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Modified Decancellation Posterior Closing-Wedge Osteotomy for Correction of Traumatic Thoracolumbar Kyphotic Deformity: A Cadaveric and Preliminary Clinical Study

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Abstract

Study design: Cadaveric and clinical studies.

Objectives: To investigate the safety and efficiency of modified decancellation posterior closing-wedge osteotomy for traumatic fixed kyphotic deformity of thoracolumbar spine.

Methods: Single-level vertebral osteotomy was performed on two groups of fresh-frozen human cadaveric lumbar spines. Group I underwent conventional decancellation posterior closing-wedge osteotomy, and Group II underwent our modified cancellation posterior closing-wedge osteotomy. Sagittal plane angulation as well as anterior height and distance between the most cephalad and caudal endplate were measured before and after osteotomy. Twenty six cases of old thoracolumbar fractures with spinal cord injury were recruited in this study. The mean age was 35.6 years. The mean time from injury to operation was 25 months ranging from 3 months to 11 years. Prior to the index surgery, 9 patients received conservative treatment, and 17 patients underwent surgical treatment. There was complete paraplegia in 10 cases and incomplete paraplegia in 14 (Frankel B in 2 cases, C 10 and D 2). Two patients had no neurological deficit. All patients suffered from low back pain, the average score of Visual Analog Scale (VAS) was 4.5 (range 2.5-6.0). The patients were found to have a mean remaining kyphotic deformity of 35° (range 20°-75°). According to the deformity angles conventional or modified decancellation posterior closing-wedge osteotomy was performed.

Results: The mean correction was 36° ± 3.6° for Group I and 49° ± 2.0° for Group II. The mean change in anterior height was only 2–4 mm for Group I and II. All cases were followed up for 10 months to 6 years with a mean of 12.5 months. Successful decompression and satisfied correction of kyphosis was noticed. The post-operatively mean angle of kyphosis deformity was 10.8°, ranging from 0° to 40°. Neurological function recovery was noted in 50% of cases. For complete spinal cord injury, 30% of cases had partial recovery (sensation) whereas recovery was observed in 64.3% of cases with incomplete spinal cord injury. The statistical difference between the groups was $p<0.01$. The mean score of visual analog scale (VAS) was 2.3 (range 1.0-3.5) at last follow-up.

Conclusion: The fixed kyphotic deformity of thoracolumbar spine in traumatic spinal cord injury could be treated with conventional or modified decancellation posterior closing-wedge osteotomy. Neurological function recovery and alleviation of low back pain is expected.

Keywords: Thoracolumbar spine; Kyphotic deformity; Osteotomy; Neurological function recovery; Alleviation of low back pain

Introduction

Thoracolumbar fractures are among the commonest levels of spinal trauma [1]. Despite early treatment, some old fractures still suffer from anterior compression and with resulting kyphosis. In case the fractures are associated with spinal cord injury, these deformities may impede restoration of nerve function and cause back pain, which will in turn make sitting and movement of the trunk difficult. Spinal osteotomy is a useful surgical treatment to correct fixed kyphotic deformity of the thoracolumbar spine [1-4]. For the past decade, decancellation osteotomy has been used for the purpose. However, no clinical report is available on the results of the operation for thoracolumbar fractures with spinal cord injuries. In order to investigate the safety and efficiency of the procedure, human cadaveric lumbar spines were used for study and 26 cases of old traumatic thoracolumbar kyphotic deformity with spinal cord injury treated with modified decancellation posterior closing-wedge osteotomy during 1999-2013 were reviewed.

Material and Method

Cadaveric study

Eleven fresh-frozen human cadaveric lumbar spines were harvested and denuded of all soft tissues except for spinal ligaments and discs. Each specimen consisted of three contiguous vertebrae and their intervening discs. There were six specimens from T12 to L2 and five specimens from L3 to L5. All specimens were completely thawed at

room temperature and then divided into two groups. Group I consisted of six specimens that had a decancellation procedure performed on the middle vertebra. The osteotomy was performed by removing all of the posterior elements including the pedicles of the middle vertebra. This was followed by decancellation of the middle vertebral body in a wedge fashion with the apex at the anterior aspect of the vertebral body. The osteotomy was closed posteriorly with collapse of the decancellated body and then stabilized with interspinous wiring (Figure 1) Group II consisted of five specimens that had our modified decancellation procedure performed. The procedure was the same as that for Group II except that the posterior two thirds of the superior endplate of the middle vertebra and the disc above were removed as well (Figure 2). The amount of lordosis or extension achieved with the osteotomy was measured using Cobb angle between the superior endplate of the cephalad vertebra and the inferior endplate of the caudal vertebra [5,6].

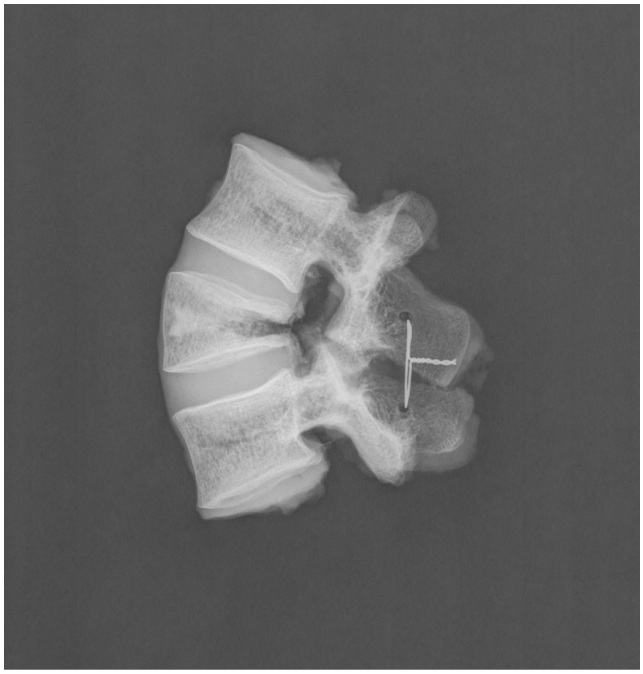

Figure 1: Conventional transpedicular decancellation closing wedge vertebral osteotomy. The osteotomy was closed posteriorly with collapse of the decancellated body and then stabilized with interspinous wiring.

Clinical research

Twenty six patients were included. The patients who can't be followed up face to face were excluded. There were 18 men and 8 women. The average age was 35.6 (range 15-57). The average gap between injury and operation was 25 months (range 3-132 months). The causes of injury were fall from height (11 cases), crash (6 cases) and traffic accident (9 cases). Fracture sites consisted of T11 (9 cases), T12 (10 cases), L1 (6 cases) and L2 (1 case). Seventeen patients had operative treatment before admission to BAMH while the remaining 9 cases had non-operative therapy. All surgically treated patients had undergone laminectomy with internal fixation including Harrington rod (2 cases), Luque rod (3 cases) and pedicle screw (8 cases) respectively except 4 cases.

Of the 26 patients, twenty four had neurological deficit whilst 2 had none. The Frankel grade was A in 10, B in 2, C in 10, D in 2 and E in 2. All 26 patients had low back pain. Their VAS averaged 4.5 (range 2.5-6).

Radiographic examination showed all patients had kyphotic deformity with average Cobb's angle was 35° (range, 20°-75°). Magnetic resonance imaging presented degeneration of spinal cord in 20 cases. Spinal cord compression was seen in 20 cases, by the fractured vertebral body only in 10 cases, by the posterior and lateral elements in 9 whilst by both vertebral body and disc in one.

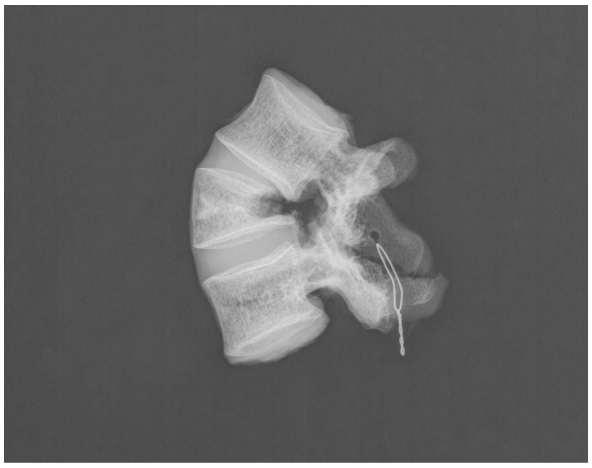

Figure 2: Modified transpedicular decancellation closing wedge vertebral osteotomy. The osteotomy was the same as that conventional transpedicular decancellation closing wedge vertebral osteotomy except that the posterior two thirds of the superior endplate of the middle vertebra and the disc above were removed as well.

Surgical Technique

The patient was placed in a prone position under local or general anesthesia. The affected vertebra and adjacent laminae were exposed through a midline approach. Pedicle screws were placed bilaterally in the pedicles caudal and cephalad to the affected vertebra. Total laminectomy was done to expose the dura and both pedicles and transverse processes of the affected vertebra. Both transverse processes were disrupted and subperiosteal stripping was performed with curved periosteal elevator to the anterior aspect of the vertebra. Wedge osteotomy of the vertebral body was performed with osteotome after removal of pedicles. A margin of 0.5 cm anterior to the apex of the wedge and a slice of the posterior border of the vertebra were preserved. This was followed by decancellation of the vertebral body in a wedge fashion with the apex at the anterior aspect of the vertebral body. After this stage, the remaining part of posterior cortex of the vertebral body was removed. The length of posterior part of the wedge is the difference between anterior border and posterior one of affected vertebra. The decancellation extended to the superior border of the vertebral body if it was involved in the compression. If the superior disc also formed part of the compression, the posterior half of the disc

and the inferior endplate of the cephalad vertebra were also resected. Internal fixation was assembled following closure of the posterior osteotomized gap carefully with presser and then tightened. Spinal fusion was performed in a circumferential fashion around the osteotomized vertebral body or bodies and neural arches of adjacent vertebrae. Autogenous bone chips from previously resected bone were used for the purpose. Negative pressure drainage was placed epidurally and kept for 48 hours. Average blood loss was 600 ml (range 200-1600 ml). The patients were ambulant in a plastic lumbosacral orthosis (LSO) 2 weeks postoperatively.

Statistical Analysis

Statistical analysis of the data was performed using SPSS 17.0 software (SPSS Inc., Chicago, IL US). Continuous variables were compared using a two-sample t test. Grouped variables were evaluated using a Pearson Chi-square test; values of <0.05 were considered significant. Probability values of <0.05 were considered to be significant.

Results

Cadaveric study

The mean correction of kyphosis was 36° ± 3.6° for the standard decancellation osteotomy and 49° ± 2.0° for the modified decancellation osteotomy. The difference between the groups was statistically significant (P=0.0015). The degree of lordosis achieved was significantly greater by modified decancellation osteotomy. For the conventional decancellation the mean increase in distance between the superior endplate of the cephalad vertebra and the inferior endplate of the caudal vertebra along the anterior border of the spine was 3.25 ± 1.23 mm. For the modified decancellation procedure the mean increase was 2.25 ± 0.91 mm. The difference was not statistically significant (P= 0.65).

Clinical research

All patients were followed up in person. Average duration of postoperative follow up was 12.5 months (range 10 months - 6 years). All patients obtained satisfactory decompression and correction of kyphotic deformity. Average postoperative Cobb's angle was 10.8°range 0°-40°and mean angle of correction of kyphosis was 240 (Figure 3). Anterior heights of vertebral canal of all patients were more than 0.8 cm. Thirteen patients50%had one-grade Frankel's recovery of neural functionX2=23.2518, P<0.001. There are 3 patients with complete paraplegia had recovery (sensory function mainly) to grade B, while there are 9 of 14 patients (64.3%) with incomplete paraplegia had variable recovery including sensory and motor function (Table 1). The difference of recovery percentage between complete and incomplete paraplegic patients was significantX2=18.0366, P<0.001. All patients had alleviation of low back pain. Average VAS score was 2.3 (range 1.0-3.5). No neurological deterioration was observed. One patient had superficial infection that healed by change of dressing. Two cases presented with deep vein thrombosis of lower limb that was cured by thrombolysis. Pedicle split resulting from intraoperative instrumental compression in 2 cases caused suboptimal placement of screws without nerve root irritation.

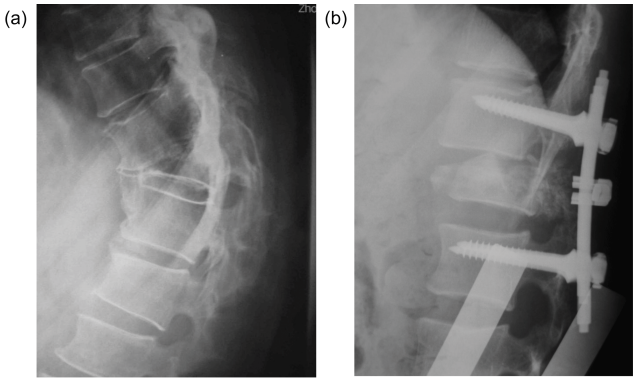

Figure 3: 41-year-old driver who is suffering from severe back pain and inability to work for 1 year. This patient returned to his previous work 9 months postoperatively. (**a**) Preoperation lateral X-ray shows post-traumatic kyphosis of T12 of 50°. (**b**) Lateral X-ray after modified transpedicular decancellation closing wedge vertebral osteotomy shows excellent correction of the deformity to 3°.

Pre operation	cases	Post operation				
		A	B	C	D	E
A	10	7	3	0	0	0
B	2	0	1	1	0	0
C	10	0	0	3	7	0
D	2	0	0	0	1	1
E	2	0	0	0	0	2

Table 1: Comprasion of frankel scores of 26 patients between preoperation and postoperation (case).

Discussion

Kyphosis is a common sequel of neglected or inadequately managed thoracolumbar fractures. Fixed kyphotic deformity of thoracolumbar spine is often accompanied with neurological deficit as a result of traumatic spinal cord injury and low back pain. Canal encroachment may hinder improvement of SCI, while low back pain detrimentally affect sitting and cause pressure sore. Compromise of respiratory function worsens quality of life. Vertebral osteotomy has been considered as an option of surgical treatment of traumatic fixed kyphotic deformity. Smith-Petersen [6] was the first to report the anterior opening-wedge/posterior closing-wedge osteotomy in 1945. This technique was very difficult and required opening of anterior column and closure of posterior column while the pivot point was situated in the middle column. The correction angle can reach 20°-40°. Weatherley [7,8] reported that correction of 45° would result in extension of the anterior border of the spine up to 2 cm. Major vessels anterior to the vertebrae are usually more tightly adhered to them in traumatic fixed kyphotic deformity of the spine. The most dangerous complication of this technique is formation of pseudarthrosis as a result of opening-up of the anterior borders of the affected vertebrae. This may damage the major vessels and pleuroperitoneum by

overstretching and/or kinking. Compared with transpedicular decancellation posterior closing-wedge osteotomy, this technique is more risky. The operative mortality was reported to be 4-10%, and the rate of postoperative neurological deterioration 30%.

Posterior closed wedge vertebral osteotomy is considered a more optimal treatment of traumatic kyphotic deformity of the spine which can result in satisfactory decompression and correction. Spinal stability and fusion after osteotomy can be achieved with very low risk of damaging major vessels. In our cadaveric research, conventional decancellation posterior closing-wedge osteotomy and modified decancellation posterior closing-wedge osteotomy gained correction of 36o and 49° respectively, while increase of anterior border of vertebrae involved was only 2-4 mm. In our clinical study, average correction of deformity was 24o without obvious increase of anterior border of vertebrae except one case (6 mm). The most susceptible site for compression is the superior posterior of affected vertebral body and the adjacent superior disc. Decompression was one of the most important purposes of correction of traumatic kyphotic deformity.

In order to obtain satisfactory result, accurate preoperative measurement of deformity angle and design of osteotomized wedge were essential. According to our experience that 1 mm osteotomizd slice resulted in 1o correction, the osteotomy should get as close as possible to the antero-superior corner of the most compressed vertebra and only the superior end plate was spared. Posterior half of the cephalad disc and the inferior endplate of the cephalad vertebra could also be resected to increase correction angle to 45°-50°.

Two problems needed attention in carrying out the procedure. One was blood loss while the other nerve injury. Vertebral body is prone to hemorrhage due to its large proportion of cancellous bone. Fortunately, once the time since injury exceeds 6 months as it was in all of our patients, profuse bleeding was rare.

Nerve injury was reported up to 30% after vertebral osteotomy [7,8]. One cause of such damage was intraoperative direct injury. Another was shortening of the middle and posterior column and change of angle and alignment of the vertebrae resulting in narrowing the spinal canal and compromising its reserve space. These changes may distort and impinge the spinal cord. In order to prevent nerve injury, special care was taken in manipulation on the vertebrae. Preservation of the medial wall of the pedicles and a slice of posterior border of the vertebra before completion of the entire procedure of osteotomy proved to be helpful. Osteotome and curette could be used alternatively as convenient. Hypothetically speaking, in case nerve injury occurs after instrumentation during the procedure, posterior decompression should be extended upwards or/and downwards to avoid compression from neural arches of adjacent vertebrae. In this series no additional nerve injury was incurred in spite of maximal correction up to 40°. Because our patients had low activities of daily living due to traumatic kyphotic deformity of the spine, short-segment fixation with pedicle screws supported by postoperative LSO would fulfill patients' needs for daily living. In osteoporotic patients who are prone to pedicle split resulting from intraoperative instrumental compression the procedure may end up with suboptimal placement of screws. It would be highly advisable that multiple-segment fixation be used in these cases to release stress.

It is controversial whether neurological function of the injured spinal cord would recover after decompression in old thoracolumbar spine fracture. Mohanty SP, Venkatram N and others [9,10] reported no correlation between decompression and neurological recovery believing that retropulsed bone fragment could be absorbed through remodeling. But majority hold the view that surgery is indicated if incomplete paraplegia is associated with retropulsion of the fractured vertebral body of T12 or L1. Preoperative MRI was helpful in predicting the prognosis [11]. Patients with mild degeneration of spinal cord or tethering had good prognosis while those with severe degeneration worse. In the latter group, although 3 of the 10 patients recovered to Frankel B, they were only radicular and sensory in nature and did not contribute to meaningful functional improvement.

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