Clinical results of percutaneous biportal endoscopic lumbar interbody fusion with application of enhanced recovery after surgery

*Dong Hwa Heo, MD, PhD, and Choon Keun Park, MD, PhD

Department of Neurosurgery, Spine Center, The Leon Wiltse Memorial Hospital, Suwon, South Korea

OBJECTIVE The aims of enhanced recovery after surgery (ERAS) are to improve surgical outcomes, shorten hospital stays, and reduce complications. The objective of this study was to introduce ERAS with biportal endoscopic transforaminal lumbar interbody fusion (TLIF) and to investigate the clinical results.

METHODS Patients were divided into two groups based on the fusion procedures. Patients who received microscopic TLIF without ERAS were classified as the non-ERAS group, whereas those who received percutaneous biportal endoscopic TLIF with ERAS were classified as the ERAS group. The mean Oswestry Disability Index (ODI) and visual analog scale (VAS) scores were compared between the two groups. In addition, demographic characteristics, diagnosis, mean operative time, estimated blood loss (EBL), fusion rate, readmissions, and complications were investigated and compared.

RESULTS Forty-six patients were grouped into the non-ERAS group (microscopic TLIF without ERAS) and 23 patients into the ERAS group (biportal endoscopic TLIF with ERAS). The VAS score for preoperative back pain on days 1 and 2 was significantly higher in the non-ERAS group than in the ERAS group ($p < 0.05$). The mean operative duration was significantly higher in the ERAS group than in the non-ERAS group, while the mean EBL was significantly lower in the ERAS group than in the non-ERAS group ($p < 0.05$). There was no significant difference in fusion rate between the two groups ($p > 0.05$). Readmission was required in 2 patients who were from the non-ERAS group. Postoperative complications occurred in 6 cases in the non-ERAS group and in 2 cases in the ERAS group.

CONCLUSIONS Percutaneous biportal endoscopic TLIF with an ERAS pathway may have good aspects in reducing bleeding and postoperative pain. Endoscopic fusion surgery along with the ERAS concept may help to accelerate recovery after surgery.

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KEYWORDS minimally invasive surgery; lumbar; endoscopy; recovery

ENHANCED recovery after surgery (ERAS) is a new concept in the surgical field.^{3,13} ERAS could be defined as a multimodal perioperative care pathway to achieve early recovery for patients who undergo major surgeries.¹³ The aims of ERAS are to improve surgical outcomes and quality of life, shorten hospital stay, and reduce complications. The ERAS pathway includes preoperative, intraoperative, and postoperative management,^{10,13} and therefore requires a team approach such as surgery, nursing, rehabilitation, and anesthesia. Recently, ERAS has been attempted in the field of spine surgery;^{3,11} it was first introduced by Michael Wang.¹³ He emphasized the

importance of endoscopic lumbar interbody fusion in the field of ERAS,^{3,13} even though the concept of ERAS may not be popular in spine surgery.

Percutaneous biportal endoscopic surgeries have been attempted for lumbar degenerative disease such as lumbar interbody fusion.^{4,13} Endoscopic lumbar interbody fusion using a percutaneous biportal endoscopic approach may reduce operative scars and traumatization of posterior musculoligamentous structures.⁴ Moreover, biportal lumbar interbody fusion can achieve direct central and foraminal neural decompression similar to conventional transforaminal lumbar interbody fusion (TLIF).⁴ The objective

ABBREVIATIONS DVT = deep vein thrombosis; EBL = estimated blood loss; ERAS = enhanced recovery after surgery; ODI = Oswestry Disability Index; PCA = patient-controlled analgesia; TLIF = transforaminal lumbar interbody fusion; VAS = visual analog scale.

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* D.H.H. and C.K.P. contributed equally to this work and share first authorship.

TABLE 1. Protocol of ERAS with percutaneous biportal endoscopic surgery

Pathway	Protocol
Preop	
Preop emotional support	Including providing operative information
Preemptive analgesic	Pregabalin 75 mg or gabapentin 300 mg
Prophylactic antibiotic injection	First-generation cephalosporin antibiotics
Preop loading of tranexamic acid	Intravenous loading
Prophylactic antiemetics	Intravenous injection for prevention of nausea and vomiting
Intraop	
Local anesthetic injection	Before skin incision and before wound closure
Maintain tranexamic acid	Intravenously maintain during operation
Secondary prophylactic antibiotic injection	Secondary loading of intravenous antibiotics
Minimally invasive spine operation	Percutaneous biportal endoscopic surgery Percutaneous pedicle screw
Insertion of drainage catheter	Prevention of epidural hematoma
Local infiltration of vancomycin powder	Spread vancomycin over wound areas
Skin closure w/o suture	Use skin bonding materials
Postop	
Postop pain control	Intravenous PCA, oral analgesic w/ pregabalin or gabapentin
DVT prophylactics	Early ambulation and anti-DVT stocking, intermittent pneumatic compression of legs
Wearing orthosis	
Postop nutrition	

of this study was to introduce the concept of ERAS with biportal endoscopic TLIF and to investigate the clinical results.

Methods

Protocol of ERAS Pathway

ERAS in spine surgery consist of three phases: preoperative, intraoperative, and postoperative treatments in the authors' hospital (Table 1). First, preoperative treatment comprised preemptive analgesia,⁶ prophylactic antibiotic administration, emotional support such as providing operative information, and preoperative loading of tranexamic acid. Second, the intraoperative setting comprised preemptive local anesthesia infiltration, intraoperative intravenous maintenance of tranexamic acid, secondary injection of prophylactic antibiotics, the setting of minimally invasive spine surgery, insertion of surgical drainage, local infiltration of vancomycin powder, and wound closure with skin bond materials. Specifically, the authors used a percutaneous biportal endoscopic approach (Fig. 1) and percutaneous pedicle screw insertion (Fig. 2) for minimally invasive spine surgery. Third, the postoperative pathway comprised postoperative pain control with patient-controlled analgesia (PCA), administration of oral analgesics with early use of gabapentin or pregabalin, prophylaxis of deep vein thrombosis (DVT), postoperative nutrition, wearing an orthosis, and early ambulation.

Patient Population

The inclusion criteria for this study were low-grade degenerative spondylolisthesis (grade 1), low-grade isthmic spondylolisthesis (grade 1), central stenosis with instabil-

ity, and central stenosis with concomitant foraminal stenosis. Cases of infection, medical history of musculoskeletal disorders, multilevel spinal stenosis, spondylodiscitis, vertebral fractures, tumor, or high-grade spondylolisthesis were excluded. Minimally invasive TLIF was performed under microscopic or endoscopic view. Microscopic TLIF was performed using Caspar lumbar retractor or tubular retractor systems (METrx, Medtronic), while endoscopic decompressive procedures were performed using percutaneous biportal endoscopic systems (Arthrex, Stryker, and

FIG. 1. Overview of percutaneous biportal endoscopic surgery.

FIG. 2. Images obtained in a 75-year-old female patient who complained of severe left-sided leg pain and neurological intermittent claudication. A preoperative CT scan (A), and T2-weighted sagittal (B and C) and axial (D and E) MR images show left-sided upwardly migrated disc herniation and degenerative spondylolisthesis with severe central canal stenosis of L4–5. Postoperative MR images (F–H) show that the central canal is fully widened after percutaneous biportal endoscopic fusion. A postoperative radiograph (I) demonstrates a straight TLIF cage (34-mm length, 12-mm height) inserted at the L4–5 area.

UBE, EndoVision). Surgical approaches were chosen according to the spine surgeon's preference and experiences. Percutaneous biportal endoscopic TLIF was performed with ERAS while microscopic TLIF was performed without an ERAS pathway.

Surgical Procedures of Percutaneous Biportal Endoscopic TLIF

Essentially, this procedure (Video 1) is similar to an endoscopic interlaminar approach and minimally invasive TLIF.⁴

VIDEO 1. Clip demonstrating left-sided endoscopic lumbar interbody fusion of L4–5. Full endoscopic lumbar interbody fusion was performed using a percutaneous biportal endoscopic approach. The biportal endoscopic fusion technique in this study is similar to minimally invasive TLIF. Copyright Dong Hwa Heo. Published with permission. [Click here to view.](#)

This endoscopic lumbar interbody fusion was described in a previous publication.⁴ The patient underwent the operation while prone, under general or epidural anesthesia. A waterproof surgical drape for endoscopic surgery was necessary. Two channels were made ipsilaterally under C-arm fluoroscopic guidance. For patients with lateralizing-dominant symptoms, a symptomatic directional approach was used, otherwise a left-sided approach was preferred. If the left-sided approach to L4–5 was performed by a right-handed surgeon, the endoscopic portal was made at the L4 pedicle and the working portal was made at the L5 pedicle. An endoscopic channel was used only for a 5.5-mm-diameter trocar with a 4-mm-diameter 0° endoscope; a working channel was used for surgical instruments such as specialized endoscopic instruments, gen-

eral spinal instruments, a drill, and radiofrequency probes. Continuous saline irrigation was used and drained from the endoscopic channel to the working channel. A trocar was inserted in the working portal for good drainage of saline irrigation, smooth insertion of instruments, and prevention of muscle injury by surgical instruments (Fig. 1). An ipsilateral laminotomy of L4–5 was performed using a drill and Kerrison punches. The ipsilateral inferior articular process was removed by punches, a drill, and micro-osteotome. The superior articular process was partially removed to ensure space for the large size of the TLIF cages. For decompression of the exiting nerve root, the superior articular process should be removed completely or more laterally. Local autologous bone chips from the facet and laminae were used for interbody fusion materials. The ipsilateral and contralateral ligamentum flavum were removed for complete decompression of bilateral traversing nerve roots and the central canal (Fig. 3). Epidural bleeding was controlled by radiofrequency probes. Bone bleeding was controlled by bone wax and radiofrequency probes. Disc material was removed after annular incision. The cartilaginous endplate was completely removed from the osseous endplate under clear endoscopic view. Various kinds of curettes, endplate shavers, and dissectors were used for complete preparation of the endplate. Specifically, if curved dissectors could be used, the cartilaginous endplate could be detached from the osseous endplate under endoscopic view without endplate injury (Fig. 4). Before inserting a cage, large amounts of fusion materials such as autologous bone chips, allograft bone chips, and demineralized bone materials were inserted into the disc space using a specialized funnel. The working-portal skin inci-

FIG. 3. Intraoperative endoscopic images from the percutaneous biportal endoscopic lumbar interbody fusion showing complete decompression status of the ipsilateral left side traversing the nerve root of L5 (A), the contralateral right side traversing the nerve root of L5 (B), and the ipsilateral left side exiting nerve root of L4 (C).

sion should be slightly extended for insertion of a large-sized TLIF cage. Finally, a large-sized TLIF cage filled with fusion materials was inserted under endoscopic and C-arm fluoroscopic guidance (Fig. 2). A drainage catheter was inserted to prevent epidural hematoma through the working channel. Two ipsilateral channels were used for percutaneous pedicle screw insertion. Local anesthesia was injected at each skin incision area, and thereafter the skin was closed with subcutaneous sutures and skin bond materials.

Analysis of Clinical and Radiological Results

This study was a retrospective analysis of prospectively collected data. Only patients who were to undergo single-level fusion were enrolled and they all underwent follow-up for more than 12 months. The patients were divided into two groups based on the fusion procedures. Patients who received microscopic TLIF without ERAS were classified as the non-ERAS group, whereas those who received percutaneous biportal endoscopic TLIF with ERAS were classified as the ERAS group.

The following clinical parameters were investigated:

FIG. 4. Endoscopic view of complete endplate preparation. This intraoperative endoscopic image shows complete endplate preparation without injury to the osseous endplate.

visual analog scale (VAS) score for back and leg pain preoperatively at day 1, day 2, and at 12 months or more postoperatively; and the Oswestry Disability Index (ODI) assessed preoperatively and postoperatively over 12 months. The mean ODI and VAS values of both groups were compared (endoscopic fusion group and microsurgical fusion group). Demographic characteristics, diagnosis, mean operative duration, estimated blood loss (EBL), readmissions, and complications related to the operation such as infection, durotomy, and hematoma were investigated and compared between the two groups. EBL included the amount of postoperative drainage via catheter and its bag. Serial plain radiographic examination for evaluation of hardware failure such as cage subsidence, pedicle screw pullout, cage migration, and fusion rate was performed. Brantigan and Steffee criteria for interbody fusion were used for evaluation of the fusion rate (Table 2).^{1,2,12} Fusion grades 4 and 5 were considered interbody fusion.

Statistical Analysis

This investigation was performed in accordance with our institutional guidelines, which comply with international laws and policies (the IRB of The Leon Wiltse Memorial Hospital). Statistical analysis was performed using a Fisher's exact test, Pearson chi-square test, Wilcoxon signed-rank test, and Mann-Whitney U-test. A p value < 0.05 was considered statistically significant. The R statistical program (version 3.1.2 for Windows) was used for statistical analysis.

Results

Demographic Data

A total of 106 patients were treated by single-level minimally invasive TLIF surgeries using microscopic or biportal endoscopy from February 2016 to October 2017. Among them, 69 patients were followed up for more than 12 months after surgery. Of the 69 patients, 46 underwent microscopic TLIF without an ERAS pathway and 23 underwent endoscopic TLIF with an ERAS pathway and were included in this study as the non-ERAS and ERAS groups, respectively. The mean follow-up period was 13.4 ± 2.5 months. There were no significant differences in the demographic data between the two groups (Table 3). There were also no statistically significant differences in age, sex, and distribution levels ($p > 0.05$, Table 3).

TABLE 2. Fusion grade for interbody fusion by Brantigan and Steffee criteria*

Fusion Grade	Result	Description
1	Obvious radiographic pseudarthrosis	Collapse of construct, loss of disc height, vertebral slip, broken screws, or resorption of bone graft
2	Probably radiographic pseudarthrosis	Visible gap or lucency > 2 mm in the fusion area
3	Radiographic status uncertain	A small visible gap with at least half of the graft area showing no lucency between the graft bone and vertebral bone
4	Probable radiographic fusion	Bone bridges the entire fusion area with at least the density originally achieved at surgery; there should be no lucency between the graft bone and vertebral bone
5	Radiographic fusion	The bone in the fusion area is more dense and more mature than originally achieved in surgery, there is no interface between the donor bone and vertebral bone; a sclerotic line between the graft and vertebral bone indicated solid fusion; other indicators of solid fusion are fusion of the facet joints and anterior progression of the graft in the disc

* Adapted with permission from Wolters Kluwer Health, Inc.: Brantigan JW, Steffee AD: A carbon fiber implant to aid interbody fusion. Two-year clinical results in the first 26 patients. *Spine (Phila Pa 1976)* 18:2106–2107, 1993.

ODI and VAS Scores

Preoperative leg pain and ODI scores were significantly reduced after surgery in both groups ($p < 0.05$). The VAS score for preoperative back pain on day 1 and day 2 was significantly higher in the non-ERAS group than in the ERAS group ($p < 0.05$, Table 3). However, there were no significant differences in the VAS back and leg pain scores and ODI at the final follow-up periods between the two groups ($p > 0.05$, Table 3).

Complications and Readmissions

Four patients in the non-ERAS group experienced postoperative complications including symptomatic postoperative epidural hematoma (1 case), dural tear (1 case), superficial wound infection (1 case), and DVT (1 case), while 1 patient in the ERAS group experienced symptomatic postoperative epidural hematoma. Postoperative epidural hematoma was treated by conservative management. Radiologically, cage subsidence occurred in 2 cases in the non-ERAS group and in 1 case in the ERAS group; although cage subsidence occurred, the depth of subsidence of the cage was within 2 mm, therefore reoperation was not required. Readmission was required in 2 patients, both in the non-ERAS group, for superficial wound infection and DVT of the leg. Overall, postoperative complications occurred in 6 cases in the non-ERAS group and 2 cases in the ERAS group. There was no significant difference in incidences of complications and readmission rates between groups (Table 3, $p > 0.05$).

Fusions Grades

The non-ERAS group comprised 12 patients with fusion grade 3 (uncertain), 28 with fusion grade 4 (probable fusion), and 6 with fusion grade 5 (fusion), whereas the ERAS group comprised 5 patients with fusion grade 3 (uncertain), 16 with fusion grade 4 (probable fusion), and 2 with fusion grade 5 (fusion). Neither group had pseudarthrosis (grade 1) or probable pseudarthrosis (grade 2). Finally, the fusion rate of the non-ERAS group was 73.9%, and 78.3% in the ERAS group. There was no significant difference in the fusion rate between the two groups ($p > 0.05$, Table 3).

TABLE 3. Demographic characteristics and comparison of parameters

Characteristic	Non-ERAS Group (microscopic TLIF)	ERAS Group (endoscopic TLIF)
Males/females (total)	19/27 (46)	7/16 (23)
Mean age $\pm$ SD, yrs	63.5 $\pm$ 10.5	61.4 $\pm$ 9.4
Distribution level, n		
L3–4	4	3
L4–5	29	17
L5–S1	13	3
Mean VAS leg pain score $\pm$ SD		
Preop	7.7 $\pm$ 1.0	8.1 $\pm$ 1.2
Postop (12 mos)	2.2 $\pm$ 0.9	2.5 $\pm$ 0.8
Mean VAS postop back pain score $\pm$ SD		
1 day*	4.9 $\pm$ 1.3	4.2 $\pm$ 1.0
2 days*	4.2 $\pm$ 0.8	2.8 $\pm$ 0.5
12 mos	2.6 $\pm$ 1.0	2.4 $\pm$ 0.9
Mean ODI score $\pm$ SD		
Preop	59.4 $\pm$ 5.9	57.8 $\pm$ 6.3
Postop	22.6 $\pm$ 3.1	21.8 $\pm$ 2.9
No. of complications	6	1
No. of readmissions	2	0
Mean EBL $\pm$ SD, ml*	289.3 $\pm$ 58.5	190.3 $\pm$ 31.0
Mean op time $\pm$ SD, mins*	122.4 $\pm$ 13.1	152.4 $\pm$ 9.6
Fusion rate	34/46, 73.9%	18/23, 78.3%
Fusion grade, n		
1 or 2 (pseudarthrosis)	0	0
3 (uncertain)	12	5
4 (probable fusion)	28	16
5 (fusion)	6	2

* $p < 0.05$.

Operative Duration and EBL

The mean operative durations were 152.4 ± 9.6 minutes in the ERAS group and 122.4 ± 13.1 minutes in the non-ERAS group. The mean amount of EBL was 190.3 ± 31.0 ml in the ERAS group and 289.3 ± 58.5 ml in the non-ERAS group. The mean operative duration was significantly higher in the ERAS group than in the non-ERAS group, while the mean EBL was significantly lower in the ERAS group than in the non-ERAS group (Table 3, $p < 0.05$).

Discussion

ERAS is a multidisciplinary, evidence-based perioperative care program.¹⁴ ERAS has been put into practice in various surgical fields.¹⁴ ERAS improves surgical outcomes and patient satisfaction, and reduces the length of hospital stay,¹³ and consists of preoperative, intraoperative, and postoperative treatments. The range of ERAS is wide and includes nutrition, emotional support, cardiovascular and pulmonary care, preemptive analgesia, surgical interventions, and postoperative care.¹³ Among them, the surgical method may be most important for postoperative recovery. Minimally invasive spine surgeries accelerate and enhance postoperative recovery. Specifically, the endoscopic spine approach minimizes the skin incision and traumatization of posterior muscle and ligaments. Endoscopic lumbar interbody fusion procedures can also minimize skin incisions and musculoligamentous damage.^{3,15} Moreover, percutaneous endoscopic surgery can be performed under local anesthesia or epidural anesthesia. According to previous studies, full endoscopic lumbar interbody fusion using uniportal endoscopic systems was performed under local anesthesia. A surgical procedure without general endotracheal anesthesia can induce fast recovery after the operation. In contrast, endoscopic lumbar interbody fusion was performed using a percutaneous biportal endoscopic approach. Two hours was needed for optimal full decompression of the central canal with nerve roots and endplate preparation of interbody fusion, as in conventional TLIF (Fig. 3). Also, additional time (about 30 minutes) was needed for percutaneous pedicle screw insertion and wound closure; general endotracheal anesthesia was preferred because of the operative duration. Epidural anesthesia with sedation may be another alternative option for minimally invasive TLIF or endoscopic TLIF.

Although a longer operation time and general endotracheal anesthesia are disadvantages of this percutaneous biportal endoscopic fusion surgery, this operation may have several advantages. First, it can achieve full direct decompression of the central canal, lateral recess, and bilateral nerve roots, like conventional open surgery or microsurgery. Second, complete endplate preparation is possible. A 5.5-mm-diameter trocar with 4-mm-diameter endoscope can be inserted into the intervertebral space. It is possible to separate and remove the cartilaginous endplate from the osseous endplate under endoscopic vision, and various instruments for endplate preparation such as curettes, shavers, and dissectors can be used (Fig. 4). Third, large-sized cages for TLIF can be inserted into the interbody space. Because the principle of biportal endoscopic TLIF is simi-

lar to minimally invasive TLIF, a large-sized TLIF cage can be inserted with retraction of the ipsilateral traversing nerve root (Fig. 2). If the expandable cages can be inserted, retraction of nerve roots could be minimized during a cage insertion. Fourth, before insertion of a cage, a lot of fusion materials can be inserted into the intervertebral space using a funnel. In this study, fusion materials are put into auto-bone chips from laminae and facet bone and demineralized bone matrix. However, longer operative durations, a steep learning curve, and general anesthesia are some of the disadvantages of this endoscopic fusion procedure.

Unfortunately, the fusion rate of this study was relatively lower than the rate reported in previously published studies.¹ It was difficult to determine interbody fusion using only follow-up radiographic examination. Moreover, a 1-year follow-up period may be too short for evaluation of fusion rate. In this study, the grade of interbody fusion was interpreted as uncertain (grade 3) or probable fusion (grade 4) rather than fusion (grade 5). Also, no pseudarthrosis of fusion levels was experienced. An evaluation of the fusion rate using CT is planned in the future.

Previously, ERAS protocols were attempted for various kinds of major surgeries.¹¹ In the department of orthopedics, ERAS pathways were used in hip and knee arthroplasty.^{7,16} ERAS may have benefits in the aspects of reduced length of hospital stay, reduction of complications, and reduction of bleeding and transfusion.⁷ A systematic review and meta-analysis of ERAS in joint arthroplasty presented the clinical advantages of this protocol.¹⁶ In spine surgery, Michael Wang¹³ presented the advantages of endoscopic lumbar interbody fusion with ERAS, and that it may be important for day surgery or an outpatient surgery center. The ERAS protocol with endoscopic fusion procedures may facilitate use of the day surgery center or outpatient surgery center in the field of spine fusion surgery.

In this study, ERAS focused on endoscopic surgery and reduction of postoperative pain and bleeding. Minimally invasive spine surgeries reduce intraoperative bleeding and its related morbidities; these approaches are so narrow in the surgical field that bleeding makes surgery difficult. Specifically, bone bleeding or epidural bleeding during endoscopic surgery blurs operative vision and interferes with surgery. Therefore, prevention and control of intraoperative bleeding is important in minimally invasive spine surgery such as endoscopic lumbar fusion surgeries. It has been reported that tranexamic acid administration may be effective in major surgeries.⁸ Intravenous administration of tranexamic acid helps prevent and reduce bleeding during surgery. For this study, preoperative loading and maintenance of intravenous tranexamic acid were included in the ERAS pathway. Contraindications of intravenous administration of tranexamic acid include previous history of cardiovascular surgery, previous history or high risk of thromboembolic disease, subarachnoid hemorrhage, and renal impairment.⁸ Tranexamic acid was not administered in the cases involving contraindications.

It has been reported that injecting a local anesthetic into the skin before incision may be effective in reducing postoperative pain.⁶ Also, injection of slowly releasing, long-acting liposomal bupivacaine into the wound before closure may be effective for controlling postoperative pain.

In this study, the ERAS protocol included local anesthetic injection before incision and wound closure. Unfortunately, long-acting liposomal bupivacaine was unavailable in South Korea. Therefore, 1% lidocaine was administered at the skin incision area. Preoperative administration of gabapentin or pregabalin is effective in reducing postoperative pain and hastening recovery in joint arthroplasty and spine surgery. In this study, 75 mg of pregabalin was administered. Epidural injection or epidural PCA may be effective for controlling postoperative pain in major spine surgeries.⁹ For this study, because only patients with single segmental fusion were included, epidural injection or epidural PCA was not performed. In the case of multilevel fusion surgeries, epidural injection or epidural PCA therapy may be useful for controlling postoperative pain.⁹

In South Korea, there is a tendency or a culture to think of inpatient treatments as resting, recharging, and rehabilitation. Moreover, hospitalization costs are very low. Many patients may want to rest, and rest after surgery in the hospital. For these reasons, the length of hospital stay could not be assessed or compared in this study. The incidence of readmissions and complications were lower in the ERAS group than in the non-ERAS group. Although there were no statistically significant differences, a low incidence of readmissions and complications may be clinically significant. Moreover, only minor complications were experienced in the ERAS group.

These were some of the limitations of our study: 1) it was not a randomized and blinded study, which contributes to selection bias; 2) the sample size of the patients was small; and 3) the follow-up period was short. Randomized controlled trials with long-term follow-up are needed to obtain accurate clinical results.

Conclusions

Percutaneous biportal endoscopic TLIF with an ERAS pathway may have good aspects in reducing bleeding, complications, and postoperative pain. However, a longer operative duration was a disadvantage. It was established that endoscopic fusion surgery with the ERAS concept may help to accelerate recovery after surgery.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Heo. Acquisition of data: Heo. Analysis and interpretation of data: Heo. Drafting the article: Heo. Critically revising the article: both authors. Reviewed submitted version of manuscript: Heo. Approved the final version of the manuscript on behalf of both authors: Heo. Administrative/technical/material support: Heo. Study supervision: both authors.

Supplemental Information

Videos

Video 1. <https://vimeo.com/316086205>.

Correspondence

Dong Hwa Heo: Leon Wiltse Memorial Hospital, Gyeonggi-do, Korea. spinesurgery@naver.com.