

Clinical Article

Unilateral Extrapedicular Vertebroplasty and Kyphoplasty in Lumbar Compression Fractures : Technique, Anatomy and Preliminary Results

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Objective : A single balloon extrapedicular kyphoplasty has been introduced as one of the unilateral approaches for thoracic compression fractures; however, the unilateral extrapedicular technique in the lumbar area needs a further understanding of structures in the lumbar area. The purpose of the present study is to describe methods and pitfalls of this procedure based on the anatomy of the lumbar area and to analyze clinical outcome and complications.

Methods : Anatomical evaluation was performed with 2 human cadavers. A retrospective review of unilateral extrapedicular approaches yielded 74 vertebral levels in 55 patients that were treated with unilateral extrapedicular vertebroplasty and kyphoplasty. Radiographic assessment included the restoration rate of vertebral height and correction of kyphosis.

Results : Anatomical evaluation indicates that the safe needle entry zone of bone for the extrapedicular approach was located in the supero-lateral aspect of the junction between the pedicle and vertebral body. The unilateral extrapedicular procedure achieved adequate pain relief with a mean decrease in pain severity of 7.25 ± 1.5 and 2.0 ± 1.4 , respectively. Complications were 1 retroperitoneal hematoma, 6 unilateral fillings and 3 epidural leak of the polymethylmethacrylate.

Conclusion : The method of a unilateral extrapedicular approach in kyphoplasty and vertebroplasty in the lumbar area might be similar to that in thoracic approach using a route via the extrapedicular space. However, different anatomical characteristics of the lumbar area should be considered.

Key Words : Kyphoplasty · Vertebroplasty · Anatomy · Lumbar vertebra · Complications · Outcome.

INTRODUCTION

Since the first report of vertebroplasty in 1987, the use of percutaneous vertebroplasty and kyphoplasty for the treatment of osteoporotic vertebral fractures has been dramatically increased during the last 20 years and various approach methods were developed to access a fractured vertebral body^{5,11,14}. A single balloon extrapedicular kyphoplasty has been already introduced as a unilateral approach for compression fracture (transcostovertebral kyphoplasty). However, previous studies have reported on kyphoplasty for the thoracic vertebra and explained methods for the thoracic area^{2,21}. There was a study in 2002 in the lit-

erature on the effect and method of unilateral vertebroplasty on the lumbar compression fracture, but it did not explain the detailed anatomical characteristics of the lumbar vertebra and it was also a transpedicular method for vertebroplasty¹¹. While the authors utilized the unilateral extrapedicular approach, it was found that there were different anatomical characteristics between the lumbar and thoracic areas. Therefore, clinicians should be aware of these differences to avoid complications. The purpose of the present study is to describe the methods and pitfalls of this procedure based on the anatomy of the lumbar area and to analyze clinical outcomes and complications.

MATERIALS AND METHODS

This retrospective study was approved by the Institutional Review Board of Hallym University College of Medicine. The 55 consecutive patients (M : F=15 : 40) who underwent percutaneous extrapedicular unilateral kyphoplasty or vertebroplasty for painful osteoporotic vertebral compression fractures at the 74

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lumbar levels between March 2006 and December 2009. All patients had persistent dorsal pain which did not respond to conservative treatment. Their diagnoses were confirmed by plain radiography and magnetic resonance imaging (MRI). Two cadavers aged 66 and 68 years (1 latex injected fresh cadaver and 1 embalmed cadaver) were used for anatomical evaluation.

Surgical technique

The operative procedure was performed under aseptic conditions in an operating room while blood pressure, heart rate, electrocardiography, and pulse oximetry parameters were continuously monitored.

The patient was placed in the prone position. Before the procedures, 25 mg of Demerol was injected intravenously to control pain. A fluoroscopic machine was used for viewing the antero-posterior and lateral projections of the spine. Usually, a right-handed operator stood on the left side of a patient for a left-side approach.

The operation started with a small stab incision. The skin entry point was determined from the axial image of preoperative MRI or computed tomography at the target level. The authors recommended targeting the tip of a needle in the vertebra was in the mid-line and anterior one-third of the vertebral body for

vertebroplasty and in the center of the body for balloon kyphoplasty (Fig. 1). The trajectory line was made between the target point of the needle tip and the skin entry point through the transverse process (TP). Once the skin incision for the entry point was made, adjusting the direction of the needle was limited due to large lumbar dorsal muscles which were larger than thoracic muscles. Since there was no protecting structure or bed-plate as a landmark such as the rib in cases of the thoracic level, the TP was important. The incision wound for the skin entry point was mostly located about 1-3 cm lateral to the tip of the left TP on the antero-posterior (AP) view of the lumbar spine. A disposable 11-gauge bone marrow needle (Manan Medical, Northbrook, IL, USA) should be aimed at the medial one-third of the left TP. When the needle tip reached the cortex of the left TP, it overstrode the superior margin of the TP and went forward scratching the supero-lateral cortex of the pedicle. At this point, the patient should be questioned whether radiating pain was felt because the nerve root passed nearby. The needle tip could be located at the supero-lateral junction between the pedicle and vertebral body. After penetrating the cortex, minor adjustments might be required as the needle was directed to the target point. The needle was inserted through the cortex by tapping its back end with a hammer. If the end of the needle reached the inside boundary of the ipsilateral pedicle in the AP view, the lateral view should be checked to see if the end of the needle did not compromise the spinal canal, and safely arrived inside the vertebral body. The entry point of bone was usually made at lateral or supero-lateral wall of the pedicle and there was no artery or nerve (Fig. 2A, B, 3A).

If the end of the needle arrived around the posterior one-fourth of the body, a guide wire was inserted through the bone marrow needle and forwarded up to the anterior two-third of the body. Instead of the bone marrow needle, a working channel was placed along the guide wire inside the vertebral body.

After the guide wire was removed, vertebroplasty or balloon kyphoplasty was performed by the usual method as described previously^{2,11,14,21}.

Image interpretation

Preoperative and postoperative imaging studies were observed to analyze the degree of vertebral height restoration and improving kyphotic deformity. The anterior and middle height of fractured vertebral body and normal vertebral bodies were measured from the lateral projection radiographs. The degree of compression fracture was expressed as the percentages of estimated pre-traumatic vertebral height. The height of a pre-traumatic vertebra was calculated by the mean of the measurements from the nearest un-fractured vertebra below the fracture site. The height restoration ratio was calculated using a method introduced by McKiernan et al.¹⁶ Kyphotic angle from the lateral radiographs was calculated using the Cobb's method; measurements were taken from the superior endplate of the vertebra one level above the treated vertebra to the inferior endplate of

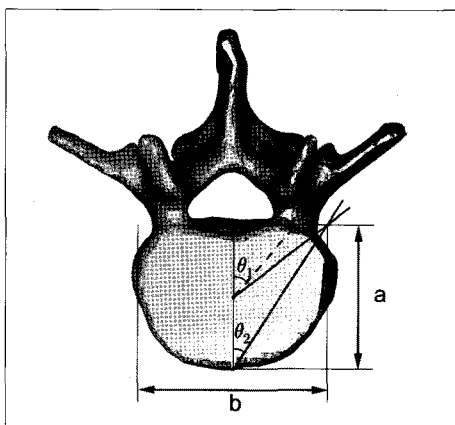


Fig. 1. Needle angle can be calculated; $\theta_1 = \tan^{-1} (b/a) \times 180/\pi = \tan^{-1} (b/a) \times 57.2957$ where, $\theta_2 = \tan^{-1} [(b/2) \times a] \times 57.2957$; The θ_1 for kyphoplasty and angles between θ_1 and θ_2 for vertebroplasty can be adequate. In the lower lumbar area, the lateral wall of the pedicle (dotted line) can be used for an entry point due to the greater width of the lower lumbar pedicle.

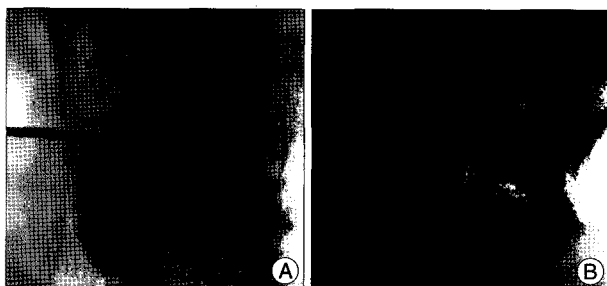


Fig. 2. Radiographs shows fluoroscopic images at the bone entry point. The needle is anchored at the superolateral area of the pedicle. An anteroposterior view (A) and a lateral view (B).

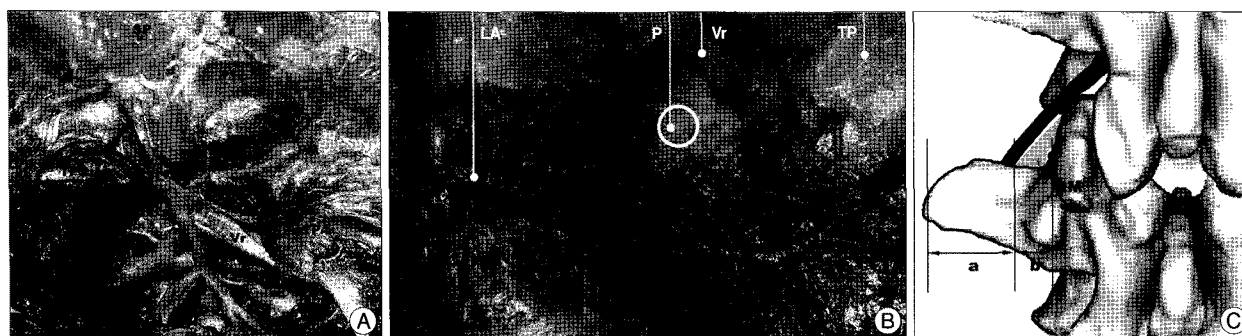


Fig. 3. Cadaveric dissection. A : Photograph shows the left posterolateral view of the extraforaminal area of L3-4. B : Photograph shows the anterior view of the left side of the L3 vertebra. The lateral wall of the pedicle has no vascular structure (white circle). C : Schematic discription shows the safe entry zone of lateral pedicle area (gray colored area). SP : spinous process, TP : transverse process, SF : sperior articular process of L4, D : intervertebral disc, YL : Y-ligament, LA : lumbar segmental artery, A : anastomotic branch, PM : posertomedial branch of lumbar artery, PL : posterolateral branch of the lumbar artery, Vr : ventral ramus, Dr : dorsal ramus.

the vertebra one level below the treated vertebra.

Clinical follow-up

The outcome data were obtained by VAS (visual analogue scale; ranged 0-10) before surgery, immediately after surgery and then every 4 weeks. If symptom of patients were change between the latest score, patients were questioned about the detailed change and the moment of the change. All data including imaging studies were statistically analyzed. Statistical verification was determined using SPSS statistic software, version 13.0 (SPSS, Inc., Chicago, IL, USA). A *p* value of <0.05 was considered statistically significant.

RESULTS

Anatomical characteristics around the entry zone

The cadaveric dissection was focused on nervous and vascular structures around the entry zone into the vertebral body at the lumbar level. The ventral ramus went out anterolaterally from the superior part of the intervertebral foramen and traversed the posterolateral aspect of the intervertebral disc. The ventral ramus passed inferolaterally and crossed the transverse process of the inferior vertebra near the mid-point of the process. The posteromedial branch traversed the inferolateral area of the facet joint and was passed into the fibrous capsule of the facet joint (Fig. 3A). The segmental lumbar arteries sprouted from the abdominal aorta and iliac artery and went around the vertebral body and passed beneath the psoas muscle. The segmental lumbar artery was regularly located at the mid-point of the vertebral body when it crossed the anterior margin of the psoas muscle (Fig. 3B). Then, it supplied muscular branches to the psoas muscle and went inferoposteriorly directed to the intervertebral foramen. The segmental artery gave off an anastomotic branch inferiorly just before entering at the anterior area of the extraforaminal area. The segmental lumbar artery divided into a branch to the lateral area and a posteromedial branch accompanying the posteromedial branch of the dorsal ramus. There were no vital vessels in the lateral aspect of the pedicle (Fig. 3B). The boundary

Table 1. Summary of patient profile

Patients (M : F)	55 (15 : 40)
Levels	74
Age (year)	72 (53-90)
BMD (T-score)	-3.24 (\pm 1.05)
Symptom period (week)	5.1 (\pm 4.1)
Follow-period (month)	17.5 (2-44)
KP/VP	28/46
Cement volume	5.12 (\pm 1.47)

BMD : bone mineral density, KP : kyphoplasty, VP : vertebroplasty

of a safe zone for the needle entry into the extraforaminal area was located medial to one-third of the superior margin of the transverse process and the most favorable area of bone entry zone was in the superolateral aspect of the pedicle (Fig. 3B, C).

Clinical outcome

The clinical data of the patients are summarized in Table 1. The distribution of lesions were 27 (36.5%), 21 (28.4%), 10 (13.5%), 12 (16.2%) and 4 (5.4%) in the L1, L2, L3, L4 and L5, respectively. The mean (\pm SD) amount of the polymethylmethacrylate (PMMA) (Vertebroplastic Radiopaque Resinous Material, DePuyAcroMed Inc., Raynham, MA, USA) was 5.12 (\pm 1.47) mL. The VAS score was significantly decreased from a preoperative value of 7.24 (\pm 1.50) to a postoperative value of 2 (\pm 1.40) (*p*<0.01). There was no difference in relief of pain between the 2 procedures (Table 2). Postoperative nonsteroidal anti-inflammatory drug (NASID) or opioid medication for controlling remnant pain was prescribed for 5.9 (\pm 6.04) weeks. Approximately 94.8% of patients showed favorable results with considerable relief of pain.

Radiographic assessment

Radiographic height loss and kyphotic deformities were obtained from 74 levels (kyphoplasty : n=28, vertebroplasty : n=46) treated by kyphoplasty or vertebroplasty. The mean preoperative segmental kyphosis was 11.6° (\pm 7.90°) and 8.6° (\pm 7.26°) in kyphoplasty and vertebroplasty, respectively, and the mean postop-

Table 2. Outcomes of vertebroplasty and kyphoplasty

	Vertebroplasty	Kyphoplasty
Preoperative VAS	7.2±0.87	7.7±1.01
Postoperative VAS	2.1±1.50	2.0±1.28
PMMA leakage into neural canal	0	3 (10.7%)
Retroperitoneal hematoma	0	1 (Kidney injury, 3.5%)
Adjacent level Fracture	4 (8.7%)	0
Fused with adjacent Level	1 (2.2%)	5 (17.9%)
Bilateral approach due to unilateral filling	3 (6.5%, L5 : 3)	3 (10.7%, L1 : 3)

VAS : visual analogue scale

Table 3. Reported restoration of height and reduction of kyphotic angle in the lumbar vertebra

Source	Level	Compression Reporting method*	Height recovery (%)	Preop Kyphotic angle (°)	Angle reduction (°)	Approach (B/U)
Lieberman (2001) ¹⁴	T, T-L	Method 3	35 (46.8), Hm	-	-	B
Theodorou (2002) ²²	T/L	Method 4	13, Ha	25.5	9.9	B
Guitanis (2005) ⁴³	T/L	Method 4	14, Ha	15.8	7.9	B
Park (2005) ¹⁹	T/L	Method 3	53, Ha	11	3.6	B
Ryu (2007) ²¹	T/L	Method 3	31.7±21, Ha	16.1	7.2	U
Lee (2007) ¹³	L	Method 4	13, Ha	-	6.9	B
Present study	L (K)	Method 4	11.1±15.1, Ha	11.68	6	U
	L (K)	Method 4	12.8±12.2, Hm			U
	L (V)	Method 4	5.01±9.9, Ha	8.6	4.4	
	L (V)	Method 4	8.6±13.7, Hm			

*Reference : Fergus McKiernan, et al. Reporting Height Restoration in Vertebral Compression Fractures. Spine 28(22) 2517-2521, Ha : anterior vertebral body height, Hm : middle vertebral body height, B : bilateral, U : unilateral

erative segmental kyphosis was 5.9° (±6.35°) and 5.34° (±6.34°) in kyphoplasty and vertebroplasty, respectively. The mean restoration rate of anterior body height was 11.1%, (±15.1% : from 23.46% to 11.27%) after the kyphoplasty and 5.0% (±9.9% : from 34.99% to 19.69%) after vertebroplasty (Table 3). There were significant restoration of height and reduction of kyphotic angle (p=0.000).

Postoperative complications

Epidural cement leakage was noted in 3 cases (4.1%) by postoperative plain radiography, but there were no neurological deficits. One case (1.4%) of retroperitoneal hemorrhage occurred after kyphoplasty due to kidney injury. The unilateral approach was failed in 6 cases (8.1% : 3 at L1 and 3 at L5) due to unilateral filling. Adjacent fractures developed in 4 case (5.4%) during the follow-up period (44 months).

DISCUSSION

Vertebroplasty and kyphoplasty are not only relatively simple procedures, but also less traumatic procedures for VCF as compared to extensive stabilization surgery. Several techniques have been developed for simpler and safer procedures during the last 2 decades^{2,7,8,11,21}.

The high-pressure injection of low viscosity of PMMA has

potential risk for neural compromise and pulmonary embolism by uncontrolled leakage. Therefore, balloon kyphoplasty and vertebroplasty using a large cannula low-pressure injection of PMMA in a high viscosity state (so called osteoplasty) has been introduced^{6,10,14}. Later, the unilateral single balloon technique (via the unipedicular, or extrapedicular route) has been developed. This technique reduces trauma to the patient, procedure time, costs and radiation exposure of a patient and an operator^{2,7,8,17,20,21}. In particular, the needle traverses a short distance of the bony structure in the extrapedicular approach, therefore, this approach causes less pain as compared to transpedicular approach and can avoid the sclerotic area of the vertebra. In the literature, there exists a detailed anatomical understanding at the thoracic level, but not the lumbar level.

It is well known that the anatomical dimensions of the lumbar vertebra are different from those of the thoracic vertebra due to the greater width of the lumbar vertebra^{15,18,24}. In the unilateral

approach, the location of cement is important mechanically although unilateral filling can control clinical pain. Even the pedicle of the lumbar vertebra is converged and the width of pedicle is greater than that of the thoracic vertebra, it is inevitable to travel extrapedicular space for a needle to reach an optimal location for kyphoplasty (for vertebroplasty, it could be performed via the unilateral transpedicular route, but, in some cases, it could not) and the anatomy of extrapedicular space in the lumbar vertebra is different from that of the thoracic area where only the costovertebral joint is present. As described above, far lateral approach can cause the injure of the retroperitoneal organ in a thin patient. A route penetrating inferior to the TP may pass through the arterial trifucation or injure the arterial branch, moreover, a large cannula for kyphoplasty can cause fracture of the TP in osteoporotic patient^{1,12,21,23}. Direct access to the body could also cause injury to an anastomotic arterial branch and the conventional posterolateral approach can transect the posteromedial branch of lumbar artery in the lower lumbar area where the large anastomotic artery network is located (Fig. 3A)^{1,3}. The bone entry point should be located in the supero-lateral wall of the pedicle to sufficient intravertebral length for the safe ballooning and safe anchoring of a working channel (Fig. 1). Retroperitoneal hemorrhage occurred during direct body access because shallow anchoring of a working channel can collapse the weakened lateral wall of an osteopo-

rotic body, subsequently injuring the retroperitoneal organ. The unilateral extrapedicular approach has some limitations in L5 (unilateral filling occurred in 3 of the 4 cases in L5) due to the iliac crest and greater width of the vertebral body.

Our clinical outcome (pain relief) is similar to those of previous studies⁹. Statistically, there was no discrepancy between the kyphoplasty and vertebroplasty groups. The 2 groups showed similar clinical features.

All patients routinely underwent the lateral radiography, and the data of the height restoration and kyphotic angle reduction were collected. Although our data failed to confirm the differences in the significant height restoration rate between the anterior and middle fractured vertebral bodies there was a tendency of height restoration to become greater in the middle area of the vertebral body than in the anterior area ($p=0.051$) and this tendency was similar to that of a previous study¹³. The comparisons of several studies are shown in Table 2. The height restoration of our study can not be compared directly to that of other studies because there is no standard method for height restoration; however, it seems likely that height restoration in the lumbar area is lesser than that of the thoracic area. Lee et al.¹³ used a very similar method and their result of the bilateral procedure is similar to that of our unilateral approach.

CONCLUSION

In this study, unilateral extrapedicular lumbar kyphoplasty/vertebroplasty showed similar clinical outcomes as thoracic cases, therefore it could be a clinically effective treatment of osteoporotic lumbar vertebra compression fractures as unilateral extrapedicular technique for thoracic compression fracture. However, there were considerable anatomical differences between the lumbar and the thoracic vertebra (such as size of the muscle, no protective structure as the costovertebral joint and the rib, the nerve root and vessels, shape of the vertebral body and the iliac crest), and thus these differences should be considered during lumbar operation. We failed to confirm discrepancy of statistical difference in height restoration and the reduction of kyphotic angle between the lumbar and thoracic vertebra. Further study with a larger sample and a longer term follow-up are needed to confirm our results.

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