matched sex, age, and type of operation. Propensity score-matched analysis is widely used in retrospective cohort studies to control for confounding biases [24]. Propensity scores, which estimate the probability of the use of a certain treatment based on patient characteristics, are calculated by a logistic regression model in which patient demographic parameters are dependent variables, with goodness of fit determined by C-statistics. This technique allows simultaneous matching for multiple characteristics to compare two similar groups.

All statistical analyses were performed using IBM SPSS Statistics software version 22.0 (IBM Corporation, Armonk, NY, USA). Paired Student's t test was used to determine any significant differences in continuous demographic variables and McNemar's test was used for categorical variables between study groups. The p values<.05 were considered statistically significant.

Results

Incidence of dural tears

Nine hundred and twenty-two patients (690 males [74.8%] and 232 females [25.2%]) were included in this study. The mean age was 65.2 years old (range: 14−90). Four hundred and seventy-four (51.4%) underwent MED for lumbar disc herniation, whereas 271 (29.4%) and 177 (19.2%) patients underwent MEL or PLIF for lumbar canal stenosis, respectively. Incidental dural tears occurred in 49 (5.3%) patients. The incidence of dural tears was 3.0%, 8.1%, and 7.3% in MED, MEL, and PLIF, respectively. Twenty-three (2.5%) patients required suture repair of the dura mater under microendoscopy (Figure), whereas 26 patients either had pinhole tears without evidence of CSF leakage or had an intact arachnoid membrane requiring fixation with fibrin glue only. In the group of patients requiring suture repairs, the majority of microendoscopic sutures entailed a single stitch, with two only exceptions requiring two and three stiches, respectively. None of the patients required conversion to open surgery (Table 1). About 23 (47%) patients with dural tears reported adverse events, such as headache, vomiting and nausea, CSF fistula, and transient leg pain; all these spontaneously improved during the postoperative course (Table 2).

Comparison of surgical outcomes between patients with and without dural tears using a propensity score-matching analysis

The mean age of patients with dural tears was 63.6, whereas that of patients without dural tears was 65.5 (p=.22). Male accounted for 68% of patients with dural tears and 75% of patients without dural tears (p=.35). Nineteen of 38 patients with dural tears (50%) underwent MEL, whereas only 29% underwent MEL in the patients without dural tears (p=.004).

Using the propensity score-matching technique, adjustments of these background data was accomplished. From 600 patients (65.1%) who completed the questionnaires both pre- and postoperatively, equal numbers of patients (n=38) with and without dural tears were selected for case-control comparisons. Demographic data of these groups as

Table 1
Comparison of clinical data in patients with dural tears among each surgical procedure (N=49)

	MED	MEL	PLIF
Incidence of DTs	14/474 (3.0%)	22/271 (8.1%)	13/177 (7.3%)
Age (mean [SD])	51.4 (12.4)	68.0 (10.9)	66.2 (5.8)
Sex			
Male	12 (86%)	18 (82%)	5 (38%)
Female	2 (14%)	4 (18%)	8 (62%)
Repair method			
Suture repair	6 (43%)	9 (41%)	8 (62%)
Fibrin glue only	8 (57%)	13 (59%)	5 (38%)
Location of DTs			
Ipsilateral side	14 (100%)	14 (64%)	8 (62%)
Contralateral side	0	8 (36%)	5 (39%)

DT, dural tear; SD, standard deviation; MED, microendoscopic discectomy; MEL, microendoscopic laminectomy; PLIF, posterior lumbar interbody fusion.

Table 2
Number of patients with postoperative complications following incidental dural tears (N=49)

	MED (N=14)	MEL (N=22)	PLIF (N=13)	Total (N=49)
Any complications	6 (43%)	10 (45%)	7 (54%)	23 (47%)
Headache	3	3	1	7
Nausea/vomiting	3	5	4	12
Cerebrospinal fluid fistula	0	2	1	3
Transient leg pain	0	0	1	1

MED, microendoscopic disectomy; MEL, microendoscopic laminectomy; PLIF, posterior lumbar interbody fusion.

well as the pre- and postoperative questionnaire scores are summarized in Table 3. Both groups demonstrated improvements from pre- to postoperative answers to all questionnaires. Comparisons between the two groups revealed that there were no significant differences in demographic data observed, but the duration of operation was longer in the dural tears group than in the nondural tears group (110 minutes vs. 67 minutes, p=.002). Nonetheless, no significant differences in either pre- or postoperative outcome scores were observed between the two groups. These similarities were specifically striking in terms of patients' satisfaction: in fact, 86% of patients with dural tears answered declared to be "very satisfied" or "somewhat satisfied" with their treatment, whereas 80% of the patients without dural tears did so (p=.53).

Discussion

In the present series, all incidental dural tears were managed microendoscopically without conversion to open surgery. The inside-out suture method using double-arm needles was useful for dural tears in microendoscopic lumbar surgery. We showed that surgical outcomes were not negatively influenced by dural tears properly repaired without open conversion.

The incidence of dural tears in microendoscopic lumbar surgery has been reported to be between 0% and 8.7% [3,15−18], with the incidence of open conversion surgery currently unclear. Some surgeons have preferred to convert to open surgery as a routine because the direct visualization could make the repair simple and straightforward [21]. Repairing the dural sac under microendoscopy can certainly be technically demanding caused by the small working space available and sometimes it requires a longer time. In particular, repair of the dural sac occurring on the opposite side of the surgical approach is technically even more demanding and requires greater time. In this study, we were able to repair dural tears with microendoscopic procedures in all patients without converting to the open method. Importantly, we used double-arm needles and sutured the dural tear from inside to outside. This procedure allows clear orientation of needles and neural fibers and aids in preventing accidental suturing of neural fibers by mistake, although this procedure requires a longer duration than the regular suture by continuous stitches. Given the long learning curve associated with microendoscopic surgery, it could take time for junior surgeons to master this technique. However, the key to success is always to reduce the herniated cauda equina rootlets and to control CSF leakage. Once the reduction can be made, because the size of the tears we experience during the microendoscopic surgery is usually small, a single stitch is enough to guarantee a satisfactory repair and fibrin patches may suffice for pinhole tears. Given the above, conversion to open surgery should be avoided as much as possible, because it inevitably negates the advantages of minimally invasive approach with

Table 3
Comparison of outcomes between patients with and without dural tears using a propensity score-matched analysis

		DTs N=38	No DTs N=38	p
Sex (male/female)		26/12	26/12	>.99
Age (mean [SD])		63.6 (12.3)	63.6 (12.3)	>.99
Type of surgery (no. of patients)				>.99
MED		10	10	
MEL		19	19	
PLIF		9	9	
Operation time (min)		110 (74)	67 (47)	.002
NRS				
Pain (low back)	Preop	4.3	4.4	.72
	Postop	2.5	2.4	.67
Pain (leg)	Preop	6.2	6.4	.68
	Postop	2.5	2.3	.61
Dysesthesia (leg)	Preop	6.6	5.3	.23
	Postop	3.3	3.1	.35
ODI	Preop	38.6	36.2	.31
	Postop	17.0	17.4	.51
JOA	Preop	12.1	12.1	.28
	Postop	16.2	15.9	.85
	Recovery rate (%)	24.3	22.5	.91
SF-36				
PF	Preop	51.5	56.6	.64
	Postop	76.0	76.5	.96
RP	Preop	44.4	44.7	.79
	Postop	73.0	67.9	.93
BP	Preop	29.3	27.7	.88
	Postop	63.2	58.9	.46
MH	Preop	52.1	58.8	.53
	Postop	62.2	62.9	.70
Patients' satisfaction				.63
Very satisfied		49%	51%	
Somewhat satisfied		37%	29%	
Somewhat dissatisfied		9%	17%	
Very dissatisfied		6%	3%	

DT, dural tears; MED, microendoscopic disectomy; MEL, microendoscopic laminectomy; PLIF, posterior lumbar interbody fusion; NRS, numeric rating scale; ODI, Oswestry Disability Index; JOA, Japanese Orthopaedic Association score; SF-36, Short Form-36; PF, physical function; RP, role physical; BP, body pain; MH, mental health; preop, preoperative; postop, postoperative.

increased blood loss, muscle devascularization, greater postoperative discomfort, and higher risk of surgical site infection. Moreover, the massive dead space may lead to increased risk of CSF fistula and expanding pseudomeningocele. We therefore recommend to spare the conversion unless nonreducible cauda equina rootlets are encountered.

Although incidental dural tears are associated with a range of complications immediately after surgery, such as nausea and headache, many studies did not report adverse outcomes during the postoperative follow-up period [2,12,13,26−33], indicating that long-term surgical outcomes may not be negatively influenced if dural tears are properly repaired. However, one previous study reported that the recovery rate of JOA score in patients with dural tears was significantly lower than that of the patients without a tear, although no significant improvements were observed using ODI score between the two groups [15]. Although the reasons underlying the discrepancy in outcomes between the ODI and JOA scores was not clear, the authors speculated that insufficient decompression caused by incidental dural tears was associated with worse postoperative outcomes in a proportion of patients. Moreover, larger skin incisions and exploration by open conversion may have led to delayed postoperative treatment and consequently negatively affected postoperative outcomes, which could be even more detrimental than standard open surgery [34]. In the present study, we managed all incidental dural tears by microendoscopic procedure without converting to open surgery, which likely led to the equivalent surgical outcomes to nondural tear patients. Several other studies have described the dural repair through microendoscopic approach and argued its advantages [16,25]. The present study is the first study in the literature to prove its effectiveness by comparing the outcomes with the nondural tear cohort with statistical robustness by way of propensity score matching.

There are several limitations in the present study. First, only 65.1% of the patients had both pre- and postoperative patient-reported outcome data. There could have been a reporting bias as with any perioperative complications. Second, the postoperative follow-up period was short, although we speculate that longer follow-up periods of over 1 year is not mandatory to investigate the effect of dural tears on surgical outcomes. Third, as an inherent limitation in the propensity score-matching analysis, the number of the patients included was somewhat limited. However, the inclusion of 38 patients was considered robust enough given the reported complication rate of about 5%. Therefore, rates of rare adverse events associated with dural tear, such as bowel bladder disturbance, might have been underrated in the present report. Fourth, all of our dural repairs were performed by microendoscopic technique, and the patients with dural repair through conversion to open surgery were not included. Thus, a direct comparison between microendoscopic and open repair was not carried out. However, based on the previous discussions, we generally advise against the conversion. Lastly, although all of our operations were performed by experienced surgeons, the learning curve bias could have existed for our microendoscopic repair technique. Nevertheless, our take-home message is that we should take our best effort to maintain the microendoscopic surgical approach to mitigate the negative impact of dural tears on postoperative outcomes. Despite all these limitations, our results might be helpful in establishing baseline statistics for the incidence of dural tears, and providing a guidance of the treatment strategy for repair of tears in microendoscopic surgery, and thus facilitating improvements in informed consent of patients undergoing this type of surgery.

Conclusion

In this group of patients, all dural tears were managed without conversion to open surgery and it was found that surgical outcomes were not influenced by dural tears that were properly repaired with a microendoscopic procedure.

References

[1] Obenchain TG. Laparoscopic lumbar discectomy: case report. J Laparoendosc Surg 1991;1:145–9.

[2] Perez-Cruet MJ, Foley KT, Isaacs RE, Rice-Wyllie L, Wellington R, Smith MM, et al. Microendoscopic lumbar discectomy: technical note. Neurosurgery 2002;51:S129–36.

[3] Matsumoto M, Hasegawa T, Ito M, Aizawa T, Konno S, Yamagata M, et al. Incidence of complications associated with spinal endoscopic surgery: nationwide survey in 2007 by the Committee on Spinal Endoscopic Surgical Skill Qualification of Japanese Orthopaedic Association. J Orthop Sci 2010;15:92–6.

[4] Oshima Y, Takeshita K, Inanami H, Takano Y, Koga H, Iwahori T, et al. Cervical microendoscopic interlaminar decompression through a midline approach in patients with cervical myelopathy: a technical note. J Neurol Surg A Cent Eur Neurosurg 2014;75:474–8.

[5] Yoshimoto M, Miyakawa T, Takebayashi T, Ida K, Tanimoto K, Kawamura S, et al. Microendoscopy-assisted muscle-preserving interlaminar decompression for lumbar spinal stenosis: clinical results of consecutive 105 cases with more than 3-year follow-up. Spine (Phila Pa 1976) 2014;39:E318–25.

[6] Minamide A, Yoshida M, Yamada H, Nakagawa Y, Hashizume H, Iwasaki H, et al. Clinical outcomes after microendoscopic laminotomy for lumbar spinal stenosis: a 5-year follow-up study. Eur Spine J 2015;24:396–403.

[7] Baba S, Oshima Y, Iwahori T, Takano Y, Inanami H, Koga H. Microendoscopic posterior decompression for the treatment of thoracic myelopathy caused by ossification of the ligamentum flavum: a technical report. Eur Spine J 2016;25:1912–9.

[8] Wiese M, Kramer J, Bernsmann K, Ernst Willburger R. The related outcome and complication rate in primary lumbar microscopic disc surgery depending on the surgeon's experience: comparative studies. Spine J 2004;4:550–6.

[9] Wang JC, Bohlman HH, Riew KD. Dural tears secondary to operations on the lumbar spine. Management and results after a two-year-minimum follow-up of eighty-eight patients. J Bone Joint Surg Am 1998;80:1728–32.

[10] Tafazal SI, Sell PJ. Incidental durotomy in lumbar spine surgery: incidence and management. Eur Spine J 2005;14:287–90.

[11] Williams BJ, Sansur CA, Smith JS, Berven SH, Broadstone PA, Choma TJ, et al. Incidence of unintended durotomy in spine surgery

based on 108,478 cases. Neurosurgery 2011;68:117–23. discussion 23-4.

[12] Guerin P, El Fegoun AB, Obeid I, Gille O, Lelong L, Luc S, et al. Incidental durotomy during spine surgery: incidence, management and complications. A retrospective review. Injury 2012;43:397–401.

[13] Wolff S, Kheirredine W, Riouallon G. Surgical dural tears: prevalence and updated management protocol based on 1359 lumbar vertebra interventions. Orthop Traumatol Surg Res 2012;98:879–86.

[14] Luszczyk MJ, Blaisdell GY, Wiater BP, Bellabarba C, Chapman JR, Agel JA, et al. Traumatic dural tears: what do we know and are they a problem? Spine J 2014;14:49–56.

[15] Tsutsumimoto T, Yui M, Uehara M, Ohta H, Kosaku H, Misawa H. A prospective study of the incidence and outcomes of incidental dural tears in microendoscopic lumbar decompressive surgery. Bone Joint J 2014;96-B:641–5.

[16] Oertel JM, Burkhardt BW. Full endoscopic treatment of dural tears in lumbar spine surgery. Eur Spine J 2017;26:2496–503.

[17] Muller SJ, Burkhardt BW, Oertel JM. Management of dural tears in endoscopic lumbar spinal surgery: a review of the literature. World Neurosurg 2018;119:494–9.

[18] Shi R, Wang F, Hong X, Wang YT, Bao JP, Liu L, et al. Comparison of percutaneous endoscopic lumbar discectomy versus microendoscopic discectomy for the treatment of lumbar disc herniation: a meta-analysis. Int Orthop 2019;43:923–37.

[19] Kamenova M, Leu S, Mariani L, Schaeren S, Soleman J. Management of incidental dural tear during lumbar spine surgery. To suture or not to suture? World Neurosurg 2016;87:455–62.

[20] Puvanesarajah V, Hassanzadeh H. The true cost of a dural tear: medical and economic ramifications of incidental durotomy during lumbar discectomy in elderly Medicare beneficiaries. Spine (Phila Pa 1976) 2017;42:770–6.

[21] Ahn Y, Lee HY, Lee SH, Lee JH. Dural tears in percutaneous endoscopic lumbar discectomy. Eur Spine J 2011;20:58–64.

[22] Fairbank J. Use of Oswestry Disability Index (ODI). Spine (Phila Pa 1976) 1995;20:1535–7.

[23] Ware Jr JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30:473–83.

[24] Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika 1983;70:41–55.

[25] Shin JK, Youn MS, Seong YJ, Goh TS, Lee JS. Iatrogenic dural tear in endoscopic lumbar spinal surgery: full endoscopic dural suture repair (Youn's technique). Eur Spine J 2018;27:544–8.

[26] Desai A, Ball PA, Bekelis K, Lurie JD, Mirza SK, Tosteson TD, et al. Outcomes after incidental durotomy during first-time lumbar discectomy. J Neurosurg Spine 2011;14:647–53.

[27] Ruban D, O'Toole JE. Management of incidental durotomy in minimally invasive spine surgery. Neurosurg Focus 2011;31:E15.

[28] Anderson DG, Popov V. Repair of lumbar dural tears with a suture patch: retrospective single-surgeon case series. Am J Orthop (Belle Mead NJ) 2013;42:E72–5.

[29] Adogwa O, Huang MI, Thompson PM, Darlington T, Cheng JS, Gokaslan ZL, et al. No difference in postoperative complications, pain, and functional outcomes up to 2 years after incidental durotomy in lumbar spinal fusion: a prospective, multi-institutional, propensity-matched analysis of 1,741 patients. Spine J 2014;14:1828–34.

[30] Grannum S, Patel MS, Attar F, Newey M. Dural tears in primary decompressive lumbar surgery. Is primary repair necessary for a good outcome? Eur Spine J 2014;23:904–8.

[31] Nandyala SV, Elboghdady IM, Marquez-Lara A, Noureldin MN, Sankaranarayanan S, Singh K. Cost analysis of incidental durotomy in spine surgery. Spine (Phila Pa 1976) 2014;39:E1042–51.

[32] O'Neill KR, Neuman BJ, Peters C, Riew KD. Risk factors for dural tears in the cervical spine. Spine (Phila Pa 1976) 2014;39:E1015–20.

[33] Dafford EE, Anderson PA. Comparison of dural repair techniques. Spine J 2015;15:1099–105.

[34] Wang B, Lu G, Liu W, Cheng I, Patel AA. Full-endoscopic interlaminar approach for the surgical treatment of lumbar disc herniation: the causes and prophylaxis of conversion to open. Arch Orthop Trauma Surg 2012;132:1531–8.