ORIGINAL

Exiting nerve root injury during full-endoscopic trans-Kambin's triangle lumbar interbody fusion (FE-KLIF) and how to avoid it : a multicenter study

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Abstract : Full-endoscopic trans-Kambin's lumbar interbody fusion (FE-KLIF) is a type of minimally invasive fusion surgery that requires only a 14-mm skin incision for cage insertion. The only surgery-related complication of concern with FE-KLIF is exiting nerve root injury (ENRI). We investigated the incidence of ENRI in 131 cases that underwent FE-KLIF at 10 hospitals. After encountering 5 cases of ENRI, all of which occurred during insertion of an open cannula, we devised a novel type of open cannula, which we call a rescue cannula, to avoid ENRI. There were 5 cases of ENRI (5.7%) in the 88 patients who underwent FE-KLIF before use of the rescue cannula. We have put the rescue cannula in the FE-KLIF system, and one can use the rescue cannula when electromyography alarms. Under such strategy to avoid the ENRI for using the rescue cannula, none of these 43 cases developed ENRI. FE-KLIF is a minimally invasive fusion surgery in which ENRI is the only worrisome complication. Use of a rescue cannula could be the solution to avoiding ENRI. J. Med. Invest. 73 : 26-31, February, 2026

Keywords **:** *full-endoscopic trans-Kambin's lumbar interbody fusion, Kambin's triangle, interbody fusion, full-endoscopic surgery*

INTRODUCTION

Minimally invasive lumbar interbody fusion (LIF) surgery includes full-endoscopic trans-Kambin's LIF (FE-KLIF) as well as anterior LIF, extreme lateral LIF, oblique LIF, posterior LIF, and transforaminal LIF. Kambin's triangle consists of an exiting nerve, the lateral aspect of the facet joint, and the endplate, and allows safe access to the disc space. During FE-KLIF, a cage is inserted into the disc space through Kambin's triangle (1, 2). The trajectory for each LIF procedure is described in Figure 1 (3). The trajectory of KLIF is just posterior to that of extreme lateral LIF.

Insertion of the cage in FE-KLIF requires only a 12-14-mm skin incision. In theory, unlike other types of LIF surgery, there should be no major complications such as vessel, colon, and ureteral injuries with FE-KLIF. Insertion of the cage does not require laminectomy and/or facetectomy ; thus, post-surgical hematoma and dural injury would be extremely rare. The only concern with FE-KLIF is exiting nerve root injury (ENRI) (4, 5, 6, 7, 8, 9).

Techniques and procedures similar to FE-KLIF, such as insertion of a cage through Kambin's triangle under full-endoscopic guidance, have been reported in the literature (10, 11, 12, 13). We have already reported the clinical results for our

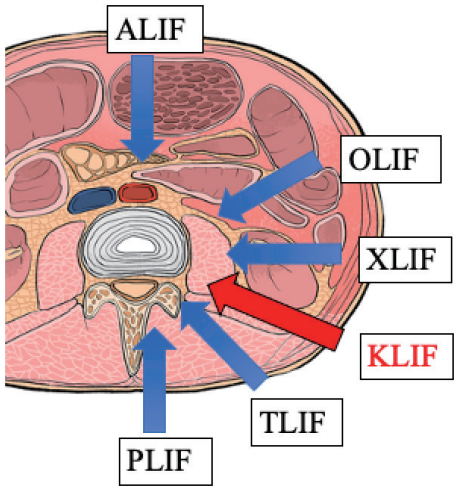

Figure 1. Anatomical trajectory of KLIF. The trajectory of KLIF is between XLIF and TLIF. ALIF, anterior lumbar interbody fusion ; KLIF, trans-Kambin lumbar interbody fusion, OLIF, oblique lumbar interbody fusion ; PLIF, posterior lumbar interbody fusion ; TLIF, transforaminal lumbar interbody fusion ; XLIF, extreme lateral lumbar interbody fusion

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first ten patients, one (10%) of whom developed transient exiting nerve root irritation that resolved within 2 weeks. The highest rate of ENRI during insertion of the cage via Kambin's triangle was reported by Lewandrowski *et al*. (10) (60.4% ; 29/48 cases) and the second highest by Morgenstern *et al*. (11) (22%). Jacquot and Gastambide identified postoperative neurological symptoms in 7 (12.3%) of 57 cases (12). However, Nakamura *et al*. did not identify any instances of ENRI among 21 patients who underwent trans-Kambin's percutaneous endoscopic LIF in which a thin custom-made slider was used for safer insertion of the cage through Kambin's triangle (13).

FE-KLIF is comparatively new, and not many hospitals are performing this procedure. We use a Fullendo-KLIF system (Surgical Spine Inc., Tokyo, Japan) when performing FE-KLIF. Analysis of the incidence of ENRI associated with FE-KLIF requires a large number of cases treated by many surgeons. We investigated how to avoid ENRI in this multicenter study, which included 10 hospitals.

METHODS

Technique

The surgical technique used during our study period has been described in detail elsewhere (5, 7). Therefore, here we have provided only a brief explanation of the important points in relation to avoiding ENRI.

First, neuromonitoring is always performed throughout the surgery. The procedure is explained here using a case of degenerative spondylolisthesis at L4 as an example. Before FE-KLIF, 4 percutaneous pedicle screws are inserted at L4 and L5. Most of the cases involve slippage ; however, to avoid screw back-out in the osteoporotic spine, we do not perform any reduction maneuver at this point. The next step entails enlargement of Kambin's triangle by foraminoplasty. This is the most important step in FE-KLIF in terms of avoiding ENRI. We recommend that 12 mm of the disc surface should be visible for safe insertion of a cage (Figure 2).

After widening to create a safer Kambin's triangle, a cannula is inserted into the disc. A guidewire with a safety ball at the tip, (Safe Guide, Surgical Spine Inc., Tokyo, Japan), is passed through the cannula and inserted into the disc. An 8-10-mm cannulated spacer is inserted through the Safe Guide to enlarge the disc space. By turning the spacer through 90 degrees, the disc height is set at 10 mm. The cage maneuver and the two rods in the reduction screws work together to reduce slippage and have strong slippage reduction capability.

Using the spacer, an open square cannula is inserted just inside the disc (Figure 3). An electromyographic monitoring system is used during this part of the procedure, during which the risk of ENRI is highest. An alarm sounds if a wider space is needed to insert the cannula. Figure 4-A shows how ENRI occurs during insertion of the open square cannula (Figure 4-A, left panel). Further foraminoplasty is required, and when the open square cannula is safely inserted, it completely protects the exiting nerve root. A specially designed curette is then

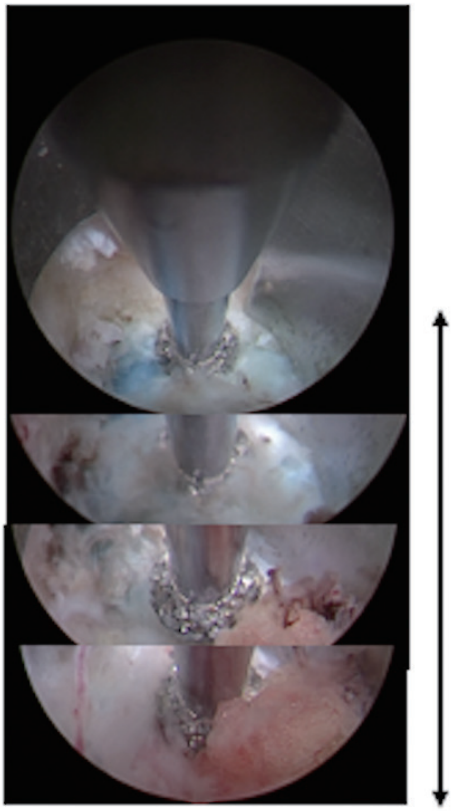

Figure 2. Confirmation of the safe window for cage insertion. We recommend that 12 mm of the disc surface should be visible.

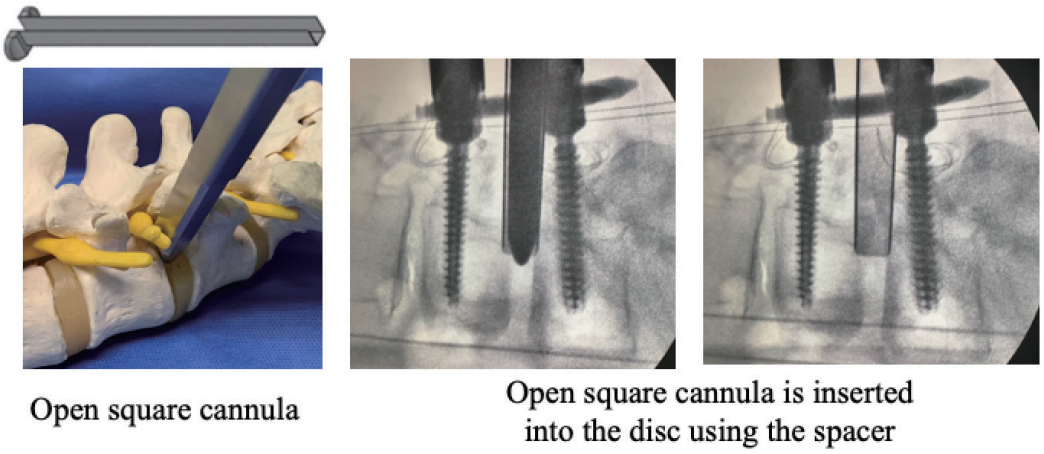

Figure 3. An open square cannula insertion. Using the spacer, an open square cannula is inserted just inside the disc.

passed through the open cannula to empty the disc space and curette the disc endplate. An autogenic or allogenic bone graft is implanted using a customized bone graft funnel. A thin expandable cage can be slid into the disc space through the open square cannula and then expanded to create a lordotic curve.

Evaluation

The incidence of the ENRI was measured in cases from 10 hospitals. Also, the ENRI was compared before and after the usage of a rescue cannula.

Indication

The indication for FE-KLIF in this study was limited to the lumbar levels between L1 and L5. The L5/S1 level was not included because a high iliac crest often restricts the surgical corridor and anomalies of the exiting nerve root are more common at this level, making the procedure less safe and therefore not recommended.

Ethics

This study was approved by the institutional review board at our institution. Informed consent was obtained from all patients included in this study.

RESULTS

The study included 131 cases (52 male, 79 female) of FE-KLIF performed at 10 hospitals in Japan (1 each in Hokkaido, Tohoku, and Tokai, and 2 in Kinki, and 5 in the Chugoku-Shikoku area).

ENRI was a complication in 5 (3.9%) of the 131 cases. All 5 of these cases occurred in the initial 88 surgeries (5.7%) performed before use of the rescue cannula. We have put the rescue cannula in the FE-KLIF system, and one can use the rescue cannula when electromyography (EMG) alarms. Under such strategy to avoid the ENRI for using the rescue cannula, none of these 43 cases developed ENRI.

Rescue cannula

Figure 4-A shows how a rescue cannula can avoid ENRI. A standard open square cannula is symmetrical and the length of the wall is 10 mm. On the other hand, one wall of the rescue cannula is 2 mm shorter than the other wall (i.e., 8 mm ; Figure 4-A, right panel). The rescue cannula is used in the opposite direction to that when using the standard cannula. The shorter wall faces the exiting nerve root (Figure 4-A, middle panel) so that ENRI can be avoided.

Figure 4-B shows the anatomical location of the rescue cannula and the exiting nerve on intraoperative radiographs. It is obvious that the open square cannula is close to the exiting nerve whereas the rescue cannula is further away. An endoscopic view is shown in Figure 4-C. The exiting nerve is running on the disc space and Kambin's triangle is too narrow for safe insertion of a cage. In such situation, a rescue cannula is very useful to avoid the ENRI.

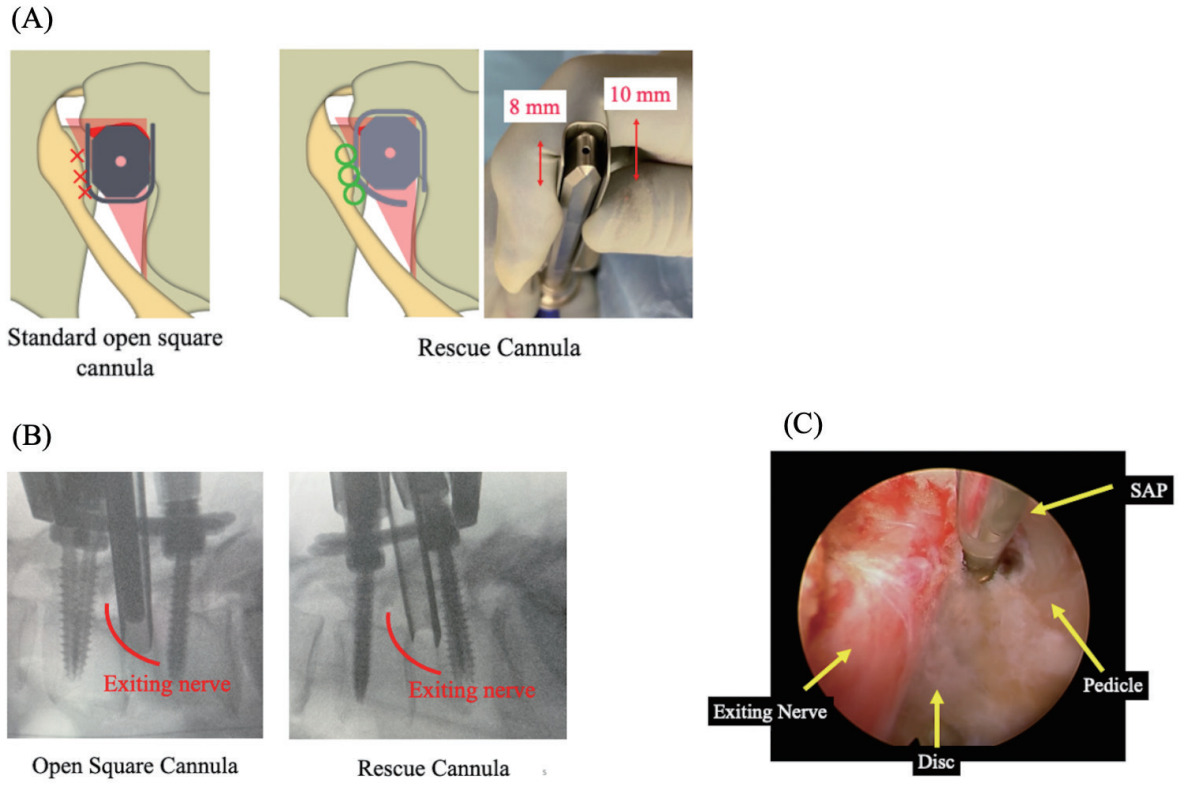

Figure 4. (A) A rescue cannula. The left panel demonstrates how the exiting nerve can be injured by the corner of an open square cannula. A standard open square cannula is symmetrical and has a wall length of 10 mm. However, one wall of the rescue cannula is 8 mm, which is 2 mm shorter than the other walls. The rescue cannula is used in the direction opposite to that of a standard cannula. The shorter wall faces the exiting nerve root (right panel), so ENRI should be avoided. (B) The anatomical location of the rescue cannula and the exiting nerve on C-arm image during FE-KLIF surgery. It is obvious that the open square cannula is close to the exiting nerve while the rescue cannula is further away from the exiting nerve. (C) An endoscopic view. The exiting nerve is running on the disc and Kambin's triangle is too narrow for safe insertion of a cage. SAP, superior articular process.

Representative case

A 72-year-old woman visited us complaining of pain in both legs and buttocks and intermittent claudication within 100 m. She had no symptoms at rest or when lying down. Sensorimotor findings and reflexes were normal on neurological examination. Figure 5-A shows the plain radiographs and a magnetic resonance imaging (MRI) scan obtained at the initial presentation. The lateral radiograph clearly demonstrated grade II forward slippage at L4. The MRI scan also showed L4 spondylolisthesis and severe spinal canal stenosis at the L4/5 level. Given that there were no symptoms at rest, this case was considered to be a good indication for FE-KLIF without decompression. When we inserted the full endoscope, we found that the exiting nerve was too close to the facet of the superior articular process at L5. After foraminoplasty, a rescue cannula was safely inserted into the disc space without triggering a warning sound from the neuromonitoring system.

As shown in Figure 5-B, the collapsed disc was opened and the slippage is reduced to 5% after surgery. Although we did not perform decompression surgery such as facetectomy or laminectomy, postoperative MRI confirmed significant decompression of the spinal canal (Figure 5-C).

DISCUSSION

Many reports have described better clinical outcomes after FE-KLIF. Literature reviews of full-endoscopic fusion surgery by Morimoto *et al*. (9) and Hu *et al*. (14) found that the clinical outcome after FE-KLIF is similar to that after traditional fusion surgery. They found that FE-KLIF had many benefits, including less estimated blood loss during surgery, a shorter time to ambulation, and a shorter hospital stay. Moreover, because the technique does not require laminectomy or facetectomy, there have been few cases of surgical site infection and post-surgical hematoma. Anatomically, there is no possibility of major vessel, colon, or ureteral injury. However, ENRI remains a concern with FE-KLIF.

ENRI during FE-KLIF

Nakamura *et al*. (13) classified FE-KLIF surgery well, although their nomenclature was different from ours. In the first group, a small cannula (sheath) (8 mm or smaller) with no cage is used (15, 16). ENRI is rare in this group. However, the fusion site is less stable without a cage, which may result in a reduced fusion rate.

In the second group, a large cannula (sheath) with a comparatively large cage was used. When inserting a cage through the inside of a cannula, the cannula needs to be large,

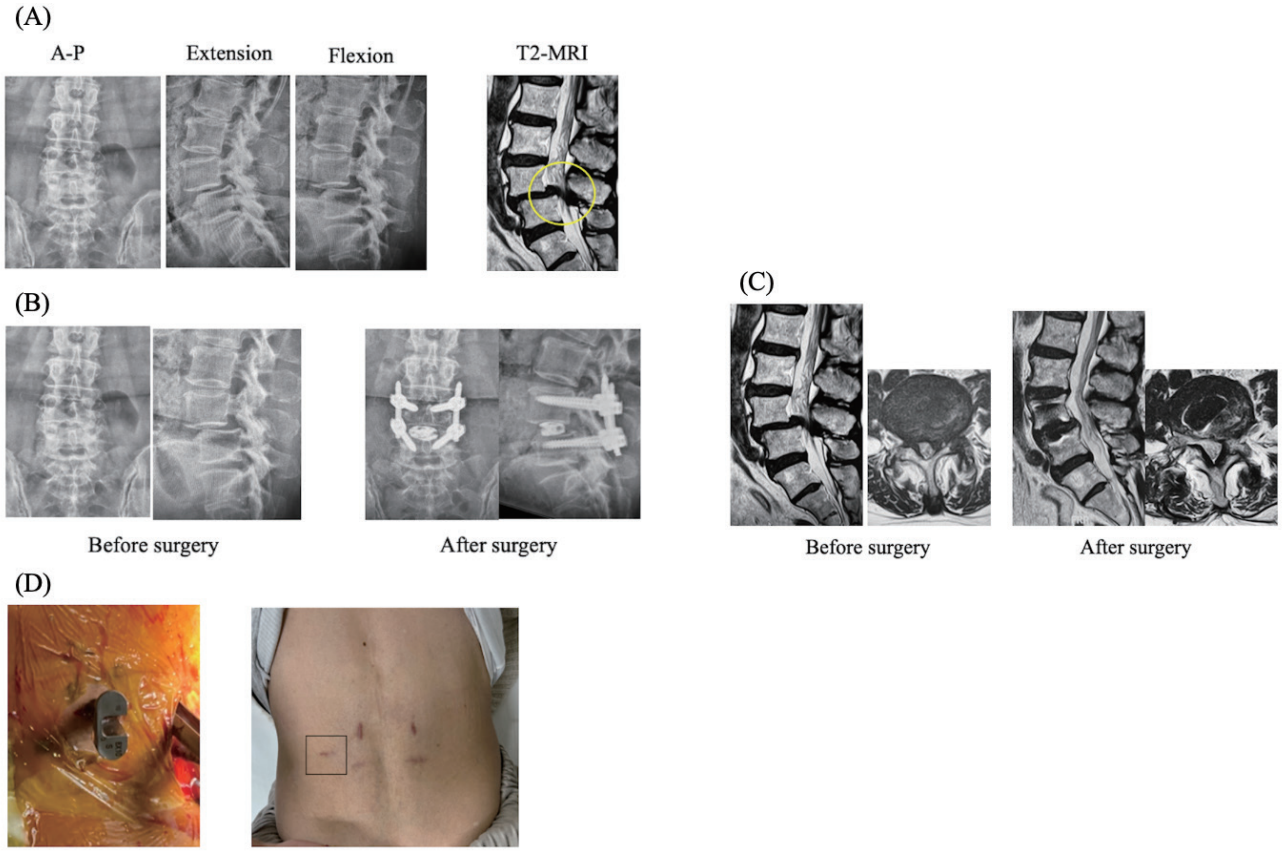

Figure 5. (A) Preoperative radiographs and an MRI scan obtained for a representative case. The lateral radiograph clearly demonstrates grade II forward slippage at L4. The MRI scan also shows L4 spondylolisthesis and severe spinal canal stenosis at the L4/5 level. A-P, anterior-posterior ; T2-MRI, T2-weighted magnetic resonance image. (B) Radiographs obtained before and after FE-KLIF surgery. The collapsed disc is opened up and slippage is reduced after surgery. FE-KLIF, full-endoscopic trans-Kambin's lumbar interbody fusion. (C) MRI scans obtained before and after FE-KLIF. Although no decompression surgery such as facetectomy or laminectomy was performed, MRI after surgery revealed significant decompression of the spinal canal. FE-KLIF, full-endoscopic trans-Kambin's lumbar interbody fusion ; MRI, magnetic resonance imaging. (D) Scar at the site of the surgical incision for insertion of an open square cannula. This image clearly demonstrates that FE-KLIF is a minimally invasive procedure. FE-KLIF, full-endoscopic trans-Kambin's lumbar interbody fusion

which increases the risk of ENRI. Morgenstern *et al*. (11) inserted a cage through a large (12-mm) cannula in 51 patients and encountered ENRI in 12% of cases. However, they performed their procedures under C-arm guidance whereas our method entails a full-endoscopic method.

In the third group, a cage is inserted into the disc without a cannula. Katzell reported that simple cannulated insertion of a cage through Kambin's triangle caused ENRI in 20-25% of cases even if neuromonitoring was used (17). He concluded that full-endoscopic foraminoplasty was necessary to enlarge Kambin's triangle and reduce the risk of ENRI.

In the fourth group, a retractable slider is used to insert the cage (13, 18). Nakamura *et al*. (13) used a small standard cannula with a diameter of 8 mm. They inserted the cannula safely through Kambin's triangle and then cleaned the area inside the disc. They passed an L-shaped slider into the disc to insert the cage while protecting the exiting nerve root.

Our FE-KLIF system uses a square open cannula measuring 8 mm × 10 mm or 10 mm × 12 mm, so is similar to the technique used in the second (large cannula) group. Using this method, we encountered 5 cases of ENRI in 131 patients, which represents a rate of approximately 4%.

How to avoid ENRI

One solution to the problem of ENRI is widening of Kambin's triangle. Katzell reported that full-endoscopic foraminoplasty was useful for reducing the risk of ENRI (17). However, his experience was limited to 5 cases. Our group always uses neuromonitoring when performing full-endoscopic foraminoplasty and has had 5 cases of ENRI when using the traditional square open cannula in 88 cases (5.7%). Therefore, the combination of full-endoscopic foraminotomy and neuromonitoring is not enough for complete avoidance of ENRI. We have now designed a novel square cannula, which we have called a rescue cannula. Shown in Figure 4-A, it is theoretically effective for avoidance of ENRI. We have put the rescue cannula in the FE-KLIF system, and one can use the rescue cannula when EMG alarms. Under such strategy to avoid the ENRI for using the rescue cannula, none of these 43 cases developed ENRI. However, more cases are needed to confirm the ability of this novel cannula to prevent ENRI.

The other method, described by Nagahama *et al*., is conversion to an open procedure when the neuromonitoring system sounds an alarm (18). They reported 25 cases of full-endoscopic fusion surgery performed between February 2016 and July 2018, and mentioned that they always explain the possibility of conversion to open transforaminal LIF to their patients before surgery. During the study period, 2 cases were converted to an open procedure. ENRI is a complication that worsens the clinical outcome of FE-KLIF and must be avoided. Based on the concept, the recommendation made by Nagahama *et al*. (18) should be one option.

LIMITATION

Despite these favorable results, this study has several limitations. First, the sample size of 131 cases is relatively small for a multicenter study. Second, the rescue cannula was used in only 43 cases, limiting conclusions about its effectiveness. Third, all procedures were performed at lumbar levels L1–L5, with no cases at L5/S1. Further studies including a larger number of cases and L5/S1 surgeries are needed to validate these findings.

CONCLUSION

In this paper, we have reported the incidence of ENRI associated with FE-KLIF to be 3.9%. The incidence of ENRI can be as high as 60% for similar surgical procedures. Therefore, it is necessary to reduce the risk of ENRI as a complication. One way to do this is to use a rescue cannula. FE-KLIF is a minimally invasive fusion surgery (Figure 5-D) and reduces the risk of ENRI. Thus, FE-KLIF should become the gold standard for minimally invasive lumbar fusion surgery.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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