Position of the Aorta Relative to Vertebrae in Patients with Degenerative Thoracolumbar or Lumbar Scoliosis: A Case-Control Study

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■ OBJECTIVE: **To investigate the position of the aorta relative to the spine in patients with de novo lumbar scoliosis (DLS).**

■ METHODS: **This study enrolled 142 patients with DLS, including 80 cases of left thoracolumbar/lumbar scoliosis (left group) and 62 cases of right scoliosis (right group). In addition, 132 cases free of deformity were allocated to the control group. Parameters of the Cobb angle and apical vertebrae were measured by radiograph, whereas the left pedicle-vertebrae angle (α), rotation angle (γ), and left pedicle-vertebrae distance (*d*) of T12-L4 were obtained by magnetic resonance imaging. Independent sample *t* test was performed to compare α, γ, and *d* between the DLS and control groups, followed by a Pearson correlation analysis to study the correlation between Cobb angle and α, γ, and *d*.**

■ RESULTS: **No difference was found between the right group and control group ($P = 0.554$). The value of mean *d* (4.62 ± 0.57 cm) gradually increased from T12 to L4 in the left group and showed significant difference with the corresponding value in the control group (4.44 ± 0.43 cm; $P < 0.001$). There was no significant difference between the right group and control group ($P = 0.762$). The value of mean *d* (4.54 ± 1.84 cm) showed no significant difference between the right group and control group ($P = 0.530$). The correlation analysis showed a significant correlation between rotation angle γ and Cobb angle ($P < 0.001$), but not in α and *d* with Cobb angle.**

■ CONCLUSIONS: **Although the position of the aorta relative to the spine showed no significant difference between patients with DLS and normal subjects, great attention should still be paid to prevent DLS-induced aorta injury.**

INTRODUCTION

Adult degenerative scoliosis (ADS) is a type of primary scoliosis occurring after skeletal maturation when the Cobb angle in the coronal plane becomes >10°.[1] As a type of ADS frequently diagnosed in people >40 years of age, de novo lumbar scoliosis (DLS) affects the thoracolumbar or lumbar spine and its prevalence reaches as high as 8.9%–12.4% in the middle-aged population.[2] A scoliosis spine is usually accompanied by displacement beyond anatomic in-site location of paraspinal muscles, tissues, and organs. In particular, the abdominal aorta located in the anterior-lateral direction to the thoracolumbar or lumbar spine is one of the most important organs affected by DLS. In fact, it would be catastrophic if the abdominal aorta is damaged inadvertently during surgeries.[3-5]

Studies on the aorta position in adolescent idiopathic scoliosis (AIS) have reached a consensus suggesting that the aorta in patients with AIS is displaced to the lateral-posterior side of the vertebrae[6,7]; however, such studies mainly focus on the thoracic aorta or the beginning segment of the abdominal aorta. As a disorder mainly affecting the thoracolumbar or lumbar spine, DLS is significantly different from AIS in terms of pathologic mechanisms and aorta anatomy,[8] pointing to the important role of relative positioning of the abdominal aorta with respect to the vertebrae in patients with DLS. Therefore, a clear understanding on the anatomy of the abdominal aorta is essential for spinal physicians to perform intraoperative manipulations without triggering vascular-related complications.

Key words
- Abdominal aorta
- Aorta-vertebrae angle
- Aorta-vertebrae distance
- De novo lumbar scoliosis
- Rotation angle

Abbreviations and Acronyms
ADS: Adult degenerative scoliosis
AIS: Adolescent idiopathic scoliosis
AS: Ankylosing spondylitis
DLS: De novo lumbar scoliosis
MRI: Magnetic resonance imaging

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Therefore, the purpose of this paper is to explore changes in the anatomic position of the aorta relative to the spine in patients with DLS suffering from left and right thoracolumbar or lumbar scoliosis.

MATERIALS AND METHODS

Participants

This retrospective single-center study was approved by the medical ethics committee of our hospital. A total of 132 healthy control subjects without spinal deformity (control group) were recruited from January 2015 to June 2018 along with 142 patients with DLS, including 80 cases of DLS with left thoracolumbar/lumbar scoliosis (left group) and 62 cases of DLS with right scoliosis (right group). All subjects met the following inclusion criteria in terms of their sagittal balance: 1) the apical vertebrae were located within the thoracolumbar or lumbar spine (T12-L4), 2) data were available on magnetic resonance imaging (MRI) of the thoracolumbar and lumbosacral spine; and 3) poster-oanterior and lateral radiographs containing the lumbar segment and entire spine were available. Exclusion criteria included the following: 1) congenital vascular abnormality, 2) previous spinal or cardiovascular surgery, 3) sagittal plane imbalance (defined as a displacement of >5.0 cm in the C7 plumb), and 4) no sagittal malformation on the local thoracolumbar or lumbar spine. Informed consent was obtained from all subjects.

There was no significant difference in sex between the left group (12 men and 68 women) and control group (20 men and 112 women) ($P = 0.634$) nor was there any significant difference between the control group and the right group (14 men and 48 women) ($P = 0.318$). The age ($P = 0.57$ and $P = 0.203$, respectively) in the left (67.2 ± 7.3 years) and right (68.1 ± 8.5 years) groups was well-matched with that in the control group (66.3 ± 8.4 years). Similarly, body mass index in the left and right groups was also well-matched with that in the control group ($P = 0.271$ and $P = 0.754$, respectively).

Measurements

Measurements on Radiographs. The standard posterior-anterior and lateral radiographic films of the lumbar and entire spine were obtained at the standing position to identify 1) left or right thoracolumbar/lumbar scoliosis, 2) Cobb angle (in degrees), 3) apical vertebrae distribution, and 4) distance of horizontal displacement on the coronal plane (mm) (i.e., vertical distance from the curvature apex to the sacral vertical line). These parameters were collected by 2 investigators independently.

Measurements on MRI. All 274 subjects underwent MRI examinations in a neutral supine position using a 1.5-T scanner (Gyroscan Intera [Philips Medical Systems, Eindhoven, The Netherlands]). Axial 4-mm slices with 1-mm overlap were acquired using 3-dimensional thick T2-weighted spin-echo axial scanning of the vertebral bodies (time of repetition: 5000 ms; time of echo: 120 ms; field of view: 250 mm; matrix size: 250 × 360). Similar MRI scanning and image acquisition protocols were applied for the supine position, and the acquired images were analyzed using PACS client software (Easy Vision IDS5, version 11.4 [Philips, Hamburg, Germany]). To clarify the position of the abdominal aorta relative to the vertebrae, the following parameters were measured using a Cartesian coordinate system on magnetic resonance images covering the area from the T12 to L5.[9]

The first was the Cartesian coordinate system. A line vconnecting the medial edges of the superior facets was used as the x axis. Subsequently, the y axis was drawn perpendicularly to the x axis, which started from the dorsal edge of the right superior facet. In addition, the place where the 2 lines intersected with each other was used as the origin O.

The second was the left pedicle-aorta angle (α). The angle formed by the y axis and a line connecting the origin and center of the aorta was defined as the left pedicle-aorta angle (α). The angle was defined as 90° and −90° when the aorta was located directly to the left and right of the original point, respectively.

The third was the vertebral rotation angle (γ). It was defined as the angle subtended by a straight line through the posterior central aspect of the vertebral foramen and the middle of the vertebral body and sagittal plane.

The fourth was the left pedicle-aorta distance (d). This distance was defined as a line connecting the origin O and the nearest edge of the aorta (Figure 1).

Statistical Analysis

The value of each parameter at each vertebral level was presented as mean ± SD. Independent sample t test was used to compare the values of α, γ, and d between the left/right group and control group, followed by Pearson correlation analyses to identify the correlation between the Cobb angle and the horizontal displacement distance and the values of α, γ, and d in the 2 scoliosis groups. $P < 0.05$ indicated significant difference. All data were analyzed using SPSS 22.0 (International Business Machines Corporation, Armonk, New York, USA).

RESULTS

Results of Radiographic Measurements

In the left group, T12-L4 was evenly distributed along the apical vertebrae, whereas L3 (40.0%) and L2 (35.0%) were the most

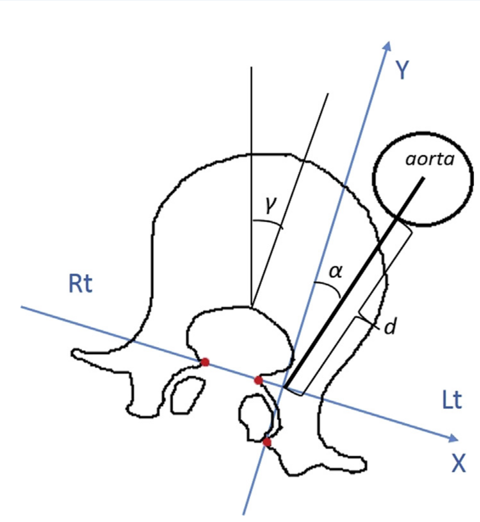

Figure 1. Position of the Cartesian coordinate system and descriptions of α, γ, and d. Lt, left; Rt, right.

Table 1. Cobb Angle, Apical Vertebrae Distribution, and Distance of Horizontal Displacement on the Coronal Plane Between the Left and Right Groups

	Left Group			Right Group		
Apical Vertebrae	Apical Body Cases	Cobb Angle	Coronal Horizontal Displacement (mm)	Apical Body Cases	Cobb Angle	Coronal Horizontal Displacement (mm)
T12	1	23.7° ± 12.7°	45.2 ± 10.7	4	20.8° ± 10.4°	47.8 ± 15.1
L1	7			8		
L2	28			22		
L3	32			19		
L4	12			9		

Values are mean ± SD or as otherwise indicated.

common ones. The average Cobb angle in the left group was 23.7° ± 12.7° (range, 10.4°–42.5°), and the distance of horizontal displacement on the coronal plane was 45.2 ± 10.7 mm (range, 25.5 mm–77.7 mm). The apical vertebrae in the right group also occupied T12 to L4 but mainly concentrated in L2 (35.5%) and L3 (30.6%). In the right group, the average Cobb angle and distance of horizontal displacement on the coronal plane were 20.8° ± 10.4° (range, 11.0°–48.4°) and 47.8 ± 15.1 mm (range, 25.4 mm–77.5 mm), respectively. There was no significant difference between the 2 groups in terms of apical vertebrae distribution ($P = 0.280$), Cobb angle ($P = 0.311$), and distance of horizontal displacement on the coronal plane ($P = 0.394$) (Table 1).

Results of MRI Measurements

Comparison of α, γ, and d Between the Left and Control Groups. In the control group, α (−2.96° ± 6.40°) gradually decreased from T12 to L4 when the abdominal aorta moved transitionally from the left lateral-anterior side of the vertebrae to the opposite lateral-anterior side via its descending trace along the diaphragm. In addition, there was no regular pattern in the α value (−2.57° ± 6.14°) of the left group, and no statistical difference was observed between the left and control groups ($P = 0.554$) (Figure 2). In the left group, the mean rotation angle γ was 5.57° ± 5.32°, whereas the maximum value of γ was located at L3 and L2. In both the control (4.44 ± 0.43 cm) and left (4.62 ± 0.57 cm) groups, the left pedicle-aorta distance d gradually increased from T12 to L4 and the difference between the 2 groups was statistically significant ($P < 0.001$) (Figure 3). Therefore, compared with normal subjects, the angle of the abdominal aorta showed no significant changes except a slightly longer distance away from the thoracolumbar/lumbar vertebrae in patients with left scoliosis (Table 2).

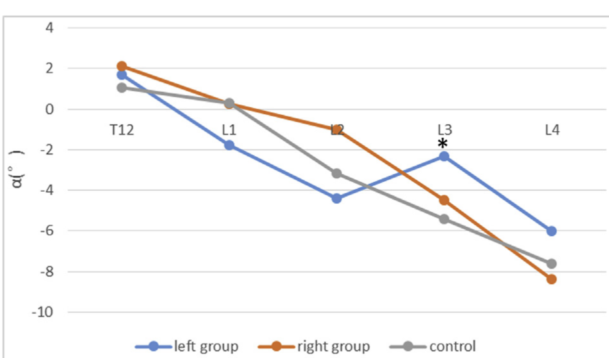

Figure 2. Left pedicle-aorta angle (α) from T12 to L4 in the left and right groups compared with the control group. $^*P < 0.05$.

Comparison of α, γ, and d Between the Right and Control Groups. In both the normal and right groups, α (−3.41° ± 9.44°) gradually decreased from T12 to L4, and no significant difference was observed between the 2 groups ($P=0.762$) (Figure 2). The mean rotation angle γ was −9.02° ± 6.71° in the right group with the maximum value located at L2 and L3. The distance d (4.54 ± 1.84 cm) also increased from T12 to L4 in the right group, and the value was statistically different from that in the control group ($P = 0.530$) (Figure 3). Therefore, compared with the values in the control group, no significant difference was found in the angle and distance between the abdominal aorta and vertebrae in the right curvature of patients with DLS (Table 3).

Correlation Analysis

A correlation was observed between the rotation angle γ and Cobb angle/distance of horizontal displacement on the coronal plane in the left group (both $P < 0.001$), suggesting that a more intensive rotation would lead to a larger Cobb angle and a longer displacement distance. However, there was no correlation between Cobb angle/distance of horizontal displacement on the coronal plane and α ($P = 0.949$ and $P = 0.987$, respectively) or d ($P = 0.942$ and $P = 0.918$, respectively). Similarly, in the right group, the Cobb angle/distance of horizontal displacement on the coronal plane was also correlated with γ (both $P < 0.001$), but not with α ($P = 0.798$ and $P = 0.705$, respectively) or d ($P = 0.918$ and $P = 0.553$, respectively) (Table 4 and Figure 4).

DISCUSSION

ADS and DLS are types of lumbar spine scoliosis caused by the asymmetry in degenerated intervertebral disk or the degeneration

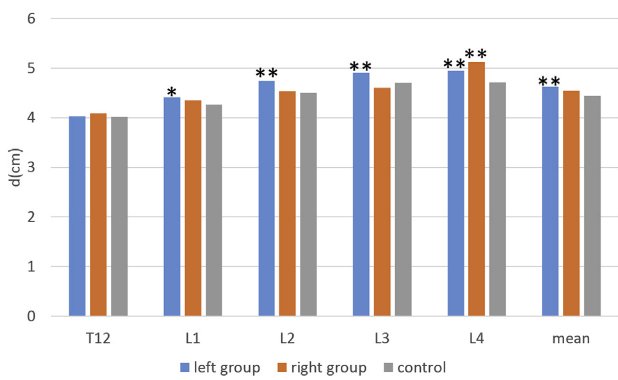

Figure 3. Left pedicle-aorta distance (*d*) from T12 to L4 in the left and right groups compared with the control group. $*P < 0.05$; $**P < 0.05$.

of facet joints and other appendices.[10] As an age-related disease, the incidence of DLS increases markedly in elderly people, rendering osteoporotic women >65 years of age more prone to degenerative scoliosis.[11,12] However, the relative position between the vertebrae and aorta in patients with DLS remains unclear because the lumbar spine in DLS usually suffers from vertebrae displacement and rotation. In patients with DLS, the incidence of aortic injury may be slightly increased; however, the probability of aortic injury in spinal surgery is only 0.01%–0.05%.[7] Studies on the relative position between the vertebrae and aorta in malformed spine, such as AIS,[6,7,13,14] Pott deformity, and ankylosing spondylitis (AS), have shown a lower range and higher risk of screw implantation via the left pedicle in patients with right thoracic AIS.[7] However, in patients with AS[15] and Pott malformations who also suffer from thoracolumbar or lumbar kyphosis,[16] their aorta is more prone to move anteriorly and medially to the vertebrae. However, to our knowledge, the relationship between the abdominal aorta and vertebrae in patients with DLS has not been reported before.

Khamanarong et al.[17] showed that the abdominal aorta bifurcation for iliac arteries is mainly located around the lower level of the L4 vertebra and the L4-5 intervertebral space; hence, the lower measurements stop at L4. Jiang et al.[6] developed a method for establishing the coordinate system in the thoracolumbar spine and lumbar vertebrae, and their results are consistent with the point and direction of the pedicle screw insertion. In this study, vertebrae and aorta parameters were obtained from 142 patients with DLS. It was found that lumbar apical vertebrae were mainly concentrated in L2, L3, and L4, and there was no significant variation between left and right scoliosis in terms of the relative position between the vertebrae and aorta. In the left group, the aorta is slightly away from the left pedicle than in normal subjects; however, no such trend was seen in the right group. Overall, the relative position between the aorta and vertebrae in patients with DLS is slightly different from that in normal people; however, such a difference was not significant. This result is in accordance with a previous report suggesting that the aorta is mostly located anterior-medially to the thoracolumbar or lumbar spine.[18]

Liljenqvist et al.[19] and Sevastik et al.[20] found a larger distance of lateral displacement and a shorter distance of vertical displacement in the relative position between the aorta and vertebrae of patients with AIS. Sucato and Duchene[7] also reported the dorsal orientation of the aorta with a right thoracic curve in AIS; however, the change was not significant in patients with DLS because of the different etiology of AIS and DLS. AIS may be manifested as a gene- and environment-related disease, whereas DLS is mainly caused by metabolic and biomechanical factors.[8] Scoliosis is related to the imbalance caused by the degeneration of intervertebral disks, facets, and paravertebral muscles. Such degeneration aggravates the stress distribution and force conduction along the spine, therefore accelerating the progression of deformity.[21] Moreover, as an important component of the 3-dimensional malformation of AIS, the axis rotation contributes to the appearance of razor deformity, which is usually accompanied by thoracic deformation. The vertebrae in patients with AIS generally rotate to the convex side, whereas a nonidiopathic type of AIS should be considered if the rotation is not obvious or even points to the opposite direction. In addition, the coronal Cobb angle in patients with DLS is usually <40°, whereas the vertebrae rotation or displacement is of a moderate size and is limited to the apical levels.[22,23] Furthermore, the purpose of AIS surgery is mainly for the correction of

Table 2. Comparison of α, γ, and *d* from T12 to L4 Between the Left and Control Groups

Levels of Vertebrae	α			γ			*d* (cm)		
	Left Group	Control Group	*P* Value	Left Group	Control Group	*P* Value	Left Group	Control Group	*P* Value
T12	1.71° ± 10.25°	1.06° ± 7.02°	0.734	2.36° ± 4.13°	−0.44° ± 1.25°	<0.001	4.03 ± 0.61	4.02 ± 0.39	0.967
L1	−1.78° ± 7.14°	0.30° ± 5.2°	0.114	4.39° ± 4.72°	−0.32° ± 1.56°	<0.001	4.41 ± 0.43	4.26 ± 0.29	0.032
L2	−4.40° ± 5.85°	−3.17° ± 4.81°	0.243	6.57° ± 5.59°	0.06° ± 1.47°	<0.001	4.74 ± 0.36	4.50 ± 0.30	<0.001
L3	−2.31° ± 7.83°	−5.41° ± 5.82°	0.034	8.00° ± 4.80°	−0.14° ± 1.51°	<0.001	4.91 ± 0.43	4.70 ± 0.33	0.007
L4	−6.00° ± 6.13°	−7.63° ± 6.13°	0.193	6.38° ± 5.54°	−0.10° ± 1.57°	<0.001	4.95 ± 0.40	4.71 ± 0.38	0.002
Mean	−2.57° ± 6.14°	−2.96° ± 6.40°	0.554	5.57° ± 5.32°	−0.18° ± 1.48°	<0.001	4.62 ± 0.57	4.44 ± 0.43	<0.001

Values are mean ± SD or as otherwise indicated.

Table 3. Comparisons on α, γ, and *d* from T12 to L4 Between Right and Control Groups

Levels of Vertebrae	α			γ			*d* (cm)		
	Right Group	Control Group	*P* Value	Right Group	Control Group	*P* Value	Right Group	Control Group	*P* Value
T12	2.11° ± 12.85°	1.06° ± 7.02°	0.679	−6.86° ± 4.42°	−0.44° ± 1.25°	<0.001	4.09 ± 0.67	4.02 ± 0.39	0.619
L1	0.28° ± 8.20°	0.30° ± 5.2°	0.990	−9.04° ± 6.84°	−0.32 ± 1.56	<0.001	4.35 ± 0.97	4.26 ± 0.29	0.609
L2	−1.01° ± 6.61°	−3.17° ± 4.81°	0.072	−11.48° ± 7.80°	0.06 ± 1.47	<0.001	4.53 ± 2.11	4.50 ± 0.30	0.957
L3	−4.47° ± 8.81°	−5.41° ± 5.82°	0.548	−10.49° ± 6.88°	−0.14 ± 1.51	<0.001	4.60 ± 3.27	4.70 ± 0.33	0.858
L4	−8.37° ± 6.76°	−7.63° ± 6.13°	0.595	−7.20° ± 6.25°	−0.10 ± 1.57	<0.001	5.12 ± 0.47	4.71 ± 0.38	<0.001
Mean	−3.41° ± 9.44°	−2.96° ± 6.40°	0.762	−9.02° ± 6.71°	−0.18 ± 1.48	<0.001	4.54 ± 1.84	4.44 ± 0.43	0.530

Values are mean ± SD or as otherwise indicated.

razorback deformity, whereas the operation on DLS mainly focuses on the removal of nerve root compression to alleviate spinal deformity and restore spinal stability.[24,25] Therefore, DLS is associated with a lower degree of malformation and a relatively stable position between the vertebrae and aorta.

According to the theory of tethering effect, the aorta in AIS is caught by the surrounding crux of the diaphragm and then forced into the concave side of the curve to generate the shortest distance between the top and bottom of the chest cavity.[26,27] Milbrandt and Sucato[5] observed the shifting of thoracic aorta to the left side of the curve, which caused the thoracic aorta to be positioned further both laterally and posteriorly from the vertebral body in the right thoracic curve. Muñoz et al.[28] showed that abdominal aorta descended from aortic hiatus and landed on the left side of the midline within the lumbar spine before gradually migrating to the front of the vertebrae at the L2 and L3 levels. In elderly patients with DLS, the rigid artery combined with the weakened tethering ability of connective tissues may help to maintain an anatomic vertebrae-aorta relationship when the pulling on the aorta by arteries branches to the spine.

Table 4. Pearson Correlation Analysis on the Correlation Between the Cobb Angle/Distance of Horizontal Displacement on the Coronal Plane and α, γ, and *d* Values in the 2 Scoliosis Groups

Cobb Angle/Distance of Horizontal Displacement	Mean α	Mean γ	Mean *d*
Cobb angle			
Left group			
r	0.010	0.569	0.012
P value	0.949	0.000	0.942
Right group			
r	0.048	−0.767	0.140
P value	0.798	0.000	0.453
Horizontal displacement distance			
Left group			
r	−0.003	0.674	0.017
P value	0.987	0.000	0.918
Right group			
r	−0.071	−0.728	0.350
P value	0.705	0.000	0.053

r, correlation coefficient.

Radiographic findings showed that when the vertebrae rotate to the left, the left pedicle moves dorsally, whereas the right pedicle moves ventrally.[14] Therefore, in the left group, the distance between the origin O and the aorta increased by an average of 1.8 mm because of the rotation and location of the coordinate system. In the right group, the vertebrae rotated right and triggered the ventral movement of the origin O and a pulling force on the aorta from surrounding tissues, rendering the distance of the displacement away from the aorta in this group similar to that in the control group. Such movement may also explain the principle of orthopedics by putting pressure on the convex side and lifting on the concave side.[9]

In 8099 cases of lumbar surgeries reviewed by Szolar et al.,[29] 4 cases suffered vascular complications. Aorta and branch injury will cause acute bleeding, pseudoaneurysm, or arteriovenous fistula,[5] whereas the rotation and disarrangement of the vertebrae in scoliosis may increase the risk of aorta injury during the placement of orthopedic screws.[7,20,30] Ayca et al.[31] performed a study on the correlation between DLS and the diameter and atherosclerotic plaque of the aorta, revealing that the aorta flexed with spinal deformity and caused hydrodynamic changes. In addition, the diameter and fragility of the aorta were significantly increased in patients with DLS.

By measuring bone mineral density in elderly patients with DLS, Sadat-Ali et al.[32] found a correlation between the severity of scoliosis and the reduction in bone mineral density. Posterior approaches are often adopted for DLS treatments, in which a weaker cortical bone located at the anterior vertebrae border of osteoporosis remarkably increases the risk of probe- or pedicle screw—induced forward breaking. Moreover, the probability of abdominal aortic injury is increased by potential damage to the anterior longitudinal ligament, which becomes fragile with the degeneration of DLS.[31] In addition, a firm adhesion formed

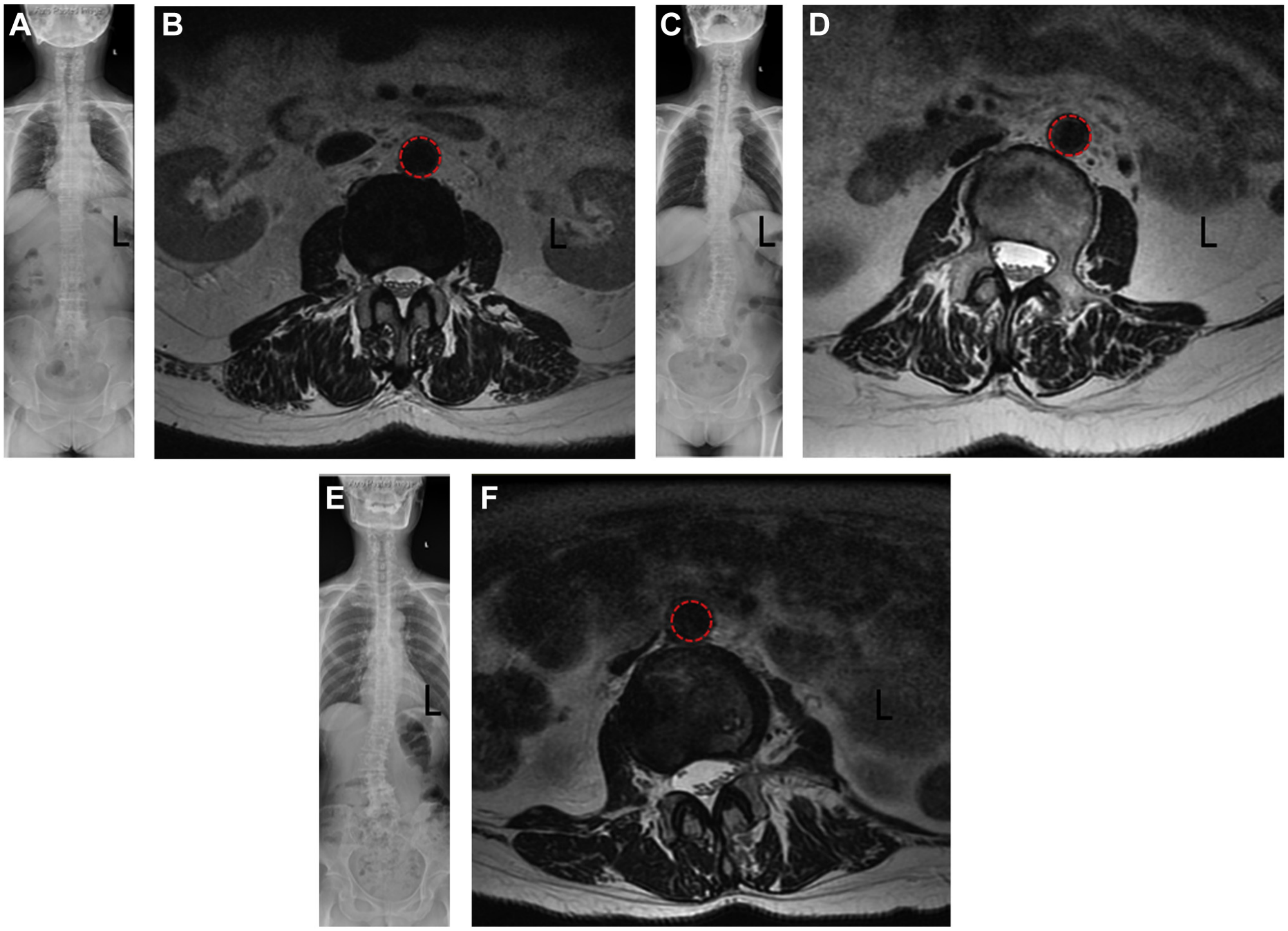

Figure 4. These was the postero-anterior radiographs of whole spine and magnetic resonance imaging (MRI) T2-weighted axis images of lumbar spine with 3 cases respectively from control, left and right groups. (**A** and **B**) The radiograph and L3-level MRI of the entire spine of a 63-year-old woman in the control group showed an α value of $-4.1°$ and a *d* value of 4. 60 mm. (**C** and **D**) The radiograph and L3-level MRI of the entire spine of a 61 year-old woman in the left group. The apical vertebra was L3, the Cobb angle was 21.3°, the α value was $-4.5°$, the γ value was 15.6°, and the *d* value was 5.32 mm. (**E** and **F**) The radiograph and L3-level MRI of the entire spine of a 63-year-old woman in the right group. The apical vertebra was L3, the Cobb angle was 22.3°, the α value was $-4.8°$, the γ value was $-13.8°$, and the *d* value was 4.73 mm. These figures illustrate a relatively fixed left pedicle-aorta angle (α) in the patients with de novo lumbar scoliosis and normal subjects. The *red circle* referres to outline and location of aorta.

between the aorta and anterior longitudinal ligament by noninfectious inflammation of the spine limits the aortic activity and is more likely to cause aorta injury during screw placement and osteotomy.[33] Sometimes, anterior osteotomy is the only effective measure to treat deformity when Smith-Petersen osteotomy performed for severe or rigid DLS fails to achieve satisfactory outcomes; however, the risk of higher aorta tension and wall tearing sharply increases with the extension of the anterior column.[16] Some reports have shown that anterior osteotomy combined with internal fixation triggered severe consequences of an injured aorta.[34,35]

There are some limitations in this study. First, one of the exclusion criteria is sagittal imbalance or severe kyphosis; however, DLS is a 3-dimensional spinal deformity and hence the conclusion may not be applicable for all DLS cases. In addition, lateral olisthesis and sagittal slippage may affect the relative position between the vertebrae and aorta. Finally, patients usually take the supine position during MRI examinations; however, their surgery is often performed in the prone position. Some studies on AIS have reported that the body position can affect the position of the aorta,[6,36] whereas Qu et al.[33] found no significant change in the relative apposition between the aorta and spine at the T9-L3 level during the measurement of patients with AS after posture conversion. Therefore, further investigation is needed to determine whether the body position used in this study is suitable for all patients with DLS.

CONCLUSIONS

The abdominal aorta maintained a relatively fixed position with respect to the vertebrae in the right group, whereas the abdominal aorta was slightly moved away from the left pedicle in the left group. There was no clear correlation between aorta-vertebrae angle/distance and the degree of scoliosis. Although the position of the aorta relative to the spine showed no significant difference between patients with DLS and normal subjects, great attention should still be paid to prevent DLS-induced aorta injury.

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