Int J Clin Exp Med 2015;8(5):8129-8134
www.ijcem.com /ISSN:1940-5901/IJCEM0005523

Original Article

Medium to long-term curative effects of long-segmental fixation and fusion on degenerative scoliosis

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Received January 4, 2015; Accepted April 28, 2015; Epub May 15, 2015; Published May 30, 2015

Abstract: Objective: To evaluate the medium to long-term curative effects of surgical long segmental fixation and fusion in degenerative scoliosis (DS). Patients and methods: From January 2001 to December 2011, 56 DS patients underwent long segmental fixation and fusion. Clinical data, including visual analogue scale (VAS) scores, Oswestry disability index (ODI), lumbar lordosis angles, coronary Cobb angles and postoperative complications were followed up for 2 to 12 years postoperatively. Results: VAS and ODI scores were significantly improved 1 year postoperatively compared to the preoperative values ($P = 0.000$). Coronary Cobb angles were significantly improved three months postoperatively ($P = 0.001$) but ≥ 1 year after surgery there was no further significant improvement compared to the preoperative values ($P = 0.585$). The lumbar lordosis angle was not significantly changed postoperatively ($P > 0.05$). Conclusions: Favorable medium to long-term curative effects can be achieved by long segmental fixation and fusion. Ideally, the fixation and fusion segments should be longer than the segments affected by scoliosis. The restoration of the lumbar lordosis angle is the key to rebuilding sagittal balance, which is closely correlated with a patient's clinical symptoms and quality of life.

Keywords: Degeneration, internal fixation, postoperative complications, scoliosis

Introduction

As the population of old people has increased so has the incidence of spinal degenerative diseases, among which degenerative scoliosis (DS) is perhaps the most debilitating [1]. Scoliosis is characterized by spinal canal stenosis, persistent low back and leg pain, as well as intermittent claudication. Most symptoms are not improved by conservative treatments and surgical intervention is usually necessary [2]. Surgical approaches for DS treatments have not been standardized and currently consist mainly of simple decompression as well as short segment or long segment fixation and fusion, all of which have different indications, advantages and disadvantages. Hansraj et al. (2001) proposed that simple decompression without internal fixation would be acceptable for DS patients with back pain when the scoliosis angle was < 20° and no obvious instability existed. Frazier et al. (1997) reported 15 cases of DS with lumbar spinal canal stenosis in patients who had a simple decompression operation without internal fixation. The VAS score was improved 0.5 to 2 years postoperatively while the improvement in the scoliosis angle did not correlate with therapeutic efficacy. Simmons et al. (2001) noted that decompression of the spinal stenosis segments, and distraction at the concave scoliosis side combined with short segmental fixation and fusion, achieved good results in DS patients with slight vertebral rotation. Currently, most research has focused on the efficacy of short-term curative procedures, but medium to long-term curative efficacies have not been studied in detail. In the present study, we have analyzed the outcome of long segmental DS fixation and fusion treatments for periods of 2 to 12 years, to evaluate the medium to long-term curative efficacies of interventions in order to establish a sound basis for further improvements in therapeutic approaches to DS.

Patients and methods

Patients

This study was approved by the Ethical Committee of the 117 hospital of PLA and informed written consent was obtained from all

Table 1. General information about the patients

	Number
Age (years)	45-78 (mean 61.3)
Gender	
Male	15
Female	41
Chief complaint low back pain	18
Low back pain with lower limb pain or numbness	34
Intermittent claudication	1
Simple lower limb pain and numbness	1
Visible scoliosis with lower limb pain and discomfort	2
Course of disease	5 months to 30 years
Scoliosis classifications	
Single lumbar scoliosis	2
Thoracic lumbar scoliosis	31
Fixation and fusion segments (up to T10, down to S1)	
Three levels	32
Four levels	13
Five levels	7
Six levels	1
Seven levels	3

Table 2. Comparison of VAS scores before and after surgery

	Mean ± SD	*P* value
VAS score preoperatively	7.035 ± 1.133	
VAS score 1 week postoperatively	3.839 ± 0.726	0.000
VAS score 3 months postoperatively	3.142 ± 0.672	0.000
VAS score 1 year postoperatively	2.842 ± 0.958	0.000
VAS score 1 to 2 years postoperatively	2.120 ± 0.833	0.000
VAS score ≥ 2 years postoperatively	2.730 ± 1.116	0.000

***Refers to the level of significance compared to the preoperative VAS score.

Table 3. Comparison of ODI before and after surgery

	Mean ± standard deviation	P
ODI score preoperatively	59.94 ± 10.34	
ODI score 3 months postoperatively	35.99 ± 8.23	0.000
ODI score 1 year postoperatively	27.25 ± 10.75	0.000
ODI score 1 to 2 years postoperatively	20.46 ± 9.36	0.000
ODI score ≥ 2 years postoperatively	25.41 ± 13.96	0.000

*P refers to the level of significance compared to the ODI score preoperatively.

participants. From January 2001 to December 2011, 56 DS patients (45-78 years old; 15 males; 41 females) with an average age of 61.3 years) who underwent long-segmental fixation and fusion (≥ three levels) in our hospital were retrospectively analyzed. The major complaints included low back pain in 18 patients, low back pain with lower limb pain or numbness in 34, intermittent claudication in 1, simple lower limb pain and numbness in 1, as well as visible scoliosis with lower limb pain and discomfort in 2 patients. The course of the disease was 5 months to 30 years. Preoperative scoliosis classifications were single lumbar scoliosis in 25 patients and thoracic lumbar scoliosis in 31. Fixation and fusion segments were up to T10 and down to S1. There were three levels of fixation and fusion in 32 patients, four levels in 13, five levels in 7, six levels in 1 and seven levels in 3 patients. The thoracolumbar vertebrae were affected in 6 patients (**Table 1**).

Methods

The medical history of each patient was taken and a physical examination carried out. The following methods were used and the parameters recorded for 2 to 12 years postoperatively (as well as the evidence for internal fixation loosening or fractures): Visual Analogue Scale (VAS) score; Oswestry disability index (ODI); Lumbar anteroposterior and lateral bending X-ray and thoracolumbar magnetic resonance imaging (MRI) results; Coronary Cobb angle X-ray results (intersection angle of the two lines perpendicular to upper and lower vertebral scoliosis endplates); Lumbar lordosis angle (intersection angle of the two lines perpendicular to upper endplates of L1 and lower endplates of S1); MRI images of fixation and fusion segments and their adjacent vertebral segment. MRI images were taken to detect new scoliosis, changes of disc space height and osteophyte formation beside the vertebrae. Likewise, potential intervertebral disc degeneration was examined by record-

Table 4. Comparison of lumbar lordosis angles before and after surgery

	Mean ± standard deviation	P
Lumbar lordosis angle preoperatively	20.29 ± 10.11	
Lumbar lordosis angle at 1 week postoperatively	24.86 ± 10.30	0.217
Lumbar lordosis angle at 3 months postoperatively	22.38 ± 10.22	0.874
Lumbar lordosis angle at 1 to 2 y postoperatively	16.82 ± 10.32	0.792
Lumbar lordosis angle at 2 y or above postoperatively	14.36 ± 7.64	0.341

*P refers to the level of significance compared to the lumbar lordosis angle preoperatively.

Table 5. Comparison of Cobb angles before and after the surgery

	Mean ± standard deviation	P
Cobb angle preoperatively	17.99 ± 7.52	
Cobb angle 1 week postoperatively	11.66 ± 5.94	0.000
Cobb angle 3 months postoperatively	12.34 ± 7.36	0.001
Cobb angle ≥ 1 year postoperatively	15.38 ± 10.45	0.585

*P refers to the level of significance compared to the Cobb angle preoperatively.

ing changes of the disc or disc space height, the degree of disc protrusion and for the presence of spinal canal stenosis.

Statistical analyses

SPSS Statistics for Windows (Version 18.0. Chicago, SPSS Inc.) was used for statistical analyses. Normally distributed measurement data are reported as mean ± standard deviation. Analysis of variance was performed to compare measurement data among groups and the subsequent post-hoc comparisons were performed using Scheffe's method. *P* values < 0.05 were considered to be statistically significant.

Results

Of the 56 patients, 28 were reexamined in our hospital 2 to 9 years postoperatively, whereas the remaining 28 patients were followed up by telephone for 2 to 12 years. One female patient died of malignant myeloma two years after her operation and 1 male patient died in a road traffic accident five years postoperatively.

Comparison of VAS scores before and after surgery

VAS scores were monitored preoperatively and at 1 week, 3 months, 1 year, 1 to 2 years and ≥ 2 years postoperatively. All scores were significantly improved compared with preoperative scores (*P* = 0.000). In particular, the VAS score 1 week after the interventions was decreased by 54.6% compared with the pre-operative value and in the follow-up periods the scores were maintained at < 30.1-44.7% of the pre-operative value (**Table 2**). The VAS score improvements were maintained during our medium to long-term postoperative follow up of patients.

Comparison of ODIs before and after surgery

ODI values were significantly reduced at 3 months, 1 year, 1 to 2 years and ≥ 2 years postoperatively (*P* = 0.000). The ODI 3 months after the intervention was reduced by 40.0% and further decreased 1-2 years later to the lowest postoperative level, which was 34.1% of the preoperative value. More than 2 years postoperatively the ODI was 42.4% of the preoperative value (**Table 3**), showing that a long-term improvement in the ODI was achieved by the surgical interventions.

Comparison of lumbar lordosis angles before and after surgery

There were no significant differences of lumbar lordosis angles at 1 week, 3 months, 1 to 2 years and 2 years after operation compared with the data before surgery (**Table 4**).

Comparison of Cobb angles before and after the surgery

Cobb angles were significantly decreased at 1 week and 3 months postoperatively compared with pre-surgery (*P* = 0.000, *P* = 0.001 respectively), but the values returned to preoperative levels after 1 year (*P* = 0.585) (**Table 5**). Thus, any improvement in the Cobb angle produced by surgery only lasts for a relatively short period of time.

Postoperative complications

28 patients were reexamined postoperatively in our clinic. There was worsened coronary scoliosis in 8 cases (28.57%), new scoliosis at the border of the original scoliosis in 6 (21.42%),

Table 6. Postoperative complications and possible risk factors

Risk factors	New scoliosis at the border of the original scoliosis (6)	Worsened coronary scoliosis (8)	Decreased lumbar lordosis angle (24)	Screw loosening, fracture (7)	pelvic tilt (2)	adjacent segment degeneration (8)
Lumbar lordosis angle						
Postoperative > preoperative	6	6	19	3	1	8
Postoperative < preoperative	0	2	5	4	1	0
Operating segments > scoliosis segments	1	1	5	1	2	1
Operating segments < scoliosis segments	4	7	16	5	0	6
Operating segments = scoliosis segments	1	0	3	1	0	1

decreased lumbar lordosis angle in 24 (85.71%), screw loosening in 4, screw fracture in 1, nuts backing out in 2, pelvic tilt in 2, segment degeneration distal to the fixation site in 3, segment degeneration proximal to the fixation site in 5 and adjacent segment compression fracture in 1 case (**Table 6**). Implants were removed from 4 patients, 2 years after their operations and no revision surgery was conducted.

Discussion

In the present study, we found that the coronal Cobb angle, lumbar lordosis angle and patients VAS scores were improved by 35.19%, 24.54%, and 45.45% respectively, after long segmental fixation and fusion, 1 week postoperatively. The VAS was improved by 69.86% 1 to 2 years postoperatively, suggesting a better therapeutic effect can be achieved for DS patients using long segmental fixation and fusion.

It was obvious that there was loss or deterioration of the sagittal lumbar lordosis angle during our follow-up examinations. This occurred in patients whose operating segments were shorter, longer than or equal to the original scoliosis segments. Thus, maintenance of lumbar lordosis was not closely correlated with the length of the fixation and fusion segments. Although an improvement in the lumbar lordosis angle may have occurred in 67.86% of patients, reaching 35% (17.99-11.66/17.99), it was not statistically significantly different to the preoperative value. We found that the VAS and ODI values had deteriorated, so the reason for the loss of lumbar lordosis angle and indeed what angle the lumbar lordosis should be restored to, is a topic worthy of further study. Similarly, the problem of the sagittal balance of the spine merits further attention. Evidence based medicine has proved that restoration of the spine sagittal balance is one of the most important factors that influences clinical efficacy and the quality of life of the patient after orthopedic surgery to correct adult spine deformity [1, 3]. The sagittal balance of the trunk mainly involves three factors namely sagittal alignment of the spine, the pelvis and the lower limbs. The sagittal balance of the trunk is determined by the spine and pelvic alignment because the lower limb alignment changes with an alteration in the spine and pelvic alignment, due to its high degree of mobility. The sagittal evaluating parameters for the spine included sagittal vertical deviation (SVA), thoracic kyphosis (TK), thoracolumbar kyphosis (TLK) and lumbar lordosis (LL), with a decrease or disappearance of LL being the most common local change associated with sagittal balance in DS patients. The sagittal evaluating parameters for the pelvis included pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). A change in spine sagittal balance can be offset by supination of the pelvis, producing a decrease in SS and an increase in PT. However, PI is a specific individual anatomic parameter that is difficult to alter. Thus, the evaluation of PI preoperatively can be used to estimate the LL value required during the operation from the association between PI and LL. Schwab et al. [3] proposed that the formula of $LL = PI \pm 9°$ could be used to estimate the ideal LL correcting angle in the orthopedic operation to correct adult spine deformity. Pelvic parameters of the cases in the present study were not evaluated, so the LL correcting angle was not estimated preoperatively. Therefore, the ideal angle may not have been achieved and lose of LL and partly worsened corresponding symptoms were found during the follow-up examinations. Therefore, better surgical efficacy can be achieved for DS by restoring LL, which can be estimated from pelvic parameters (especially PI).

We found that if the fixation and fusion segments were shorter than the scoliosis affected segments (20 patients), the incidence of complications was highest. Sagittal loss of the lumbar lordosis angle occurred in 80% of patients, coronary Cobb angles were decreased in 35% and adjacent segment degeneration occurred in 30%. Loosening or breakage of implants occurred in 25% and new scoliosis at the border of the original scoliosis occurred in 20% of patients. Conversely, in cases where the fixation and fusion segments were longer (5 patients), or the fixation and fusion segments were equal to or just covered the scoliosis segments (3 patients), the coronary Cobb angles were maintained in a better condition, but sagittal loss of the lumbar lordosis angle still occurred. Therefore, we suggest that the maintenance of the coronary Cobb angle closely correlates with the number of fixation and fusion segments, which is in agreement with a previous report in which the authors suggested that long segmental fixation and fusion would be preferable for DS patients with a large Cobb angle, as well as coronary and sagittal imbalance [4]. If the fixation and fusion segments are shorter than the scoliosis segments, the scoliosis correction may not be satisfactory, the coronal Cobb angle improvement may disappear and new scoliosis at the border of the original scoliosis may arise. These problems are considered by some researchers to be the result of trunk imbalance due to an abnormal coronal spinal axis in the standing position and attempts to achieve balance producing compensatory new scoliosis at the border of the original occurrence. Previous reports also mentioned that loss of therapeutic efficacy and adjacent segment degeneration may occur if the upper and lower end vertebrae operated on are located inside the scoliosis [2, 5].

Loss or deterioration of sagittal lumbar lordosis angles during follow-up occurred in patients with operation segments that was shorter, longer than, or equal in length to the scoliosis segments. Although improvement of lumbar lordosis angles was achieved in 67.86% of patients, maintenance of lumbar lordosis angles was not closely correlated with the surgical approach of segment fixation and fusion. On the other hand, we found that VAS and ODI values were highly influenced by the lumbar lordosis angle, which is in agreement with a previous report about a health-related quality of life investigation of DS patients. This report revealed that quality of life was mainly associated with sagittal rather than coronary deformities [6].

Two patients experienced pelvic tilt 2 years after their operations, but coronary and sagittal balance was well maintained. Both patients accepted thoracolumbar long segment fixations, the fixation segments being longer than the original scoliosis segments. The lower fixation and fusion segment was located at S1, indicating that long segment fixation indeed maintains good coronary and sagittal restoration effects. However, this procedure also limited compensatory flexion or rotation of the thoracic lumbar and lumbosacral junction, thereby reducing mechanical balance to pelvic tilt.

Screw loosening or fractures appeared in 7 patients' ≥ 2 years after operation, 6 of who underwent surgical fixations and fusions of segments shorter than the original scoliosis (1-2 segments). We suggest that stress resulting from spine activities may occur mainly in the fixation-moving interface when vertebrae are fixed within the scoliosis segment. In addition, six cases of screw fractures (5 cases of sacral screws) were found close to the lower segments; it may be that distal screws bear a heavier mechanical load. A further complicating factor is the relatively poor bone condition of the sacral pedicle, which may further contribute to the increased risk of screw fractures.

In conclusion, favorable medium to long-term curative effects can be achieved by long segmental fixation and fusion treatments in DS patients. The fixation segments should be equal to or longer than the segments affected by scoliosis, potentially avoiding the need for lumbosacral fusion. If lumbosacral fixation is required, the sacral screws should be inserted using the bi-cortical technique to increase 'anti-pulling out' forces. The lumbar lordosis angle is the key to rebuilding sagittal balance and is closely correlated with the patient's clinical symptoms and quality of life.

Acknowledgements

This work was supported by the grants of The Major Project of Nanjing military Region (ZX38) and Public Project from Science and Technology Department of Zhejiang Province (2014c-33121).

Disclosure of conflict of interest

None.

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