

Comparison of Posterior Unilateral Vertebral Column Resection Versus Posterior Vertebral Column Resection for Severe Thoracolumbar Angular Kyphosis as a Revision Surgical Modality

A Retrospective Cohort Study

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Objective: The objective of this study was to determine the safety and efficacy of posterior unilateral vertebral column resection (PUVCR) as revision surgery for severe thoracolumbar angular kyphosis.

Patients and Methods: This is a retrospective cohort study. Adult patients undergoing revision surgery for severe thoracolumbar angular kyphosis in 2010–2016 with ≥ 2 -year follow-up at our institution were assessed. Perioperative complications and clinical outcomes, including blood loss, operation time, Visual Analog Scale score, Oswestry Disability Index, and preoperative and postoperative kyphotic angles, were analyzed.

Results: This study included 58 patients who were divided into the PUVCR group and the posterior vertebral column resection (PVCr) group. Age ($P=0.810$), sex distribution ($P=0.500$), and vertebrae that underwent surgery ($P=0.638$) were similar in the 2 groups. Shorter mean operation time was observed in the PUVCR group as compared with the PVCr group ($P<0.001$). In addition, less blood loss was recorded in the PUVCR group as compared with the PVCr group ($P=0.001$). There were no significant differences between the 2 groups in a change of Visual Analog Scale scores postoperation versus preoperation ($P=0.961$), and at postoperative 3 months ($P=0.906$), 12 months ($P=0.752$), and 24 months ($P=0.811$) versus postoperation, respectively. There were no significant differences between the 2 groups in Oswestry Disability Index changes postoperation versus preoperation ($P=0.157$), and at postoperative 3 months ($P=0.899$), 12 months ($P=0.947$), and 24 months ($P=0.811$) versus postoperation,

respectively. PUVCR and PVCr were comparable in deformity correction ($P=0.434$) and final angle correction ($P=0.790$). Complication rates in the PUVCR and PVCr groups were 7.1% and 36.7%, respectively.

Conclusion: PUVCR has comparable safety and efficacy to PVCr in treating severe thoracolumbar angular kyphosis, with the advantages of the shorter operation time, less blood loss, and fewer complications.

Key Words: unilateral posterior vertebral column resection, posterior vertebral column resection, unilateral approach

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For patients with spinal deformity, one goal of the initial surgery is to create a fusion¹ in the affected area besides the deformity correction. The patients should be carefully screened and prepared, for the surgery to result in significant relief of pain and fatigue, as well as cosmetic improvement. However, revision surgery may be necessary when deformities progress, for example, symptom persistence or deterioration, development of new or different symptoms, especially severe thoracolumbar angular kyphosis. The revision of kyphotic deformities presents a greater challenge for spine surgeons as compared with the first operation. Moreover, the best surgical option remains controversial, based on the few available studies. Both pedicle subtraction osteotomy surgery and surgery of combined approaches (anteroposterior) may be used as the options for acceptable efficacy, but both have problems such as more traumatic, longer operation time, more blood loss, and complications.^{2,3} Some reports consider posterior vertebral column resection (PVCr) as the prime solution,⁴ but it is also a technically challenging and exhausting procedure with possible risks of major complications. Indeed, surgery-related serious complications are relatively common.^{5–7} Therefore, a simpler operation with reduced risks and complications will be very useful.

To ensure good surgical efficacy and minimize the technical difficulties during the operation, we treated the patients by PVCr through a unilateral-only approach, without involving the contralateral vertebrae and pedicle.

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This method was coined “posterior unilateral vertebral column resection (PUVCR).⁸” In the current study, the safety and efficacy of PUVCR as revision surgery for treating severe thoracolumbar kyphotic deformities was assessed as compared with PVCRC surgery.

PATIENTS AND METHODS

Informed consent was obtained from all patients, and the study was approved by the ethics committee of our hospital.

A retrospective analysis of prospectively collected data of 62 adult patients (age above 18 y), who underwent revision surgery between January 2010 and July 2016, was performed. All the patients were divided into 2 groups according to the different surgical procedures randomly. One was the PUVCR group and the other was the PVCRC group. A 2-year follow-up was required to be included in the study. Inclusion criteria of the study: (1) the kyphotic angle > 60 degrees; (2) the patients who were required to have revision surgery because of back pain with/without unilateral lower extremity neurological symptoms caused by thoracolumbar angular kyphosis; (3) the Osteotomy Classification of the first surgery indicated no osteotomy, grade 1 and 2 osteotomy,⁹ respectively; (4) the first operation failed because of pseudarthrosis,¹⁰ which is due to failed bone fusion as observed by computed tomography (CT) scan. Exclusion criteria of the study: (1) the patients had already received revision surgery before; (2) the patients who needed revision surgery but had neurological symptoms at bilateral lower extremities; (3) the patients could not undergo revision surgery.

The angle of the deformity was measured with lines projected from the upper border of the vertebra above the compressed vertebrae and the lower border of the vertebra below the compressed vertebrae, and severe thoracolumbar angular kyphosis was defined by an angle > 60 degrees. The kyphosis angle was independently measured by 3 doctors with > 2 years of related experience and averaged to obtain the final measurement. Preoperative and postoperative clinical outcome measures included the Visual Analog Scale score, Oswestry Disability Index, and kyphotic angle.

Standing lateral radiographs were needed to evaluate the change of deformity correction angle preoperation and postoperation (patients were allowed out of bed at 7 d after the operation). All patients were asked to undergo follow-up at our clinic at 3, 6, 12, and 24 months postoperation. Standing posterior-anterior and lateral radiographs as well as CT scans were obtained at 3 months postoperation. If the complete fusion of the bone graft was determined by CT, only lateral radiographs were acquired at each subsequent follow-up; otherwise, CT was performed until complete fusion.

Statistical Analysis

Data were analyzed using Statistical Product and Service Solutions software (version 19.0; SPSS Inc., Chicago, IL). Distribution of variables were given as a mean and SD. χ^2 test was used to evaluate sex composition. The intraclass correlation coefficient was used to assess the interobserver reliability of angle measurements. Differences between the 2

groups were analyzed by the Student *t* test. *P*-value < 0.05 was considered to be statistically significant.

Surgical Methods

All revision surgeries were performed under general anesthesia by 2 spinal deformity surgeons at the same institution, who had 30 years of combined surgical experience. Motor evoked potentials and somatosensory evoked potentials were used in each surgery.

The patients were positioned prone on the operating table. In both groups, the patients were exposed from the posterior according to the standard procedure. After removing old implants, pedicle screws were inserted 3 levels above and below the target vertebrae under C-arm guidance. The dura mater was fully exposed after the laminectomy. A rod was placed on one side for temporary stabilization. On the opposite side of the rod, subperiosteal dissection was carefully performed, following the lateral wall of the vertebral body until the anterior aspect. The lateral aspect of the vertebral body and the pedicle were removed by high-speed drill and rongeur. The incision extended to the contralateral side through the medial area after resection of the vertebral body and the affected disks, leaving the posterior wall bone as a “thin shell” in front of the dural sac.

In the PUVCR group, after resecting the contralateral vertebral body in an abrasive way from an oblique direction, the “thin shell” was removed with a reverse-cutting curette. Ipsilateral nerve roots were protected during all procedures. After the stabilizing rod was replaced with the contour corrected rod, a suitable size mesh cage was placed anteriorly (Fig. 1A).

In the PVCRC group, to completely remove the bone or disk, the second rod was placed on the working side which was prebent to fit the shape of the deformity, removing the rod on the other side. Then the “thin shell” was removed with a reverse-cutting curette. The nerve roots were protected

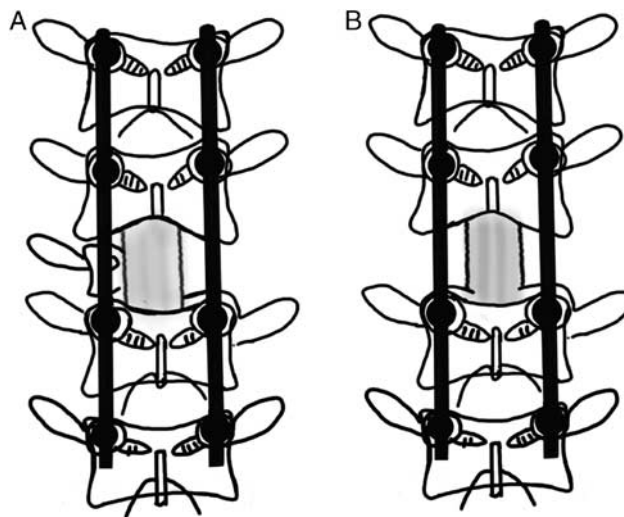


FIGURE 1. In the posterior unilateral vertebral column resection group, the unilateral pedicle and most of the vertebrae and adjacent disks were resected from a side.

TABLE 1. Patient Demographics and Vertebrae Underwent Surgery

Clinical Data	PUVCR Group	PVCR Group	P
Age (mean ± SD)	56 ± 9	58 ± 11	0.810
Sex			0.500
Male	18	22	
Female	10	8	
Vertebrae			0.638
T11	6	8	
T12	12	14	
L1	10	8	

PUVCR indicates posterior unilateral vertebral column resection; PVCRC, posterior vertebral column resection. Statistical significance was set at $P < 0.05$.

from both sides during all procedures. After the stabilizing rod was replaced with the contour corrected rod, a suitable size mesh cage was placed anteriorly (Fig. 1B).

Before closing the wound layer by layer, posterior firm fusion, adequate hemostasis, full irrigation by saline, and suction drain closing were completed. The drains were retained until blood loss was ≤ 50 mL/24 h. Patients were allowed out of bed with a custom-made plastic thoracolumbosacral orthosis brace at the seventh day postoperation. The thoracolumbosacral orthosis brace was kept for 3 months.

RESULTS

A total of 62 patients were included in the current study and 58 patients completed all the follow-ups, the other 4 patients were failed to achieve the bony fusion and underwent the revision surgery again, 2 in the PUVCR group and 2 in the PVCRC group. PUVCR was performed on 30 patients (19 males and 11 females), while PVCRC was performed on 32 patients (23 males and 9 females). Mean ages of patients were 56 ± 9 and 58 ± 11 years in the PUVCR and PVCRC groups, respectively. No statistically significant differences were found in age ($P = 0.810$), sex composition ($P = 0.500$), and the vertebrae that underwent surgery ($P = 0.638$) (Table 1). The interobserver reliability of angle measurements was very good ($\kappa = 0.863$).

All surgeries were successfully completed in both groups, and dural tear was found in 2 cases of the PUVCR group. In the PVCRC group, intraoperative nerve root impingement occurred in 6 cases, and dural tear was found in 5 cases. The complication rates were 7.1% vs. 36.7% (PUVCR

TABLE 2. Operation Time and Blood Loss

Operation Data	PUVCR Group (Mean ± SD)	PVCR Group (Mean ± SD)	P
Operation time (min)	187.13 ± 18.25	252.33 ± 34.73	< 0.001
Blood loss (mL)	818.50 ± 63.10	986.25 ± 114.68	0.001
Complication rates [n/N (%)]	2/28 (7.1)	11/30 (36.7)	0.011

PUVCR indicates posterior unilateral vertebral column resection; PVCRC, posterior vertebral column resection. Statistical significance was set at $P < 0.05$.

TABLE 3. Preoperative and Postoperative Clinical Results

Change of Clinical Results	PUVCR Group (Mean ± SD)	PVCR Group (Mean ± SD)	P
Change of VAS			
Postoperative vs. preoperative	3.88 ± 1.81	3.92 ± 1.88	0.961
3 mo postoperative vs. postoperative	1.63 ± 0.74	1.67 ± 0.78	0.906
12 mo postoperative vs. postoperative	2.13 ± 0.83	2.25 ± 0.87	0.752
24 mo postoperative vs. postoperative	2.25 ± 0.71	2.33 ± 0.78	0.811
Change of ODI			
Postoperative vs. preoperative (%)	23.20 ± 10.99	31.98 ± 14.18	0.157
3 mo postoperative vs. postoperative	6.40 ± 3.37	6.65 ± 4.73	0.899
12 mo postoperative vs. postoperative	10.40 ± 5.01	10.55 ± 4.72	0.947
24 mo postoperative vs. postoperative	14.40 ± 4.91	15.03 ± 6.18	0.811
Change of kyphotic angle			
Postoperative vs. preoperative (deg.)	47.50 ± 4.63	49.08 ± 4.14	0.434
3 mo postoperative vs. postoperative*	1.25 ± 1.16	1.50 ± 1.51	0.697
12 mo postoperative vs. postoperative*	2.13 ± 2.10	2.42 ± 2.07	0.762
24 mo postoperative vs. postoperative*	2.38 ± 2.33	2.67 ± 2.39	0.790

*Means kyphotic angle loss.

ODI indicates Oswestry Disability Index; PUVCR, posterior unilateral vertebral column resection; PVCRC, posterior vertebral column resection; VAS, Visual Analog Scale.

Statistical significance was set at $P < 0.05$.

vs. PVCRC), $P = 0.011$. The mean operating time was shorter in the PUVCR group as compared with the PVCRC group (187.13 ± 18.25 vs. 252.33 ± 34.73 min; $P < 0.001$). In addition, less severe blood loss was recorded in the PUVCR group as compared with the PVCRC group (818.50 ± 63.10 vs. 986.25 ± 114.68 mL; $P = 0.001$) (Table 2).

No statistically significant differences were found in Visual Analog Scale score change, Oswestry Disability Index change, and kyphotic angle change between the 2 groups during the follow-up period (Table 3). Bony fusion was achieved in 58 patients, reflected by the presence of trabecular bone bridge at the osteotomy area in 2-year follow-up; no pseudarthrosis and instrumentation-related failure occurred during the follow-up period. (A case of PUVCR showed in Figs. 2A–E.)

DISCUSSION

The decision to perform revision surgery in patients with severe thoracolumbar angular kyphosis is a common dilemma for spinal deformity surgeons and can be very challenging. Therefore, the treating surgeon must weigh the risks and benefits of the revision surgery. Most studies focused on key factors in revision surgery such as patient selection, ways to deal with pseudarthrosis, number of levels fused, etc.,^{11,12} but few have assessed the surgical strategy.

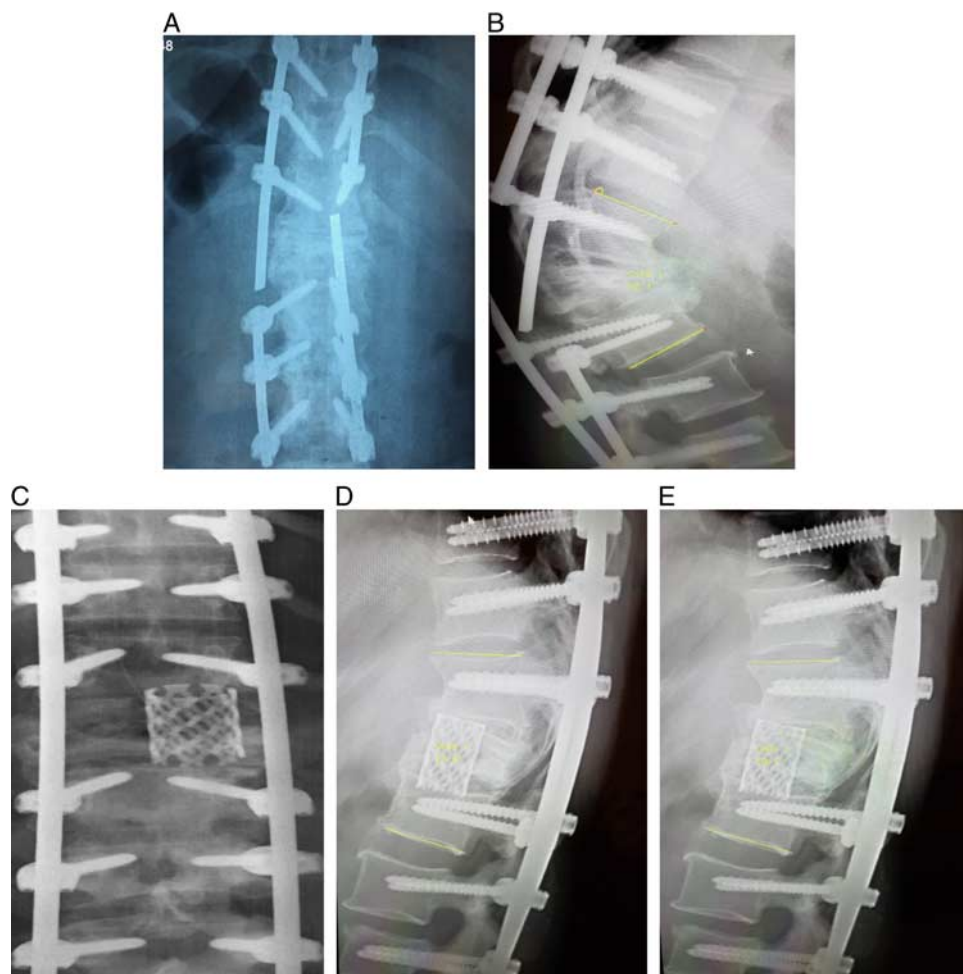


FIGURE 2. In the posterior vertebral column resection group, bilateral pedicle, and the whole vertebrae and adjacent disks were completely resected through 2 sides. A 56-year-old woman with severe kyphotic deformity due to failed first surgery. A, Preoperative x-ray image (anteroposterior). B, Severe compression of the L1 vertebrae by x-ray (lateral); the Cobb angle is 62.1 degrees. C, Postoperative x-ray image (anteroposterior) at 7 days showing removed left side of the L1 vertebrae and rebuilding with a mesh cage; the right side of the vertebrae was partially shifted left. D, Postoperative x-ray image (lateral) at 7 days showing the Cobb angle at 17.6 degrees, with overt correction of the L1 vertebrae. E, Postoperative x-ray image (lateral) at 2 years showing 1.5 degrees of kyphotic angle lost; the Cobb angle was 19.1 degrees then.

PVCR, as an alternative strategy for vertebral column resection, requires a posterior bilateral approach and has a shorter operation time and reduced blood loss as compared with the traditional vertebral column resection.^{13–15} Yang et al⁶ demonstrated that as the first operative approach, the overall prevalence of PVCR complications was 32%, with the most common being neurological complications (8%). Chen and Dai⁴ reported a 40% complication rate with PVCR as a revision strategy, which is similar to the above rate for PVCR as revision surgery (36.7%), but significantly higher than that of PUVCR complications (7.1%). Formica et al¹⁶ used extreme lateral access in revision surgery, which could not significantly contribute to deformity correction.

In the current study, the PUVCR technique, as a simplified surgical procedure as compared with the traditional

PVCR, could shorten operation time, lower blood loss, and reduce the risk of neurological injury, while achieving the same surgical efficacy.

The PUVCR has its unique advantages. For revision surgery, due to surgical scars left by the first operation, the anatomic structure is disordered, and it is difficult to find normal anatomic landmarks. Therefore, surgical time and blood loss would increase with additional exposition difficulty. To minimize the impact of the previous surgery, only one side was exposed and decompressed during the PUVCR in this study, thereby reducing the invasion of the spinal canal and the nonexposed side, which resulted in less time needed for hemostasis and protected the segmental veins. Therefore, PUVCR could reduce operation time and blood loss. As for surgical risks and complications, due to adhesion caused by the previous surgical scar, nerve stimulation is increased in the revision surgery.

In PUVCR, given the unilateral approach, the opposite side of the vertebrae is approached in an extremely inclined direction, and finally, most of the opposite side is decompressed, thereby achieving a decompression range of 300–320 degrees. Although it is impossible to achieve 360 degrees decompression, in the whole process, the nerve vessels on only one side need to be protected, with no stimulation on the contralateral nerve vessels, thus reducing the odds of risks and complications.

Whether the difference in decompression scope overtly affects the clinical outcome remains unclear based on previous reports. Our follow-up data showed no significant differences in correction results, both at 1 week and 2 years postoperation. Indeed, both groups obtained and maintained ≥ 45 degrees correction without significant correction loss. Therefore, we inferred that the osteotomy scope is not a key factor in the correction of sagittal deformities. Kyphotic deformities lead to neurological dysfunction and back pain, which can be relieved by kyphotic deformity correction,¹⁷ independent of the osteotomy scope. Therefore, PUVCR remains a suitable choice for surgeons despite its smaller osteotomy range.

In this study, PUVCR for revision surgery due to failed first operation resulted in significantly reduced kyphotic angle, with satisfactory results for up to 2 years. Our primary results showed that this technique is a suitable choice as revision surgery for severe kyphotic deformity. However, this study had some limitations. First, this was not a randomized controlled study, and thus could not accurately assess whether or not PUVCR is always warranted. Second, larger sample size and long-term follow-up are needed to verify the effectiveness and safety of this method.

CONCLUSIONS

The PUVCR technique may not be the only solution for severe thoracolumbar angular kyphosis as a revision surgical strategy; however, it is a viable option with less operation time and blood loss and reduced risks and complications. Importantly, PUVCR has the same effect as PVCRC in deformity correction.

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