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ORIGINAL ARTICLE

Risk management in posterior spinal endoscopic surgery in lumbar diseases

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Abstract
Background Minimally invasive posterior spinal endoscopic surgery has increased in popularity. However, a steep learning curve may result in a high frequency of complications. Additionally, device failure may occur during routine use. We retrospectively investigated the incidence of such safety issues in a population of patients undergoing endoscopic spinal surgery at our institution.
Patients/materials and methods A total of 611 cases were included. Underlying diseases that required endoscopic surgery were lumbar disc herniation in 382 patients, lumbar spinal stenosis in 123 patients, lumbar degenerated spondylolisthesis in 100 patients, and lumbar facet joint cysts in 6 patients. Surgical complications, anatomic abnormality, and mechanical failure and/or damage of surgical instruments were considered adverse events associated with the surgery. The time period was divided into first and second halves in order to investigate the effects of the learning curve.
Results and conclusion Complications were divided into perioperative and postoperative complications. Due to operator inexperience, complications such as intraoperative dural tear, wrong disc level surgery, and contralateral symptoms due to lack of nerve decompression were more common during the first 5 years. In contrast, no improvement was seen in the frequency of epidural hematoma in the late phase. This report indicates that during endoscopic spinal surgery, some safety issues and surgical complications are independent of surgeon experience, and may include radicular anomaly, postoperative hematoma, and mechanical damage of instruments.

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Introduction

In Japan, endoscopic spinal surgery using a micro endoscopic discectomy (MED) system by Medtronics was performed on a patient with a lumbar herniated disc for the first time in 1998. The popularity of posterior spinal endoscopic surgery has increased in Japan, and the number of medical institutions performing the surgery has risen accordingly [1]. These types of operations are highly useful as a less invasive technique to meet the needs of patients. One particular example is microendoscopic laminotomy (MEL) for lumbar spinal stenosis, which is much less invasive than the comparable open procedure; it enables bilateral decompression through a unilateral approach by taking advantage of stroboscopic characteristics [2–7]. However, there is a concern that the microendoscopic technique has too steep a learning curve, which may result in a high incidence of complications during the learning phase [8]. Additionally, the endoscopic device may be broken or damaged during routine use, which can necessitate conversion to open surgery [6, 9]. Although the Japanese Orthopaedic Association annually investigated the incidence of complications associated with spinal endoscopic surgery as a nationwide survey, their survey is a cross-sectional study. Therefore, the purpose of this study

was to analyze the safety of posterior spinal endoscopic surgery by performing a retrospective review of peri- and post-operative data in patients undergoing these procedures at our institution longitudinally and to reveal the relationship between complications and surgeons' experience with the technique.

Patients and methods

Eight surgeons were involved in the cases. They had all worked as physicians for more than 10 years after graduation from medical school and were certified physicians by the Japanese Board of Orthopaedic Surgery and the Japanese Spine Research Society. They had performed more than 1,000 spinal surgeries, but only 5 cases of MED had been conducted by physicians who had graduated from medical school within the previous 10 years. Their mean duration of experience as a physician was 14 years. A total of 611 cases were included in the present study. We performed microendoscopic decompression surgery on degenerative spondylolisthesis without any instrumentation using a 16 mm tubular rectractor. These operations were performed from December 2000 to August 2009 and included 335 males and 226 females, aged 48.5 ± 12.4 (range 16–86) years. Underlying disease states requiring endoscopic surgery were lumbar disc herniation in 382 patients, lumbar spinal stenosis in 123 patients, lumbar degenerated spondylolisthesis in 100 patients, and lumbar facet joint cysts in 6 patients. In the current longitudinal study, we retrospectively reviewed our medical records and operative reports regarding our consecutive surgical cases from 2000 to 2009.

Surgical complications, anatomic abnormality (radicular anomaly), and mechanical failure and/or damage of surgical instruments were considered adverse events associated with the surgery. The time period was divided into first and second halves (early and late phases) in order to investigate the effects of the learning curve.

Statistical analysis was performed using a Mann–Whitney *U* test to evaluate significant difference between the early and the late phases. $P < 0.05$ was considered significant.

The institutional review board of our institution approved this study. Informed consent was obtained from all patients before their participation in this study.

Results

Surgical complications were divided into perioperative and postoperative complications, which are shown in Table 1. Due to operator inexperience, complications such as intraoperative dural tear, wrong disc level surgery, and contralateral symptoms due to lack of nerve decompression were more common during the first 5 years or early phase. Most cases of dural tearing were merely the size of a pinhole. Therefore, these cases did not show any symptoms after surgery or require any change in postoperative treatment. However, three cases showed relatively large dural tears. We sutured such larger dural tears during surgery and had the patients remain in bed for 5 days postoperatively to avoid retearing. In the microdiscectomy group, 6 incidences of dural tearing occurred in the early phase and 4 in the late phase, whereas in the microsurgical decompression group, 7 incidences of dural tearing occurred in the early phase and 3 in the late phase. However, there was a significant reduction in dural tearing in the late phase as indicated by a Mann–Whitney *U* test. Two postoperative cases of inferior articular process (IAP) fracture showed lumbar radiculopathy and additional posterior lumbar interbody fusion was performed. The other two cases did not show any symptoms. We performed 11 reoperations within 3 months, including 5 cases of recurrent disc herniation or incomplete disc herniation removal, 2 cases of intraforaminal stenosis, and 4 cases of postoperative hematoma. Twenty-six open conversion cases were composed of 14 cases of intraoperative dural tear, 10 cases because of insufficient skill in microendoscopic surgery, one case of radicular nerve anomaly, and one case of intraoperative mechanical failure. In contrast, no improvement was seen in the frequency of epidural hematoma, even in the late phase (second 5 years). Postoperative lumbar radiculopathy on the side contralateral to the surgical approach was seen in 5 cases in the early phase, but not seen in the late phase. All postoperative cases of motor deficits were evident in the extensor hallucis longus muscle as indicated by manual muscle test (MMT) scores that ranged from 2 to 3. However, the MMT score had returned to normal in all patients within 3–6 months

Table 1 Surgical complications

	Total	307 cases of early	307 cases of late
Perioperative complications			
Dural tear	20	13	7
Wrong level operation	3	3	0
Fracture of IAP	4	2	2
Open conversion	26	19	7
Postoperative complications			
Pulmonary infarction	1	0	1
Epidural hematoma (reoperation required)	13 (4)	7 (2)	6 (2)
Deep infection	4	1	3
Contralateral symptom	5	5	0
Motor weakness	3	2	1

Table 2 Surgical procedures and incident rate

Incident	Incident level					Total	Incident rate
	1	2	3a	3b	4		
Lumbar discectomy ($n = 382$)							
Dural injury	0	0	6	6	0	12	3.14
Root injury	0	0	1	0	0	1	0.26
Hematoma	0	2	2	2	0	6	1.57
Wrong level	0	0	3	0	0	3	0.79
Facet fracture	0	1	1	0	0	2	0.52
Pulmonary embolism	0	0	0	1	0	1	0.26
Total	7	3	13	9	0	32	6.55
Lumbar spinal stenosis ($n = 223$)							
Dural injury	0	3	3	2	0	8	3.59
Cauda injury	0	0	0	0	1	1	0.45
Root injury	0	0	1	0	0	1	0.45
Hematoma	0	0	5	2	0	7	3.14
Facet fracture	0	1	0	1	0	2	0.90
Total	2	4	9	5	1	21	8.52

postoperatively (Table 1). Other operative concerns included the detection of a radicular nerve anomaly during surgery. Five cases of radicular anomaly were classified as type 2 nerve root anomalies according to the Neidre and MacNab classification system [10], the level of which was L4/5 in one patient and L5/S1 in 4 patients. None of these cases could be diagnosed by routine magnetic resonance imaging (MRI) and preoperative computed tomography (CT). None of these 5 cases had undergone 3DMRI. One of these cases was found to be unsuitable for MED, and required open conversion.

We also examined the differences between complications of lumbar discectomy and lumbar spinal stenosis (Table 2). Although dural injury and hematoma were common in both groups, there was no significant difference in complications between these groups.

Surgical instrument malfunction during the operation was common. Intraoperative mechanical failure or damage to surgical devices including rongeurs (11 cases), the flexible arm (8 cases), the scope (8 cases), and drill (6 cases) occurred in 54 patients (8.8 %). As stated above, one patient required open conversion.

Discussion

Endoscopic surgery has been developed mainly because less tissue invasion alleviates postoperative pain, thereby improving postoperative outcomes such as early ambulation [11]. In particular, MEL for bilateral decompression through unilateral invasion is much less invasive than MED for lumbar disc herniation [12]. Concerns are related to problems with the visual field such as deficient depth perception (specific to endoscopic surgery), and difficulty in maintaining deep retraction, and these are especially relevant during the early phase of the learning curve. This results in more complications during this part of the learning curve. According to a report from the Spinal Endoscopic Surgery/Endoscopic Technical Accreditation System Committee of The Japanese Orthopaedic Association (JOA), the number of medical institutions performing endoscopic surgery in Japan increased 1.07 times in a year-to-year comparison in 2006 (208–222 institutions), and in 2007 it increased 1.16 times (222–257 institutions) [13]. Similarly, the number of operations increased 1.09 times in 2006 (4,215–4,611 operations) and 1.35 times in 2007 (4,611–6,239 operations).

Hasegawa et al. proposed the following for prevention of adverse intraoperative incidents: (1) development of instruments and apparatus; (2) establishment of an education system for technical learning; (3) establishment of an evaluation system for technical capability; and, (4) establishment of an identification and prevention system for complications [14]. Nakagawa et al. [8] also stressed that it is important to identify and understand complications specific to endoscopic surgery.

Training to overcome initial difficulty with the technique and measures for prevention of complications are considered essential safety measures to be taken for endoscopic operations, but may not always be sufficient to prevent malfunction of surgical instruments. Therefore, it will be specifically necessary to predict, overcome, and circumvent pitfalls in the surgical plan in order to flatten the learning curve as a preventative measure in regards to complications. In particular, the incidence of dural damage, wrong disc level, and contralateral radicular symptoms were higher during the early part of the learning curve, whereas the incidence was lower in the hands of expert surgeons. The use of Kerrison rongeurs is commonly associated with a risk of dural damage. Therefore, we always hold an aspirator or a retractor to create sufficient space between dura and flavum when using Kerrison rongeurs. In addition, we have to pay attention to determine the region of adhesion between the dura and surrounding tissues in particular. It is important to start surgery from the normal and unadhering region before going on to detach dura from the adhesive region. Epidural hematoma is a frequent and recognized complication of endoscopic spinal surgery [1, 12, 14]. Postoperative hematoma remains a serious concern, because this complication occurs even after refinement of surgical technique. Postoperative lumbar radiculopathy on the side contralateral to the surgical approach was common after a microendoscopic bilateral decompression by novice

microendoscopic surgeons using a unilateral approach with a tubular retractor, mainly because of incomplete decompression. A significant difference was observed between the reduced coronal dimensions of the facet joint on the approach side compared with the contralateral side [2]. Thus, decompression of nerve roots on the contralateral side is difficult. However, these complications have not been seen in more recent cases managed by experienced skilled surgeons who have revised the surgical technique for contralateral lamina resection. In addition, there was no statistically significant difference in deep infection between the early and the late phase. In current series, the incidence of wrong level surgery was 0.49 %. A 16 mm tubular rectractor is easy to move from the target surgical disc level to an adjacent level. To avoid this complication, we revised the surgical technique as follows: (1) the angle of the surgical table is adjusted such that the surgical target disc should be perpendicular under fluoroscopic control before surgery. (2) The surgeon maintains attention to the angle of the tubular rectractor during surgery. (3) If the surgeon feels something different, he or she must confirm the surgical level with a fluoroscopy during surgery. Thereby the incidence of surgery at the wrong level was markedly reduced in the late phase. In a recent report from the Spinal Endoscopic Surgery/Endoscopic Technical Accreditation System Committee of JOA, it was pointed out that the incidence of postoperative hematoma remains constant even when measures are taken to prevent complications [1, 13, 14]. When a radicular anomaly is unexpectedly encountered during surgery, endoscopic surgery may be difficult to perform [15]. In fact, one of our cases required open conversion. It has been reported that 3DMRI can predict radicular anomaly, but it may be impractical for all surgical patients to receive 3DMRI preoperatively. It is impossible to recognize nerve root anomaly in all cases preoperatively. Thus, when nerve root anomalies are discovered during surgery, we recommend performing a wide laminectomy or fenestration to fully comprehend the junction between the dura and the nerve root, and create sufficient space to safely operate on the root to the center to remove herniated disc tissues.

Mechanical damage was found in 54 patients (8.8 %), and some of these cases may have been preventable if physicians were better-acquainted with the handling of surgical instruments and knew ahead of time what measures were to be taken in case of damage. We suggest that unique surgical techniques should be used in isolation at each institution, but that knowledge and information on issues regarding surgical instruments and apparatus should be shared by participating medical institutions in order to provide optimal safety for spinal endoscopic surgery.

Conclusions

1. Safety issues related to posterior spinal endoscopic surgery were reported in our institutions.
2. Although the incidence of some problems involving intraoperative surgical device failure or other complications can be reduced with improved surgical skill, some complications are unavoidable despite preventative measures and proper training.
3. Examples of unavoidable complications include the presence of a radicular anomaly, postoperative hematoma, and mechanical damage of instruments.

Conflict of interest The authors declare that they have no conflict of interest.

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