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ORIGINAL ARTICLE

Enhanced recovery after surgery pathway with modified biportal endoscopic transforaminal lumbar interbody fusion using a large cage. Comparative study with minimally invasive microscopic transforaminal lumbar interbody fusion

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Abstract

Purpose Studies about the clinical efficacy of endoscopic lumbar interbody fusion using an enhanced recovery after surgery (ERAS) pathway are insufficient. Thus, the purpose of this study was to investigate clinical usefulness of biportal endoscopic transforaminal lumbar interbody fusion (TLIF) using an ERAS compared with microscopic TLIF.

Methods Prospectively collected data were retrospectively analyzed. Patients who received modified biportal endoscopic TLIF with ERAS were grouped into an endoscopic TLIF group. Those who received microscopic TLIF without ERAS were grouped into a microscopic TLIF group. Clinical and radiologic parameters were compared between two groups. Fusion rate was evaluated using sagittal reconstruction images of postoperative computed tomographic (CT) scan.

Results There were 32 patients in the endoscopic TLIF group with ERAS and 41 patients in the microscopic TLIF group without ERAS. Visual analog scale (VAS) scores for back pain preoperatively at day one and day two were significantly ($p < 0.05$) higher in the non-ERAS microscopic TLIF group than in the ERAS endoscopic TLIF group. Preoperative Oswestry Disability Index were significantly improved at the last follow-up in both groups. The fusion rate at postoperative one year was 87.5% in the endoscopic TLIF group and 85.4% in the microscopic TLIF group.

Conclusion Biportal endoscopic TLIF with ERAS pathway may have good aspect to accelerate recovery after surgery. There was no inferiority of fusion rate of endoscopic TLIF comparing to microscopic TLIF. Biportal endoscopic TLIF using a large cage with ERAS pathway may be a good alternative treatment for lumbar degenerative disease.

Keywords Fusion · Lumbar · Endoscopy · Recovery · Biportal

Introduction

The proportion of the elderly population is increasing with the improvement of living standards and health care systems. Degenerative spinal diseases presenting with back pain and radicular pain are among the most frequently developed disease entities in the health care system. Recently, the number of patients with spinal diseases is rapidly increasing with extended life expectancy, increasing the burden of an individual's life and human society [1]. Initial treatment option for a degenerative spinal disease is conservative treatment including bed rest, physiotherapy, pain killer medications, and pain procedures. Despite various conservative treatment options, some patients who have failed conservative management require surgical intervention to improve their quality of life.

Enhance recovery after surgery (ERAS) pathway is a widely accepted program in various surgical fields such as cancer surgery, orthopedic surgery, gynecologic surgery, abdominal surgery, and vascular surgery [2, 3]. Compared to other departments, the ERAS pathway might not be popular in the field of spinal surgery [3]. ERAS protocol usually consists of preoperative, intraoperative, and postoperative courses [2]. The most important part of ERAS may be the

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intraoperative course. A minimally invasive spine surgery including an endoscopic spine approach might be the most important intraoperative factor in ERAS for lumbar interbody fusion. Recently, biportal endoscopic spine surgery has become increasingly popular, and indications for biportal endoscopic spine surgery are gradually expanding from simple decompression to spinal fusion [4–7]. In the past, endoscopic spinal surgery was mainly used for lumbar disc diseases such as lumbar disc herniation; however, it is now used to treat stenosis, spondylolisthesis, and instability. Endoscopic lumbar interbody fusion surgeries including biportal endoscopic approaches have been attempted to treat lumbar degenerative diseases including stenosis, instability, and spondylolisthesis. Compared to conventional fusion surgeries or microscopic minimally invasive (MIS) transforaminal lumbar interbody fusion (TLIF), biportal endoscopic lumbar interbody fusion has several advantages [8, 9]. It can reduce immediate postoperative back pain, complications, and bleeding [3, 8].

The purpose of ERAS pathway is to accelerate recovery and reduce perioperative complications after surgery so that patients could eventually return to their normal social life earlier. The ERAS pathway can also increase satisfaction of patients as well as medical staff. There might be a synergic effect when endoscopic TLIF is combined with the ERAS pathway. However, clinical studies on the usefulness of endoscopic lumbar interbody fusion and ERAS are limited. Thus, the purpose of this study was to investigate the clinical usefulness of the ERAS pathway with biportal endoscopic TLIF compared with MIS TLIF.

Materials and methods

Patients

Regarding the study design, it was a retrospective analysis of prospectively collected data. There were 99 consecutive patients who underwent modified biportal endoscopic TLIF with the ERAS pathway (45 patients) or microscopic MIS TLIF without the ERAS pathway (54 patients) from January 2020 to November 2021.

We only enrolled patients who received a single-level fusion surgery. Inclusion criteria were those with degenerative spondylolisthesis, isthmic spondylolisthesis, foraminal stenosis, central stenosis with segmental instability, and recurrent disc herniation. Only lower lumbar levels (L4-5 or L5-S1) of TLIF were included. Upper lumbar levels (L1-2, L2-3, and L3-4) of TLIF were excluded from this study. Those with multilevel fusion surgeries, high-grade spondylolisthesis, infection, and traumatic lesion such as vertebral fractures were also excluded. MIS TLIF and biportal endoscopic TLIF were performed by two surgeons. The surgical method was determined according to the preference of the operator, respectively. Especially, in cases of biportal endoscopic TLIF, we performed a modified biportal endoscopic TLIF using a large-sized cage. In contrast, a routine TLIF cage was inserted in patients with microscopic MIS TLIF. A routine TLIF cage was smaller than the large cage which was inserted in the modified biportal endoscopic TLIF.

We enrolled patients who received MIS TLIF without ERAS and biportal endoscopic TLIF with ERAS. Only patients who were followed up for more than 12 months after surgery were included in this study.

Surgical technique of modified biportal endoscopic TLIF using a large-sized cage

Our technique of modified biportal endoscopic TLIF used a large-sized cage (Fig. 1a) [5, 6]. The design of a large-sized cage was similar to a cage using oblique lumbar interbody fusion (OLIF) [5]. The width of the cage used biportal endoscopic TLIF was 15 mm or 17 mm, and its length was 40 mm (Boaz LT cage, Synusbio, South Korea, Fig. 1b). The height of the cage was selected based on the patient's disc height of operation level. Two portals were made around the operation level for the modified biportal endoscopic TLIF. Endoscopic viewing portal was made at the medial border pedicle. The working portal was made at the lateral border pedicle (Fig. 2a). Skin incision length was 5 mm for the endoscopic viewing portal and about 15 to 20 mm for the working portal (Fig. 2a) [5, 6]. A working sheath is usually inserted for well drainage of saline irrigation and smooth insertion of spinal instruments (Fig. 2b). If we did the left-sided modified biportal endoscopic TLIF of L4-5, we should dissect and expose the left lamina and facet joint. Unilateral laminotomy of L4-5 and facetectomy of left L4-5 were done. Bilateral ligamentum flava were removed for decompression of central canal and lateral recess stenosis (Fig. 3). Total discectomy was done using pituitary forceps and various sizes of shavers. Cartilaginous endplate could be separated from the osseous endplate using dissectors and curets (Fig. 3d). Complete endplate preparation was performed under clearly magnified endoscopic view. A dura and a traversing nerve root were medially retracted with a customized dura retractor and a cage guidance inserted into the interbody disc space (Fig. 4a and b). A large-sized cage was then filled with fusion materials such as auto bone and demineralized bone matrix (DBM). The cage was obliquely inserted and rotated transversely using a cage impactor (Fig. 4c). A hemovac drainage catheter was inserted. Percutaneous pedicle screws were inserted under C-arm fluoroscopic guidance (Fig. 5). A local anesthetic agent was injected into the surgical wound before skin closure. In contrast, microscopic MIS TLIF was performed using tubular retractor or Caspar retractor systems

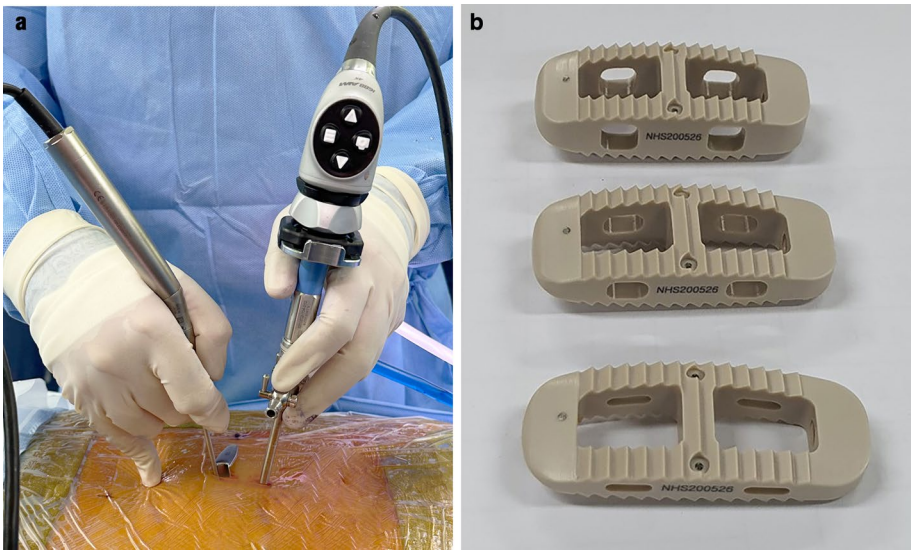

Fig. 1 Overview of modified biportal endoscopic lumbar interbody fusion **a** large-sized cages which were used in modified biportal transforaminal lumbar interbody fusion

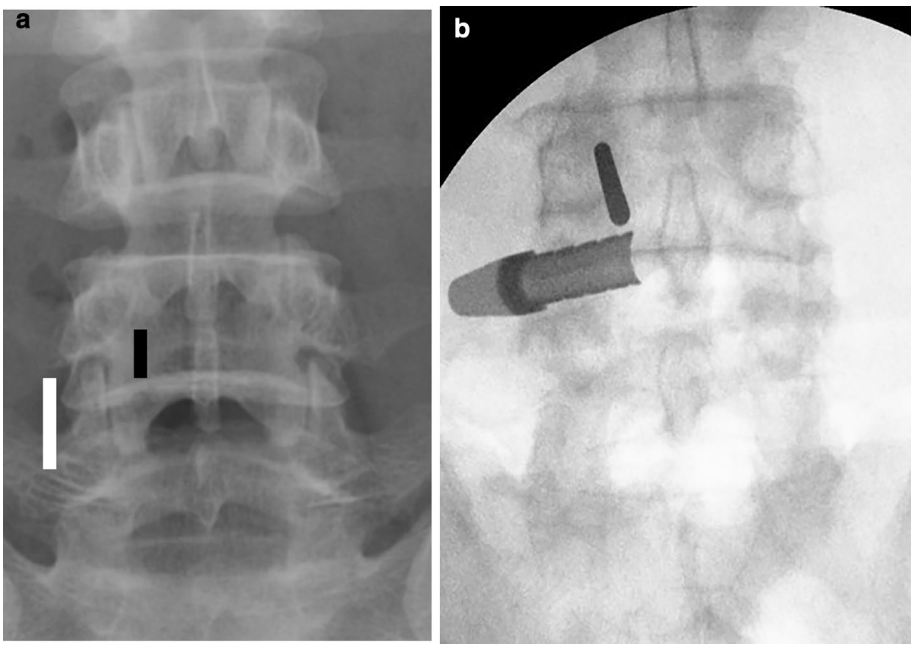

Fig. 2 Skin incision points for biportal endoscopic transforaminal lumbar interbody fusion **a** Black line is skin incision point for an endoscopic viewing portal, and white line is skin incision point for a working portal. C-arm fluoroscopic X-ray image after making two portals **b** A working sheath was inserted into working portal

under a microscope. Common TLIF cages were inserted in microscopic MIS TLIF.

ERAS pathway protocols

Our ERAS pathway included preoperative, intraoperative, and postoperative phases (Table 1) [2, 3]. Preoperative ERAS protocol consisted of patient education, cessation of smoking and alcohol, blood sugar and blood pressure control, preemptive analgesia, prophylactic antibiotics, and loading of tranexamic acid. Intraoperative ERAS protocol consisted of biportal endoscopic spine surgery with percutaneous pedicle screw fixation (Fig. 5), local infiltration of vancomycin powder, and local anesthesia injection at wound. The final postoperative ERAS protocol was comprised patient-controlled analgesia (PCA), early rehabilitation and ambulation, prophylactics of deep-vein thrombosis, prevention of nausea and vomiting, wearing orthosis, and administration of oral analgesics with early use of gabapentin or pregabalin.

Analysis of clinical and radiological outcomes

Patients who received modified biportal endoscopic TLIF with ERAS pathway were classified into the endoscopic TLIF group, and patients who received microscopic TLIF without ERAS pathway were classified into the microscopic TLIF group. Clinical parameters were investigated and

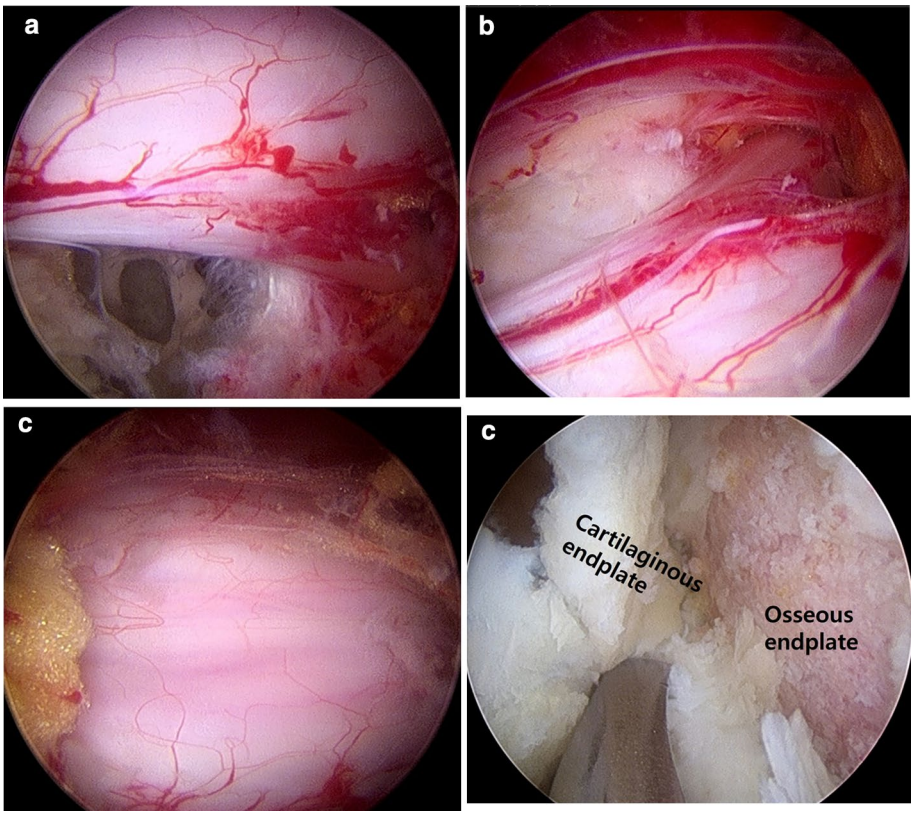

Fig. 3 Intraoperative endoscopic images of modified biportal endoscopic transforaminal lumbar interbody fusion. Fully decompressive status of left ipsilateral traversing nerve root **a** Contralateral traversing nerve root **b** Central canal **c** Endoscopic endplate preparation image **d** cartilaginous endplate is separated from osseous endplate using a dissector

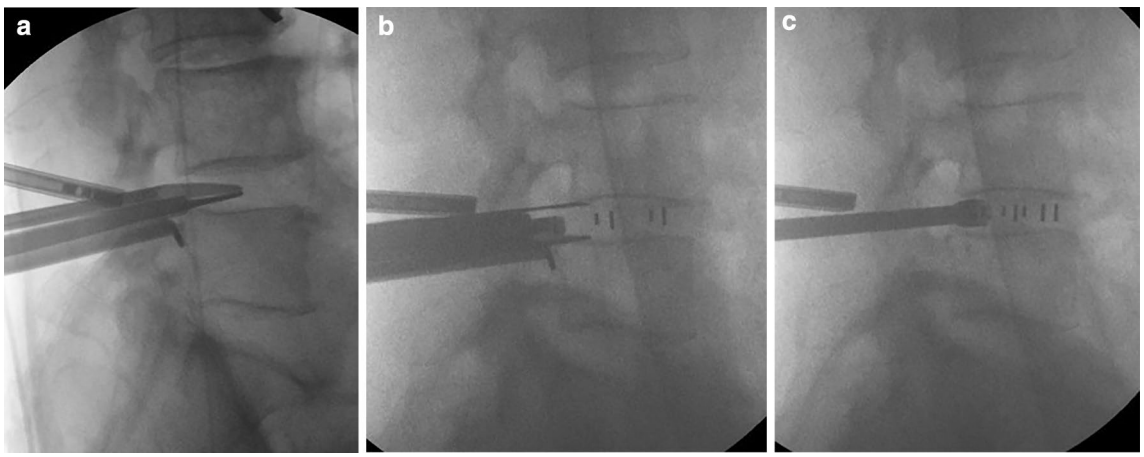

Fig. 4 Intraoperative C arm fluoroscopic X-ray images of a large size cage insertion. A large cage inserted through a cage guidance after dura retraction (**a** and **b**). The cage was rotated transversely (**c**)

compared between the two groups, including demographic characteristics, diagnosis visual analog scale (VAS) score for back and leg pain, Oswestry Disability Index (ODI), complications, estimated blood loss, and operation time. Estimated blood loss included intraoperative bleeding as well as postoperative hemovac drainage via catheter.

VAS scores of back pain and leg pain were assessed preoperatively, postoperative first day, postoperative second day, and at the last follow-up. ODI score was assessed preoperatively and at the last follow-up. VAS and ODI were evaluated by research nurses who did not know the type of surgery. Mean values of ODI and VAS score were compared between the endoscopic TLIF group and the microscopic TLIF group.

Serial plain X-ray examinations were performed to evaluate hardware failure such as cage subsidence, pullout of pedicle screw, and cage migration. Significant cage subsidence was defined more than 2 mm of cage migration into the

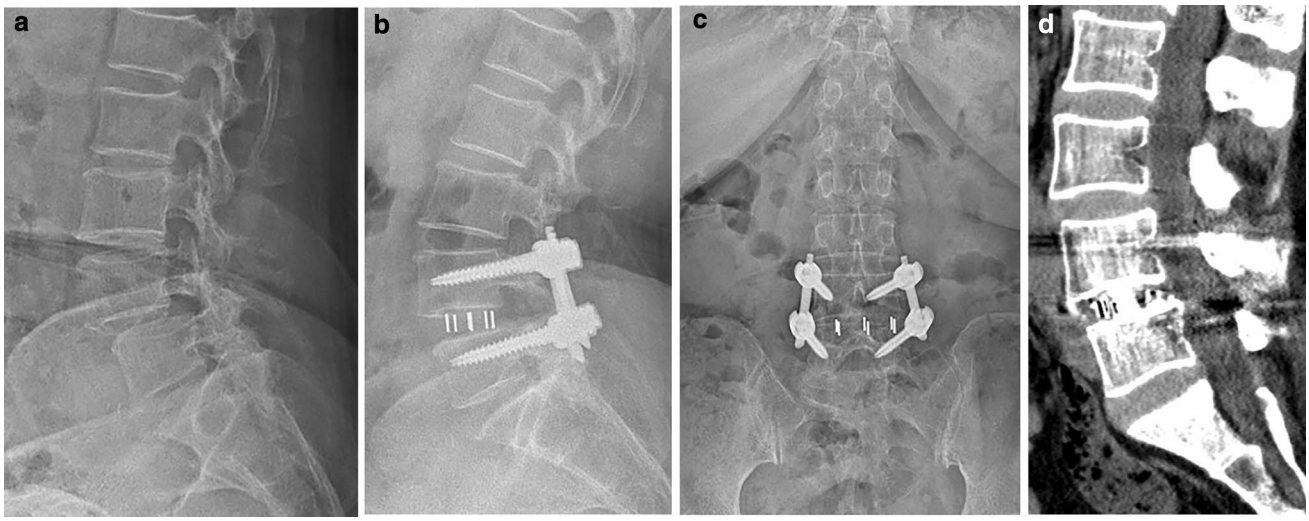

Fig. 5 A 63-year-old female patients presented with back pain, bilateral legs pain, and claudication. Preoperative X-ray image shows the degenerative spondylolisthesis of L45 (**a**). This patient underwent modified biportal endoscopic transforaminal lumbar interbody fusion using a large cage (**b** and **c**). 1-year follow-up CT reveals bone bridge formation between L4 and L5 (**d**)

Table 1 Protocol of ERAS with percutaneous biportal endoscopic surgery

Pathway	Protocol
Preoperative	Education of endoscopic spine surgery using YouTube and conversation
	Cessation alcohol and smoking
	Preoperative preemptive analgesia (Gabapentin 300 mg or Pregabalin 75 mg)
	Prophylactic antibiotics injection
	Preoperative intravenous loading of tranexamic acid
Intraoperative	Wearing of anti DVT stockings
	Biportal endoscopic lumbar interbody fusion
	Percutaneous pedicle screw insertion
	Large-sized interbody cage (15 or 17 mm width and 40 mm length)
	FloSeal application before finishing endoscopic surgery
	Insertion of epidural drainage catheter (prevention of postoperative hematoma)
	Local infiltration of vancomycin powder
	Local anesthesia injection at skin incision sites
Postoperative	Intravenous or epidural patient-controlled analgesia (PCA)
	Oral analgesics with pregabalin or gabapentin (consider early short-term administration opioid)
	Control of postoperative nausea and vomiting (ondansetron)
	Ealy ambulation with physical therapist support and education
	Wearing orthosis

vertebral body [10]. Postoperative computed tomography (CT) was taken at 12 months after surgery. Interbody fusion rate was determined using sagittal reconstruction images of postoperative CT scans (Fig. 5). Bridwell grade was used to determine interbody fusion. Grade 1 of Bridwell grade was a solid interbody fusion with bone bridge.

This study was performed in accordance with our institutional guidelines. It complied with international laws and policies as well as those of the institutional review board of hospitals where the authors were affiliated. Statistical analyses were performed using Fisher's exact test, Pearson's Chi-square test, Wilcoxon signed-rank test, and Mann–Whitney *U* test. Statistical significance was considered at $p < 0.05$. R 4.2.2 for Windows was used for all statistical analyses.

Results

Finally, 73 patients were enrolled. They were followed up for more than 12 months after a single-level TLIF surgery. There were 32 patients in the endoscopic TLIF group with ERAS and 41 patients in the microscopic TLIF group without ERAS. There were no significant differences in demographics, fusion level, or preoperative diagnosis between

the two groups (all $p > 0.05$, Table 2). The mean follow-up period was 14.5 ± 3.1 months.

Preoperative ODI was significantly reduced at the last follow-up in both groups ($p < 0.05$). VAS scores for back pain preoperatively at day one and day two were significantly higher in the non-ERAS group than in the ERAS group ($p < 0.05$, Table 3). However, there was no significant difference in VAS of back or leg pain or ODI at the final follow-up between the two groups (all $p > 0.05$, Table 3).

Perioperative complications were usually minor in both groups. Seven patients in the microscopic TLIF group experienced postoperative complications including symptomatic postoperative epidural hematoma (2 cases), pneumonia (1 case), transient neurologic symptoms (1 case), postoperative ileus (1 case), dura tear (1 case), and wound dehiscence (1 case), while two patients in the endoscopic TLIF group experienced complications including symptomatic postoperative epidural hematoma (1 case) and transient neurologic symptom (1 case). Postoperative complications of both groups were treated by conservative managements. There was no significant ($p > 0.05$) difference in incidence of complications between the two groups (Table 3).

Radiologically, significant cage subsidence occurred in one case in the endoscopic TLIF group and four cases in the microscopic TLIF group ($p > 0.05$). Bridwell grade 1 solid fusion was detected in 28 of 32 patients of the endoscopic TLIF group (fusion rate, 87.5%) and 35 of 41 patients of the microscopic TLIF group (fusion rate, 85.4%). Although fusion rate of the endoscopic TLIF group was higher than that of the microscopic TLIF group, the difference between the two was not statistically significant ($p > 0.05$).

The mean operation time was 150.2 ± 8.1 min in the endoscopic TLIF group and 123.9 ± 12.8 min in the microscopic TLIF group. The mean amount of EBL was 192.5 ± 31.8 ml in the endoscopic TLIF group and 287.6 ± 55.8 ml in the microscopic TLIF group. The mean operation time was significantly higher in the endoscopic TLIF group than in the microscopic TLIF group, whereas the mean EBL amount was significantly lower in the endoscopic TLIF group than in the microscopic TLIF group (Table 3, $p < 0.05$).

Table 3 Comparison of clinical and radiologic outcomes

	Endoscopic TLIF group (with ERAS)	Microscopic TLIF group (without ERAS)
VAS leg pain		
Preoperative	7.7 ± 0.9	7.9 ± 1.1
Postoperative 12 months	2.4 ± 0.7	2.1 ± 0.9
VAS back pain		
Preoperative	6.5 ± 0.9	6.7 ± 1.1
Postoperative 1 day*	3.9 ± 0.9	4.9 ± 1.3
Postoperative 2 days*	2.8 ± 0.5	4.2 ± 0.9
Postoperative 12 months	2.6 ± 1.1	2.7 ± 1.1
ODI		
Preoperative	58.2 ± 6.1	59.8 ± 5.9
Postoperative	21.8 ± 2.6	22.7 ± 3.0
Complications (cases)	2	7
Estimated blood loss (ml)*	198.8 ± 41.9	299.0 ± 57.3
Operation time (minute)*	150.8 ± 8.0	122.2 ± 13.5
Cage subsidence (cases)	1	4
Fusion rate (Bridwell grade 1)	(28/32) 87.5%	(35/41) 85.4%

$P < 0.05$*

Discussion

Goals of surgical procedures for degenerative spinal diseases are to achieve adequate neural decompression for neural compressive lesions and stabilization through

Table 2 Demographic characteristics

	Endoscopic TLIF group (with ERAS)	Microscopic TLIF group (without ERAS)
Gender (male/female)	10/22 (32)	16/25 (41)
Age (year)	65.2 ± 19.5	62.3 ± 10.6
Mean follow-up periods (month)	13.9 ± 2.6	15.0 ± 3.3
Level distribution		
L4-5	27	30
L5-S1	5	11
Diagnosis		
Degenerative spondylolisthesis	20	27
Isthmic spondylolisthesis	5	5
Central stenosis	4	5
Foraminal stenosis	3	2
Recurrent disc herniatio	0	2

fusion surgery for an unstable spine. Most cases of degenerative spinal disease can be treated by adequate neural decompression; however, fusion surgery might be needed for some cases with unstable spondylolisthesis, severe foraminal stenosis, segmental instability, and recurred degenerative spinal disease. Despite the development of fusion surgery from posterolateral fusion (PLF) to posterior lumbar interbody fusion (PLIF), extensive dissection of paraspinal soft tissues is required during surgery. Extensive paraspinal soft tissue damages might disturb back muscle's performance, result in persistent backache and require a long time to return to patient's normal social life [11]. Therefore, spine surgeons always make great efforts to reduce damage to normal paraspinal tissues during a spinal surgery, especially during fusion procedures.

ERAS proposal was introduced by Kehlet in 1997 to accelerate patient recovery time, reduce the length of hospital stay, enhance clinical outcomes, and early return to their normal social life [12]. ERAS includes optimizing preoperative, intraoperative, and postoperative protocols to enhance results. In surgical field for spinal disease, efforts to reduce surgery-related complications, reduce postoperative pain, and shorten hospital stay have been continuously attempted [13]. To achieve this goal, MIS surgery has been conspicuously developed in the last three two decades to reduce damage to normal spinal structures during an operation and improve functional outcomes [14]. MIS-TLIF has been developed and prolonged with the development of tubular retractor system and percutaneous pedicle screw fixation (PPSF) and sometimes ERAS protocols were also added to obtain patient's early recovery. MIS-TLIF with ERAS protocols could decrease the length of hospital stay and lead to early back pain relief compared to a conventional open posterior fusion surgery [15, 16]. Although MIS-TLIF can preserve normal paraspinal muscles or soft tissues compared to a traditional open surgery, paraspinal muscle dissections or some resections are also required to make a surgical window, which might disturb early recovery after surgery. Surgeons try to find more lesser invasive techniques compared to MIS-TLIF to apply more developed ERAS pathway [17].

Endoscopic spine surgery (ESS) has been used widely during the last two decades with technologically developed equipment and more minimal invasive concepts compared to a tubular retractor system. Endoscopic discectomy or canal decompression is the main procedure of ESS for a long time. However, endoscopic spine surgery is recently extending to lumbar interbody fusion for treating degenerative lumbar spinal disease with satisfactory clinical and radiological outcomes [8, 18, 19]. An endoscopic lumbar interbody fusion was initially performed through the Kambin triangle, this technique could be performed under local anesthesia as the most minimally invasive fusion technique. However, its initial results showed relatively high rates (20–30%) of complications such as transient exiting nerve injury, subsidence, incomplete decompression, and nonunion [20].

Recently, biportal endoscopic spine surgery has been performed and widely spread, especially in Korea [21]. Biportal endoscopic spine surgery has very similar surgical anatomy to open microscopic spine surgery. It can also provide a clean magnified surgical view through hydrostatic pressure and continuous saline irrigation. Initially, biportal surgery was performed in lumbar decompression. Indications of biportal surgery now include cervical and thoracic spinal decompression. Lumbar fusion was also initiated several years ago via biportal endoscopic surgery with results already reported [8, 22]. Initial preliminary results showed acceptable clinical and radiological outcomes with a relatively low rate of surgery-related complications. However, reports about the effectiveness of endoscopic lumbar interbody fusion with ERAS pathway are nearly none. Therefore, the authors implemented the ERAS protocol in patients undergoing biportal endoscopic TLIF and determined how much benefit could be obtained with biportal endoscopic TLIF compared to microscopic MIS-TLIF.

In the present study, basic demographic features and spinal disease entities were similar between the non-ERAS MIS-TLIF group and the ERAS biportal endoscopic TLIF group. Clinically, VAS scores for back and leg pain were significantly improved at the last follow-up in both groups. The final improvement of ODI score was also very similar in the two groups, indicating that both fusion techniques could be effective surgical procedures for degenerative spinal diseases. However, biportal endoscopic TLIF with ERAS protocol showed significantly lower VAS scores for back pain on postoperative day (POD) 1 and POD 2. Early back pain improvement can be explained by several reasons. Firstly, paraspinal muscle or tissues injury is lesser in ESS comparing in open surgery. Choi et al. have reported that the group receiving an open microscopic spine surgery shows higher elevation of serum CK level than the group receiving an endoscopic spine surgery [23]. Postoperative back pain during hospital admission and the duration of hospital stay are also significantly higher in the microscopic group than in the endoscopic group. These results suggest that reducing iatrogenic injury to paraspinal tissues through an endoscopic approach might be helpful for obtaining early activity and return to work. The limitation of our study did not include an enzymatic study related to tissue injury. Second is the cage size. The interbody cage was generally located obliquely in the central area of the disc in MIS-TLIF, and a single cage with 12 mm in width and 34 mm in length was mainly inserted. Therefore, a relatively small interbody cage was located on the weak portion of the vertebral endplate, which might

increase the loading between the cage and the weak bony endplate and lead to the development of early subsidence due to endplate breakage. Continuous irritation between the interbody cage and bony endplates might be the reason for an early postoperative severe back pain. On contrast, the cage used for modified biportal endoscopic TLIF with ERAS pathway was slightly smaller than an OLIF cage but significantly larger than a general TLIF cage. Therefore, the inserted cage is located on the peripheral side of the endplate and the vertebral body, which is the part where the strength of the endplate is strong. The use of large-sized interbody cage in out ERAS pathway can serve immediately strong fixation power within the interbody space and reduce irritation on weak bony endplate. It can serve the back pain relief at immediately after surgery. Previous reported comparative studies have reported that postoperative back pain during hospital admission and duration of hospital stay are higher in the microscopic group than in the endoscopic group [3, 8, 17].

In the present study, modified biportal endoscopic TLIF using a large cage was mainly performed at the lower lumbar level, including L4-5 and L5-S1 levels [5]. It is not usually performed at the upper lumbar level because of a high possibility of exiting nerve root injury when inserting a large-sized cage [5]. Therefore, in this study, only lower lumbar level fusion surgery was studied. Third point is endplate preparation. Most process of endplate preparation was performed blindly in microscopic MIS-TLIF through narrow surgical field. It has the risk of the development of endplate damage during fusion bed preparation. The damage of bony endplates can be the cause of early postoperative back pain. During the endoscopic fusion, fusion bed preparation could be completed via direct endoscopic view and the possibility of endplate damage could be reduced [8]. Last point is the preemptive analgesia and postoperative patient-controlled analgesia (PCA). Our biportal endoscopic TLIF with ERAS pathway included preemptive analgesia using pregabalin or gabapentin, and also included PCA. Despite PCA was generally administered in patients received microscopic MIS-TLIS, preemptive analgesia was not routinely adapted in microscopic MIS-TLIF. The effect of preemptive analgesia and PCA was well-known salvage methods to relief early postoperative pain in spine surgery [16].

Some surgeons have great worries about the development of pseudoarthrosis or nonunion in an endoscopic lumbar fusion surgery. However, fusion rates at one year after surgery were slightly higher in the biportal endoscopic TLIF group than in the MIS-TLIF group. Already we mentioned, one of the main advantages of endoscopic TLIF is fusion bed preparation under direct viewing of interbody disc space. Complete endplate preparation can be performed reliably without damaging the osseous endplate on a magnified endoscopic view [5, 6]. We also used 30-degree spinal endoscopy during contralateral endplate preparation, and it could make possible wide fusion bed completely. Pseudoarthrosis is associated with cage subsidence. Our results also showed four cases with significant subsidence in the non-ERAS MIS-TLIF group but only one case of subsidence in the ERAS biportal endoscopic TLIF group. It might be made by complete fusion bed preparation and the usage of large-sized cage under endoscopic view in our ERAS pathway. In the future, complete and wide denudation of fusion bed under a clear endoscopic view, development of 3D-printing cage, and effective delivery system of fusion materials such as bone morphogenetic proteins (BMPs) and demineralized bone matrix (DBM) might play important roles in an endoscopic fusion surgery to increase successful solid fusion.

To reduce perioperative complications, reducing operation time is very important. However, an endoscopic lumbar fusion needs a relatively long operation time, although it has advantages of minimal tissue trauma and rapid pain relief after surgery. The main disadvantage of an endoscopic spine surgery is its stiff learning curve. However, learning curve of biportal surgery is not stiff because the technique has similar surgical anatomy comparing in open surgery and free usage of spinal instruments through working portal [24]. Two surgeons in our study had sufficient experience of MIS-TLIF, although their experience of biportal endoscopic TLIF was less than that of MIS-TLLF. The difference in operative running time between the two was about 27 min. If the operative experience of endoscopic TLIF is increased, operative time of biportal endoscopic TLIF might be decreased.

The complication rate tended to be less in the biportal endoscopic TLIF group, although the difference between the two groups was not statistically significant. Early ambulation and early rehabilitation were possible because there was little pain at the surgical site after surgery, there were few postoperative complications. Various approaches of the ERAS pathway protocol might have played an important role in reducing postoperative complications. Opioids are frequently used to reduce postoperative severe back pain in non-ERAS microscopic MIS-TLIF. However, opioid-related complications such as respiratory depression, cognitive dysfunction, or delirium can develop. They are associated with the development of severe morbidity or mortality in elderly patients. Decreased use of opioids could be achieved not only through a surgical technique such as a biportal endoscopic TLIF but also through preemptive analgesia and multimodal pain control through the ERAS pathway [25, 26]. It is very important to reduce perioperative complications. Despite long operation time in biportal endoscopic TLIF group compared to MIS-TLIF group, intraoperative blood loss was less in the biportal endoscopic TLIF group than in the MIS-TLIF group. It might be associated with hydrostatic pressure for controlling the bleedings from epidural vessels and oozing from

exposed cancellous bones during the surgery in biportal endoscopic TLIF. And our ERAS pathway included preoperative intravenous loading of tranexamic acid. During the endplate preparation, bleeding was frequently occurred from interbody space in microscopic MIS-TLIF, and we could not find the origin of bleeding. It might be associated with endplate damage. These intraoperative and perioperative ERAS pathways might play an important role in reducing postoperative back pain and perioperative complications [25]. Early pain relief and reduction of perioperative complications can eventually reduce hospital stay and make early return to normal social life. About 2.5 days of hospital stay was reduced in biportal endoscopic TLIF group with ERAS compared to non-ERAS MIS-TLIF group.

This study has several limitations. First, it was a case–control study, not a blinded randomized study. In addition, the surgical method was determined by the operator's preference. Moreover, the sample size was small. Due to these limitations of this study, results of the study might have been biased. A randomized case–control study using a large cohort is needed in the future to establish an accurate comparative study and determine advantages of biportal endoscopic fusion surgery with ERAS pathway.

Conclusions

Modified biportal endoscopic TLIF using a large-sized cage with ERAS pathway may have good effect in reduction of immediate postoperative pain and blood loss. There was no inferiority of fusion rate of endoscopic TLIF comparing to microscopic MIS TLIF. However, the high technical demanding and long operation time are the disadvantages of modified biportal endoscopic TLIF operation. Biportal endoscopic TLIF with ERAS concept may have good aspect to accelerate recovery after surgery.

Declarations

Conflict of interest The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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