

# Radiographic, clinical, and patients' assessment of segmental direct vertebral body derotation versus simple rod derotation in main thoracic adolescent idiopathic scoliosis: a prospective, comparative cohort study

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## Abstract

**Purpose** The application of vertebral body derotation (DVBD) is still controversial by now; the purpose of this prospective cohort study was to compare comprehensive outcomes between segmental DVBD and simple rod derotation (SRD) especially in main thoracic adolescent idiopathic scoliosis.

**Methods** 36 patients in DVBD group and 45 patients in SRD group were with a 2-year follow-up. Among them, 19 DVBD patients and 16 SRD patients received CT scan examinations.

**Results** There were no significant difference between the groups in preoperative main thoracic Cobb, apical vertebral rotation and rib hump. Apical vertebral rotation measured from CT scans was  $9.7^\circ \pm 2.0^\circ$  versus  $15.3^\circ \pm 2.4^\circ$  ( $p < 0.001$ ) postoperatively in the DVBD and SRD patients, respectively. At 2-year follow-up, the main thoracic Cobb was  $14.2^\circ \pm 1.6^\circ$  versus  $14.7^\circ \pm 1.7^\circ$  ( $p = 0.18$ ), rib hump was  $6.4^\circ \pm 3.8^\circ$  versus  $6.8^\circ \pm 3.1^\circ$  ( $p = 0.60$ ) in DVBD group and SRD group. Patients' assessments of both groups were improved in Spinal Appearance Questionnaire (SAQ) and Scoliosis Research Society-22 Questionnaire (SRS-22), but showed no significant difference at follow-up ( $p = 0.47$  and  $0.60$ ).

**Conclusion** Although segmental DVBD showed excellent radiographic correction of axial spinal deformity postoperatively, there was no more correction of clinical rib hump or better patients' assessment than SRD at follow-up in our data.

**Keywords** Adolescent idiopathic scoliosis · Spinal fusion · Derotation · Rib hump

## Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity, involving imbalanced shoulder, rib hump, waist asymmetry, and truck shift in clinical. Harrington instrumentation applied coronal correction by distraction and compression forces, but was unsatisfactory in sagittal and axial correction [1, 2]. Later on, Cotrel-Dubousset instrumentation and pedicle screw instrumentation enabled a three-dimensional with simple rod derotation (SRD) [2–4]. Lee et al. [5] described the concept of direct vertebral body derotation (DVBD), which demonstrated 42.5 % axial correction of the apical vertebral bodies as compared with only 2.5 % by SRD in CT scans. Importantly, this powerful corrective technique helped improve about 50 % of clinical rib hump in the report of Hwang et al. [6, 7].

However, the application of this technique is still controversial by now. There were two types of basic maneuvers of DVBD: segmental and En bloc [7, 9]. In the study of Mattila et al. [8] although En bloc DVBD provided excellent radiographic axial spinal column derotation, it was not reflected by better rib hump correction at follow-up. The similar results were showed in Lenke Type 5 curves, the improvement of rib hump and lumbar

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prominence in DVBD group seemed not different from the control group [9].

Regrettably, several limitations were likely to affect the results of previous studies. Most studies included small number of patients with wide range of curve type. Lee et al. applied DBVB in 17 patients with King I–V curves [5]. Mattila et al. [8] reviewed patients with limited consistency, containing Lenke 1–4 and 6 types, AIS and juvenile idiopathic scoliosis, more than half of the patients received Ponte procedure. While the latter study, totally reviewed 19 patients in a multicenter database, who experience different DVBD maneuvers: segmental, En bloc, or both [9]. Meanwhile, DVBD group and control group in the studies received treatment in different periods of time, and the outcomes may be affected by a probable learning curve [8, 9].

In addition, CT scans supplied more accurate information about radiographic vertebral body rotation than X-ray; Spinal Appearance Questionnaire (SAQ) provided more details about patient's appearance than other questionnaires and was not used by previous studies [10]. In the present study, we followed up a consecutive series of 81 of 90 main thoracic AIS patients, who received segmental DVBD or SRD by the same surgeon in the same periods of time. Besides X-ray, CT scans and clinical materials, we collected the scores of SAQ to explore the patients' subjective assessment, which may be more important to patients.

## Materials and methods

A consecutive series of 90 main thoracic AIS patients with Lenke I and Lenke II curves were identified from a single institution prospective database, and operated by the same senior surgeon from June 2010 to August 2012. Two cohorts were formed: 39 patients received segmental DVBD, and 51 patients received SRD. Radiographic and clinical materials, SAQ and simplified Chinese (mainland) version of Scoliosis Research Society-22 Questionnaire (SRS-22) were collected preoperatively, postoperatively (when patients got out of bed), and at last follow-up [10, 11]. The senior surgeon who operated all the patients did not involve in the data collection to avoid interference with operation maneuvers. Three SRD patients and two DVBD patients did not perform SRS-22 or SAQ preoperatively. Three SRD patients and one DVBD patients lost follow-up.

At last, a total of 81 patients with ages between 12 and 18 years remained for analysis; the DVBD group included 36 of 39 (92 %) patients, while the SRD group included 45 of 51 (88 %) patients. All the patients underwent posterior fusion using all-pedicle screw constructs and Ti Alloy rods, they were all with a 2-year follow-up. Risser sign was between 4 and 5. The two groups were matched in age, Risser sign, number of levels fused, proportion of

**Table 1** Cohort patients' characteristics

Items	DVBD ( <i>n</i> = 36)	SRD ( <i>n</i> = 45)	<i>P</i>
Age, year	14.9 ± 1.8	15.1 ± 1.6	0.60
Sex (male/female), <i>n</i>	3/33	3/42	0.78
Lenke type (I/II), <i>n</i>	28/8	34/11	0.81
Number of levels fused, <i>n</i>	10.8 ± 1.3	11.2 ± 1.4	0.19
Risser sign	4.6 ± 0.5	4.7 ± 0.5	0.37

\* Statistically significant difference in the value between DVBD group and SRD group (*P* < 0.05)

\*\* Statistically significant difference in the value between DVBD group and SRD group (*P* < 0.001)

sex and Lenke type (Table 1). Patients with juvenile idiopathic scoliosis, intraoperative Ponte procedure or other osteotomies, selective segmental pedicle screw instrumentation, insufficient data were ruled out the study. Ponte procedure may increase the flexibility of the thoracic spine, while selective segmental pedicle screw instrumentation was unable to do DVBD maneuver on each segment. Informed consent was obtained from each patient and legal guardian.

## Radiographic and clinical measurements

Radiographic parameters were measured from the posterior–anterior and lateral spinal radiographs, including upper thoracic Cobb, main thoracic Cobb, lumbar Cobb, T2–T5 kyphosis, coronal balance. Coronal balance was the horizontal distance between C7 plumb line and the center sacral line.

Residual Cobb angles of main thoracic curve were measured on side-bending radiographs. The flexibility of main thoracic curve = (main thoracic Cobb° before surgery – bending residual main thoracic Cobb°)/main thoracic Cobb° before surgery.

The angles of rib hump were obtained by inclinometer. Patients were asked to keep legs straight, and then lean forward with their arms extended toward the floor. The inclinometer was centered over the spinous process, and to get the largest measure for thoracic regions.

## Patients' assessment

SAQ and SRS-22 were completed preoperatively, postoperatively, and at last follow-up. The SAQ with 20 questions evaluated the patients' assessment of their spinal appearance using standardized drawings [10]. Question 2 addressed the deformity of rib hump, and was analyzed in the present study. The self-image domain of SRS-22 included questions 4, 6, 10, 14 and 19. The average score of five questions was acquired for analysis in the study.

**Table 2** Spinal rotation of patients with computed tomography (CT) scans measurements

Items	DVBD ( <i>n</i> = 19)	SRD ( <i>n</i> = 16)	<i>P</i>
Age, year	15.4 ± 1.8	16.1 ± 1.6	0.24
Sex (male/female), <i>n</i>	2/17	1/15	0.78
Lenke type (I/II), <i>n</i>	13/6	11/5	0.81
Number of levels fused, <i>n</i>	11.3 ± 1.5	11.7 ± 1.3	0.41
Preoperative main thoracic curve (°)	53.7 ± 11.4	55.2 ± 11.3	0.70
Flexibility of main thoracic curve (%)	43.8 ± 12.1	41.6 ± 10.3	0.57
Risser sign	4.6 ± 0.5	4.7 ± 0.5	0.56
Apical RAsag-N (°)			
Preop	17.8 ± 3.6	18.5 ± 2.3	0.51
Postop	9.7 ± 2.0	15.3 ± 2.4	<0.001*
Rib hump (°)			
Preop	13.5 ± 4.2	14.2 ± 5.0	0.66
Follow-up	6.2 ± 3.8	7.0 ± 3.1	0.51

\* Statistically significant difference in the value between DVBD group and SRD group ( $P < 0.001$ )

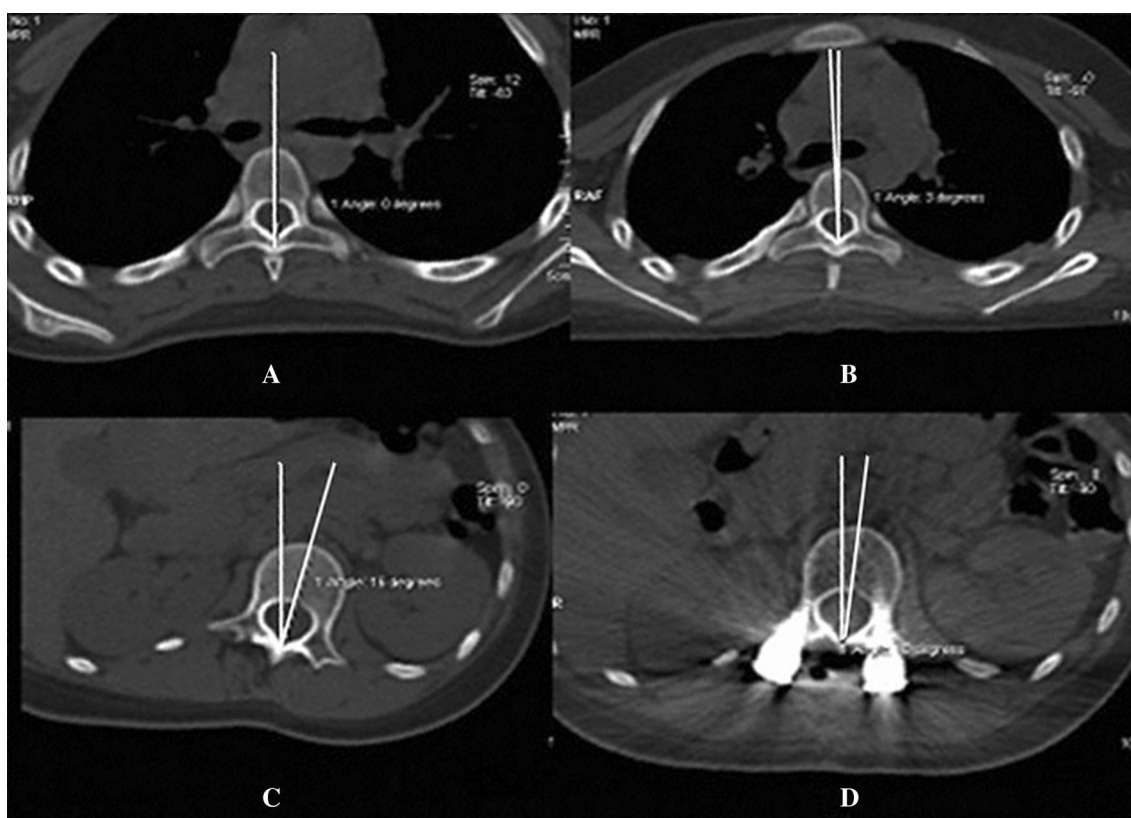
### Measurements of radiographic apical vertebral rotation

Some of the patients received CT scan examinations preoperatively and postoperatively, including 19 DVBD patients and 16 SRD patients, to lower the risk of pedicle screw misplacement and make sure no adjacent vessels damage. There were no significant differences in age, Risser sign, number of levels fused, proportion of sex and Lenke type (Table 2) between DVBD patients and SRD patients who received CT scan examinations.

The apical vertebral rotation was measured on axial CT using the methods adopted by Aaro and Dahlborn [12]. We chose the upper neutral vertebrae of thoracic curves as the reference vertebrae to obtain exact radiographic apical vertebral rotation (rotational angle to neutral vertebrae, RAsag-N) (Fig. 1).

### Statistical analysis

A two-tailed independent t test was used to evaluate the level of significance for continuous variables in the two groups. While  $\chi^2$  test was used for categorical variables,



**Fig. 1** Measurement of RAsag-N. Upper neutral vertebra was the ideal reference vertebra to obtain exact radiographic apical vertebral rotation. **a, c** Preoperatively, upper neutral vertebra was 0°, apical

vertebra was 16.3°, RAsag-N was 16.3°. **b, d** Preoperatively, upper neutral vertebra was -2.6°, apical vertebra was 7°, RAsag-N was 9.6°. Correction of RAsag-N was 41.1 %

and Wilcoxon rank sum test (nonparametric) for evaluating the scores of SAQ and SRS-22. Results are reported as mean  $\pm$  SD. All the statistical analyses were performed by SPSS 12.0 for Windows (SPSS Inc., Chicago, IL). Statistical significance was set at  $P < 0.05$ .

## Results

### Radiographic outcomes

There were no significant differences between the two groups in preoperative upper thoracic Cobb, main thoracic Cobb, flexibility of main thoracic curve, thoracic kyphosis T5–T12 and coronal balance (Table 2). Preoperatively, main thoracic Cobb was  $51.6^\circ \pm 10.1^\circ$  versus  $50.7^\circ \pm 8.9^\circ$  ( $p = 0.67$ ), and was corrected to  $13.8^\circ \pm 1.3^\circ$  versus  $14.2^\circ \pm 1.8^\circ$  ( $p = 0.27$ ) postoperatively,  $14.2^\circ \pm 1.6^\circ$  versus  $14.7^\circ \pm 1.7^\circ$  ( $p = 0.18$ ) at 2-year follow-up, in DVBD and SRD patients, respectively. Thoracic kyphosis T5–T12 was  $19.1^\circ \pm 3.8^\circ$  versus  $18.4^\circ \pm 3.5^\circ$  ( $p = 0.39$ ) preoperatively, and was reduced to  $16.0^\circ \pm 2.3^\circ$  versus  $16.5^\circ \pm 2.4^\circ$  ( $p = 0.36$ ) postoperatively,  $16.2^\circ \pm 2.1^\circ$  versus  $16.8^\circ \pm 2.6^\circ$  ( $p = 0.27$ ) at 2-year follow-up in the two groups. Coronal balance was  $14.3 \pm 10.7$  mm versus  $16.3 \pm 11.9$  mm ( $p = 0.43$ ) preoperatively, and was corrected to  $17.2 \pm 9.3$  mm versus  $17.5 \pm 7.9$  mm ( $p = 0.88$ ) postoperatively,  $8.1 \pm 3.4$  mm versus  $7.7 \pm 3.6$  mm ( $p = 0.61$ ) at 2-year follow-up. The DVBD and SRD patients were also similar in upper thoracic Cobb and lumbar Cobb postoperatively and at 2-year follow-up (Table 3).

### Rib hump

The changes in rib hump were shown in Table 4. We did not get angles of immediately postoperative rib hump, because of not yet solid fusion that time and possible back pain when patients leaning forward. In DVBD and SRD patients, respectively, rib hump was  $13.2^\circ \pm 4.9^\circ$  versus  $12.7^\circ \pm 5.2^\circ$  ( $p = 0.66$ ) before surgery, and was corrected to  $6.4^\circ \pm 3.8^\circ$  versus  $6.8^\circ \pm 3.1^\circ$  ( $p = 0.60$ ) at 2-year follow-up. No significant difference was found in clinical rib hump between the two groups at follow-up (Figs. 2, 3).

### Patients' assessment

Preoperatively, the scores of SAQ were  $3.2 \pm 0.7$  and  $3.1 \pm 0.5$  ( $p = 0.46$ ), while the mean values of average scores in SRS-22 questions 4, 6, 10, 14 and 19 were  $2.7 \pm 0.6$  and  $2.9 \pm 0.8$  ( $p = 0.22$ ) for DVBD patients and SRD patients, respectively (Table 5). The scores of the two questionnaires were all improved for the total cohort

**Table 3** Radiographical outcomes

Parameter	DVBD ( <i>n</i> = 36)	SRD ( <i>n</i> = 45)	<i>P</i>
Upper thoracic curve (°)			
Preop	28.7 $\pm$ 6.9	27.8 $\pm$ 6.2	0.54
Postop	12.9 $\pm$ 1.2	13.4 $\pm$ 1.7	0.14
Follow-up	13.1 $\pm$ 1.5	13.5 $\pm$ 1.6	0.25
Main thoracic curve (°)			
Preop	51.6 $\pm$ 10.1	50.7 $\pm$ 8.9	0.67
Postop	13.8 $\pm$ 1.3	14.2 $\pm$ 1.8	0.27
Follow-up	14.2 $\pm$ 1.6	14.7 $\pm$ 1.7	0.18
Flexibility of main thoracic curve (%)	49.6 $\pm$ 13.2	48.3 $\pm$ 11.9	0.64
Lumbar curve (°)			
Preop	33.5 $\pm$ 8.1	31.7 $\pm$ 7.2	0.29
Postop	11.9 $\pm$ 1.1	11.6 $\pm$ 1.5	0.32
Follow-up	12.3 $\pm$ 1.3	11.9 $\pm$ 1.2	0.15
Thoracic kyphosis T5–T12 (°)			
Preop	19.1 $\pm$ 3.8	18.4 $\pm$ 3.5	0.39
Postop	16.0 $\pm$ 2.3	16.5 $\pm$ 2.4	0.36
Follow-up	16.2 $\pm$ 2.1	16.8 $\pm$ 2.6	0.27
Coronal balance (mm)			
Preop	14.3 $\pm$ 10.7	16.3 $\pm$ 11.9	0.43
Postop	17.2 $\pm$ 9.3	17.5 $\pm$ 7.9	0.88
Follow-up	8.1 $\pm$ 3.4	7.7 $\pm$ 3.6	0.61

Coronal balance was translated into absolute value

\* Statistically significant difference in the value between DVBD group and SRD group ( $P < 0.05$ )

\*\* Statistically significant difference in the value between DVBD group and SRD group ( $P < 0.001$ )

patients, but showed no significant difference postoperatively ( $2.1 \pm 0.4$  versus  $2.1 \pm 0.6$ ,  $p = 1$ ;  $3.7 \pm 0.7$  versus  $3.8 \pm 0.7$ ,  $p = 0.52$ ) and at follow-up ( $2.2 \pm 0.5$  versus  $2.3 \pm 0.7$ ,  $p = 0.47$ ;  $3.5 \pm 0.9$  versus  $3.6 \pm 0.8$ ,  $p = 0.60$ ) between the two groups.

### Apical vertebral rotation in CT scans

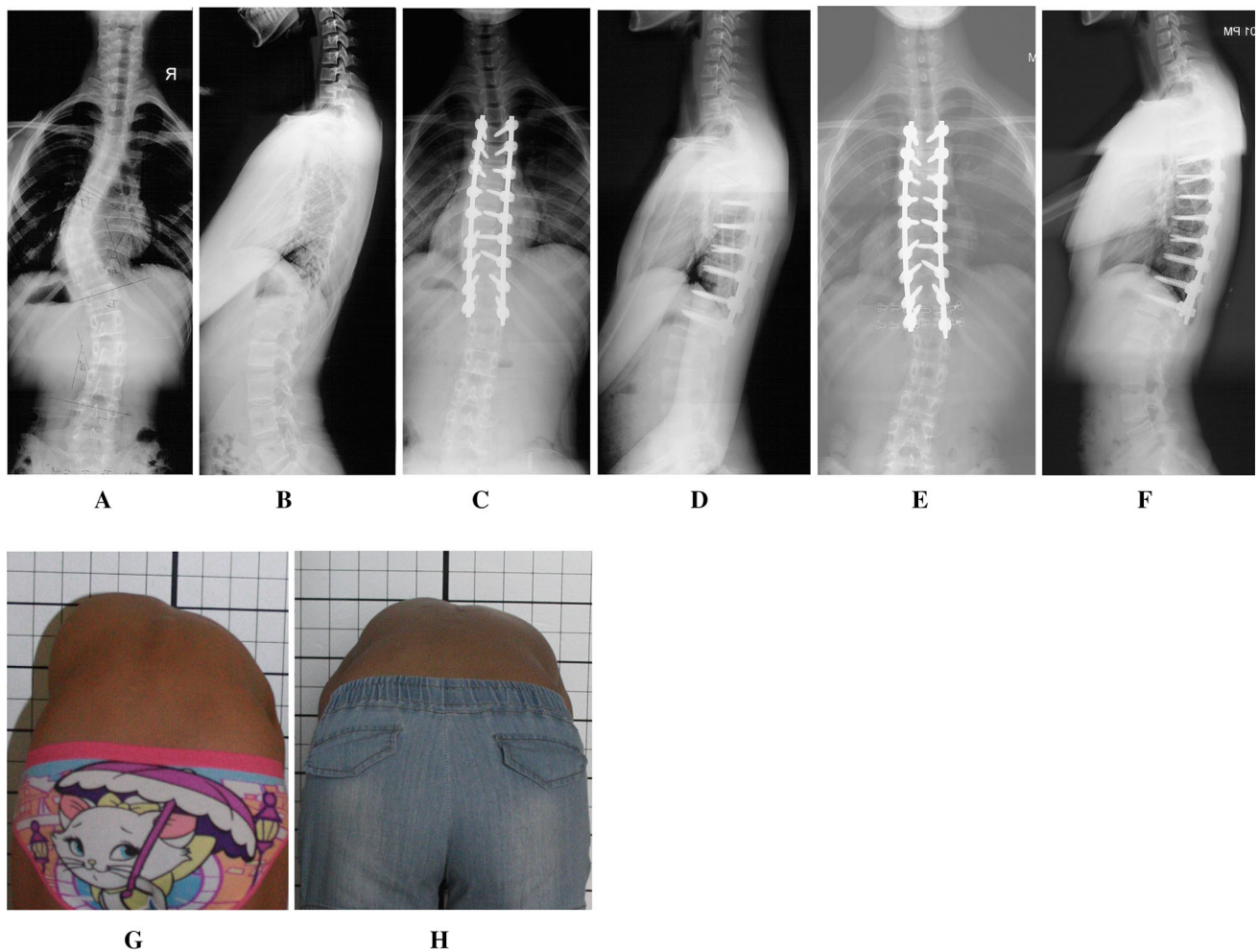
The 19 DVBD patients and 16 SRD patients with CT scan examinations were well matched in the study. RASag-N

**Table 4** Measurements of rib hump

Rib hump (°)	DVBD ( <i>n</i> = 36)	SRD ( <i>n</i> = 45)	<i>P</i>
Preop	13.2 $\pm$ 4.9	12.7 $\pm$ 5.2	0.66
Follow-up	6.4 $\pm$ 3.8	6.8 $\pm$ 3.1	0.60

\* Statistically significant difference in the value between DVD group and SRD group ( $P < 0.05$ )

\*\* Statistically significant difference in the value between DVD group and SRD group ( $P < 0.001$ )



**Fig. 2** 13-year-old female, Lenke I curve, received DVBD in surgery. **a, b** Preoperatively, main thoracic Cobb 49.3°, T5–T12 thoracic kyphosis 10.1°. **c, d** Postoperatively, main thoracic Cobb 14.2°, T5–T12 thoracic kyphosis 18.6°. **e, f** At follow-up, main

thoracic Cobb 16.6° (66.3 % correction), T5–T12 thoracic kyphosis 20.2°. **g, h** Preoperative rib hump was 20°, rib hump at follow-up was 8° (60.0 % correction)

was  $17.8^\circ \pm 3.6^\circ$  versus  $18.5^\circ \pm 2.3^\circ$  ( $p = 0.51$ ) preoperatively, and corrected to  $9.7^\circ \pm 2.0^\circ$  versus  $15.3^\circ \pm 2.4^\circ$  ( $p < 0.001$ ) postoperatively in DVBD patients and SRD patients, respectively. Significant difference was shown in RAsag-N after surgery between patients under different maneuvers: DVBD or SRD (Table 2).

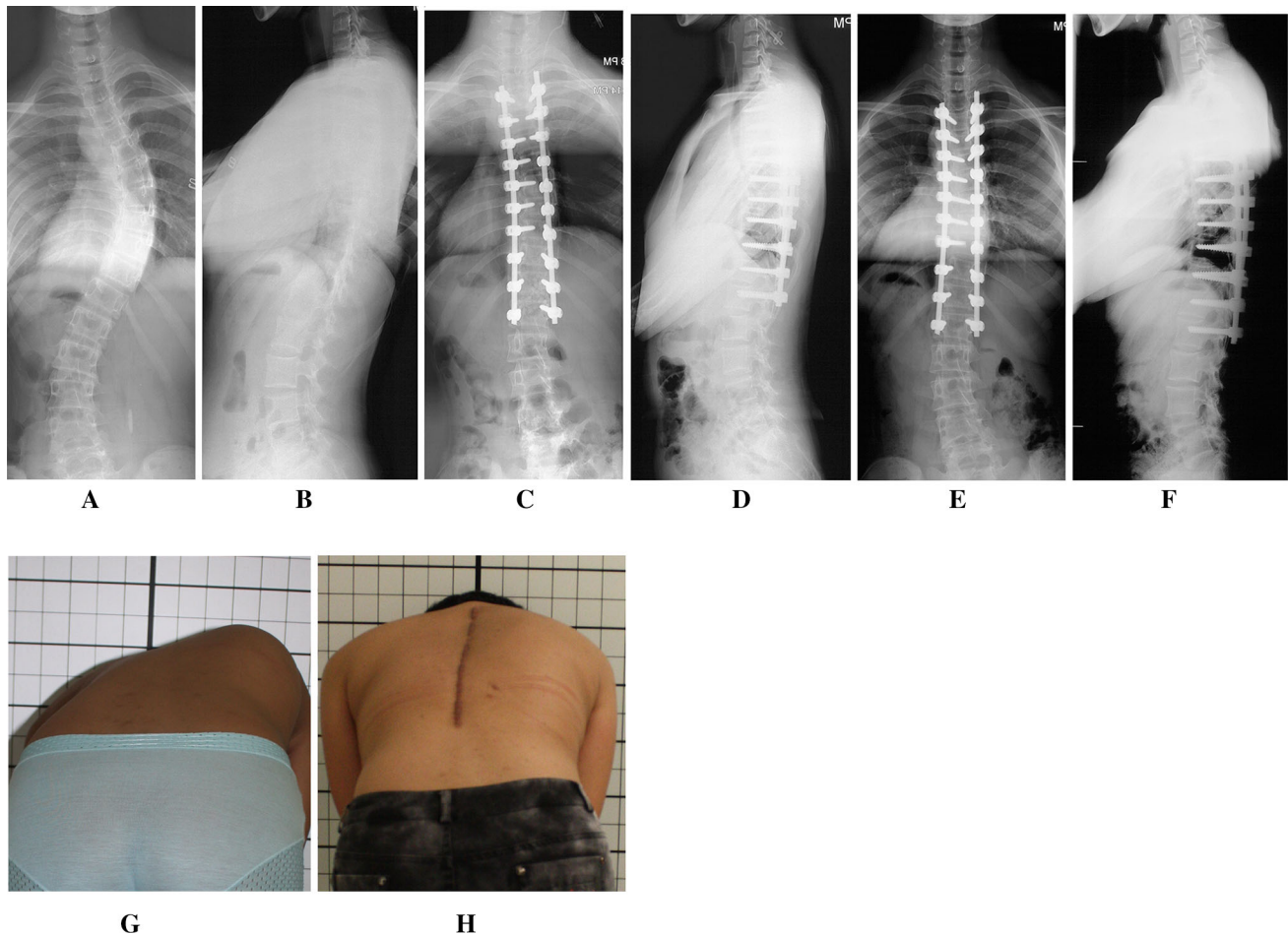
## Discussion

### Comparison of the outcomes between DVBD and SRD

Lee et al. [5] initially described the application of DBVB in 17 patients with King I–V curves, and reported 42.5 % vertebral body derotation in CT scans as compared with 2.5 % in SRD patients. Mattila et al. [8] demonstrated better correction of axial spinal deformity in Upasani score using En bloc DVBD than SRD. DVBD also showed

excellent apical vertebral derotation in main thoracic curves in the study of Silvestre et al. [13]. In the present study, RAsag-N was  $17.8^\circ \pm 3.6^\circ$  versus  $18.5^\circ \pm 2.3^\circ$  ( $p = 0.51$ ) preoperatively, and corrected to  $9.7^\circ \pm 2.0^\circ$  versus  $15.3^\circ \pm 2.4^\circ$  ( $p < 0.001$ ) in the matched DVBD and SRD patients, respectively (Table 2). DVBD obtained significantly better radiographic apical vertebral rotation postoperatively than SRD as previous studies.

Better coronal correction in DVBD patients was shown in some studies [5, 13], but not in Mattila's report [8]. In our data, although DVBD group got average smaller main thoracic curve postoperatively (DVBD  $14.2 \pm 1.6$  versus SRD  $14.7 \pm 1.7$ ,  $p = 0.18$ ), no significant difference was found in the two groups (Table 3). For sagittal plane, the average postoperative T5–T12 thoracic kyphosis tended to change flatter, and showed no difference in the two groups ( $16.2 \pm 2.1$  versus  $16.8 \pm 2.6$ ,  $p = 0.27$ ). The outcome of sagittal plane in DVBD patients was the same as most



**Fig. 3** 12-year-old female, Lenke I curve, received SRD in surgery. **a, b** Preoperatively, main thoracic Cobb 55.4°, T5–T12 thoracic kyphosis 15.6°. **c, d** Postoperatively, main thoracic Cobb 14.5°, T5–T12 thoracic kyphosis 12.1°. **e, f** At follow-up, main thoracic Cobb

15.9° (71.3 % correction), T5–T12 thoracic kyphosis 12.6°. **g, h** Preoperative rib hump was 21°, rib hump at follow-up was 7° (66.7 % correction)

**Table 5** Changes in Spinal Appearance Questionnaire (SAQ) and Scoliosis Research Society-22 Questionnaire (SRS-22)

Questionnaire	DVBD ( <i>n</i> = 36)	SRD ( <i>n</i> = 45)	<i>P</i>
<b>SAQ</b>			
Preop	3.2 ± 0.7	3.1 ± 0.5	0.46
Postop	2.1 ± 0.4	2.1 ± 0.6	1
Follow-up	2.2 ± 0.5	2.3 ± 0.7	0.47
<b>SRS-22</b>			
Preop	2.7 ± 0.6	2.9 ± 0.8	0.22
Postop	3.7 ± 0.7	3.8 ± 0.7	0.52
Follow-up	3.5 ± 0.9	3.6 ± 0.8	0.60

\* Statistically significant difference in the value between DVBD group and SRD group (*P* < 0.05)

\*\* Statistically significant difference in the value between DVBD group and SRD group (*P* < 0.001)

previous studies [8, 13, 14], although Lee et al. [5] demonstrated certain improvement in thoracic kyphosis. We attributed these differences to different curve types, curve flexibility, Risser sign, and DVBD or other surgical maneuvers. Figure 2 demonstrated a patient who improved her thoracic kyphosis after DVBD. Thus, multiple factors may affect the coronal and sagittal correction when using DVBD.

Although DVBD was reported to offer improvement of clinical rib hump by authors [6, 7, 15, 16], there was no obvious advantage when comparing with SRD at follow-up (Figs. 2, 3). Rib hump was 13.2° ± 4.9° versus 12.7° ± 5.2° (*p* = 0.66) preoperatively, and corrected to 6.4° ± 3.8° versus 6.8° ± 3.1° (*p* = 0.60) at follow-up in DVBD and SRD groups, respectively (Table 4). The same results were shown in the matched 19 DVBD patients and 16 SRD patients with CT scan examinations. Thus, seg-

mental DVBD provided almost the same rib hump correction as SRD in main thoracic curves.

SAQ provided more details about patient's appearance than other questionnaires, and used to detect patient's assessment of appearance, but not employed by previous related studies [10]. In this study, the scores of SAQ were improved to  $2.2 \pm 0.5$  versus  $2.3 \pm 0.7$  ( $p = 0.47$ ) at 2-year follow-up in the two groups (Table 5). DVBD provided no better patients' assessment than SRD. The result was supported by the outcomes of SRS-22 Questionnaire. As reported by authors [8, 16], scores of SRS-22 showed no significant difference between the two groups at follow-up in the present study.

DVBD providing forceful spinal derotation raised the risk of pedicle screws plowing and aortic abutment [17]. Meanwhile, addition DVBD maneuvers will potentially impact on the operating time, blood loss and other complications. For main thoracic curves, although segmental DVBD offered excellent radiographic axial spinal correction, there was no more rib hump correction or better patients' assessment than SRD at follow-up in our data.

#### Bias assessment of the data

The advantages of this study are prospective data collection with fair homogeneity of the subjects. The follow-up rate was 92 % in DVBD group and 88 % in SRD group, excluding the patients with insufficient materials and lack of follow-up. Only thoracic Lenke I and Lenke II AIS curves were identified without juvenile idiopathic scoliosis and adult idiopathic scoliosis, and operated by a single surgeon in the same periods of time and with same technical proficiency in surgical processes. No patient underwent Ponte procedure, any osteotomy, or thoracoplasty. Segmental DVBD was adopted without En bloc, or both of segmental and En bloc DVBD.

We did not manage to employ blind methods; patients and parents were informed whether DVBD was used. However, this did not influence the scores of SAQ and SRS-22, the DVBD group and SRD group gained the similar subjective assessment in the two questionnaires. Moreover, to avoid interference with operation maneuvers intraoperatively, the senior surgeon who operated all the patients did not involve in the data collection.

Not all the patients performed the CT scan examinations, on the account of additional exposure to radiation. Patients who have difficulty in pedicle screw insertion, and possibility of adjacent vessels damage especially in DVBD group, needed additional CT scan examinations. However, these patients in the two groups were well matched for analysis. Thus, measurements from CT scans in the study were still able to provide useful information.

To evaluate exact axial spinal deformity, we measured apical vertebral rotation on axial CT, and compared it to upper neutral vertebrae rather than sacrum adopted by Lee et al. [5] (Fig. 1). Sacrum may be rotated by examining table through pressing the lumbar hump, when patients receiving the CT examination. While the apical vertebra in thoracic curves was not totally rotated with sacrum, because of the flexible lumbar curve between thoracic curve and sacrum. On the contrary, the upper neutral vertebra was less affected when taking CT examination, and was the ideal reference vertebra to obtain exact radiographic apical vertebral rotation.

#### Limitation of the comparative study

Firstly, subjects in the present study were older and more mature (Risser sign  $>4$ ), whereas in Sivistre's report the age was 1 year younger and the average Risser Sign was 1.4. Simultaneously, the present study only included patients with mild curves and moderate rib hump magnitude. Taking into account the referred risks of DVBD, this maneuver can be avoided in cases like the present series. Meanwhile, DVBD in patients with younger age and more severe deformities is needed in further studies. Secondly, there was no Chinese version of SAQ questionnaire at the beginning of this study, English version of SAQ Questionnaire was employed, and no validated translation of the questionnaire was used. However, SAQ Questionnaire was mainly described by pictures, and all the patients had elementary to middle level of reading ability in English, so it is easily understood by patients.

**Conflict of interest** None.

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