Original Article
New instrument for percutaneous posterolateral lumbar foraminoplasty: case series of 134 with instrument design, surgical technique and outcomes

Zhenzhou Li, Shuxun Hou, Weilin Shang, Keran Song, Hongliang Zhao

Department of Orthopedics, The First Affiliated Hospital of General Hospital of People’s Liberation Army, Beijing 100048, China

Received July 3, 2015; Accepted September 5, 2015; Epub September 15, 2015; Published September 30, 2015

Abstract: Current solutions for treating uncontained lumbar disk herniation include laser assisted endoscopic foraminoplasty and Transforaminal Endoscopic Spine System, both of which have some issues in clinical practice. This study aims to report the design of a new instrument for percutaneous posterolateral foraminoplasty. 148 patients with uncontained lumbar disk herniation were treated with percutaneous foraminoplasty followed by transforaminal endoscopic discectomy. Follow up were obtained for 134 cases. The VAS scores of pre-operative and post-operative low back pain and sciatica were compared. Oswestry Disability Index (ODI) and MacNab scores were also obtained. Follow-up was up to 5 years postoperatively. There were 75 of excellent, 49 of good and 5 of fair according to MacNab score system, with total successful rate up to 92.5%. 5 cases with L5S1 disc herniation complained about irritation to the dorsal root ganglion. In conclusion, the new transforaminal endoscopic discectomy instrument is safe and effective for percutaneous foraminoplasty.

Keywords: Lumbar disk herniation, minimally invasive treatment, foraminoplasty, transforaminal endoscopic discectomy

Introduction
Since first report of posterolateral endoscopic discectomy in 1992, it is widely used to treat patients with uncontained lumbar disk herniation [1]. The current two techniques used for transforaminal posterolateral endoscopic discectomy were firstly described by Yeung [2] and Hoogland [3]. Dr. Yeung’s technique applied single channel or double channel through which herniation was gradually removed from inner side to outer side of disc. With new generation of transforaminal endoscopic equipment, which allows progressively opening of foramen, surgeons can put tools in space in front of spinal dural sac, and resect herniated disc directly. Superior articular process (SAP) is the main obstacle for rod-shaped endoscope when going to the space in front of the spinal dural sac posterolateral. One solution is laser assisted endoscopic foraminoplasty which widens lumbar intervertebral foramen [4, 5]. Using a side firing holmium laser probe, epidural scarring, extruded and sequestrated disc protrusions or osteophytes are ablated with protection of saline solution under direct vision. Problems with laser assisted techniques includes expensive equipment, low working efficiency, and risk of heat-damage to surrounding peripheral nerves. Another solution is THESSYS (Transforaminal Endoscopic Spine System) invented by Hoogland [3] et al. With the help of a cannulated trephines and accompanying instruments, foramen is gradually widened in a step-wise fashion for removal of herniated disc materials. However, cannulated trephines directly reaches para-foramen soft tissue and nerve roots without any protection, arising concerns of damage to nerves [6].

To address these issues of existing methods, we invented new instrument for percutaneous posterolateral lumbar foraminoplasty [7]. We combined Dr. Yeung’s posterolateral endoscopic system and our new device to perform lumbar foraminoplasty on 148 patients with uncon-
Instrument for percutaneous posterolateral foraminoplasty

Table 1. Inclusion and exclusion criteria

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Low back pain accompanied by sciatica</td>
<td>(1) Cauda equina syndrome</td>
</tr>
<tr>
<td>(2) Leg pain is heavier than low back pain</td>
<td>(2) Recurrence after discectomy</td>
</tr>
<tr>
<td>(3) Non-contained disc herniation as indicated by MRI or CT</td>
<td>(3) Central spinal stenosis as shown by radiology</td>
</tr>
<tr>
<td>(4) No surgical history of the same segment on lumbar spine</td>
<td>(4) Pathological conditions with combined infection, tumor, or fracture</td>
</tr>
<tr>
<td>(5) Low efficacy with conservative treatment</td>
<td>(5) Foramen and far lateral disc herniation</td>
</tr>
<tr>
<td>(6) Single segmental disc herniation or prolapse</td>
<td>(6) Segmental instability of lumbar spine</td>
</tr>
<tr>
<td>(7) Positive for straight leg raising test</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Patented instrument of percutaneous foraminoplasty. A: Guidewire; B: Obturator; C: Graded duckmouth-like cannulas; D: Trephine.

Outcome of up to 5 years follow-up is summarized in this case series report.

Materials and methods

Patients

This study was approved by institutional review board of the First Affiliated Hospital of General Hospital of People’s Liberation Army. Inclusion and exclusion criteria are shown in Table 1.

From April of 2007 to April of 2009, 148 patients meet inclusion criteria were treated. Follow up data were obtained from 134 cases out of 148, including 14 cases on L3-4, 78 cases on L4-5 and 42 cases on L5S1. Patients ranged in age from 18-78 years (mean age, 41.4 years), including 68 males and 66 females. 108 cases are prolapse type, while 26 cases are sequestration type. Reasons for losing follow-up data in some patients includes loss of contact and die from other diseases. Preoperative symptoms and deficits included nerve root dermatome hypoesthesia in 98 patients (73%), nerve root myotome muscle weakness in 32 patients (23%), and weakening or disappearance of tendon reflex in 43 patients (32%).

Surgical tools

YESS® Spine Endoscope produced by Richard Wolf Medical Instruments Corporation (Vernon Hills, IL); patented instrument of percutaneous foraminoplasty with a guide-wire, an obturator, a graded duck-mouth cannulas and graded trephine (Figure 1). The distal end of duck mouth-like cannulas is 2 cm in length. Half of it is flat, the other half is bevel design. The bevel part is thin, so that it may go through gap between lower half of intervertebral foramen and anterior to facet joints. The tip of cannulas may be fixed on vertebrae, preventing cannulas from moving. The trephine works inside the cannulas avoiding any damage to nerves. The dimensions of new instrument was listed in Table 2.

Surgical procedures

(1) Anesthesia: Local (0.5% lidocaine solution) plus intravenous strengthen (1 mg of midazolam and 100 μg of fentanyl).

(2) Position: Lying prone on spinal surgery shelf, avoiding pressure on abdomen.

(3) Location: Positioning the surgical segment by C-arm fluoroscopy.

Surgical protocol

(1) Puncture (Figure 2A): Following Dr. Yeung’s technique, needle was punctured through foramen, 12-15 cm away from posterior longitudinal middle line on diseased side. Fluoroscopy was used to confirm that needle went into nucleus pulposus tissue of intervertebral disc. A mixture of 8 ml of omnipaque and 2 ml of methylene blue was injected for staining purpose. After taking out inner core of the nee-
Instrument for percutaneous posterolateral foraminoplasty

Table 2. The dimensions of the new instruments

<table>
<thead>
<tr>
<th></th>
<th>Length (cm)</th>
<th>Diameter (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidewire</td>
<td>25</td>
<td>1</td>
<td>Oribator</td>
</tr>
<tr>
<td>Oribator</td>
<td>20</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Graded duckmouth-like cannulas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>18</td>
<td>7-8 (inner-outer)</td>
<td>Tip of duckmouth-like cannulas is 2 cm long with half flat and half bevel</td>
</tr>
<tr>
<td>Secondary</td>
<td>17</td>
<td>8-9 (inner-outer)</td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td>16</td>
<td>9-10 (inner-outer)</td>
<td></td>
</tr>
<tr>
<td>Quaternary</td>
<td>15</td>
<td>10-11 (inner-outer)</td>
<td></td>
</tr>
<tr>
<td>Trephine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>18</td>
<td>5-7 (inner-outer) 5</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>18</td>
<td>8-10 (inner-outer)</td>
<td></td>
</tr>
</tbody>
</table>

Outcome assessment

One to two days after surgery, all patients were examined by MRI to check if herniated tissue was removed completely (Figures 2E, 2F, 3E). Outcomes of symptoms were evaluated by follow-up interviews at 3 months, 6 months, 1 year and 5 years after surgery. Low back pain and leg pain were measured by Visual Analog Scale (VAS) score (1-100). Functional outcomes were assessed by using Oswestry Disability Index (ODI) [8] and modified MacNab criteria [9, 10]. For MacNab criteria at year 5 after surgery, “excellent” was given to patients who were free of pain and deficit, without restriction of mobility; “good” was given to patients with residual symptoms or deficits not impeding the ability to normal life; “fair” was given to patients with some improvement of functionality but who remained handicapped; “poor” was given to patients with no improvement at all.

Statistical analysis

Statistical analysis was performed with SPSS 11.5 software (SPSS Inc., Chicago, IL). Preoperative and postoperative (3 month, 6 months, 1 year and 5 years) VAS scores of low back pain and leg pain, as well as ODI values were analyzed with ANOVA. Preoperative and postoperative related nerve root function status was analyzed with Chi-square test. P<0.01 was considered as significant.

Results

Using new instrument, 148 patients with disk herniation were surgically treated, 134 cases were followed up. No case required conversion to an open procedure during the surgery. No patient needed a blood transfusion. No patients had infections. Operative time ranged from 40-80 minutes (average, 65 minutes).
Estimated blood loss ranged from 20-50 mL (average, 30 mL). Low back pain and leg pain were relieved immediately after surgery in all patients. Five patients were complicated with “sunburn syndrome” who were all operated at L5S1. Complain were reduced after treatment with pulsed electro-stimulation. MRI examination showed adequate removal of herniated disc. Five cases required a revision surgery (3.7%) after recurrence, thus being excluded from patient list of quantitative indices follow-up. The rest 129 cases were analyzed with complete follow-up data. Pre-operative and post-operative VAS scores of low back pain and leg pain, as well as ODI were summarized in Table 3. As the data shows, VAS scores and ODI values were significantly lower in all time-points after surgery than before surgery. MacNab scores at 5 years after surgery were obtained from 134 patients. 75 cases were given “excellent”; 49 were given “good”. 5 patients experienced heavier low back pain, thus being classi-
fied as “fair”. 5 cases with recurrence were given “poor”. Preoperative and postoperative (5 years follow-up) related nerve root function status was summarized in Supplementary Table 1. Sensation and muscle strength recovered significantly (P<0.01), while tendon reflex was not changed (P=0.782).

Discussion

Safety of instrument for percutaneous lumbar foraminoplasty

Knight et al. reported a laser assisted method to widen the lumbar foramen by removing part
of bone and cartilage tissue surrounding foramen [4]. However, disadvantage with laser technology is quite obvious, for example, expensive equipment, low working efficiency, and risk of heat-damage to surrounding spinal nerves [11]. Hoogland et al. [3], invented THESSYS technique, in which they make use of graded trephine to widen the foramen gradually. But in such surgery, trephine blade makes contact to para-foramen soft tissue and nerve roots, arising concerns of damage to nerves [11]. Based on Dr. Hoogland’s method, we invented new instrument for percutaneous lumbar foramino-plasty. With graded duck mouth-like cannulas which was next to the ventral side of facet joint, excluding the exiting nerve root from the working zone of trephine. Driven by hand, trephine could only cut bone, but not ligament. Meanwhile, patients kept awake under local anesthesia, which marked it possible for surgeons to get instant feedback from patients. 0.5% lidocaine solution anesthetized sino-vertebral nerve surrounding foramen, reducing pain without affecting nerve root. This is important to ensure safety of foramino-plasty.

**Herniation suitable to be treated with foramino-plasty**

There’s no need to decompress the foramen and lateral recess. Using secondary trephine of 10 mm in diameter, we could widen foramen and limit cut to 5 mm due to protection of duck mouth-like cannulas. Upper part of lower SAP and part of ventral SAP of facet joint could be cut, thus decompressed foramen and lateral recess effectively [12].

**Influence of foramino-plasty to the stability of lumbar segment**

The main function of lumbar facet joint is oriented control. Roughly, lumbar facet joint surface is vertical to transverse plane and angles 45 to coronal plane. This is good for flexion and extension, but not good for rotation [13]. Osman et al. compared stability of lumbar vertebrae [14]. After transfominal decompression, the intervertebral foraminal area increased about 45.5%. However, surgical technique used is different from what is actually used in clinic. In this study [12], we mimicked posterolateral lumbar foramino-plasty on human lumbar vertebrae specimen, and studied its mechanical properties before and after surgery. Our data showed that there is no damage to joint surface of lumbar facet and joint capsule at all, after primary foramino-plasty. Therefore, no changes of stability were observed. However, secondary foramino-plasty might increase lumbar lateral bending and shift neutral zone without mechanical loading, but not affecting the axial rotation flexibility. More data is needed to clarify the influence of increased lumbar flexion to lumbar vertebra.

**Outcomes of endoscopic discectomy after percutaneous posterolateral lumbar foramino-plasty**

Nellensteijn et al., reported that current evidence is not enough to support a better efficacy of transfominal endoscopic surgery over open microdiscectomy in patients with symp-
Instrument for percutaneous posterolateral foraminoplasty

tomatic lumbar disc herniation or vice versa [15]. Kambin et al. reported an 88.3% of success rate in case series of 169 patients of lumbar disc herniation in 24 month follow-up [16]. Meanwhile, open laminectomy and discectomy request patients to use narcotics for a longer duration postoperatively than video-assisted arthroscopic microdiscectomy.

Application of foraminoplasty further improved effectiveness of endoscopic discectomy in treating lumbar disc herniation. Lee et al. reported advantages of foraminoplastic approach in treating extruded disk herniation at L5-S1 level [17]. Out of 25, 22 patients (88%) had favorable outcomes. Only two patients converted to open microdiscectomy due to incomplete decompression and recurrent disk herniation. Using same technique, Choi et al. treated 59 cases of highly migrated intracanal lumbar disc herniation. 91.4% patients experienced satisfactory outcome. Three cases complained about persistent leg pain after surgery. Two patients reported recurrent herniation at same level 6 month post-operation. In present study, we reported case series of 134 patients of lumbar disc herniation treated with endoscopic discectomy post percutaneous foraminoplasty. 92.5% of cases were given “excellent” or “good” of MacNab scores. Five cases had recurrent herniation at same level. These results are better than previous studies. One of reasons might be that new instrument not only widened foramen but also effectively protect nerve root.

Some patients may experience “sunburn syndrome” which is irritation to dorsal root ganglion, after discectomy post foraminoplasty, due to retardation or over-sensation of nerve root. It happened in 5-15% of patients, usually at L5S1. Most likely, it is temporary, and disappeared after conservative treatment. In our study, 5 patients complained with “sunburn syndrome” were all operated at L5S1. Complaints were reduced after treatment of pulsed electro-stimulation.

In conclusion, the advantages of endoscopic discectomy after percutaneous posterosalateral lumbar foraminoplasty include: (1) No general anesthesia; (2) Little or no damage to nerves due to surgery; (3) Few infections; (4) Direct removal of herniated discs; (5) No damage to ligament, leaving few scars; (6) No scar tissue as obstacle for re-operation after recurrence [18]. Our instrument for percutaneous foraminoplasty is effective and safe for transforaminal endoscopic discectomy in treating uncontained lumbar disk herniation.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Zhenzhou Li,
Department of Orthopedics, The First Affiliated Hospital of General Hospital of Chinese People’s Liberation Army, Beijing 100048, China. Tel: +86 10 68989121; Fax: +86 10 68989121; E-mail: lizhenzbj@sina.com

References

Instrument for percutaneous posterolateral foraminoplasty.


Supplementary Figure 1. Posterolateral insertion of stylet pin and guide wire into low part of intervertebral foramen (A). Lateral view of fluoroscopy show the tip arriving the posterior aspect of upper endplate of caudle vertebral body (B).

Supplementary Figure 2. Oburator insertion into low part of intervertebral foramen over guide wire (A). Lateral view of fluoroscopy show the tip of oburator arriving the posterior aspect of upper endplate of caudle vertebral body (B).

Supplementary Figure 3. Gradual protective cannula insertion into low part of intervertebral foramen over oburator (A, B). Lateral view of fluoroscopy show the tip of protective cannula arriving the posterior aspect of upper endplate of caudle vertebral body (C), Anteroposterior view of fluoroscopy show the tip of protective cannula arriving the ventral aspect of superior articular process of caudle vertebral body (D).
Supplementary Figure 4. Foraminoplasty with trephine rotating and advancing in protective cannula (A), exiting nerve root was kept outside of protective cannula while transversing nerve root was protected by lateral flavum ligament. Anteroposterior view of fluoroscopy show the tip of trephine arriving the medial border line of pedicle of caudle vertebral body (B).

Supplementary Figure 5. Working cannula insertion into ventral epidural space over oburator which was insertion into lumbar canal through protective cannula (A, B), bevel opening of working cannula was placed toward extruded disc tissue posteriorly.

Supplementary Figure 6. Partial resection of extruded disc tissue (A) until part of transversing nerve root descending into endoscopic field (B). NP-nucleus pulposus, NRT-nerve root, D-dorsal, V-ventral, H-head, F-foot.
Supplementary Figure 7. Protection of transversing nerve root and further exposure and resection of extruded disc tissue by rotating working cannula 180 degree with bevel opening toward disk space anteriorly (A, B). Position of working cannula should be confirmed by fluroscopy (C, D). NP-nucleus pulposus, NRT-nerve root, D-dorsal, V-ventral, H-head, F-foot.

Supplementary Figure 8. Exploration the decompression of transversing nerve root by rotating working cannula with bevel opening toward transversing nerve root posteriorly (A, B). IVD-intervertebral disc, NRT-nerve root, FL-favum ligament, PLL-posterior longitudinal ligament, D-dorsal, V-ventral, H-head, F-foot.

Supplementary Table 1. Comparison of preoperative and postoperative function of related nerve roots

<table>
<thead>
<tr>
<th>Function of Nerve roots</th>
<th>Condition</th>
<th>Pro-operation</th>
<th>5 years post-operation</th>
<th>P values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensation</td>
<td>Normal</td>
<td>39</td>
<td>115</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Decreased</td>
<td>90</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Muscle strength</td>
<td>Normal</td>
<td>104</td>
<td>127</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Decreased</td>
<td>25</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Reflex</td>
<td>Normal</td>
<td>91</td>
<td>94</td>
<td>0.782</td>
</tr>
<tr>
<td></td>
<td>Decreased</td>
<td>38</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

*Chi-square test.