Radiological assessment of shoulder balance following posterior spinal fusion for thoracic adolescent idiopathic scoliosis

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Abstract

Background: The objective of this study was to evaluate shoulder balance following posterior spinal fusion for thoracic adolescent idiopathic scoliosis (AIS).

Methods: Twenty-four patients (22 females) with thoracic AIS who had undergone posterior fusion with segmental pedicle screws were retrospectively reviewed. The mean follow-up duration was 29 (range, 24–55) months. Fifteen patients had type 1 curves, seven had type 2 curves, and two had type 3 curves according to the Lenke classification. The proximal thoracic (PT) and main thoracic (MT) Cobb angles, percent correction of PT (PTC) and MT (MTC) curves, T1 tilt, and shoulder asymmetry according to radiographic shoulder height (RSH) were measured on preoperative, immediately postoperative, and final follow-up radiographs. The preoperative PT and MT curve side-bending percent correction (PTBC and MTBC) were also measured. The PTC:MTC ratio was employed as an index of PTC and MTC matching. Patients were divided into two groups according to radiographic findings immediately postoperatively: the balanced group (|RSH| < 20 mm) and imbalanced group (|RSH| ≥ 20 mm). The preoperative indices (RSH, PTBC, MTBC, PTC, and MTC), preoperative and postoperative T1 tilt, and PTC:MTC ratio were compared between the two groups.

Results: The mean PT and MT were 33.0° and 64.2° preoperatively, 16.1° (50.5%) and 16.8° (74.0%) immediately postoperatively, and 16.9° (49.0%) and 19.2° (70.3%) at final follow-up, respectively. The mean preoperative RSH of −12.3 mm changed to +11.1 mm immediately postoperatively and improved to +5.7 mm at final follow-up. Seventeen patients were "balanced" and seven were "imbalanced" immediately postoperatively. There were significant differences in the PTC (p=0.04), postoperative T1 tilt (p=0.04), and PTC:MTC ratio (p=0.02) between the two groups (Wilcoxon rank-sum test). Only one patient had an imbalanced shoulder at the final follow-up. She had marked shoulder imbalance immediately postoperatively (RSH: +40 mm).

Conclusions: Sufficient correction of PT curves that is matched with correction of MT curves is necessary to prevent postoperative shoulder imbalance. Almost all patients in our series had satisfactory results in terms of shoulder balance at final follow-up, but one patient with marked shoulder imbalance immediately postoperatively may have residual long-term shoulder imbalance.
Background

Well-balanced shoulders are important for patient satisfaction after surgery for adolescent idiopathic scoliosis (AIS). In recent years, segmental pedicle screws (SPS) have been used more frequently in posterior spinal fusion for AIS. These constructs ensure better correction of coronal deformities. However, vigorous correction of the main thoracic curve can induce postoperative shoulder decompensation, which can result in shoulder imbalance. The objective of the present study was to evaluate shoulder balance after posterior spinal fusion with SPS constructs for thoracic AIS.

Methods

Twenty-four patients (22 females) with thoracic AIS who had undergone posterior fusion at a single institution (Osaka City General Hospital) from 2008 through 2011 were retrospectively reviewed. The mean patient age at surgery was 15.8 (range, 12.1–20.5) years. A mini-OP (Osaka City General Hospital) from 2008 through 2011 were retrospectively reviewed. The mean patient age at surgery was 15.8 (range, 12.1–20.5) years. A mini-OP (Osaka City General Hospital) from 2008 through 2011 were retrospectively reviewed. The mean patient age at surgery was 15.8 (range, 12.1–20.5) years. A mini-OP (Osaka City General Hospital) from 2008 through 2011 were retrospectively reviewed. The mean patient age at surgery was 15.8 (range, 12.1–20.5) years. A mini-

For thoracic AIS.

As a measure of preoperative flexibility, preoperative PT and MT curve side-bending correction (PTBC and MTBC, respectively) were calculated using the following formula:

\[ \text{PTBC or MTBC} = \frac{\text{preoperative erect Cobb angle} - \text{supine side-bending Cobb angle}}{\text{preoperative erect Cobb angle}} \times 100\% \]

Postoperative PT correction (PTC) and MT correction (MTC) were calculated using the following formula:

\[ \text{PTC or MTC} = \frac{\text{preoperative erect Cobb angle} - \text{postoperative erect Cobb angle}}{\text{preoperative erect Cobb angle}} \times 100\% \]

The PTC:MTC ratio was defined as an index of the matching of PTC and MTC.

Patients were divided into two groups according to radiographs taken immediately postoperatively: the balanced group (|RSH| <20 mm) and imbalanced group (|RSH| ≥20 mm). Preoperative indices (RSH, T1 tilt, PTBC, and MTBC) were compared with the PTC, MTC, T1 tilt, and PTC:MTC ratio immediately postoperatively between the two groups. The Wilcoxon rank-sum test was used to assess differences between the two groups. A p value of <0.05 was considered statistically significant.

Written informed consent was obtained from the patients for publication of this report and any accompanying images. Ethical approval was not required because this was a retrospective observational study.

Results

The mean preoperative Cobb angle of the PT curve was 33.0° (range, 11°–50°). The PT curve was corrected to 16.1° (range, 3°–28°), and the PTC immediately postoperatively was 50.5% (21.1%–72.7%). At the final follow-up, the mean Cobb angle was 16.9° (range, 2°–27°) and the final PTC was 49.0% (15.8%–81.8%). The mean preoperative Cobb angle of the MT curve was 64.2° (range, 48°–89°). The MT curve was corrected to 16.8° (range, 6°–26°), and the PTC immediately postoperatively was 74.0% (64.9%–90.3%). At the final follow-up, the mean Cobb angle was 19.2° (range, 11°–33°) and the final MTC was 70.3% (56.2%–82.1%). The mean preoperative RSH of −12.3 mm (range, −35 to +20 mm) changed to +11.1 mm (−4 to +40 mm) immediately postoperatively. At the final follow-up, the RSH had improved to +5.7 mm (range, −9 to +36 mm) (Figure 1). Changes in the other preoperative and postoperative radiological parameters, including comparison of single thoracic and double thoracic patterns, are shown in Table 1.

Seventeen patients were placed in the balanced group and seven patients were placed in the imbalanced group according to immediately postoperative radiographs. The preoperative RSH was −13.6 mm (range, −35 to
Figure 1 Fourteen-year-old girl with Lenke type 2C adolescent idiopathic scoliosis. A, The preoperative Cobb angle of the PT and MT curves were 50° and 78°, respectively. B, Immediately after surgery, the PT and MT curves were corrected to 28° (44.0%) and 17° (78.2%), respectively. The PTC:MTC ratio was calculated as 0.56. This patient had postoperative shoulder imbalance (RSH: +22 mm). C, Five years postoperatively, the RSH had decreased to +6 mm and the postoperative shoulder imbalance had improved. Consent for publication of this figure was obtained from the patient’s parents.

|                          | All cases | Single thoracic | Double thoracic | P-value* |
|--------------------------|-----------|----------------|-----------------|----------|
| PT Preop (°)             | 33.0      | 28.5           | 43.9            | 0.0003   |
| Postop (°)               | 16.1      | 14.8           | 19.3            | 0.09     |
| Postop PTC (%)           | 50.5      | 48.1           | 56.2            | 0.14     |
| Final follow-up (°)      | 16.8      | 15.1           | 21.4            | 0.02     |
| Final follow-up PTC (%)  | 49.0      | 48.0           | 51.2            | 0.50     |
| MT Preop (°)             | 49.5      | 61.1           | 71.7            | 0.04     |
| Postop (°)               | 16.8      | 16.3           | 17.9            | 0.36     |
| Postop MTC (%)           | 74.0      | 73.3           | 75.5            | 0.25     |
| Final follow-up (°)      | 19.2      | 18.9           | 19.9            | 0.90     |
| Final follow-up PTC (%)  | 70.3      | 69.4           | 72.5            | 0.31     |
| RSH Preop (mm)           | −12.7     | −14.8          | −6.3            | 0.39     |
| Postop (mm)              | +11.1     | +12.4          | +6.7            | 0.55     |
| Final follow-up (mm)     | +5.7      | +5.1           | +7.1            | 0.39     |
| T1 tilt Preop (°)        | −1.8      | −3.4           | +2.1            | 0.01     |
| Postop (°)               | +4.8      | +3.8           | +7.3            | 0.06     |
| Final follow-up (°)      | +3.3      | +2.2           | +6.0            | 0.09     |
| PTC:MTC ratio Postop     | 0.68      | 0.65           | 0.74            | 0.18     |

*Statistical analysis was performed to compare the single thoracic pattern (Lenke type 1 or 3) with the double thoracic pattern (Lenke type 2) using the Wilcoxon rank-sum test.
Postoperative shoulder imbalance was chronologically improved in almost all patients during the minimum 2-year follow-up period. However, one patient continued to have an imbalanced shoulder at the final follow-up. Thus, patients with marked shoulder imbalance immediately postoperatively may have long-term residual shoulder imbalance. Additionally, Cao et al. [6] reported RSH to be significantly correlated with the parameters of distal adding-on. Therefore, avoiding shoulder imbalance immediately postoperatively should be emphasized for favorable long-term patient satisfaction and operative outcomes.

### Conclusions

Sufficient correction of PT curves matched to correction of MT curves is necessary to prevent postoperative shoulder imbalance. Almost all patients in our series had satisfactory outcomes in terms of shoulder balance at the final follow-up. However, avoiding shoulder imbalance immediately postoperatively is important because marked shoulder imbalance immediately postoperatively could induce residual shoulder imbalance in the long term.

This study was presented at the 10th Meeting of the International Research Society of Spinal Deformities (IRSSD 2014 Sapporo) [7].

### Competing interests

The authors declare that they have no competing interests.

### Authors’ contributions

TN made substantial contributions to the study design, analysis and interpretation of the data, and drafting of the manuscript. AM and MK performed the surgical procedures, obtained the radiographs, and collected the data. KH collected the data. HN coordinated the project. All authors read and approved the final manuscript.

### Declarations

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