CLINICAL ARTICLE

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A Morphometric Analysis of Neuroforamen in Grade I Isthmic Spondylolisthesis by Anterior Lumbar Interbody Fusion with Pedicle Screw Fixation

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Objective : The aim of this study was to evaluate the morphometric changes in neuroforamen in grade I isthmic spondylolisthesis by anterior lumbar interbody fusion (ALIF).

Methods : Fourteen patients with grade I isthmic spondylolisthesis who underwent single level ALIF with percutaneous pedicle screw fixation were enrolled. All patients underwent standing lateral radiography and magnetic resonance imaging (MRI) before surgery and at 1 week after surgery. For quantitative analysis, the foraminal height, foraminal width, epidural foraminal height, epidural foraminal width, and epidural foraminal area were evaluated at the mid-portion of 28 foramens using T2-weighted sagittal MRI. For qualitative analysis, degree of neural compression in mid-portion of 28 foramens was classified into 4 grades using T2-weighted sagittal MRI. Clinical outcomes were assessed using Visual Analogue Sale (VAS) scores for leg pain and Oswestry disability index before surgery and at 1 year after surgery.

Results : The affected levels were L4-5 in 10 cases and L5-S1 in 4. The mean foraminal height was increased ($p < 0.001$), and the mean foraminal width was decreased ($p = 0.014$) significantly after surgery. The mean epidural foraminal height ($p < 0.001$), epidural foraminal width ($p < 0.001$), and epidural foraminal area ($p < 0.001$) showed a significant increase after surgery. The mean grade for neural compression was decreased significantly after surgery ($p < 0.001$). VAS scores for leg pain ($p = 0.001$) and Oswestry disability index ($p = 0.001$) was decreased significantly at one year after surgery.

Conclusion : Foraminal stenosis in grade I isthmic spondylolisthesis may effectively decompressed by ALIF with percutaneous pedicle screw fixation.

KEY WORDS : Anterior lumbar interbody fusion (ALIF) · Isthmic spondylolisthesis · Neuroforamen.

Introduction

Anterior lumbar interbody fusion (ALIF) is one of the treatment options for various degenerative lumbar spinal diseases[3,5,6,10,13,14,16,18]. One of the advantages of ALIF over posterior fusion surgery is that decompression and fusion can be performed without the need to remove any bone or retract the neural structures[3,6,8,9,14]. In this regard, several studies have reported favorable clinical results from ALIF with/without supplemental posterior fixation for low-grade isthmic spondylolisthesis[2,8,13,14]. Surgeons favoring ALIF insist that a foraminal stenosis in isthmic spondylolisthesis can be effectively decompressed via anterior decompression and fusion. However, despite the promising clinical outcomes of ALIF, surgeons who do not favor ALIF are skeptical about the effectiveness of foraminal decompression by ALIF because direct decompression of the nerve root is not possible with this procedure[12].

Until now, there have been no clinical studies focusing on the morphometric changes in the neuroforamen by ALIF in low-grade isthmic spondylolisthesis. Accordingly, in the current study, the effectiveness of foraminal decompression by ALIF was evaluated by quantifying and qualifying the morphometric changes in the neuroforamen in grade I isthmic spondylolisthesis after ALIF with percutaneous pedicle screw fixation (PSF).

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Materials and Methods

Fourteen consecutive patients who underwent single level ALIF with percutaneous PSF for grade I isthmic spondylolisthesis from November 2004 to May 2005 were enrolled. There were 4 males and 10 females with a mean age of 48.4 years (range, 42 to 57 years). The affected levels were L4-5 in 10 cases and L5-S1 in 4. The inclusion criteria were as follows; 1) single level grade I isthmic spondylolisthesis with bilateral foraminal stenosis demonstrated on simple radiography, computed tomographic (CT) scan and magnetic resonance imaging (MRI), 2) radicular leg pain and/or back pain consistent with the radiologic findings, and 3) unsuccessful conservative therapy for at least 6 weeks. The exclusion criteria were; 1) isthmic spondylolisthesis grade II or higher, 2) concomitant lateral recess stenosis or extraforaminal stenosis requiring simultaneous posterior decompression of the fused segment, 3) simultaneous decompression adjacent to the fused segment, and 4) previous history of spine surgery.

Standing lateral radiography and MRI were performed before and at 1 week after surgery. The MRI scans were performed using an Intera 1.5 tesla (Philips, Netherland) with a slice thickness of 4 mm. To minimize metal artifact, scan settings of the MRI was adjusted as follows; repetition time [TR], 3735.0 msec and echo time [TE], 120.0 msec in T2-weighted images; repetition time [TR], 830.0 msec and echo time [TE], 10.0 msec in T1-weighted images. The disc height and percentage of slippage were checked using standing lateral radiography. For quantitative analysis of neuroforamen, the foraminal height, foraminal width, epidural foraminal height, epidural foraminal width and epidural foraminal area were evaluated at the mid-portion of the 28 foramens using sagittal MRI (Fig. 1). All measurements were performed by a single radiologist, who was blinded to the aims of this study, using picture archiving and communications systems and the results were expressed as a mean ± standard deviation. After the first measurements, the second measurements were performed more than one month later in order to ensure there would be no recollection of previous results. The means of the two measurements were calculated in order to minimize the intraobserver error. The mean intraobserver error was found to be 0.9 mm (range, 0.1 mm to 2.7 mm) for the disc height, foraminal height, foraminal width, epidural foraminal height and epidural foraminal width. For the epidural foraminal area, the mean intraobserver error was 6.2 mm^2 (range, 1.4 mm^2 to 21.4 mm^2). The mean values for each parameter obtained before and after surgery were compared. For qualitative analysis of neuroforamen, the degree of neural compression in mid-portion of 28 foramens was evaluated using T2-weighted sagittal MRI and was classified into 4 grades : 1, no compression; 2, mild compression (visible epidural fat around nerve root); 3, moderate compression (contacts but does not distort nerve root); and 4, severe compression (distorts nerve root).

Visual Analogue Sale (VAS) scores for leg pain and Oswestry disability index (ODI) were performed to assess the clinical outcomes. VAS score and ODI were checked the day before surgery. All patients were seen at the office and VAS score and ODI were checked again at 1 year after surgery.

Statistical analysis was performed using Wilcoxon signed rank test. A p value less than 0.05 was considered significant.

Surgical technique

All operations were followed a standard pattern[13,14], supervised by a senior surgeon. The retroperitoneal exposure was performed by a vascular surgeon in all cases. The patient was placed in the supine position under general anesthesia. The retroperitoneal approach was performed through a midline skin incision. The anterior longitudinal ligament and anterior annulus were removed after careful dissection and retraction of the common iliac artery and vein. Disc removal and preparation of the end plate was then performed. With removing posterior annulus using a Kerrison punch, anterior decompression of nerve root in the foramen was performed until the posterior longitudinal ligament had been exposed. Then, decompression of nerve root in the bilateral foramen was confirmed with probing. The appropriate anterior

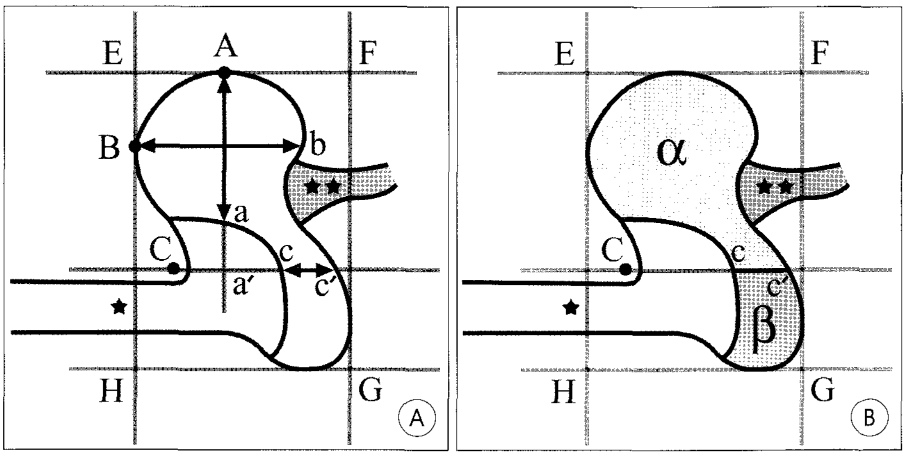

Fig. 1. The foraminal height (| EH |), foraminal width (| HG |), epidural foraminal height (| Aa |), epidural foraminal width (| cc′ |) (A), whole epidural foraminal area ($\alpha+\beta$) (B) were measured at the mid-potion of the foramen. | Cc′ | and | HG | are parallel to | EF | . | EH | , | FG | and | Aa′ | are perpendicular to | EF | . | EF | ; a line drawn along the inferior border of the upper pedicle, C; posterior inferior corner of the upper vertebral body, ★; intervertebral disc, ★★; lysis.

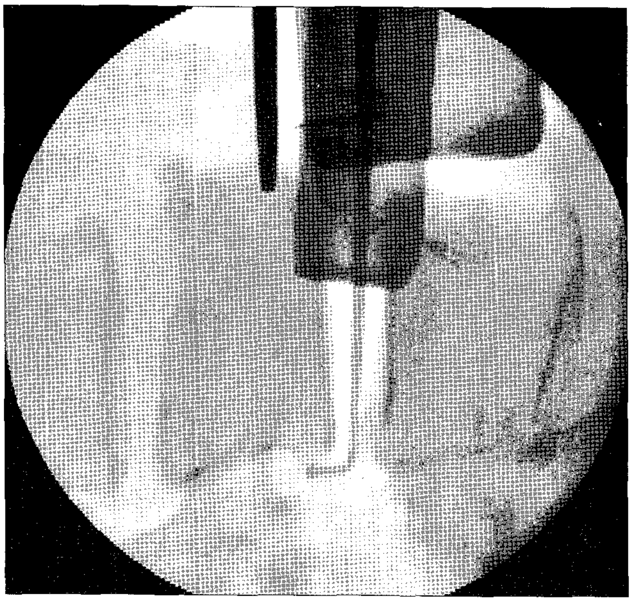

Fig. 2. Lateral view of the fluoroscopic images. Free passage of the probe into the foramen after an anterior decompression was considered an indication of adequate decompression of the neuroforamen via the anterior approach (used with the permission of the Journal of Korean Neurosurgical Society)[14].

decompression was indicated by the free passage of the probe into the bilateral foramen on fluoroscopic images (Fig. 2)[13]. For interbody fusion, single lordotic cage, which had a lordosis of 12 degrees, was used in all cases. A polyetheretherketone cage was used in all cases in order to minimize metal artifacts on MRI. The cage filled with the graft material was placed into the disc space. The patient was then placed into the prone position for supplemental percutaneous PSF. Under the guidance of C-arm fluoroscopy, bilateral pedicle screw-rod placement was accomplished using the percutanous pedicle screw fixation system made of titanium.

Results

Patient characteristics

The male to female ratio was 4 to 10. The mean age of the patients at the time of operation was 48.4 years (range 42 to 57 years). All patients had suffered from low back pain with leg pain and / or neurogenic claudication. The affected levels were L4-5 in 10 cases and L5-S1 in 4.

Operative data

All patients underwent ALIF with percutaneous PSF. The mean operation time was 177.9 minutes (range 135 to 255 minutes). The mean blood loss during operation was 142.0 cc (range 150 to 500 cc). There were no intraoperative complications.

Radiological outcome

The disc height (mm) was increased significantly after surgery

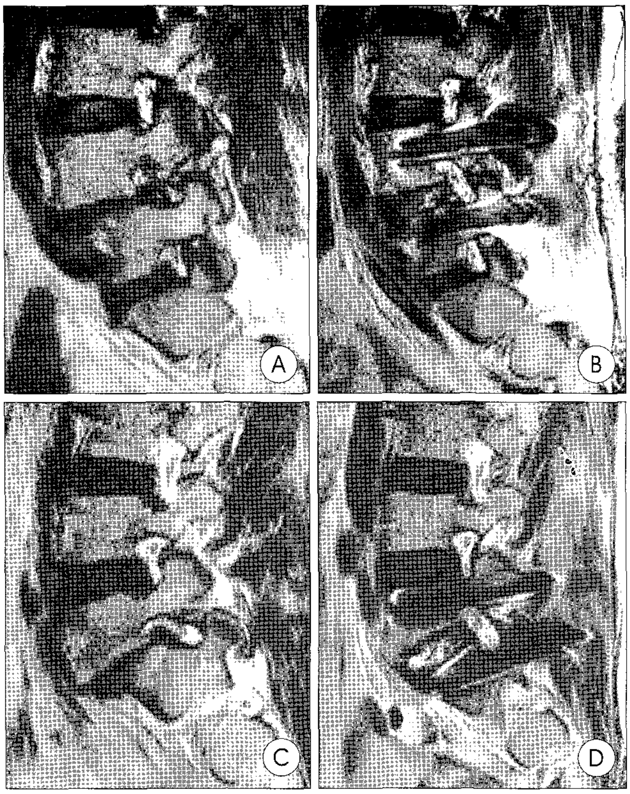

Fig. 3. Preoperative and postoperative magnetic resonance imaging showing an increase in the whole epidural foraminal area after anterior lumbar interbody fusion with percutaneous pedicle screw fixation at the L4−5 level (A, B) and at the L5−S1 level (C, D).

(before surgery : 5.9±3.1, after surgery : 15.1±1.9; $p<0.001$). The percentage of slippage (%) was decreased significantly after surgery (before : 19.5±8.6, after : 7.5±7.3, $p<0.001$).

The mean foraminal height was increased significantly (before : 14.9±3.0, after : 19.7±2.1, $p<0.001$), and the mean foraminal width was decreased significantly (before : 17.8±2.4, after : 16.2±3.8, p=0.014) after surgery. The mean epidural foraminal height (mm) (before : 5.2±1.7, after : 7.8 ±1.7, $p<0.001$) and mean epidural foraminal width (mm) (before : 4.5±2.2, after : 8.1±2.7, $p<0.001$) were increased significantly after surgery. The mean epidural foraminal area (mm^2) was also increased significantly after surgery (before : 88.8±28.1, after : 142.8±25.2, $p<0.001$) (Fig. 3). The mean degrees of neural compression was decreased significantly after surgery (before : 3.8±0.4, after : 1.8±0.9, $p<0.001$) (Table 1).

Clinical outcome

There was no mortality or major morbidity in the perioperative period. There was no postoperative complication. At discharge, all patients showed improvement of their leg symptoms. At one year after surgery, the mean VAS scores for leg pain (before : 6.9±1.1, after : 0.9±1.3, p=0.001) and mean ODI (before : 51.5±15.1, after : 12.9±5.4, p=0.001) were decreased significantly.

Table 1. Results of morphometric analysis after anterior lumbar interbody fusion with percutaneous pedicle screw fixation

	Before surgery	After surgery	*p* value*
Foraminal height (mm)	14.9±3.0	19.7±2.1	<0.001
Foraminal width (mm)	17.8±2.4	16.2±3.8	0.014
Epidural foraminal height (mm)	5.2±1.7	7.8±1.7	< 0.001
Epidural foraminal width (mm)	4.5±2.2	8.1±2.7	< 0.001
Epidural foraminal area (mm^2)	88.8±28.1	142.8±25.2	< 0.001
Degree of neural compression (grade)	3.8±0.4	1.8±0.9	< 0.001

*As calculated with the Wilcoxon signed rank test

Discussion

The main advantage of ALIF over posterior fusion surgery is that decompression and fusion can be achieved without removing the posterior bony structures and retracting the neural structures. This is because the foramen is usually opened with a restoration of the disc height, and a correction of the kyphosis and stability provided by fusion also alleviates the root symptomatology[12]. In addition, the retroperitoneal exposure used in ALIF avoids the stripping of the lumbar paraspinal muscles that are believed to contribute to the so-called "fusion disease"[12]. Clinical studies of ALIF with/without PSF for low-grade isthmic spondylolisthesis have been reported favorable[2,13,14]. According to Ishihara et al.[8], ALIF provided satisfactory long-term clinical results for isthmic spondylolisthesis, although the fusion rate was relatively low. Because biomechanical studies have demonstrated that anterior fusion alone is insufficient for neutralizing the axial rotation and extensional forces, many surgeons currently perform ALIF followed by posterior augmentation using pedicle screws or facet screws[4,7,9,13,14,20,21]. In this regard, Lee et al.[14] reported a success and fusion rate of 94.5% and 97.3%, respectively, from mini-ALIF supplemented with percutaneous PSF for low-grade isthmic spondylolisthesis.

Considering the morphometric changes in the neuroforamen after ALIF, Chen et al.[1] demonstrated in a cadevaric study that only an increase in the disc height with the BAK system could significantly increase the neuroforaminal volume and area, providing adequate space for the nerve root and improving neuroforaminal stenosis. However, many spine surgeons suspect the effectiveness of foraminal decompression by ALIF because direct decompression of the nerve root is not possible with this procedure[12]. The present authors also agree that complete decompression of neuroforamen is not always possible with indirect decompression by just increasing disc height.

Isthmic spondylolisthesis is characterized by a lysis of the pars interarticularis and formation of pseudojoint. Patients may present with leg pain due to compression of nerve root in the parapedicular trajectory underneath the pseudojoint. Therefore, it is generally considered that the majority of leg pain in these patients is caused by compression of the nerve root underneath the pseudojoint and posterior decompression and/or fusion surgeries have been traditionally performed. Anterior approach has been considered unlikely to decompress the nerve root since the pseudojoint is located dorsally from the nerve root. In patients with isthmic spondylolisthesis, the present authors observed that the nerve root in the foramen was usually compressed by not only pseudojoint posteriorly, but also pseudoherniated disc anteriorly. In ALIF, anterior removal of pseudoherniated disc decompresses nerve root first. Then, disc height elevation and slippage reduction enlarge neuroforamen, that results in additional decompression of nerve root in the neuroforamen. Thus, nerve root in the neuroforamen can be decompressed effectively by ALIF without removing pseudojoint. In the current study, anterior decompression of nerve root in the neuroforamen was attempted in all patients. For anterior decompression, authors beleive that removal of the posterior annulus is essential[13]. After removing posterior annuls, herniated disc in subligamentous portion can be removed effectively. The decompression of nerve root in the neuroforamen was considered adequate when the probe was freely passed into the neuroforamen on fluoroscopic images[13]. After finishing anterior decompression, placement of interbody cage into the disc space resulted in disc height elevation and additional widening of the neuroforamen.

In the current study, both quantitative and qualitative factors concerning the morphometric changes of neuroforamen showed successful decompression of neuroforamen after surgery. The changes of foraminal height and foraminal width, which represent factors about bony foramen, showed significant elevation of disc height and reduction of anterolisthesis after surgery. Because factors concerning bony foramen could not represent real decompression of nerve root in the neuroforamen, we also analyzed the changes in epidural foraminal area using quantitative factors such as epidural foraminal height, width, and area. All three parameters showed a significant increase after surgery, with successful decompression of nerve root in the neuroforamen. Qualitative analysis of changes in neuroforamen also showed an improvement of neuoforaminal stenosis after surgery. The surgical technique used in this study, anterior decompression of nerve root in the neuroforamen with additional disc height elevation by the cage insertion, is the main cause of successful foraminal decompression by ALIF with percutaneous PSF, which was demonstrated in both quantitative and qualitative analysis. We assessed the clinical outcome by the VAS scores of leg pain and ODI at 1 year after operation, and the improvement of both VAS scores and ODI represent the successful decompression of the nerve root in the neuroforamen.

Although ALIF with percutaneous PSF shows favorable radiological and clinical results for foraminal stenosis in grade 1 isthmic spondylolisthesis, concomitant lateral recess or extraforaminal stenosis can't be decompressed effectively via anterior approach. Therefore in such cases, posterior decompression and fusion should be considered first. For young male patients with the risk of causing retrograde ejaculation or elderly patients with severe calcified atherosclerosis in abdominal arteries, posterior decompression and fusion is also preferred[12,13]. Anterior approaches do carry some risks of catastrophic injury to major vessels and other retroperitoneal and intraperitoneal structures[11]. Arterial embolism, deep vein thrombosis, delayed hydronephrosis, retroperitoneal hematoma, and incisonal hernia are other complications reported after ALIF[15]. To avoid approach related complications, we performed team surgery with a well-experienced vascular surgeon in all cases, and there was no perioperative complication in this series.

There are several shortcomings in the current study. First, although we analyzed morphometric changes in 28 neuroforamen, the number of patients seen is relatively limited. Second, we analyzed morphometric changes of neuroforamen at perioperative period. Therefore, there is possibility that further changes in neuroforamen could develop with progressive subsidence of cage in time. Third, although we adjusted scan settings of MRI to minimize metal artifact caused by cage and screws, it is still possible that distortion of MR images might affect the result of the current study.

Conclusion

Foraminal stenosis in grade I isthmic spondylolisthesis can be effectively decompressed by ALIF with percutaneous pedicle screw fixation.

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