



## Review Article

# State-of-the-art transforaminal percutaneous endoscopic lumbar surgery under local anesthesia: Discectomy, foraminoplasty, and ventral facetectomy<sup>☆</sup>

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## ARTICLE INFO

## Article history:

Received 20 June 2017

Received in revised form

23 September 2017

Accepted 9 November 2017

Available online 13 December 2017

## ABSTRACT

Transforaminal (TF) percutaneous endoscopic surgery for the lumbar spine under the local anesthesia was initiated in 2003 in Japan. Since it requires only an 8-mm skin incision and damage of the paravertebral muscles would be minimum, it would be the least invasive spinal surgery at present. At the beginning, the technique was used for discectomy; thus, the procedure was called PELD (percutaneous endoscopic lumbar discectomy). TF approach can be done under the local anesthesia, there are great benefits. During the surgery patients would be in awake and aware condition; thus, severe nerve root damage can be avoided. Furthermore, the procedure is possible for the elderly patients with poor general condition, which does not allow the general anesthesia. Historically, the technique was first applied for the herniated nucleus pulposus. Then, foraminoplasty, which is the enlargement surgery of the narrow foramen, became possible thanks to the development of the high speed drill. It was called the percutaneous endoscopic lumbar foraminoplasty (PELF). More recently, this technique was applied to decompress the lateral recess stenosis, and the technique was named percutaneous endoscopic ventral facetectomy (PEVF). In this review article, we explain in detail the development of the surgical technique of with time with showing our typical cases.

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## 1. Introduction

In the last century percutaneous nucleotomy (PN) was developed by Hijikata [1]. Since the skin incision was minimal and small cannula was inserted into the canal, it can be performed under local anesthesia. According to the Hijikata method, the position of the cannula was confirmed under the C-arm fluoroscopic not the endoscopic guidance; therefore, it was unable to introduce a cannula into a herniated mass in the neural canal. Following some frontiers tried to introduce the spinal endoscope with the PN technique [2–6], with single-portal endoscopic discectomy being developed around the end of the last century [4–6]. This technique is called as the percutaneous endoscopic lumbar discectomy (PELD). This procedure was introduced by

Dezawa in 2003 in Japan [7]. The PELD was initially indicated for herniated nucleus pulposus (HNP) [4–8].

Basically, the PELD cannula is inserted through the intervertebral foramen from the posterolateral side of the back like the Hijikata's PN technique [4–6], and this procedure is called transforaminal (TF) approach. It can be done under the local anesthesia. The shortcoming of TF-PELD would be difficulty of the access into the spinal canal through the L5-s intervertebral foramen in cases with high iliac crest. In such cases, a cannula would be very hard to safely inserted appropriately into the spinal canal from the posterolateral aspect; thus, interlaminar (IL) approach was developed [9,10]. However, IL-PELD usually requires general anesthesia, which is its main disadvantage compared with TF-PED. TF-PED can be done with the local anesthesia.

The greatest benefit of the TF-PELD would be what can be done with the local anesthesia. Kitahama et al. [11] reported a successfully treated HNP case by TF-PELD under the local synesthesia, who were combined with severe general comorbidities and were not allowed to have the general anesthesia. In the developed countries, the population is getting elderly year by year, and aging society is quickly coming. Many aged patients would be combined with

<sup>☆</sup> This Review Article was presented at the 90th Annual Meeting of the Japanese Orthopaedic Association, Sendai, May 19, 2017.

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general comorbidities such as lung, heart, and kidney dysfunction, may not be indicated for procedures performed under general anesthesia. For such standpoint, the endoscopic surgery under the local anesthesia must be beneficial for elderly patients.

The TF-PELD technique has been developing recently with the invention of the ultra-thin high speed surgical drill [9,10,12]. Using the drill, bone resection can be safely done under the endoscopic guidance. Percutaneous endoscopic lumbar foraminoplasty (PELF) is the second stage following the PELD, and it is the enlargement surgery of the foraminal stenosis of the lumbar spine using trephine and/or the high speed drill [13–15]. Finally, more recently, the PEVF (percutaneous endoscopic ventral facetectomy) was proposed [16]. Using the PEVF technique, both of foraminal and lateral recess stenosis can be decompressed. In this review article, we explain in detail the PELD, PELF and PELF surgery with introducing the typical cases.

## 2. PELD (percutaneous endoscopic lumbar discectomy)

As described in the introduction section, the PELD was established early in the 21st century [4–6]. In Japan, the PELD was introduced by Prof. Dezawa in 2003 [7]. Initially, the PELD would be the endoscopic technique based on the Hijikata's PN technique [1]; thus, the transforaminal approach was the main procedure [4–8]. Most of the type of the herniated nucleus pulposus (HNP) except intra-canalicular type at L5-s with the high iliac crest would be the good indication. According to the review article by Gore and Yeung [17], the clinical results of TF-PED was good, and almost 90% of the patients reported satisfactory. Morgenstern et al. [18] analyzed the learning curve of this procedure. They stated that after 72 cases of experience, one may reach the goal of 90% of good/excellent results for TF-PELD.

Fig. 1 is a typical case of the TF-PELD. This patient was 16 y.o. girl, and long jump athletes. After the 3 months conservative treatment, she was referred to us with the severe left leg pain and muscle weakness. SLRT was positive at 10° at the left side. T2-MRI at L4-5 indicates herniated nucleus pulposus (HNP) at the left side (Fig. 1, left). Immediately after the surgery, pain disappeared. By the TF-PELD, the HNP was successfully removed under the local anesthesia (Fig. 1, right). There were no surgery-related complications.

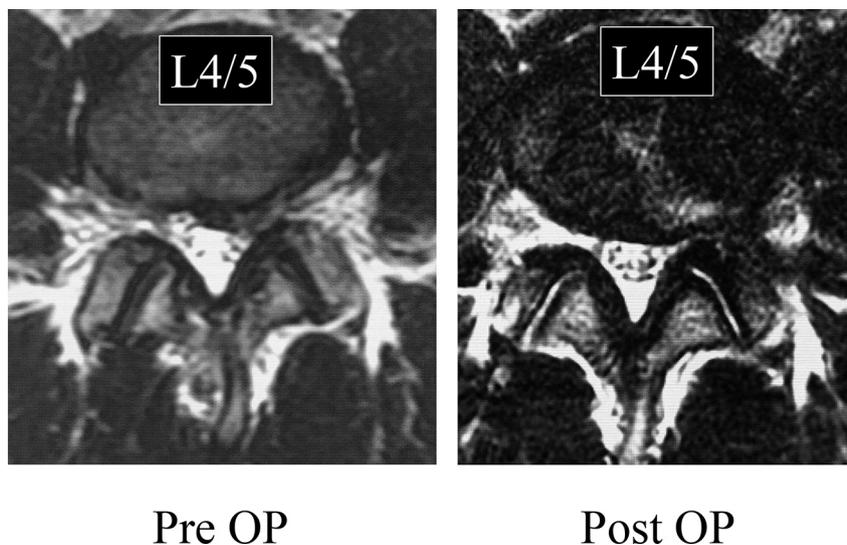


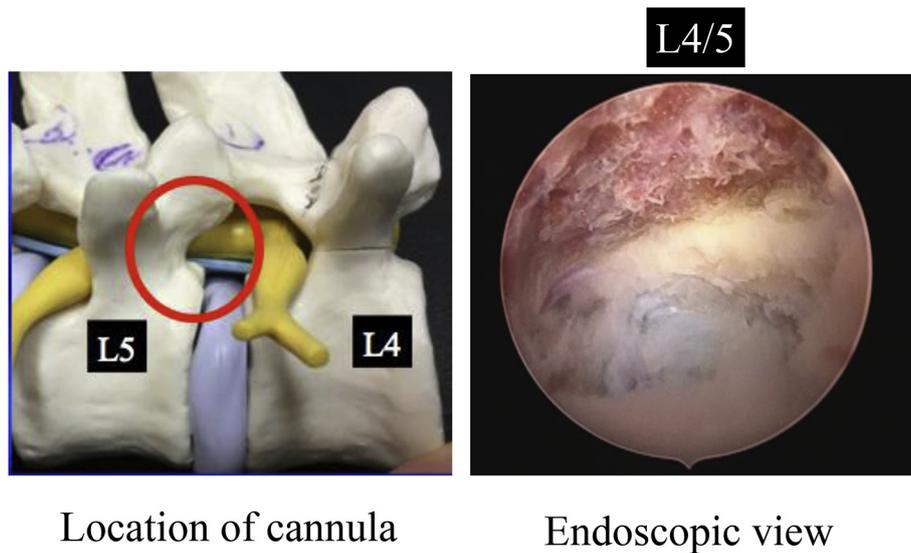
Fig. 1. Typical case of the TF-PELD. This patient was 16 y.o. girl, and long jump athletes. T2-MRI at L4-5 indicates herniated nucleus pulposus (HNP) at the left side (left). The HNP was successfully removed under the local anesthesia (right).

For four weeks after the surgery, she concentrated on stretching and trunk core muscle training. Thereafter, jogging and jumping was started. Eight weeks after the surgery, she attended local competition.

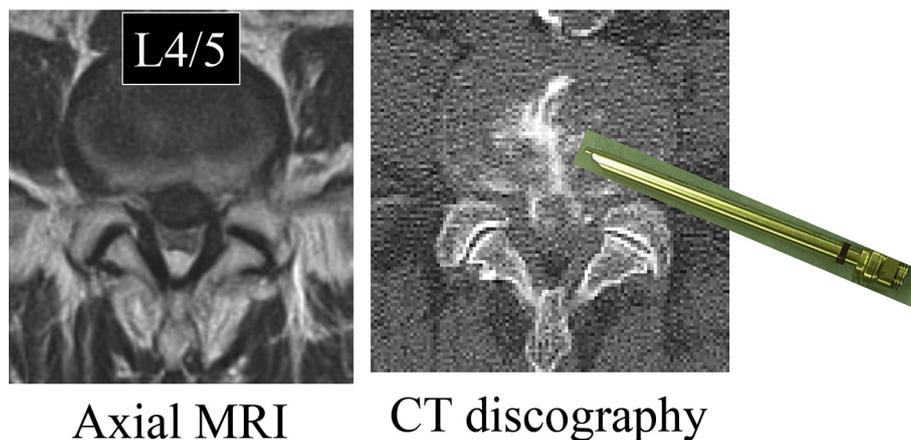
### 2.1. Advanced technique of the PELD – foraminoplastic PELD

If you insert the cannula in the narrow foramen, the cannula may compress the exiting nerve root, causing post-operative dysesthesia. To prevent this complication, foraminoplastic TF-PELD was established and to perform foraminoplasty, high speed drill and/or trephine reamer have been used [14,15,19–22]. Henmi et al. [22] measured foraminal distance (distance between posterior edge of the disc and ventral aspect of the facet joint) and found that in most of the cases the distance was less than 8 (mm), which is the diameter of the cannula of PELD. After the foraminotomy, it increased over 8 (mm); thus, they concluded that the foraminoplasty would be effective to prevent the exiting nerve injury. Fig. 2 demonstrates the endoscopic view after the foraminoplasty. The superior articular process of L5 was shaved smoothly and cancellous bone was observed. Ligamentum flavum is also clearly identified, and migrated HNP fragment was dyed in blue. With looking at the color, the HNP could be safely removed.

Fig. 3 presents the HNP case at L4-5 with hypertrophy of facet joint. This case is 86 years old, male. He complained of severe left leg pain. As for the pre-surgical planning, the insertion of the cannula on an appropriate location would be considered to be hard because of the hypertrophy of the facet joint. The right panel indicates CT-discography. Due to the hypertrophy of the facet joint, the cannula seems to be hard to access close to the HNP fragment in the spinal canal. We conducted enlargement of the intervertebral foramen by the foraminoplasty to safely insert the cannula just beneath the HNP (Fig. 4, left). Arrows in the Fig. 4 (left) indicate the area of the foraminoplasty. The HNP was successfully removed by TF-PELD after the foraminoplasty (Fig. 4, right). Immediately after the surgery, the strong leg pain decreased. There was no surgery-related complication. This patient was very old aged over 85; thus, the surgery under the local anesthesia was helpful for him. He started walking 1 h after the surgery.



**Fig. 2.** The endoscopic view after the foraminoplasty. The superior articular process of L5 is shaved smoothly by a high-speed drill and cancellous bone is observed. Ligamentum flavum is also clearly identified (color in yellow), and migrated HNP fragment is dyed in blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



**Fig. 3.** MRI and CT-discography before surgery in the HNP case at L4-5 with hypertrophy of facet joint in the aged. The right panel indicates CT-discography. Due to the hypertrophy of the facet joint, the cannula seems to be hard to access close to the HNP fragment in the spinal canal.

## 2.2. Foraminoplastic TF-PELD at the level of L5-s

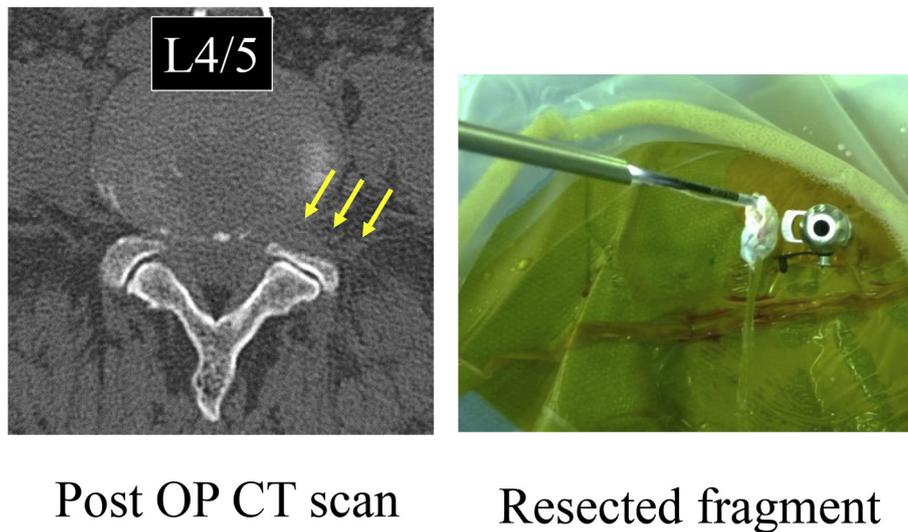
The transforaminal approach was reported to be hard to conduct at the level of L5-s, because iliac crest may bother the cannula installation through the intervertebral foramen especially for the high iliac cases. Thus, safely PELD access through the interlaminar space was proposed [8,9]. On the other hand, there are some papers on TF-PELD, and they stated the usefulness of the foraminoplasty for this safely access [23–25]. Indeed, Choi et al. [24] conducted the TF-PELD for 100 cases of HNP at L5-s level. They successfully performed the surgery, and 19 cases of 100 required foraminoplasty. They found that in the foraminoplasty group, the iliac crest was above the mid L5 pedicle on lateral radiography in all cases. The iliac crests below the mid L5 pedicle did not require foraminoplasty in any cases [24]. Even in the high iliac cases, the TF-PELD may be possible with using the foraminoplasty.

Fig. 5 presents CT and endoscopic view at L5-s. Following the foraminoplasty at the right L5-s, intervertebral foramen was enlarged. The red circle in Fig. 5 (right) indicates the location of the resected area of the superior facet process (SAP) of S1. After the

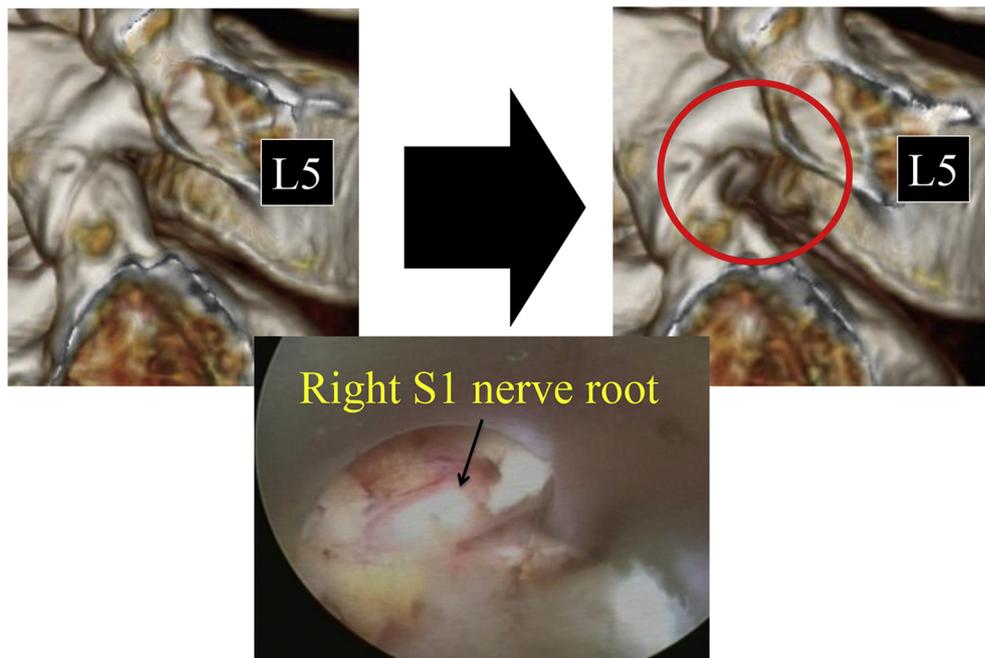
enlargement of the foramen, the cannula was safely inserted through the intervertebral foramen into the neural canal. Then, with observing the S1 nerve root under the endoscopic guidance (Fig. 5, middle panel), the HNP was removed. Fig. 6 presents another HNP case at L5-s. This patient was a very active high-class rugby player in Japan. MRI indicates the HNP at L5-s before surgery. On the 3-dimensional CT scan clearly demonstrates that the disc level at L5-s is completely covered with the iliac crest (the left panel). Following the appropriate foraminoplasty, a cannula could be inserted just beneath the HNP. The fragment was removed from the inside of the disc without any complications, and leg pain disappeared during the surgery. MRI after the surgery demonstrates the resection of the HNP fragment. Eight weeks after the surgery, he returned to the original competitive level.

## 3. PELF (percutaneous endoscopic lumbar foraminoplasty)

Percutaneous endoscopic lumbar foraminoplasty (PELF) is the second stage following the PELD, and it is the enlargement surgery



**Fig. 4.** CT scan after operation and the resected fragment. We conducted enlargement of the intervertebral foramen by the foraminoplasty to safely insert the cannula just beneath the HNP. Arrows in the left panel indicate the area of the foraminoplasty. The HNP was successfully removed en-bloc by TF-PELD after the foraminoplasty as show in the right panel.



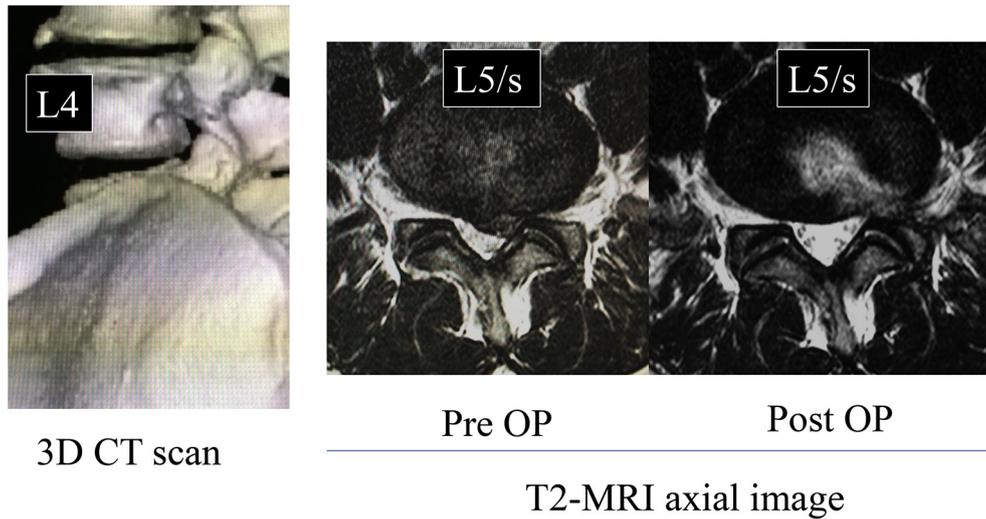
**Fig. 5.** CT and endoscopic view at L5-s. The red circle in the right panel indicates the location of the resected area of the superior facet process (SAP) of S1. As comparing to the CT scan taken before surgery in the left panel, the foramen is obviously enlarged. With observing the S1 nerve root under the endoscopic guidance as shown in the middle panel, HNP fragments can be removed safely. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of the foraminal stenosis of the lumbar spine using trephine and/or the high speed drill [13–15,26].

The foraminal stenosis is sometimes difficult to get the precise diagnosis [27,28]. Ohba et al. reviewed 68 cases with the foraminal stenosis, and found as the radiological characteristics that on MRI revealed that the prevalence of Type 3 Modic changes was significantly higher [27]. Very recently, Kanamoto et al. investigated the effectiveness of diffusion tensor imaging (DTI) on understanding the pathology of the foraminal stenosis [28]. Yeung and Gore also stated that foraminal stenosis would be one of the biggest pathologies for the failed back syndrome [13]. For the foraminal stenosis, TF-PELD would be applied to enlarge the

narrow foramen. We call this technique PELF (percutaneous endoscopic lumbar foraminoplasty).

Yeung and Gore reviewed 30 patients treated with TELF under local anesthesia. The mean visual analog score in these patients improved from 7.2 preoperatively to 4.0 postoperatively and the Oswestry Disability Index from 48% to 31%. With this result, they emphasized the efficacy of the PELF to solve this condition. Lewandrowski [15] also reported 220 cases with foraminal disorders including stenosis and herniation. He applied TF-PFLF for all cases, and obtained excellent and good results in 85% of cases. Their technique was outside-in technique, and used cannulated reamer as well as the high speed drill.



**Fig. 6.** CT scan and MRIs for a case of HNP at L5-s. MRI indicates the HNP at L5-s before surgery. On the 3-dimensional CT scan clearly demonstrates that the disc level at L5-s is completely covered with the iliac crest (the left panel). MRI after the surgery demonstrates the resection of the HNP fragment.

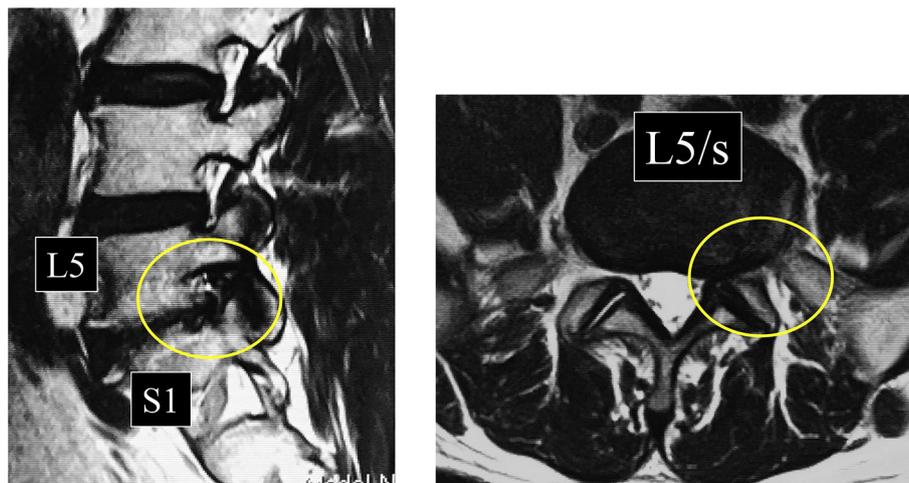
Fig. 7 demonstrates the L5-s foraminal stenosis with herniated nucleus pulposus (HNP) before surgery. This case was 75 y.o. female. Due to the slight scoliosis, the left intervertebral foramen becomes stenotic. Also, far lateral HNP at the left L5-s is observed. Thus, the left L5 nerve root was impinged by both of osseous stenosis and HNP. Outside-in technique was selected for the case. The superior articular process of S1 and sacral alar was partially removed (Fig. 8), leading to the foraminal widening. The laterally migrated HNP was, then, removed. Following the osseous decompression and HNP removal, L5 nerve root can be decompressed. On the CT scans taken before and after the surgery, the area of the foraminoplasty, indicating the foraminal widening, is clearly seen in Fig. 8. Immediately after the surgery, her leg pain and numbness improved.

**4. PEVF (percutaneous endoscopic ventral facetectomy)**

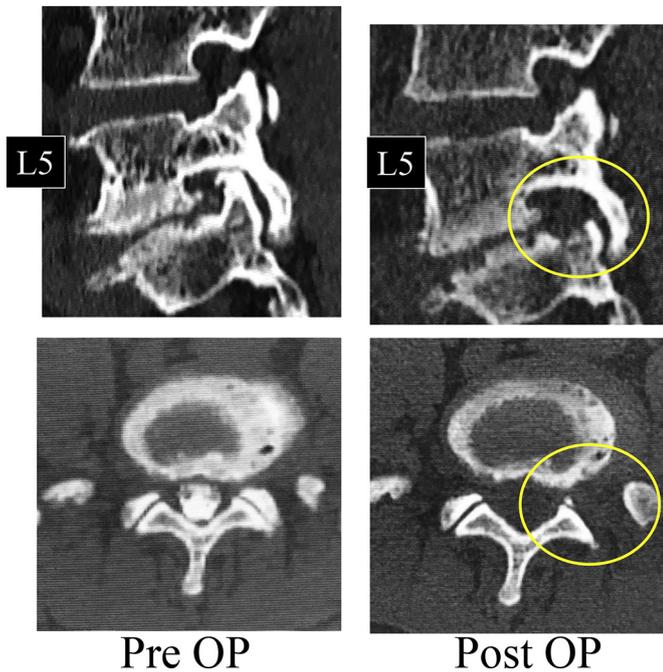
Very recently, the new concept of the PEVF (percutaneous endoscopic ventral facetectomy) has been proposed from our group [16]. This is the advanced technique of the PELF as described before.

After widening the intervertebral foramen, the cannula is further proceeded into the spinal canal, so that the lateral recess can be decompressed. As shown in the Fig. 9, the ventral side of the facet joint is removed; thus, this procedure was named percutaneous endoscopic lumbar ventral facetectomy (PEVF). With the PEVF technique, the lateral recess stenosis as well as the foraminal stenosis can be decompressed simultaneously under the local anesthesia. There are three types of the lumbar spinal canal stenosis: i.e., central, lateral recess and foraminal stenosis. Thus, percutaneous endoscopic technique can manage the two types of the stenotic conditions except the central canal stenosis.

For this procedure, this is no long term results so far. However, in the short term results have been acceptable. The strongest benefit of the PEVF is that it can be done under the local anesthesia. Seymour and Vaz [29] analyzed 288 cases who had surgeries under the general anesthesia aged over 65. They found post-operative complications in about 60% of cases. The respiratory complication was the commonest: 17% of patients having simple atelectasis, 12% acute bronchitis and 10% pneumonia. In this paper, post-operative delirium was 7%. On the other hand, Neufeld et al. [30] reported



**Fig. 7.** Preoperative radiological examinations for the L5-s foraminal stenosis case. This case is 75 y.o. female. Due to the slight scoliosis, the left intervertebral foramen becomes stenotic. Also, far lateral HNP at the left L5-s is observed. Thus, the left L5 nerve root was impinged by both of osseous stenosis and HNP.

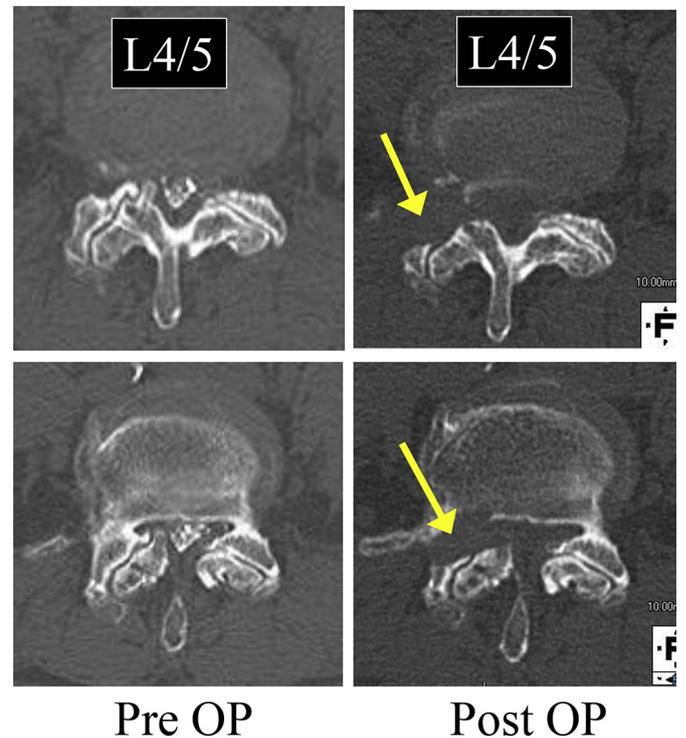


**Fig. 8.** CT scans taken before and after the surgery. They demonstrate the area of the foraminoplasty. The yellow circle indicates the location of the osseous decompression. The superior articular process is removed, so that the foraminal widening is enabled. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

very high rate over 30% of the post-operative delirium following the general anesthesia in the elderly patients aged over 70. The general anesthesia for the elderly patients would, thus, be harmful, and if there is the surgical technique which can be done under the local anesthesia for the elderly patients, it should be very benefit for such patients.

However, generalized reactions during surgery have been reported [31]. Very recently, Yamaya et al. [31] reported general complications related to the PED performed under local anesthesia. From a review of 113 cases (mean age: 44 years) who underwent PED under local anesthesia, the report states that the procedure could be completed under local anesthesia, though additional medication was needed in 23 of the 113 cases (20.4%). Thirteen cases showed high blood pressure with systolic blood pressure of >200 mmHg; calcium channel blocker was used to normalize the blood pressure. In 6 cases, sudden bradycardia <50 bpm occurred, and this could be due to vasovagal reaction. Atropine was used for treating this condition. Also, 5 cases complained of severe back pain during cannula insertion, and this was treated with the addition of intravenous injection of 7.5 mg pentazocine. Thus, they concluded that PED can possibly be performed under local anesthesia; however, surgeons must be aware of the general complications that could arise during surgery under local anesthesia.

The lumbar spinal canal stenosis (LSS) is the disease mainly for the elderly people. The gold standard for the disorder is the decompression surgery with or without spinal fusion under the general anesthesia. As described earlier, surgeries without general anesthesia such as with the local anesthesia would be the best for the elderly population to avoid the post-surgical complication, if possible. In this article, we introduced two kinds of the percutaneous endoscopic decompression surgery for LSS: i.e. PELF and PEVF. Using these two procedure, the foraminal stenosis and lateral recess stenosis can be decompressed under the local anesthesia. Nowadays, especially for the developed countries, the population is



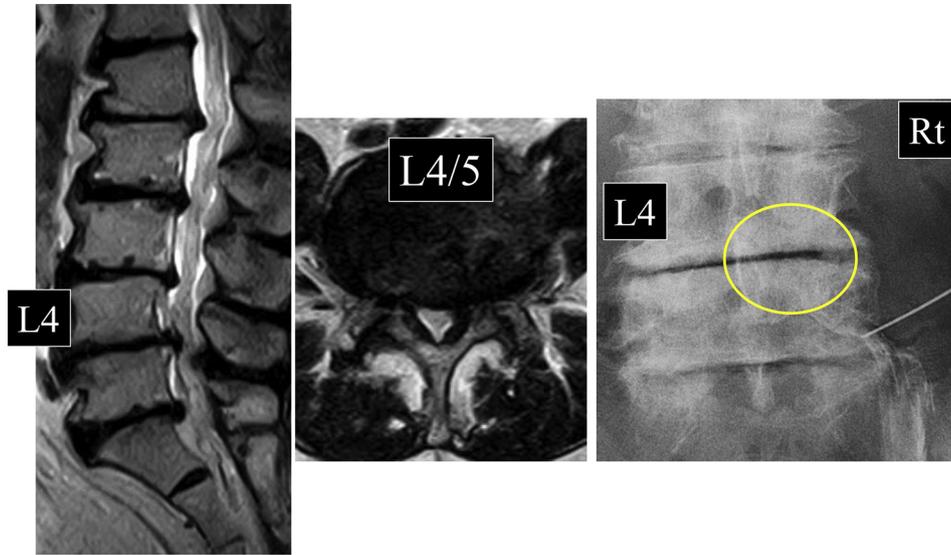
**Fig. 9.** CT scans taken before and after the surgery of PEVF. Note the ventral side of the facet joint including the lateral recess is removed; thus, this procedure is named percutaneous endoscopic lumbar ventral facetectomy (PEVF). With the PEVF technique, the lateral recess stenosis as well as the foraminal stenosis can be decompressed simultaneously under the local anesthesia.

aging rapidly. In such situation, the advancement of the percutaneous endoscopic decompression surgery under the local anesthesia is the great benefit.

**Fig. 10** demonstrates a representative case who underwent the PEVF. This patient is 65 y.o., male, physician. He complained of the strong right leg pain. He could not lay on the bed in the supine position, and could not stand upright strait position. He had general co-morbidities such as uncontrolled diabetes mellitus and coronary insufficiency. He was taking anticoagulant regularly. Therefore, we decided to conduct the PEVF surgery under the local anesthesia. MRI revealed the multilevel lumbar stenosis; however, L5 nerve root impingement was diagnosed as the main lesion since L5 selective nerve root block showed the temporary pain remission (**Fig. 10**, right panel).

The PELF at the right L4-5 level was conducted under the local anesthesia. The narrow foramen and lateral recess was completely decompressed. During and after the operation there was no complication such as nerve root injury, dural tear, hematoma and so on. Immediately after the surgery, he could lay on the supine position without any leg pain. One hour later, he started walking without any leg pain, and his standing posture was upright and straight. **Fig. 11** demonstrates the CT scans before and after the surgery. Note the decompression of the L5 nerve root was completed due to the exact removal of the lateral recess which was composed by the ventral facet joint at L4-L5.

Percutaneous endoscopic ventral facetectomy (PEVF) is a recent technique; there are as yet no long-term outcomes reported in the literature. The procedure requires complete removal of the superior articular process (SAP) and thus, spinal instability is a possible surgery-related complication. In 2017, Kashima et al. [32] evaluated the contribution of the SAP to the facet contact area as the SAP facet contact area (%) of the total facet joint, because the entire SAP is



**Fig. 10.** Radiological presentation for a case undertaken PEVF. This case is 65 y.o. male, physician. MRI revealed the multilevel lumbar stenosis. L5 nerve root impingement is diagnosed as the main lesion since L5 selective nerve root block shows the temporary pain remission.

removed during PEVF. The results show that SAP facet contact (%) was 74.5%, 67.3%, 55.0%, 53.4%, and 55.0% at L1/2, L2/3, L3/4, L4/5, and L5/S1, respectively. Therefore, at the lower levels of the lumbar spine, the contact area of the SAP was found to be around 50% of the total facet contact area. Furthermore, there was a positive correlation between disc height and SAP facet contact. SAP facet contact % decreased as the disc space reduced. This tendency was dominant in the lower intervertebral levels. During PEVF, the SAP would sometimes be removed in its entirety. Even in such situations, nearly half of the facet contact could be maintained in the vertebral body of the lower intervertebral levels. Furthermore, in degenerated spine with disc collapse, preservation of facet contact after PEVF could be promising. Based on this information, in cases of

young patients and/or higher lumbar levels, PEVF would be contraindicated because of possible instability after the operation.

**5. Conclusion**

In this paper, we described the current state of the transforaminal (TF) percutaneous endoscopic disc surgery such as traditional PELD and foraminoplastic PELD. Furthermore, we discussed on the perspectives of the TF percutaneous endoscopic surgery for application to the LSS. Using the PELF and PEVF technique, both of the foraminal and lateral recess stenosis can be decompressed. All three procedure of PELD, PELF and PEVF are usage of the transforaminal approach, and can be done with the local anesthesia. Our nation is rapidly progressing the aging society, and local anesthesia would be minimally invasive for the elderly people as comparing to the general anesthesia.

Another approach for percutaneous endoscopic surgery is the interlaminar PED (IL-PED) technique [9,10,19]. Basically, IL-PED requires general anesthesia as stated in the literature, and the technique has been applied for decompression of spinal canal stenosis [33]. The procedure requires touching and retracting the nerve root, therefore, it theoretically requires general anesthesia. However, IL-PED is less invasive, and could possibly be performed under local or epidural anesthesia. In the near future, PED procedures involving both transforaminal and IL approaches will likely be accepted as minimally invasive spinal decompression surgeries.

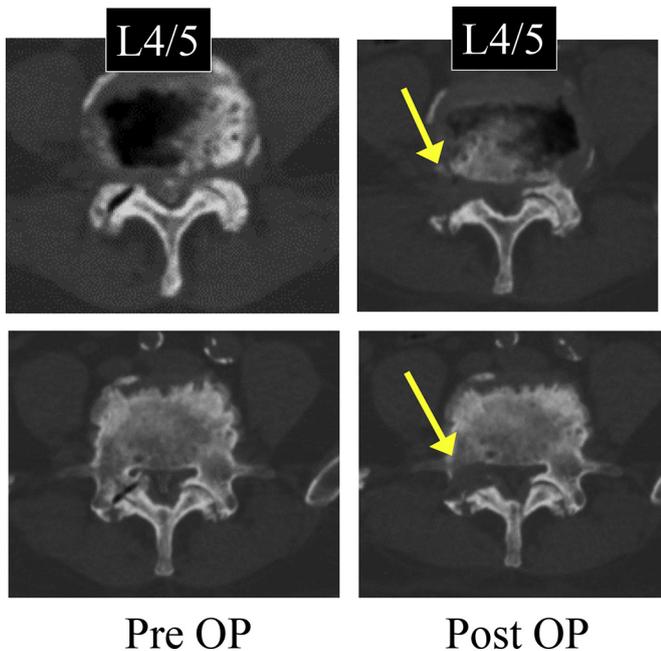
In conclusion, the transforaminal percutaneous endoscopic surgery would be at present minimally invasive surgery on the basis of the damage of the spinal structures including back muscles as well as the method of anesthesia for the surgeries.

**Conflict of interest**

The authors declare that they have no conflict of interest.

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**Fig. 11.** CT scans before and after the PEVF surgery. Note the decompression of the L5 nerve root is completed due to the exact removal of the lateral recess which is composed by the ventral facet joint at L4-L5.

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