Short-segment decompression/fusion versus long-segment decompression/fusion and osteotomy for Lenke-Silva type VI adult degenerative scoliosis

Hao-Cong Zhang, Hai-Long Yu, Hui-Feng Yang, Peng-Fei Sun, Hao-Tian Wu, Yang Zhan, Zheng Wang, Liang-Bi Xiang

1Department of Orthopaedics, The General Hospital of Northern Theater Command, Shenyang, Liaoning 110016, China;
2Department of Orthopaedics, Chinese PLA General Hospital, Beijing 100853, China.

Abstract

Background: The effect of short-segment decompression/fusion versus long-segment decompression/fusion and osteotomy for Lenke-Silva type VI adult degenerative scoliosis (ADS) has not been clarified. This study aimed to compare the clinical and radiographic results of short-segment fusion vs. long-segment fusion and osteotomy for patients with Lenke-Silva type VI ADS.

Methods: Data of 28 patients who underwent spinal surgery for ADS from January 2012 to January 2014 in the General Hospital of Northern Theater Command were reviewed. Of the 28 patients, 12 received short-segment fusion and osteotomy and 16 received short-segment fusion. Radiographic imaging parameters and clinical outcomes, including the sagittal vertical axis (SVA), lumbar lordosis (LL) angle, pelvic tilt (PT), sacral slope (SS), the visual analog scale (VAS), Japanese Orthopedic Association (JOA), Oswestry disability index (ODI), and lumbar stiffness disability index (LSDI) scores, were recorded. The difference between groups was compared using the dependent t test or Chi-squared test.

Results: The Cobb and LL angles and SVA improved in both groups; however, PT and SS angles did not improve following short fusion. There were significant differences in the post-operative SVA (26.8 ± 5.4 mm vs. 47.5 ± 7.6 mm, t = –8.066, P < 0.001), PT (14.7 ± 1.8° vs. 29.1 ± 3.4°, t = –13.277, P < 0.001), and SS (39.8 ± 7.2° vs. 26.1 ± 3.3°, t = 6.175, P < 0.001) between the long and short fusion groups. All patients had improved ODI, JOA, and VAS scores post-operatively (all P < 0.001), with no significant difference between the groups (all P > 0.05). The post-operative LSDI score was 3.5 ± 0.5 in the long fusion group, which was significantly higher than that of the short fusion group (1.4 ± 0.7; P < 0.001).

Conclusions: The clinical outcomes of patients with Lenke-Silva type VI ADS who underwent short-segment decompression/fusion were comparable to those of patients who underwent long-segment decompression/fusion and osteotomy despite poor correction of sagittal imbalance. Moreover, short-segment decompression/fusion showed a shorter operation time and reduced surgical trauma.

Keywords: Degenerative scoliosis; Short fusion; Long fusion; Spine surgery; Lenke-Silva type VI

Introduction

Adult degenerative scoliosis (ADS), typically defined as a curvature >10° using the Cobb method, is a common spinal deformity in a skeletally mature individual. It is a process of degenerative changes of the disks and facets leading to progressive deformity in three dimensions: the coronal, sagittal, and axial planes. Its prevalence has been reported in 9% of the middle-aged patients (>40 years) who have exhibited scoliosis, with a far higher rate of 68% in the elderly asymptomatic population (>60 years). Patients with ADS usually present symptoms of spinal stenosis, aggravated back pain, radiculopathy, inability to stand in a normal posture, or a combination of these symptoms. At present, with the rapid increase in the number of elderly Chinese population, ADS is becoming more prevalent with significant impact on health and disability.

Traditionally, non-operative management was initially recommended for patients with ADS with slight curvature and no spinal stenosis. For symptomatic patients with failed non-operative treatment, open decompression and fusion procedures were usually performed using posterior instrumentation with or without inter-body fusion. Silva and Lenke proposed six levels of treatment for ADS based on patient symptoms and radiographic findings as follows: level I, simple posterior lumbar decompression and fusion with decompression; level II, short-segment decompression and fusion with decompression and osteotomy; level III, long-segment decompression and fusion with decompression and osteotomy; level IV, short-segment decompression and fusion with decompression and osteotomy; level V, long-segment decompression and fusion with decompression and osteotomy; and level VI, short-segment decompression and fusion with decompression and osteotomy. The Lenke-Silva type VI ADS is a common type of ADS, and it is important to develop effective treatments for this type. This study aimed to compare the clinical and radiographic results of short-segment fusion vs. long-segment fusion and osteotomy for patients with Lenke-Silva type VI ADS.
without fusion; level II, decompression and limited instrumented posterior spinal fusion; level III, decompression and posterior long-segment fixation and fusion; level IV, posterior lumbar decompression with anterior and posterior fusion; level V, thoracic instrumentation and fusion extension; and level VI, decompression and osteotomies for specific deformities and posterior fusion. Patients with Lenke-Silva treatment level VI ADS characterized by low back pain, Cobb angle > 30°, flexibility < 30%, detachment > 2 mm, lateral slippage > 6 mm, and sagittal vertical axis (SVA) > 50 mm are required to undergo long-segment fusion and osteotomies. However, complex surgeries are associated with abundant blood loss and substantial complication and high risk of nerve damage.[9,10] Among a large number of studies comparing short-segment and long-segment fusion in patients with ADS,[11,12] only a few studies evaluated the curative effect of different fusion approaches for Lenke-Silva treatment level VI ADS. Moreover, under the premise of ensuring good post-operative results, minimizing surgical trauma has become a research topic of current DS (degenerative scoliosis) treatment. This study was conducted to compare the clinical and radiographic results of short-segment decompression/fusion vs. long-segment decompression/fusion and osteotomy for patients with Lenke-Silva treatment level VI ADS.

**Methods**

**Ethical approval**

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the General Hospital of Northern Theater Command, Shenyang, China. Informed written consent was obtained from all patients prior to their enrollment in this study.

**Patients**

The retrospective study reviewed a total of 28 patients (6 men and 22 women; mean age of 64.5 ± 4.1 years, range: 55–75 years) who underwent spinal surgery for ADS in our hospital from January 2012 to January 2014. All patients presented with adult scoliosis defined by the coronal Cobb angle above 10° and meeting the diagnostic criteria of Lenke-Silva treatment level VI according to the Lenke-Silva classification for ADS.[1,2] They all exhibited symptoms of nerve root compression and intermittent claudication. The exclusion criteria were as follows: (1) history of previous scoliosis or spinal surgery; (2) spinal lesions including wound, tumor, and infection; and (3) incomplete follow-up data.

Among the 28 patients, 12 patients received long-segment decompression/fusion and osteotomy (long fusion group); 2 men and 10 women; mean age of 64.3 ± 4.1 years), and 16 patients underwent purely short-segment decompression/fusion (short fusion group; 4 men and 12 women; mean age of 64.6 ± 4.7 years). Non-steroidal anti-inflammatory drugs were administered in all patients; however, such drugs were less effective. Moreover, 19 patients (11 in the long-segment fusion group and eight in the short fusion group) who complained of severe lumbodorsal pain were unable to walk for a long period of time and had poor rest.

**Operative procedures and follow-up**

In this study, long fusion was performed in patients who exhibited sagittal imbalance, decreased back muscle strength, and more than two degenerated disk spaces which need to be fixed in multiple segments; patients with dynamic spinal instability and progressive kyphosis; and if the patient can tolerate long-segment fixation and fusion. Short fusion was mostly performed in patients with sagittal imbalance (1) whose spinal muscle strength was acceptable, (2) who had one degenerated disk space, (3) whose thoracic and lumbar kyphosis caused stiffness and had no angular deformity which required no osteotomy, and (4) who were unable to tolerate major surgery caused by poor physical condition. Thus, patients were placed in a prone position for surgical procedures. After disinfection and draping, the muscle tissue was peeled off layer by layer according to the pre-operative positioning incision, and the bilateral vertebral lamina was exposed. The pedicle screw was placed, and spinal canal decompression was performed followed by inter-vertebral exploration, nucleus pulposus removal, and fixation and fusion using inter-body cages. Long-segment fixation reached the upper thoracic spine T10 and lower lumbar vertebrae L5 or S1. According to the pre-operative design, the titanium rods were fused to the spine to correct curvatures, and spine kyphosis was properly corrected. If fluoroscopic findings revealed a good internal fixation position and the orthopedic effect was satisfactory, the surgery was completed and suturing was performed.

Anteroposterior and lateral standing radiographs of the spinal column of each patient were evaluated by two experienced orthopedists before and after the surgery using the Surgimap Spine Imaging Software (version 2.2.9.7, www.surgimap.com; Nemaris Inc., New York, NY, USA).[13] The coronal balance parameter was the lumbar Cobb angle; the sagittal balance parameters consisted of the SVA and lumbar lordosis (LL) angle; and the pelvic parameters included the pelvic tilt (PT), pelvic incidence (PI), and sacral slope (SS). The SVA was the linear distance between the C7 plumb line and sacral posterior angle. Positive balance was defined in the case of the plumb line in the front; otherwise, negative balance was considered.[14] LL was measured as the angle from the upper endplate of L1 to the endplate of S1.[15]

Posterior lumbar decompression and fusion were performed by the same chief physician as previously described.[11] Intraoperative data such as operative time, blood loss volume, decompression segment, and hospital stay were recorded. The patients completed the evaluation questionnaires with the assistance of the resident physician pre-operatively during admission and post-operatively at the last follow-up, including the visual analog scale (VAS) score of skelalgia, the Japanese Orthopedic Association (JOA) score of low back pain,[15] Oswestry disability index (ODI),[16] and lumbar stiffness disability index (LSDI).[17] The full-length standing spinal radiographs were captured during the follow-up sessions at 3, 6, 12, and 18 months.
post-operatively. The average follow-up period was 1.5 years.

Statistical analysis

Data were shown as percentage or mean ± standard deviation and analyzed using the paired or dependent t test and Chi-squared test, respectively. All analyses were performed using the SPSS version 19.0 statistical software (SPSS Inc., Chicago, IL, USA). A P ≤ 0.05 was considered as statistically significant.

Results

As shown in Table 1, patients in the long and short fusion groups were well-matched in terms of gender and age (P > 0.050 for both). The mean duration of long-segment decompression/fusion and osteotomy was 6.9 ± 0.5 h, which was longer than that of short-segment decompression/fusion (4.3 ± 0.9 h, P < 0.001). Patients in the short fusion group had less blood loss volume than that in the long fusion group (571.9 ± 202.5 mL vs. 1162.5 ± 117.3 mL, P < 0.001). No significant difference was observed in the decompression segment between the two operative procedures (P = 0.490). Post-operatively, two patients in the long fusion group suffered from poor wound healing and cerebrospinal fluid leakage. Meanwhile, no complications occurred among patients receiving short-segment decompression/fusion. The mean length of hospital stay following the short-segment decompression/fusion procedure was 10.8 ± 2.3 days, which was shorter than that of long-segment decompression/fusion and osteotomy procedure (P < 0.001).

Table 2 presents the radiographic imaging parameters of the patients. Pre-operative radiography revealed that both...
groups had similar Cobb and LL angles, SVA length, PT, and SS [Figures 1 and 2]. After the surgical treatment, the mean Cobb angle was corrected from $18.9 \pm 4.1^\circ$ to $2.8 \pm 1.4^\circ$ in the long fusion group ($t = 11.044, \ P < 0.001$). The SVA length was $81.2 \pm 15.5 \text{mm}$ and $81.0 \pm 18.0 \text{mm}$ pre-operatively in
the long and short fusion groups, respectively, and decreased to \(26.8 \pm 5.4\) mm and \(47.5 \pm 7.6\) mm post-operatively (\(P < 0.001\) for both). The LL angle decreased from \(-28.1 \pm 5.6^\circ\) pre-operatively to \(-40.8 \pm 5.4^\circ\) post-operatively in the long fusion group and changed from \(-30.5 \pm 3.7^\circ\) to \(-38.5 \pm 3.7^\circ\) in the short fusion group (\(P < 0.001\) for both). The PT and SS angles significantly changed after long-segment decompression/fusion and osteotomy procedure (PT: \(29.3 \pm 3.5^\circ\) vs. \(14.7 \pm 1.8^\circ\), \(P < 0.001\); SS: \(26.9 \pm 5.6^\circ\) vs. \(39.8 \pm 7.2^\circ\), \(P < 0.001\). However, post-operative PT and SS angles were similar with the pre-operative values in the short fusion group (\(P = 0.206\) for both). Furthermore, significant differences were noted in the pre-operative SVA (\(P < 0.001\)), PT (\(P < 0.001\)), and SS (\(P < 0.001\)) between both groups. In addition, there was no significant difference in the mean PI between the long fusion (\(61.0 \pm 3.5^\circ\)) and short fusion groups (\(60.0 \pm 2.8^\circ\), \(P = 0.76\)).

Furthermore, the clinical outcome was analyzed using the ODI, JOA, VAS, and LSDI evaluation questionnaires [Table 3]. Both groups had improved ODI, JOA, and VAS scores after the surgery (\(P < 0.001\) for all), with no significant difference in the above mentioned variables between two groups (\(P > 0.05\) for all). In addition, the post-operative LSDI score was \(3.5 \pm 0.5\) in the long fusion group, which was significantly higher than \(1.4 \pm 0.7\) in the short fusion group (\(P < 0.001\)).

## Discussion

Recently, the surgical treatment of ADS has gradually attracted more attention because of the increasing concerns regarding the high quality of life.\(^{18-20}\) Relief of lower back and radiating pain in the lower extremities along with the correction of the deformity should be the goals of surgical treatment.\(^{11,21}\) Nevertheless, studies have shown that 81% of the total number of patients with ADS were accompanied with the loss of LL. Sagittal imbalance was more related to the clinical symptoms of ADS than spinal coronal imbalance. Hence, correction of sagittal imbalance was equally important as decompression of the stenotic segments.\(^{12-23}\) With the complexity of the disease features of ADS and various best treatment methods for different cases, the surgical treatment strategies of ADS are currently controversial.\(^{14}\)

Classification systems may be of great importance in determining the surgical approach for better disease awareness and development of surgical strategies. Previously, scholars have classified all DS patients using different systems such as the Schwab, Scoliosis Research Society,\(^{26}\) Ploumis, Faldini, Simmons, and coronal imbalance classifications.\(^{14}\) Moreover, the Lenke-Silva classification, a system proposed by Silva and Lenke\(^{21}\) dividing the surgical treatments into six levels, has been the most commonly used system in choosing the type of surgery. In Lenke-Silva type VI ADS, long-segment decompression/fusion and osteotomy are required for correction of sagittal imbalance. However, as patients with ADS are typically quite elderly and usually have comorbidities, the surgery is associated with a high risk of complications and nerve injury. This study evaluated the clinical and radiographic results of short-segment decompression/fusion vs. long-segment decompression/fusion and osteotomy in patients with Lenke-Silva type VI ADS.

In this study, the Cobb and LL angle, SVA length, PT, and SS improved after long-segment decompression/fusion and osteotomy. In contrast, short-segment decompression/fusion had no effect on the PT and SS angles. Significant differences in the post-operative SVA, PT, and SS between the two groups suggested that long-segment decompression/fusion and osteotomy had better efficacy in the correction of sagittal imbalance. This was in contrast with a previous study by Faldini \textit{et al}\(^{12}\) that coronal imbalance was better improved by long fusion than by short fusion.

### Table 3: Pre- and post-operative clinical outcomes of patients with Lenke-Silva level VI degenerative scoliosis.

| Variables                        | Long fusion group (\(n = 12\)) | Short fusion group (\(n = 16\)) | \(t\)   | \(P\)  |
|----------------------------------|--------------------------------|--------------------------------|--------|--------|
| Oswestry disability index        |                                |                                |        |        |
| Pre-operative                    | \(74.2 \pm 6.6\)                | \(72.7 \pm 6.9\)               | 0.555  | 0.580  |
| Post-operative                   | \(19.8 \pm 5.9\)                | \(15.9 \pm 5.8\)               | 1.730  | 0.100  |
| \(t\)                            | 24.277                         | 33.898                         |        |        |
| \(P\)                            | <0.001                         | <0.001                         |        |        |
| Japanese Orthopaedic Association score |                                |                                |        |        |
| Pre-operative                    | \(8.7 \pm 3.0\)                | \(8.9 \pm 2.8\)                | -0.114 | 0.910  |
| Post-operative                   | \(22.1 \pm 2.7\)               | \(22.1 \pm 2.6\)               | 0.020  | 0.980  |
| \(t\)                            | -14.562                        | -15.468                        |        |        |
| \(P\)                            | <0.001                         | <0.001                         |        |        |
| Visual analog scale              |                                |                                |        |        |
| Pre-operative                    | \(7.0 \pm 1.0\)                | \(7.2 \pm 1.4\)                | -0.402 | 0.690  |
| Post-operative                   | \(2.6 \pm 0.8\)                | \(2.7 \pm 1.0\)                | -0.305 | 0.760  |
| \(t\)                            | 14.119                         | 11.309                         |        |        |
| \(P\)                            | <0.001                         | <0.001                         |        |        |
| Lumbar stiffness disability index |                                |                                |        |        |
| Pre-operative                    | \(3.5 \pm 0.5\)                | \(1.4 \pm 0.7\)                | 8.654  | <0.001 |

The data are shown as mean±standard deviation.
Nonetheless, correction of LL and sagittal imbalance was similar in both groups. The inconsistent results might be attributed to the different inclusion of patients, as patients in our study were all classified under the Lenke-Silva treatment level VI. Meanwhile, in our study, these patients received short- or long-segment fusion based on the defined criterion, and they had different Cobb and LL angles. The SS of the two groups was 26.9 ± 5.6° in long-segment fusion group and 27.2 ± 4.2° in short-segment fusion group, and the LL was -40.8 ± 5.4° in long-segment fusion and -38.5 ± 3.7° in short-segment fusion, respectively (P > 0.050). The difference was small and not statistically significant. This was because the previous study in our hospital suggested that the PI-LL value was controlled between 10° and 20°, and the post-operative function of the patient was better than that proposed by Schwab et al. [28,29] which indicated a correction strategy of LL = PI ± 9°. Therefore, the patient’s LL and SS correction rates were small. Hence, the difference in the LL and SS angle between both groups was small.

Being the main goal of surgical treatment, relief of leg and back pain was evaluated using the VAS, JOA, ODI, and LSlD scores. The result revealed that the post-operative ODI, JOA, and VAS scores were all improved during the last follow-up, with no significant difference in the short or long fusion groups. Sagittal imbalance following surgery or proximal junctional kyphosis is a relatively long-term complication in patients with ADS. It usually occurs 1 year after surgery. [28,29] We compared the patient’s pre- and post-operative follow-up data and observed the spinal deformity correction and functional score. The patients were generally reviewed at 18 months post-operatively, and a three-dimensional CT of the spine was performed. After the fusion effect was determined, the patient was no longer examined. It was suggested that short-segment decompression/fusion had equal efficacy with long-segment decompression/fusion and osteotomy in terms of the clinical outcomes, despite poor correction of sagittal imbalance. In addition, the lower LSlD scores in the short fusion group further supported that short-segment decompression/fusion preserved more functions of the lumbar vertebra. In addition, short-segment fixation and fusion had less damage to the posterior spine and lower intraoperative risk and caused less bleeding. More lumbar function was retained after surgery.

Several limitations of our study must be addressed. First, this was a retrospective study and not a randomized control trial. Second, the number of included cases was insufficient because data collection was only performed for 2 years, and Lenke-Silva level VI ADS was infrequently encountered in the clinic. Third, the follow-up period was short. In general, patients were reviewed at 18 months post-operatively, and a three-dimensional CT of the spine was performed. After the fusion effect was determined, the patient was no longer examined. Long-term recovery of sagittal imbalance and operative complications were not observed. Furthermore, data on bone mineral density were not available. Hence, further study is necessary to prospectively collect a large sample of patients with Lenke-Silva type VI ADS from multiple research centers during a long follow-up period and compare the treatment outcomes and operative complications of short-segment decompression/fusion vs. long-segment decompression/fusion and osteotomy. The specific indication of short-segment fusion treatment for these patients remains to be further studied.

In conclusion, the clinical outcomes of patients with Lenke-Silva type VI ADS who underwent short-segment decompression/fusion were comparable to those of patients who underwent long-segment decompression/fusion and osteotomy despite poor correction of sagittal imbalance. Moreover, short-segment decompression/fusion showed a short operation time, and reduced surgical trauma. However, the clinical indication of short-segment decompression/fusion for Lenke-Silva treatment level VI ADS is to be further determined.

Conflicts of interest

None.

References

1. Aebi M. The adult scoliosis. Eur Spine J 2005;14:925–948. doi: 10.1007/s00586-005-1033-9.
2. Silva FE, Lenke LG. Adult degenerative scoliosis: evaluation and management. Neurosurg Focus 2010;28:E1. doi: 10.3171/2010.1. FOCUS09271.
3. Shu B, Koh EY, Ludwig SC. Minimally invasive spine surgery for the treatment of adult degenerative deformity. Semin Spine Surg 2013;25:164–169. doi: 10.1053/j.semss.2013.04.004.
4. Regan C, Kang JD. The role of the minimally invasive extreme lateral interbody fusion procedure for complex spinal reconstruction. Oper Tech Orthop 2013;23:28–32. doi: 10.1053/j.oto.2013.04.002.
5. Schwab F, Dubey A, Gamez L, El Fegoun AB, Hwang K, Pagala M, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine 2005;30:1082–1085. doi: 10.1097/0.00001608.42434.82.
6. Bridwell KH, Lenke LG, Cho SK, Pahys JM, Zebala LP, Dorward IG, et al. Proximal junctional kyphosis in primary adult deformity surgery; evaluation of 20 degrees as a critical angle. Neurosurgery 2013;72:899–906. doi: 10.12772/NEU.00013.e3182B8ad8.
7. Birknes JK, White AP, Albert TJ, Shaffer CI, Harrop JS. Adult degenerative scoliosis: a review. Neurosurgery 2008;63:94–103. doi: 10.1227/01.NEU.0000253485.49323.B2.
8. Everett CR, Patel RK. A systematic literature review of nonsurgical treatment in adult scoliosis. Spine 2007;32:130–134. doi: 10.1097/BRS.0b013e31813aea88.
9. Daubs MD, Lenke LG, Cheh G, Stobbs G, Bridwell KH. Adult spinal deformity surgery: complications and outcomes in patients over age 60. Spine 2007;32:2238–2244. doi: 10.1097/BRs.0b013e318141e24a.
10. Carreon LY, Puno RM, Nd DJ, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar degeneration and arthrodesis in older adults. J Bone Joint Surg Am Volume 2003;85:2089–2092. doi: 10.2106/00004623-200311100-00004.
11. Cho KJ, Suk SI, Park SK, Kim JH, Kim SS, Lee TJ, et al. Short fusion versus long fusion for degenerative lumbar scoliosis. Eur Spine J 2008;17:630–636. doi: 10.1007/s00586-008-0615-z.
12. Faldini C, Martino AD, Borghi R, Perna F, Toscano A, Traina F. Long vs. short fusions for adult lumbar degenerative scoliosis: does balance matter? Eur Spine J 2015;24:163–172. doi: 10.1007/s00586-015-4266-6.
13. Akbar M, Terran J, Ames CP, Lafage V, Schwab F. Use of surgimap spine in sagittal plane analysis, osteotomy planning, and correction calculation. Neurosurg Clin N Am 2013;24:163–172. doi: 10.1016/j. ncc.2012.12.007.
14. Du J, Tang X, Li N, Lin Z, Zhang X. Limited long-segment fusion for degenerative lower lumbar scoliosis: a special kind of scoliosis. Int Orthop 2016;40:1227–1231. doi: 10.1007/s00264-016-3128-0.
15. Fukui M, Chiba K, Kawakami M, Kikuchi S, Konno S, Miyamoto M, et al. Japanese Orthopaedic Association Back Pain Evaluation Questionnaire. Part 2. Verification of its reliability. The Subcommittee on Low Back Pain and Cervical Myelopathy of the Clinical Outcome Committee of the Japanese Orthopaedic Association. J Orthop Sci 2007;12:526–532. doi: 10.1007/s00776-007-1168-4.

16. Fairbank JCT, Pynsent PB. The Oswestry disability index. Spine 2000;25:2940–2953. doi: 10.1097/00007632-200011150-00017.

17. Hart RA, Pro SL, Gundle KR, Marshall LM. Lumbar stiffness as a collateral outcome of spinal arthrodesis: a preliminary clinical study. Spine J 2013;13:150–156. doi: 10.1016/j.spinee.2012.10.014.

18. Schwab FJ, Smith VA, Biserni M, Gamez L, Farcy JP, Pagala M. Adult scoliosis: a quantitative radiographic and clinical analysis. Spine 2002;27:387–392. doi: 10.4172/2165-7939.1000269.

19. Fogelson JL. Adult Scoliosis: treatment and challenges. Chin J Bone Joint 2015;4:167–171. doi: 10.3969/j.issn.2095-252X.2015.03.003.

20. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. Spine 2005;30:682–688. doi: 10.1097/01.brs.0000155425.04536.f7.

21. Hwang DW, Jeon SH, Kim JW, Kim EH, Lee JH, et al. Radiographic progression of degenerative lumbar scoliosis after short segment decompression and fusion. Asian Spine J 2009;3:58–65. doi: 10.4184/asj.2009.3.2.58.

22. Frazier DD, Lipson SJ, Fossil AH, Katz JN. Associations between spinal deformity and outcomes after decompression for spinal stenosis. Spine 1997;22:2025–2029. doi: 10.1097/00007632-199709010-00017.

23. Zeng Y, White AP, Albert TJ, Chen Z. Surgical strategy in adult lumbar scoliosis: the utility of categorization into 2 groups based on primary symptom, each with 2-year minimum follow-up. Spine 1976;37:E56–E561. doi: 10.1097/BRS.0b013e31824a15c6.

24. Jang JS, Lee SH, Min JH, Maeng DH. Changes in sagittal alignment after restoration of lower lumbar lordosis in patients with degenerative flat back syndrome. J Neurosurg Spine 2007;7:387–392. doi: 10.3171/spi.2007.7.4.387.

25. Schwab F, Lafage V, Patel A, Farcy JP. Sagittal plane considerations and the pelvis in the adult patient. Spine 2009;34:1828–1833. doi: 10.1097/brs.0b013e3181a13e08.

26. Schwab F, Ungar B, Blondel B, Buchowski J, Coe J, Deinlein D, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine 2012;37:1077–1082. doi: 10.1097/brs.0b013e31823e15e2.

27. Schwab F, Blondel B, Chay E, Demakakos J, Lenke L, Tropiano P, et al. The comprehensive anatomical spinal osteotomy classification. Neurosurgery 2013;76:S33–S41. doi: 10.1227/ness.0000000000000182.

28. Mendoza-Lattes S, Ries Z, Gao Y, Weinstein SL. Proximal junctional kyphosis in adult reconstructive spine surgery results from incomplete restoration of the lumbar lordosis relative to the magnitude of the thoracic kyphosis. Iowa Orthop J 2011;31:199–206.

29. Glassman SD, Coseo MP, Carreon LY. Sagittal balance is more than just alignment: why PJK remains an unresolved problem. Scoliosis Spinal Disord 2016;11:1. doi: 10.1186/s13013-016-0064-0.

How to cite this article: Zhang HC, Yu HL, Yang HF, Sun PF, Wu HT, Zhan Y, Wang Z, Xiang LB. Short-segment decompression/fusion versus long-segment decompression/fusion and osteotomy for Lenke-Silva type VI adult degenerative scoliosis. Chin Med J 2019;132:2543–2549. doi: 10.1097/CMJ.0000000000000474.