Spine

SPINE Volume 36, Number 23, pp E1519–E1524
©2011, Lippincott Williams & Wilkins

DEFORMITY

Is a Right Pedicle Screw Always Away From the Aorta in Scoliosis?

Katsushi Takeshita, MD,* Toru Maruyama, MD,† Shurei Sugita, MD,* Yasushi Oshima, MD,* Jiro Morii, MD,* Hirotaka Chikuda, MD,* Takashi Ono, MD,* and Kozo Nakamura, MD*

Study Design. Retrospective analysis.

Objective. We evaluated the aorta safety in placement of a right pedicle screw in scoliotic patients.

Summary of Background Data. Past reports emphasized the aorta risk in placing pedicle screws on the concave left side in right thoracic scoliosis. However, risk on the right side has drawn limited interest.

Methods. Thirty-four scoliotic patients with an average age of 18.0 years were evaluated. The Cobb angle averaged 59.0° ± 14.0°. From computed tomographic data, we evaluated the aorta location relative to the spine at each level from T4 to L4 and simulated placement of a right pedicle screw with a direction different from the ideal trajectory. Sensitivity analysis was performed independently by variable direction errors and screw length: the maximum error of trajectory was set to 5° in the medial direction and to 5°, 10°, or 20° in the lateral direction, and a screw length was set at 40, 45 or 50 mm. We defined "aorta-at-risk" when a patient has some level where a simulated pedicle screw involves the aorta, and compared the curve characteristics (the apical vertebral translation, the Cobb angle and the Nash-Moe grade) between the aorta-at-risk cases and the aorta-no-risk cases.

Results. In left thoracic or lumbar curves, the aorta often resided in front of right pedicles at the periapical level. In a scenario of a simulated pedicle screw with a maximum error of 20° in the lateral direction and a screw length of 50 mm, the aorta was at risk in 7 (33%) of 21 left lumbar curves. Curve characteristics of the aorta-at-risk cases at L1 were a larger apical vertebral translation ($P = 0.003$), a larger Cobb angle ($P = 0.006$), and a larger Nash-Moe grade ($P = 0.017$) compared with those of the aorta-no-risk cases.

Conclusion. Surgeons need to pay attention to the position of the aorta in placing a pedicle screw on the right at the periapical level of a left curve either in thoracic or lumbar spine.

Key words: scoliosis, aorta, pedicle, screw. **Spine 2011;36: E1519–E1524**

One of the disadvantages of a pedicle screw is the possibility of aorta involvement. The aorta is located on the left side of the thoracic spine and stays in front of the lumbar spine in normal subjects,[1] and past reports emphasized the aorta risk in placing a screw on the concave side, which is usually left in right thoracic scoliosis.[2,3] On the contrary, risk on the right side in scoliosis has drawn limited interest. The purpose of this study was to evaluate the safety of the aorta in placement of a right pedicle screw in scoliosis surgery.

MATERIALS AND METHODS

A total of 34 patients with scoliosis were evaluated after excluding congenital scoliosis and soft-tissue related disease such as Marfan syndrome. The average age at a computed tomographic examination was 18.0 years (range = 10–30), and there were 4 males and 30 females. Scoliosis was idiopathic in 30 patients, Chiari-syrinx in 2, multiple epiphyseal dysplasia in 1, and Noonan syndrome in 1. There were 29 thoracic curves and 24 lumbar curves, and the Cobb angle averaged 59.0° ± 14.0° (28° to 100°; Table 1).

Computed tomography (CT) was taken for surgical planning with a thickness of 1.25 mm, and data were transferred to a personal computer for analysis (ExaView LITE: Ziosoft, Tokyo, Japan). In the thoracic spine, we selected the middle of the base of the right superior facet where a pedicle screw is placed as the point of origin of the coordinate system (Figure 1A). A line connecting both of the middle points of bases of the superior facets was defined as the X-axis. In the lumbar spine, we drew a line between both the medial edges of superior facets as the X-axis (Figure 1B). The Y-axis was drawn perpendicular to the X-axis starting from the dorsal edge of the right superior facet. In thoracic and lumbar spine, the angle formed by the Y-axis and a line connecting the origin and the center of the aorta was defined as the right pedicle-aorta angle, and length of a line connecting the origin and the edge of the aorta as the right pedicle-aorta distance. From the repeatability test in our

---

From the *Department of Orthopaedic Surgery, the University of Tokyo, Tokyo, Japan; †Department of Orthopaedic Surgery, the Saitama Medical Center, Saitama, Japan.

Acknowledgment date: April 7, 2010. First revision date: September 6, 2010. Second revision date: December 22, 2010. Acceptance date: January 8, 2011.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Correspondence and reprint requests to Katsushi Takeshita, MD, Department of Orthopaedic Surgery, Faculty of Medicine, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8655, Japan; E-mail: Takeshita-ort@h.u-tokyo.ac.jp

DOI: 10.1097/BRS.0b013e31820f8e6b

TABLE 1. Properties of Scoliosis

ID	Diagnosis	Age (yr)	Sex	Th Side	Th Cobb (degrees)	Th Apx	L Side	L Cobb (degrees)	L Apx
8	idio	17	F	R	53	T9	n.d.	n.d.	n.d.
11	idio	19	F	R	63	T10	n.d.	n.d.	n.d.
12	idio	19	F	R	83	T9	n.d.	n.d.	n.d.
13	idio	20	F	R	51	T7	L	28	L1/2
14	idio	16	F	n.d.	n.d.	n.d.	R	50	L1
15	idio	19	F	R	57	T8	L	49	L2
19	idio	29	F	n.d.	n.d.	n.d.	L	71	L1
21	idio	12	F	R	87	T9/T10	n.d.	n.d.	n.d.
23	idio	17	F	R	57	T8	L	62	L2
24	Chiari	15	F	R	62	T4/T5	L	88	L1/2
26	idio	16	F	R	54	T7/T8	L	54	L2
27	idio	16	F	R	52	T8/T9	L	42	L2
28	idio	20	F	R	54	T7	L	37	L2
29	idio	18	M	R	50	T8/T9	L	31	L2
30	idio	18	F	R	58	T9	n.d.	n.d.	n.d.
32	idio	13	F	R	58	T8/T9	L	40	L2
33	idio	11	F	L	79	T5	R	100	L1
34	Chiari	12	M	R	52	T8/T9	L	65	L4
35	idio	29	F	R	54	T8	L	67	L2
37	idio	15	F	R	68	T9	n.d.	n.d.	n.d.
39	idio	19	F	R	57	T10	n.d.	n.d.	n.d.
40	idio	23	F	R	63	T9/T10	n.d.	n.d.	n.d.
41	idio	10	F	R	61	T10	L	35	L3
44	Noonan	23	F	R	78	T9	n.d.	n.d.	n.d.
46	idio	13	M	R	83	T9/T10	L	63	L2/3
48	MED	16	M	R	62	T9	L	42	L2/3
49	idio	21	F	n.d.	n.d.	n.d.	L	56	L1
50	idio	19	F	L	63	T5	R	64	T12
51	idio	17	F	R	66	T7	L	67	L1
53	idio	30	F	n.d.	n.d.	n.d.	L	55	L2
54	idio	13	F	R	57	T8	L	55	L2
56	idio	29	F	R	50	T7	L	55	L3
57	idio	16	F	R	58	T9	n.d.	n.d.	n.d.
58	idio	13	F	n.d.	n.d.	n.d.	L	60	L3

Dx indicates diagnosis of scoliosis; idio, idiopathic; L side, convex side of a lumbar curve; L Cobb, Cobb angle of a lumbar curve; L Apx, apex level of a lumbar curve; MED, multiple epiphyseal dysplasia; n.d., not deformed; T side, convex side of a thoracic curve; T Cobb, Cobb angle of a thoracic curve; T Apx, apex level of a thoracic curve.

previous study,[4] interclass correlation coefficients were 0.922 to 0.957 in the intraobserver measurement and 0.896 to 0.929 (0.864–0.961) in the interobserver measurement.

We evaluated the location of the aorta relative to the spine at each level from T4 to L4 and simulated placement of a right pedicle screw with a direction different from the ideal

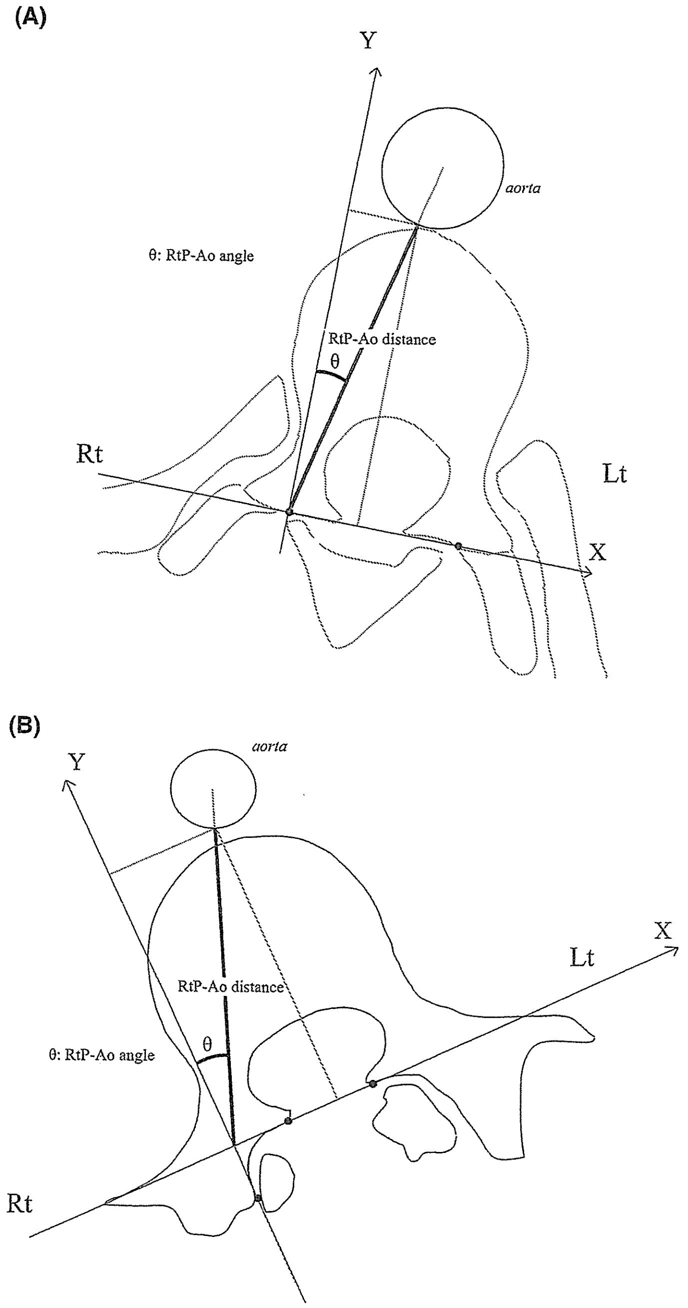


Figure 1. Measurement of two aorta parameters: right pedicle-aorta distance (Rt P-Ao distance) and right pedicle-aorta angle (Rt P-Ao angle). A, Schematic drawing in a thoracic curve. The origin was set at the middle point of the base of a right superior facet, and the X-axis was determined by connecting the middle point of the base of a left superior facet and the origin. B, Schematic drawing in a lumbar curve. The X-axis was determined first by connecting both the medial edges of the superior facets; the Y-axis was drawn perpendicular to the X-axis from the dorsal edge of a left superior facet, and the origin was determined.

trajectory. Sensitivity analysis was performed by variable direction errors and a screw length independently. We defined "aorta-at-risk" when a patient has some level where the simulated pedicle screw involves the aorta. As preliminary analysis had shown that the aorta-at-risk level was observed mostly in the lumbar spine, the maximum error of trajectory was set to

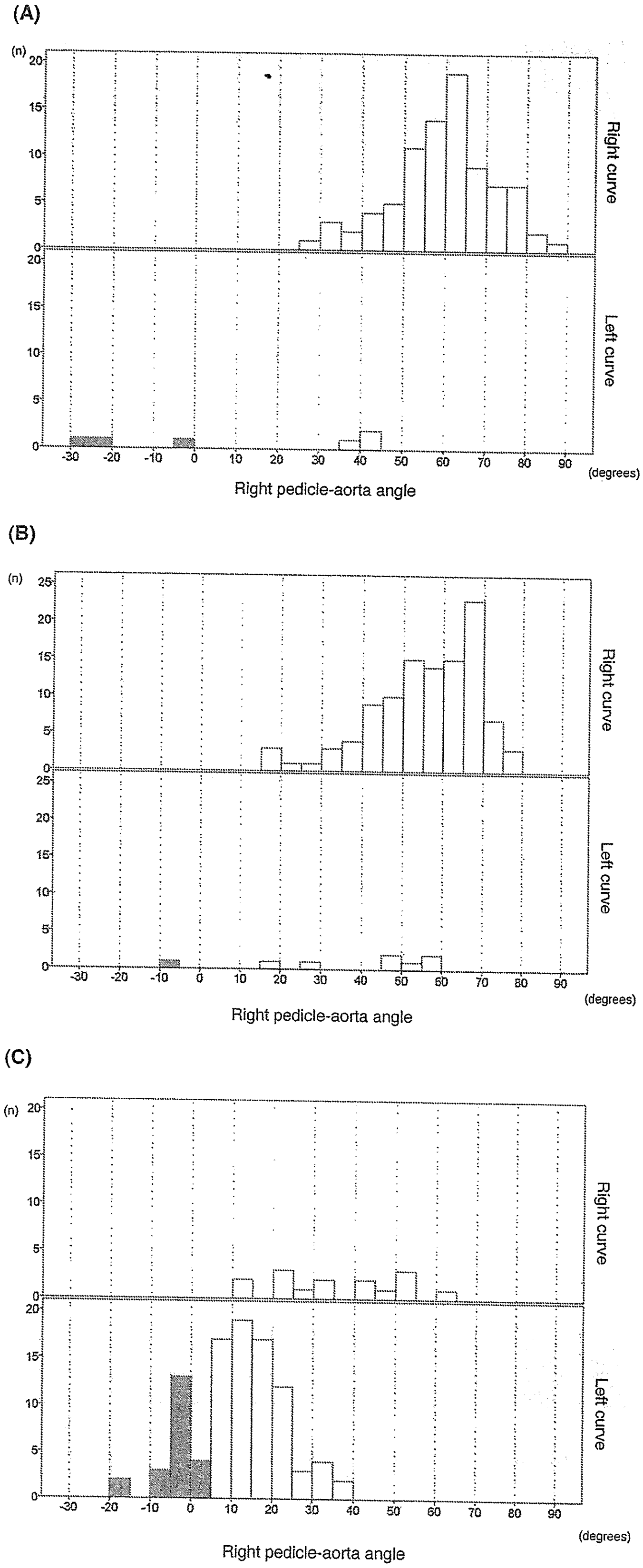


Figure 2. Distribution of right pedicle-aorta angles at 385-spine level. Bar is shaded if a right pedicle-aorta angle was below 5°. A, Histogram at T4 to T7. Upper: right curves, lower: left curves. B, Histogram at T8 to T11. Upper: right curves, lower: left curves. C, Histogram at T12 to L4. Upper: right curves, lower: left curves.

TABLE 2. Distribution of the Aorta-At-Risk Cases With Left Lumbar Curves in Simulated Scenarios

Angle (degree)	Length (mm)	Level	T4 to T11	T12	L1	L2	L3	L4
		Total	147	21	21	21	20	13
5	40	%	0	0	0	0	0	0
		No	0	0	0	0	0	0
5	45	%	0	0	14	5	0	0
		No	0	0	3	1	0	0
5	50	%	0	5	24	29	10	0
		No	0	1	5	6	2	0
10	40	%	0	0	0	0	0	0
		No	0	0	0	0	0	0
10	45	%	0	0	14	10	0	0
		No	0	0	3	2	0	0
10	50	%	0	5	29	33	10	0
		No	0	1	6	7	2	0
20	40	%	0	5	5	0	0	0
		No	0	1	1	0	0	0
20	45	%	0	5	19	10	0	0
		No	0	1	4	2	0	0
20	50	%	0	10	33	33	10	0
		No	0	2	7	7	2	0

The maximum error of medial trajectory of a pedicle screw was 5° in all scenarios.

Angle indicates the maximum error of lateral trajectory of a pedicle screw; Length, simulated screw length; No, number of the aorta-at-risk cases.

5° in the medial direction and to 5°, 10°, or 20° in the lateral direction, and the length of the screw was set at 40, 45 or 50 mm. We compared the curves between the aorta-at-risk cases and the aorta-no-risk cases. Analyzed curve characteristics were the apical vertebral translation (AVT), the Cobb angle and the Nash-Moe grade.

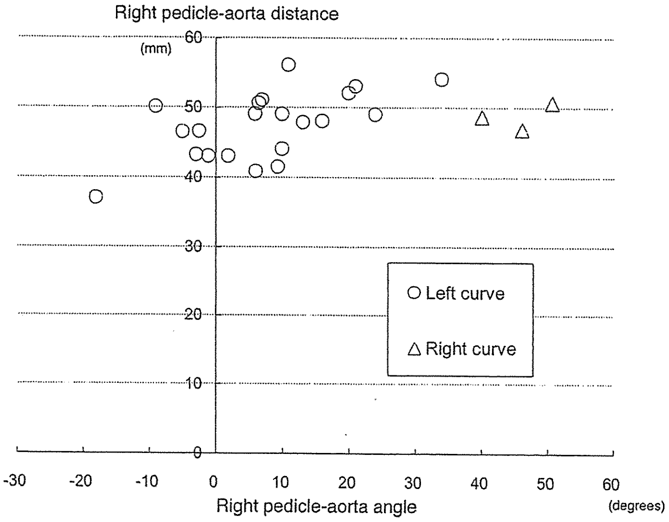


Figure 3. Scatter graph of the aorta location at 1st lumbar level. A circle denotes a case with a left lumbar curve and a triangle denotes a case with a right lumbar curve.

RESULTS

A total of 385 spines were evaluated to locate the aorta position relative to the spine. The aorta often resided in front of a right pedicle at periapical level in left curves (Figure 2). The number of levels where the right pedicle-aorta angle was below 5° was 1 of 2 left thoracic curves and 7 (33%) of 21 left lumbar curves (Table 2). On the contrary, there was no level where the right pedicle-aorta angle was below 5° in 27 right thoracic curves and in three right lumbar curves.

Distribution of the aorta-at-risk cases in nine simulated scenarios indicated that a simulated pedicle screw with a length of 50 mm at L1 or L2 posed potential risk (24%–44%) irrespective of trajectory errors among patients with left lumbar curves (Table 3). Curve characteristics of the aorta-at-risk cases at L1 (Figure 3) were a larger AVT (P = 0.003), a larger Cobb angle (P = 0.006), and larger Nash-Moe grade (P = 0.017) compared with those of the aorta-no-risk cases. AVT, the Cobb angle and Nash-Moe grade were highly correlated with each other: correlative coefficient was 0.814 (P = 0.000) between AVT and the Cobb angle, 0.737 (P = 0.000) between AVT and Nash-Moe grade, and 0.602 (P = 0.004) between the Cobb angle and Nash-Moe grade.

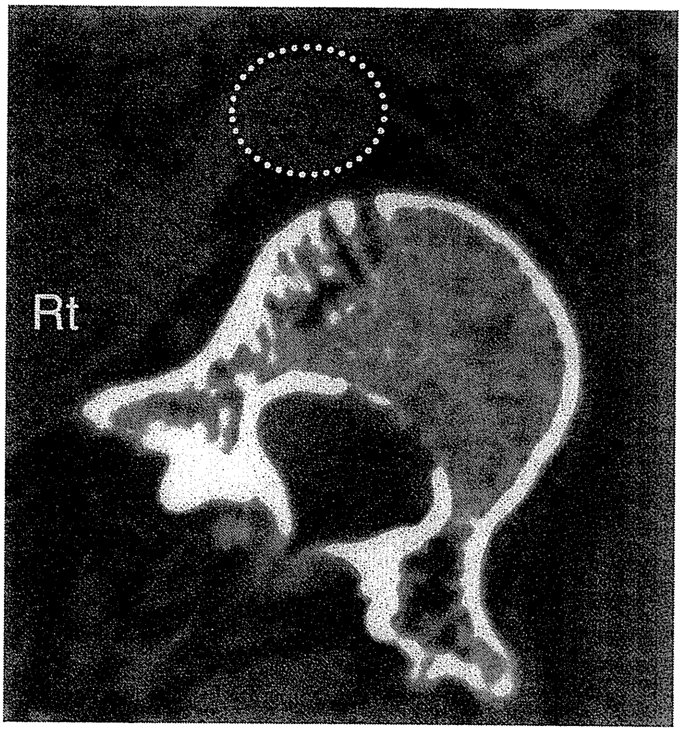
TABLE 3. Past Reports of Aortic Abutment by Thoracic Pedicle Screws Analyzed by Computed Tomography in Patients With Scoliosis

First Author	No. of patients	Follow-up Period (months)	No. of Pedicle Screws	No. of Screw with Aorta Abutment	Left /Right
Liljenqvist[6]	32	na	110	1 (0.9%)	1/0
Smorgick[7]	25	na	112	2 (1.8%)	2/0
Sarlak[8]	19	35.9	185	7 (3.8%)	na*
Total	76		1442	13 (2.5%)	3/0

na indicates not available.

**Reported with convex/concave. One screw of 7 screws was at the convex side.*

(A)



(B)

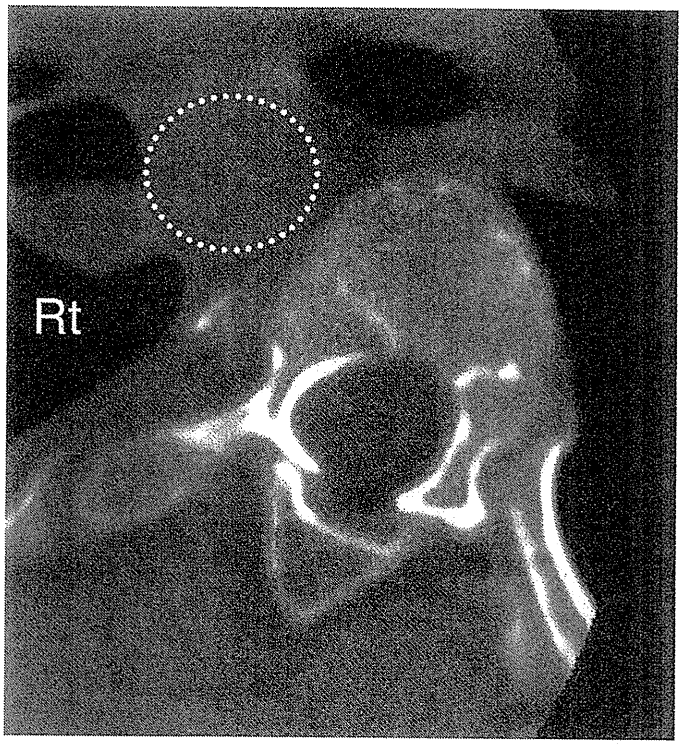


Figure 4. Representative cases in which the aorta resided laterally to the right of the spine. Dotted line circles the aorta. **A,** A 1st lumbar level in a left 88° lumbar curve. **B,** A 6th thoracic level in a left 100° thoracic curve.

DISCUSSION

We investigated lumbar curves in addition to thoracic curves, and found that the aorta moved to the right side of the vertebral body in a left curve, and the safety of the aorta from a long pedicle screw decreased either in the thoracic spine or in the lumbar spine. In a case with a large left curve, the aorta shifted to the right lateral side of the vertebral body, and a lateral deviation from an ideal trajectory could result in aorta indentation even by a pedicle screw of a moderate length (Figure 4).

Many spine surgeons prefer to use pedicle screws in thoracic or lumbar spine because of its easiness of placement inside the bony structure and its sound capability in correction and stabilization. However, Kakkos and Shepard[5] reviewed the delayed aorta injury by pedicle screws in five patients including three deformity cases. They stated, "The true incidence of this complication is probably under-reported" in their conclusion. We found three past studies,[6–8] which analyzed thoracic curves exclusively by computed-tomography postoperatively (Table 3), and the aorta involvement in 6 (2.5%) of the 1442 screws is substantial. Though the true risk of aortic abutment is unknown, a screw will stay just next to the aorta in such a young generation and it is impractical to monitor such patients closely for over tens of years. In fact, 6 of 76 patients of the past three reports had reoperation.

The aorta resides on the left side of the normal thoracic spine,[1] and past reports dealt with a thoracic pedicle screw on the concave side which is usually the left side of the thoracic curve.[2,3,7] In scoliosis, a three-dimensional spinal deformity changes the spatial relationship between the aorta and the spine depending on the severity of scoliosis, and the aorta might resides on the right side of a vertebral body. Only one past report by Milbrandt and Sucato[9] discussed the aorta risk on the right side. They analyzed left thoracic scoliosis and stated "the aorta was in a high-risk position for a (right) posterior screw that exit the lateral border of the pedicle or body in the largest curve of our series." Our present study confirmed the aorta risk by a right pedicle screw in left thoracic or lumbar scoliosis. We believe a deliberate planning by multiplanar reconstructed images of multidetector-CT is most crucial to prevent an annoying situation. Moreover, we prefer to use a computer-navigation system by preoperative CT for safe placement of pedicle screws.

Judging from high correlations between curve characteristics and the aorta risk in the present study, surgeons need to pay attention to the position of the aorta in placing a pedicle screw on the right in a left curve either in a thoracic or lumbar spine.

➢ Key Points:

- ☐ The aorta is often located in front of right pedicles at the periapical level in left thoracic or lumbar curves.
- ☐ Curve characteristics of the aorta-at-risk cases were a larger apical vertebral translation, a larger Cobb angle, and a larger Nash-Moe grade.
- ☐ Surgeons need to pay attention to the position of the aorta in placing a pedicle screw on the right at the periapical level of a left curve either in thoracic or lumbar spine.

References

1. Moore KL. The thoracic and abdominal aorta. In: Moore KL, ed. *Clinically Oriented Anatomy*. 6th ed. Baltimore, MD: Williams & Wilkins; 2010:167–313.
2. Sucato DJ, Duchene C. The position of the aorta relative to the spine: a comparison of patients with and without idiopathic scoliosis. *J Bone Joint Surg Am* 2003;85-A:1461–9.
3. Takeshita K, Maruyama T, Ono T, et al. New parameters to represent the position of the aorta relative to the spine for pedicle screw placement. *Eur Spine J* 2010;19:815–20.
4. Takeshita K, Maruyama T, Chikuda H, et al. Diameter, length, and direction of pedicle screws for scoliotic spine—analysis by multiplanar reconstruction of computed tomography. *Spine* 2009;34:798–803.
5. Kakkos SK, Shepard AD. Delayed presentation of aortic injury by pedicle screws: report of two cases and review of the literature. *J Vasc Surg* 2008;47:1074–82.
6. Liljenqvist UR, Halm HF, Link TM. Pedicle screw instrumentation of the thoracic spine in idiopathic scoliosis. *Spine* 1997;22:2239–45.
7. Smorgick Y, Millgram MA, Anekstein Y, et al. Accuracy and safety of thoracic pedicle screw placement in spinal deformities. *J Spinal Disord Tech* 2005;18:522–6.
8. Sarlak AY, Tosun B, Atmaca H, et al. Evaluation of thoracic pedicle screw placement in adolescent idiopathic scoliosis. *Eur Spine J* 2009;18:1892–7.
9. Milbrandt TA, Sucato DJ. The position of the aorta relative to the spine in patients with left thoracic scoliosis: a comparison with normal patients. *Spine* 2007;32:E348–53.

Spine

SPINE Volume 36, Number 18, pp 1453–1458
©2011, Lippincott Williams & Wilkins

CERVICAL SPINE

Acute Cervical Spinal Cord Injury Complicated by Preexisting Ossification of the Posterior Longitudinal Ligament

A Multicenter Study

Hirotaka Chikuda, MD, PhD,* Atsushi Seichi, MD, PhD,† Katsushi Takeshita, MD, PhD,*
Shunji Matsunaga, MD, PhD,‡ Masahiko Watanabe, MD, PhD,§ Yukihiro Nakagawa, MD, PhD,¶
Kazuya Oshima, MD, PhD,|| Yutaka Sasao, MD, PhD,** Yasuaki Tokuhashi, MD, PhD,††
Shinnosuke Nakahara, MD,‡‡ Kenji Endo, MD, PhD,§§ Kenzo Uchida, MD, PhD,¶¶ Masahiko Takahata, MD,||||
Toru Yokoyama, MD,*** Kei Yamada, MD, PhD,††† Yutaka Nohara, MD,‡‡‡ Shiro Imagama, MD,§§§
Hideo Hosoe, MD,¶¶¶ Hiroshi Ohtsu, MS,|||||| Hiroshi Kawaguchi, MD, PhD,* Yoshiaki Toyama, MD, PhD,****
and Kozo Nakamura, MD, PhD,*

Study Design. Retrospective multicenter study.

Objective. To review the clinical characteristics of traumatic cervical spinal cord injury (SCI) associated with ossification of the posterior longitudinal ligament (OPLL).

Summary of Background Data. Despite its potentially devastating consequences, there is a lack of information about acute cervical SCI complicated by OPLL.

Methods. This study included consecutive patients with acute traumatic cervical SCI (Frankel A, B, and C) who were admitted within 48 hours of injury to 34 spine institutions across Japan. For analysis of neurologic outcome, patients who had completed at least a 6-month follow-up were included. Neurologic improvement was defined as at least one grade conversion in Frankel grade.

Results. A total of 453 patients were identified (367 men, 86 women; mean age, 59 years). OPLL was found in 106 (23%) patients (87 men, 19 women; mean age, 66 years). Most of the patients with OPLL (94 of 106) were without bone injury, presenting with incomplete SCI. The prevalence of OPLL reached 34% in SCI without bone injury. The cause of SCI was predominantly falls (74%). Only 25% of the patients were aware of OPLL. Half of the OPLL patients reported gait disturbance before injury. Forty-eight (52%) OPLL patients without bone injury underwent surgery (median, 13.5 days after injury), mostly laminoplasty. Overall, no significant difference was noted in neurologic improvement between surgery group and conservative group. However, further stratification showed that surgery was associated with greater neurologic recovery in patients who had gait disturbance before injury ($P = 0.04$).

Conclusion. Prevalence of OPLL among cervical SCI was alarmingly high, especially in those without bone injury. Most of cervical SCI associated with OPLL were incomplete, without bone injury, and caused predominantly by low-energy trauma. The majority of the patients were unaware of OPLL. Surgery produced better neurologic recovery in patients who had gait disturbance before injury.

From the *Department of Orthopaedic Surgery, Faculty of Medicine, the University of Tokyo, Tokyo, Japan; †Department of Orthopaedics, Jichi Medical University, Tochigi, Japan; ‡Department of Orthopaedic Surgery, Imakiire General Hospital, Kagoshima, Japan; §Department of Orthopaedic Surgery Surgical Science Tokai University School of Medicine, Kanagawa, Japan; ¶Department of Orthopaedic Surgery, Wakayama Medical University, Wakayama, Japan; ||Department of Orthopaedic Surgery, Osaka University Graduate School of Medicine, Osaka, Japan; **Department of Orthopeadic Surgery, St. Marianna School of Medicine, Kanagawa, Japan; ††Department of Orthopaedic Surgery, Nihon University School of Medicine, Tokyo, Japan; ‡‡Department of Orthopaedic Surgery, National Okayama Medical Center, Okayama, Japan; §§Department of Orthopedic Surgery, Tokyo Medical University, Tokyo, Japan; ¶¶Department of Orthopaedics and Rehabilitation Medicine, Fukui University Faculty of Medical Sciences, Fukui, Japan; ||||Department of Orthopaedic Surgery, Graduate School of Medicine, Hokkaido University, Hokkaido, Japan; ***Department of Orthopaedics Surgery, Hirosaki University Graduate School of Medicine, Aomori, Japan; †††Department of Orthopaedic Surgery, Kurume University, Fukuoka, Japan; ‡‡‡Department of Orthopaedic Surgery, Dokkyo Medical University, Tochigi Japan;, §§§Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine, Aichi, Japan; ¶¶¶Department of Orthopaedic Surgery, Gifu University School of Medicine, Gifu, Japan; ||||||Department of Clinical Trial Data Management, Graduate School of Medicine, the University of Tokyo, Tokyo, Japan; and ****Departments of Orthopaedic Surgery, School of Medicine, Keio University, Tokyo, Japan.

Acknowledgment date: March 30, 2010. Revision date: July 19, 2010. Acceptance date: July 20, 2010.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

This study was performed with the aid of the Investigation Committee on the Ossification of the Spinal Ligaments of the Japanese Ministry of Health, Labor and Welfare.

Address correspondence and reprint requests to Hirotaka Chikuda, MD, PhD, Department of Orthopaedic Surgery, Faculty of Medicine, the University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan; E-mail: chikuda-tky@umin.ac.jp

DOI: 10.1097/BRS.0b013e3181f49718

Key words: canal stenosis, myelopathy, ossification of the posterior longitudinal ligament, patient awareness, spinal cord injury, surgery, trauma, treatment. **Spine 2011;36:1453–1458**

Ossification of the posterior longitudinal ligament (OPLL) affects about 2% of Japanese[1,2] and is a major cause of cervical canal stenosis in Japan. Although individuals with OPLL often remain asymptomatic, chronic cord compression may lead to myelopathy, especially in those with severe canal compromise.

OPLL is also known to predispose these individuals to severe neurologic deterioration after trauma. Despite its potentially devastating consequences, there is a lack of information about acute cervical spinal cord injury (SCI) complicated by OPLL. Except for a few case series, reports on this subgroup of SCI patients remain largely anecdotal.[3,4] The prevalence of OPLL among patients with acute cervical SCI has not been determined, and the clinical characteristics of SCI patients with OPLL remain unclear as well. In particular, little attention has been paid to a patient's status before injury such as his or her awareness of OPLL. In addition, optimum treatment of SCI complicated by OPLL remains controversial; a dilemma reflected by the wide variations in current treatment options, ranging from emergency surgery to conservative treatment. Although surgical decompression is widely believed to have a beneficial role for those with persistent cord compression, there is no comparative study supporting this hypothesis.

Here, we conducted a retrospective multicenter study to determine the prevalence of OPLL among cervical SCI and clarify the clinical characteristics of SCI patients with OPLL, and further evaluated the efficacy of surgical treatment.

MATERIALS AND METHODS

This multicenter study was conducted by a Research Group for Ossification of the Spinal Ligament sponsored by the Japanese Ministry of Health, Labor and Welfare. This study included all consecutive patients with acute traumatic cervical SCI (Frankel A, B, and C) who were admitted within 48 hours of injury from January 2000 to June 2006. Thirty-four institutions to which the members of the research group belong joined this study. Severity of SCI was assessed by Frankel grade classification.[5] Presence of OPLL was confirmed using plain radiographs or computed tomography (CT). On the basis of the criteria established by the Japanese Ministry of Public Health and Welfare, OPLL was classified into the following types: continuous, segmental, localized, and mixed.[6] The maximum percentage of spinal canal stenosis was evaluated using plain radiographs as previously reported.[7]

To assess patients' medical status at admission and complications after the injury, we consulted medical charts and nursing summaries. Complications that occurred within 1 month after injury were included in this study. The charts were also evaluated for patient status before injury including awareness of OPLL and preexisting gait disturbance. For analysis of neurologic recovery, patients who had completed a 6-month follow-up were included.

Neurologic improvement was defined as one grade or greater improvement in Frankel grade. The ratio of patients who achieved neurologic improvement was calculated. Patients were stratified by whether they had gait disturbance before injury.

Continuous variables were compared using Student t test or Dunnett test, and categorical data were analyzed using the χ^2 test. Fisher exact test was used when appropriate. All statistics were calculated using SPSS, version 13.0 (SPSS Inc, Chicago, IL). Values were considered statistically significant for P less than 0.05.

RESULTS

A total of 453 patients were initially identified (Table 1), including 367 men and 86 women with a mean age of 59 years. OPLL was found in 106 patients (87 men, 19 women; mean age: 66 years), accounting for 23% of all patients. Peak incidence of SCI in patients with OPLL occurred between 70 and 75 years of age, and about 80% of OPLL-associated SCI patients (85 of 106) were classified as incomplete. Of the 453 patients, 274 (60%) were without bone injury, such as fracture or dislocation, and nearly 90% of the patients with OPLL (94 of 106) were also without bone injury. The prevalence of OPLL was 34% among this subgroup of patients.

Clinical characteristics of SCI patients with OPLL were further examined (Table 2). The primary cause of SCI in OPLL patients was predominantly falls, followed by motor vehicle accidents. Influence of alcohol use was reported in 19 patients (18%). Of note, among patients who were aware of OPLL, only one was under the influence of alcohol at the time of injury. Concurrent fractures at other sites or visceral organ injuries were relatively rare in this subgroup of SCI patients. Only 25% of patients were aware of OPLL before their injury, and even fewer patients (17%) were regularly visiting a physician

TABLE 1. Characteristics of Enrolled Patients

	SCI With OPLL	SCI Without OPLL	Total
No. (% of total) of patients	106 (23%)	347	453
Sex (men/women)	87/19	280/67	367/86
Mean age at injury (yrs, mean ± SD)	66.2 ± 11.5*	57.0 ± 18.6	59.2 ± 17.6
Frankel grade at admission			
A	21	125	146
B	29	76	105
C	56	146	202
SCI without fracture or dislocation (%)	94 (34%)	180	274

**Between-group difference was significant (P < 0.01).*

SCI indicates spinal cord injury; OPLL, ossification of the posterior longitudinal ligament; SD, standard deviation.

TABLE 2. Clinical Characteristics of SCI Patients With OPLL

	SCI Patients With OPLL (n = 106)
Cause of SCI	
Falling (% of total)	78 (74%)
Falling on one's rear	9
Falling on a flat surface	42
Falling down stairs	16
Falling from a height	11
Motor vehicle accident	19
Sports-related	3
Not specified	6
Alcohol involvement (% of total)	19 (18%)
Concurrent fracture at other site	4
Concurrent visceral organ injury	2
Awareness of OPLL before injury (% of total)	26 (25%)
Regular doctor visit for OPLL (% of total)	18 (17%)
Gait disturbance before injury (% of total)	47 (44%)

SCI indicates spinal cord injury; OPLL, ossification of the posterior longitudinal ligament.

TABLE 3. Characteristics and Complications* of OPLL Patients Without Bone Injury

	Surgery Group (n = 48)	Conservative Group (n = 46)
Age (yrs; mean [SD])	64 (10)	68 (13)
Sex (men/women)	38/10	40/6
Severity of SCI (no. of patients [%])		
Complete	8 (17)	8 (17)
Incomplete	40 (83)	38 (83)
Maximum canal stenosis (%; mean [SD])	46 (13)	46 (14)
Corticosteroid (no. of patients [%])	29 (60)	39 (85)†
Complications		
Tracheotomy	7 (15)	6 (13)
Pneumonia	9 (19)	11 (24)
Sepsis	2 (7)	3 (7)
Gastrointestinal bleeding	3 (6)	2 (4)
Urinary tract infection	8 (17)	13 (28)
Wound infection	3 (6)	2 (4)

**Complications occurring within 1 month of injury were included.*

†significantly higher in conservative group ($P < 0.01$); continuous variables were compared using Student t test; categorical data were analyzed using Fischer exact test.

for OPLL at the time of injury. Approximately half of patients (44%) reported preexisting gait disturbance of varying degrees.

On radiographic evaluation, ossification type was found to be continuous in 46 patients, mixed in 38, segmental in 12, localized in 5, and unclassified in 5. Mean maximum percentage of spinal canal stenosis was 46 ± 13% (mean ± SD; range: 19%–85%). No significant difference was noted in maximal canal compromise between Frankel grade groups at admission (Dunnett test).

We also evaluated the use of corticosteroids for treatment of SCI. Of the 106 SCI patients with OPLL, 76 (72%) received intravenous administration of corticosteroids. The Second National Acute Spinal Cord Injury Study protocol[8] was applied in 57 patients, whereas intermittent administration of a lower dosage was performed in the remaining 19. Complications associated with intravenous corticosteroid administration were reported in 10 patients, including gastrointestinal bleeding or ulcer in 6, pulmonary complications in 2, and wound infection and exacerbation of diabetes mellitus in 1 each.

We then examined the efficacy and safety of surgical treatment, focusing on patients without bone injury (Table 3). Of the 94 patients in this category, 48 (52%) underwent surgery (median: 13.5 days after injury) whereas the remaining 46 received some form of nonoperative treatment. Clinical characteristics of the two groups were comparable with regard to age, sex, maximum canal stenosis, and severity of SCI. Most of the surgery group patients (43 of 48) received laminoplasty. The conservative group was more likely to receive intravenous corticosteroids ($P < 0.01$). No significant difference was noted in documented complications between the surgery and conservative groups.

Neurologic improvement was then examined in patients who had completed at least 6 months of follow-up (Table 4). Overall, 72 of the 106 patients with OPLL underwent follow-up at 6 months postinjury. Of the 94 OPLL patients presented with SCI without bone injury, 64 (68%) were followed up for at least 6 months after injury (mean: 25 months; range: 6–27 months). Of these 64 patients, 41 showed neurologic recovery at follow-up, as defined by one grade or greater improvement in Frankel grade. No significant difference was noted in neurologic improvement between the surgery and conservative groups (surgery group: 71%, conservative group: 52%; $P = 0.13$).

We then stratified patients according to presence or absence of gait disturbance before injury (Table 5). In this preplanned analysis, surgery was associated with better neurologic recovery in those who had gait disturbance before injury (surgery group: 82%, conservative group: 44%; $P = 0.04$).

DISCUSSION

Our study had three major findings. First, we found an alarmingly high prevalence of OPLL among cervical SCI, particularly in those without bone injury. Second, we also identified

TABLE 4. Neurological Outcome of OPLL Patients Without Bone Injury*

	Surgery (n = 41)						Conservative (n = 23)				
	Grade at follow-up						Grade at follow-up				
	A	B	C	D	E		A	B	C	D	E
Grade at admission						Grade at admission					
A	3	2	2			A	3			1	
B		3	5	4	1	B			1	2	
C		1	5	11	4	C		2	6	8	

Frankel grade was used as outcome measure.

**Patients who had completed at least 6 mo of follow-up were included.*

the clinical characteristics of these patients: most of cervical SCI associated with OPLL were incomplete, without bone injury, and caused primarily by low-energy trauma. The vast majority of patients were elderly and unaware of OPLL. Last, we also found that surgery was associated with greater neurologic recovery than conservative treatment in patients who had gait disturbance before injury.

In this study, we focused on patients who had lost ambulatory ability immediately after injury (Frankel A, B, and C). From a practical point of view, traumatic SCI is intellectually indistinguishable from aggravation of preexisting myelopathy in individuals with OPLL, particularly when presented with mild symptoms. Our sample of more than 100 patients with OPLL represents the largest study of its subject matter ever reported.

OPLL was found to be highly prevalent in patients with acute traumatic cervical SCI: in particular, OPLL was found in 34% of cervical SCI patients without bone injury. Our findings underscore the important role of OPLL in occurrence of acute traumatic cervical SCI. In line with our present finding, Koyanagi *et al*[9] also previously reported that OPLL was highly prevalent (38%) in SCI patients without bone injury. The prevalence of OPLL among cervical SCI patients appears to be increasing because prevalence values reported in earlier studies have historically been less than 10%.[3,10]

TABLE 5. Neurological Outcome of Patients Stratified by Presence of Gait Disturbance Before Injury*

Patients who had gait disturbance before injury (n = 31)

	Surgery (n = 19)					Conservative (n = 12)			
	Grade at follow-up					Grade at follow-up			
	A	B	C	D/E		A	B	C	D
Grade at admission					Grade at admission				
A	3	1	1		A	2			1
B		3	1	2	B				2
C		1	1	6	C		2	2	3

Patients without gait disturbance before injury (n = 31)

	Surgery (n = 22)					Conservative (n = 9)			
	Grade at follow-up					Grade at follow-up			
	A	B	C	D		A	B	C	D
Grade at admission					Grade at admission				
A		1	1		A	1			
B			4	3	B			1	
C			4	9	C			4	3

Frankel grade was used as outcome measure.

**Patients who had completed at least 6 mo of follow-up were included.*

We also sought to clarify the clinical characteristics of SCI patients with OPLL. The majority of such patients were elderly with the peak incidence in those occurring between 70 and 75 years of age. Most of these patients were without bone injury and presented with incomplete SCI. Concomitant injuries were relatively rare, and the primary cause of SCI was minor trauma, such as a fall (74%). Patients suffered severe neurologic deficit after experiencing even subtle trauma such as falling from a standing height or falling onto one's rear, underscoring the fact that individuals with OPLL are extremely vulnerable to trauma.

Despite its potential role in preventing SCI, patient awareness of OPLL has not been fully investigated. We found that the vast majority of SCI patients with OPLL were unaware of OPLL before injury. An earlier study has suggested that once patients are made aware of OPLL and its potential risk, they are expected to more carefully avoid high-risk behaviors such as walking on a slippery slope or drinking too much alcohol.[7] Indeed, in this study, SCI associated with alcohol ingestion was significantly decreased when patients had been made aware of OPLL. This finding underscores the importance of patient awareness and indicates the effectiveness of patient education in reducing cervical SCI in those with OPLL.

The efficacy of decompressive surgery in treating cervical SCI remains controversial,[11,12] particularly in patients without bone injury. Some authors recommend surgery for patients with preexisting canal stenosis, as persistent cord compression may hinder neurologic improvement.[13–15] In contrast, other researchers have reported no additional benefit with surgery in comparison to conservative treatment.[16,17]

In this study, we evaluated the safety and efficacy of surgical treatment in patients with OPLL. Most of the surgeries we conducted here were classified as "late surgery," with a median interval of 2 weeks from injury to surgery. The surgery and conservative groups were comparable with regard to age, maximum canal compromise, and initial severity of neurologic injury (Table 3), and both groups had similar rates of complications. Overall, no significant difference was noted between the groups in neurologic recovery as defined by improvement in Frankel grade (surgery group: 71%, conservative group: 52%). However, further stratification showed that surgery was associated with better neurologic recovery in those who had gait disturbance before injury (surgery group: 82%, conservative group: 44%).

The reason why surgery benefitted patients with preexisting gait disturbance is not clear. In most patients, presence of gait disturbance indicated that the patient had already developed myelopathy. Contrary to our initial hypothesis, however, our results indicated that this subgroup of patients experienced improved neurologic recovery after decompressive surgery.

Two distinct factors must be considered in understanding the pathomechanism of SCI in patients with OPLL: direct injury by traumatic force, which is believed to be irreversible; and preexisting cord compromise because of long-standing compression. The relative contribution of these two factors may vary among patients. Decompressive surgery may have little or no benefit on primary cord injury caused by traumatic force, but may in turn benefit cord compromise brought on by persistent compression. Presumably, the contribution of traumatic force, an irreversible factor, may be smaller in patients with gait disturbance before injury than in those without gait disturbance. Patients with preexisting cord compromise may be particularly vulnerable and may easily become paraplegic on suffering minor trauma. In this study, we assumed that the variable contribution of these two factors accounts for the seemingly perplexing results obtained here. Further research in this field may provide valuable information for predicting neurologic recovery after decompressive surgery in SCI patients with preexisting canal stenosis.

Several limitations to our study warrant mention. First, the follow-up period was relatively short. Although significant improvement in motor function is known to be achieved within 6 months after injury, longer term follow-up studies may yield additional information.[14] Our follow-up rate was 68% at 6 months postinjury. This could have influenced the validity of our conclusion, although we found no apparent bias in the patients who were lost to follow-up within 6 months. Reasons for the dropout are not specified and can vary. This study was carried out at academic tertiary referral centers serving a relatively large area. SCI patients admitted to these medical centers are subsequently transferred to local hospitals near their residence after the acute phase. Presumably, some patients, especially who remained nonambulatory, required a great deal of assistance for transport. These patients might have found it difficult to travel a long distance from their residence to the hospital. We can also speculate that some patients, especially elderly patients, might have been suffering from complications after injury or comorbidities. These medically fragile patients might have been in poor or deteriorated health status and unable to show up at prescheduled checkup. The conclusions of this study need to be verified by future prospective studies. Second, Frankel grade was used as an outcome measure. Frankel grade has been widely used to rank severity of SCI in the literature despite its low discriminative ability. We therefore may have underestimated the neurologic recovery of the patients. Other validated outcome measures with high-discriminative ability may provide more detailed information. In addition, the indications and timing of surgery were not standardized between institutions, and thus selection bias cannot be entirely discounted. Despite these limitations, however, we feel that our study contains valuable information of clinical importance, providing a basis for future research.

CONCLUSION

In conclusion, our results underscore the importance of OPLL in the occurrence of acute traumatic cervical SCI in Japan, particularly in patients without bone injury. Our data indicate that patient awareness of OPLL may aid in preventing cervical SCI. Furthermore, our results suggest the efficacy of surgical decompression in patients with preexisting gait disturbance. These findings may aid in implementing an action plan aimed at prevention and better treatment of cervical SCI complicated by OPLL.

➢ Key Points

- ☐ OPLL was highly prevalent in patients with acute SCI, particularly in those without bone injury.
- ☐ Most of cervical SCI associated with OPLL were incomplete, without bone injury, and caused primarily by low-energy trauma. Majority of these patients was elderly and unaware of OPLL before injury.
- ☐ Decompression surgery was associated with better neurologic recovery compared with conservative treatment in patients who had gait disturbance before injury.

References

1. Iwasaki M, Yonenobu K. Ossification of the posterior longitudinal ligament. In: Herkowitz H, Garfin S, Eismont F, et al. eds. *Rothman-Simeone The Spine*. 5th ed. Philadelphia, PA: Saunders; 2006: 896–912.
2. Matsunaga S, Sakou T. OPLL: disease entity, incidence, literature search, and prognosis. In: Yonenobu K, Nakamura K, Toyama Y, eds. *OPLL Ossification of the Posterior Longitudinal Ligament*. 2nd ed. Tokyo, Japan: Springer, 2006:11–17.
3. Endo S, Shimamura T, Nakae H, et al. Cervical spinal cord injury associated with ossification of the posterior longitudinal ligament. *Arch Orthop Trauma Surg* 1994;113:218–21.
4. Koyanagi I, Iwasaki Y, Hida K, et al. Acute cervical cord injury associated with ossification of the posterior longitudinal ligament. *Neurosurgery* 2003;53:887–91; discussion 91–2.
5. Frankel HL, Hancock DO, Hyslop G, et al. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I. *Paraplegia* 1969;7:179–92.
6. Tsuyama N. Ossification of the posterior longitudinal ligament of the spine. *Clin Orthop Relat Res* 1984:71–84.
7. Matsunaga S, Sakou T, Hayashi K, et al. Trauma-induced myelopathy in patients with ossification of the posterior longitudinal ligament. *J Neurosurg* 2002;97:172–5.
8. Bracken MB, Shepard MJ, Collins WF, et al. A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal-cord injury. Results of the Second National Acute Spinal Cord Injury Study. *N Engl J Med* 1990;322:1405–11.
9. Koyanagi I, Iwasaki Y, Hida K, et al. Acute cervical cord injury without fracture or dislocation of the spinal column. *J Neurosurg* 2000;93:15–20.
10. Mihara K, Torigoe Y, Konishi H. Cervical spinal cord injury associated with ossification of the posterior longitudinal ligament [in Japanese]. *Orthop Traumatol* 1991;40:763–5.
11. Fehlings MG, Sekhon LH, Tator C. The role and timing of decompression in acute spinal cord injury: what do we know? What should we do? *Spine (Phila Pa 1976)* 2001;26:S101–10.
12. Fehlings MG, Skaf G. A review of the pathophysiology of cervical spondylotic myelopathy with insights for potential novel mechanisms drawn from traumatic spinal cord injury. *Spine (Phila Pa 1976)* 1998;23:2730–7.
13. Bose B, Northrup BE, Osterholm JL, et al. Reanalysis of central cervical cord injury management. *Neurosurgery* 1984;15:367–72.
14. Chen L, Yang H, Yang T, et al. Effectiveness of surgical treatment for traumatic central cord syndrome. *J Neurosurg Spine* 2009;10:3–8.
15. Guest J, Eleraky MA, Apostolides PJ, et al. Traumatic central cord syndrome: results of surgical management. *J Neurosurg* 2002;97:25–32.
16. McKinley W, Meade MA, Kirshblum S, et al. Outcomes of early surgical management versus late or no surgical intervention after acute spinal cord injury. *Arch Phys Med Rehabil* 2004;85:1818–25.
17. Pollard ME, Apple DF. Factors associated with improved neurologic outcomes in patients with incomplete tetraplegia. *Spine (Phila Pa 1976)* 2003;28:33–9.

SPINE Volume 35, Number 26, pp E1571–E1576
©2010, Lippincott Williams & Wilkins

Aorta Movement in Patients With Scoliosis After Posterior Surgery

Katsushi Takeshita, MD,* Toru Maruyama, MD,† Yusuke Nakao, MD,† Takashi Ono, MD,*
Yuki Taniguchi, MD,* Hirotaka Chikuda, MD,* Naoki Shoda, MD,* Yasushi Oshima, MD,*
Akiro Higashikawa, MD,* and Kozo Nakamura, MD*

Study Design. Retrospective analysis.

Objective. To evaluate movement of the aorta in patients with scoliosis who have undergone the posterior correction and fusion.

Summary of Background Data. Surgeons check preoperative imaging for pedicle screw placement, but past analyses indicated that the aorta shifts after scoliosis surgery. Few studies, however, evaluated the aorta movement in detail.

Methods. A total of 22 patients with a right thoracic curve underwent posterior instrumentation and fusion. The average age at surgery was 17.2 years. The average of the preoperative Cobb angle was 65.2° which decreased to 20.0°.

Computed-tomographic data were analyzed by multiplanar reconstruction. In our coordinate system, the middle of the base of the left superior facet was set as the origin and a line connecting the middle points of both bases of the superior facets was defined as the X-axis. We defined the angle and the distance to describe the aorta position and analyzed the movement of the aorta relative to the spine. Deformity parameters were examined to determine their correlation with the aorta parameters.

We simulated variable pedicle screw placement and defined a warning pedicle when the aorta enters the expected area of the screw and examined them in 24 scenarios.

Results. The aorta moved 4.7 ± 3.0 mm on an average. The aorta had a tendency to migrate in the anteromedial direction and this movement correlated with preoperative apical vertebral translation, preoperative sagittal alignment, and change of sagittal alignment. The ratio of warning pedicles at the middle thoracic level (T7–T9) increased after deformity correction.

Conclusion. The aorta moved anteromedially relative to the spine after the posterior correction and the risk of the aorta by a pedicle screw increased by correction of the deformity at the middle thoracic spine. Surgeons are recommended to anticipate the aorta movement in the surgical planning.

Key words: scoliosis, pedicle screw, aorta, computed tomography. **Spine 2010;35:E1571–E1576**

Posterior correction and fusion by instrumentation is popular in the deformity surgery and pedicle screws have been the dominant anchors for the last decade. However, several authors[1–3] reported a possible risk of aorta injury by a pedicle screw. Although surgeons use preoperative radiographic imaging in placing pedicle screws to prevent the aorta containment, the aorta may move after surgical correction of the spinal deformity. Few analyses of the movement of this organ after posterior surgery have been reported. The purpose of the present study was to evaluate the aorta movement after the posterior correction and fusion in scoliosis surgery.

Materials and Methods

A total of 37 patients with scoliosis underwent posterior instrumentation and fusion at the University Hospital between 2005 and 2007 and 22 patients with a right thoracic curve were included in this study. Scoliosis was idiopathic in 18 patients, Chiari-syrinx in 2, multiple epiphyseal dysplasia in 1, and Noonan syndrome in 1. A total of 15 patients were excluded: 5 patients with congenital scoliosis, 4 with idiopathic scoliosis with no thoracic curve, 3 with Marfan syndrome who might have had abnormal vascular movement, 2 with idiopathic scoliosis with left thoracic curve, and 1 with tubular sclerosis with left thoracic curve. Patient age at surgery was 10 to 29 (mean, 17.2) years old and 18 were women and 4 were men. Lenke's classification of scoliosis was type 1 in 8 patients, type 2 in 5, type 3 in 1, type 4 in 4, type 5 in 1, and type 6 in 3. The preoperative Cobb angle averaged 65.2° ± 11.6° (range, 50°–88°) and corrected to 36.3° ± 12.0° (range, 18°–70°) on bending films, and to 26.6° ± 10.0° (range, 13°–44°) on fulcrum-bending films.[4] The apex vertebra of the thoracic curve ranged from T5–T10 (T5:1, T7:2, T8:6, T9:5, T10:8). All patients were treated by posterior correction and fusion by pedicle screw instrumentation. The average number of instrumented vertebrae was 12.2 ± 1.6 (9–16 vertebrae). Postoperative Cobb angle averaged 20.0° ± 7.7° (range, 11°–39°) and correction rate was 69.6% ± 8.5% (53%–83.1%). Cincinnati correction index[5] was 1.74 ± 0.57 (0.95–3.38) and Fulcrum bending correction index[6] was 1.18 ± 0.16 (0.78–1.48).

The patients were evaluated by computed tomography (CT) before and after surgery. Preoperative examination was for the computer-assisted placement of pedicle screws and the postoperative one was to confirm the location of pedicle screws. There was no need to replace any screw. The preoperative CT was obtained from the upper thoracic to the lower lumbar spine with a width of 1.25 mm as directed by a naviga-

---

From the *Department of Orthopaedic Surgery, the University of Tokyo, Tokyo, Japan; and the †Department of Orthopaedic Surgery, the Saitama Medical Center, Saitama, Japan.

Acknowledgment date: April 17, 2009. First revision date: August 8, 2009. Second revision date: November 23, 2009. Third revision date: November 30, 2009. Acceptance date: December 1, 2009.

No funds were received in support of this work. Although one or more of the author(s) has/have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this manuscript, benefits will be directed solely to a research fund, foundation, educational institution, or other nonprofit organization which the author(s) has/have been associated.

Address correspondence and reprints requests to Katsushi Takeshita, MD, Department of Orthopaedic Surgery, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan 113-8655; E-mail: Takeshita-ort@h.u-tokyo.ac.jp

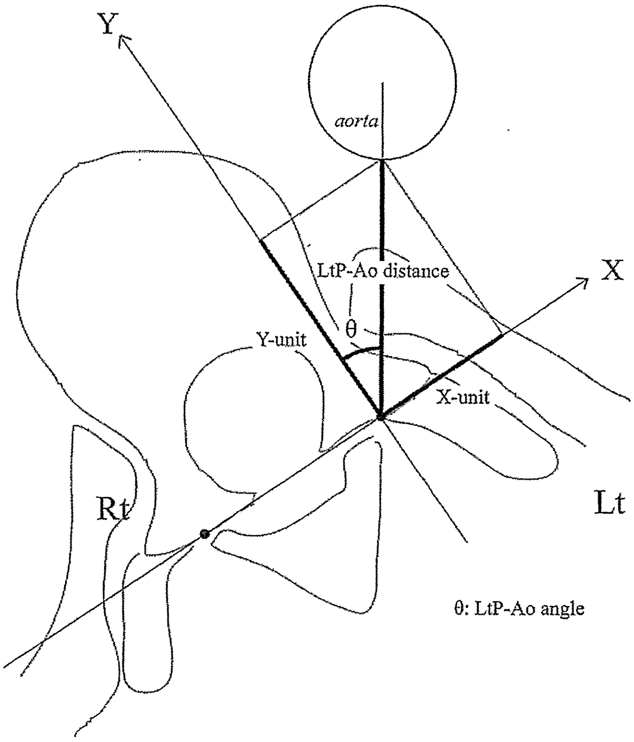


Figure 1. Aorta parameters. The origin is set in the middle of the base of the left superior facet. A line connecting the 2 middle points of both bases of the superior facets is defined as X-axis. LtP-Ao distance indicates the left pedicle-aorta distance; LtP-Ao angle, the left pedicle-aorta angle.

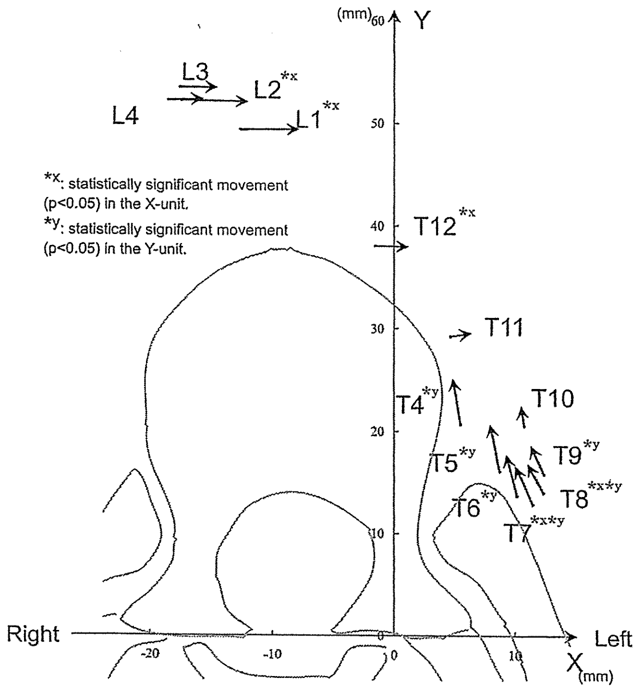


Figure 2. The aorta movement relative to the spine before and after posterior correction and fusion in our Cartesian coordinate system. The aorta moved to the anterior direction at the upper and middle thoracic levels and to the medial direction at the lower thoracic and lumbar levels.

tion protocol, and the postoperative CT was obtained with a helical scan and developed with a width of 1.00 mm less than 2 weeks after surgery. All Digital Imaging and Communication in Medicine data were transferred to a personal computer and analyzed by Digital Imaging and Communication in Medicine or DICOM software (ExaView LITE: Ziosoft, Tokyo, Japan). In the present study, we used our original Cartesian coordinate system and measured parameters describing the location of the aorta from T4 to L4 of the 22 patients. We selected the middle of the base of the left superior facet as the point of origin of this coordinate system (Figure 1) because the most probable threat to the aorta is by a pedicle screw on the left side at the thoracic spine. A line connecting the 2 middle points of both bases of the superior facets was defined as the X-axis; the Y-axis is determined to be parallel to the upper endplate of each vertebral body. The angle formed by the Y-axis and a line connecting the origin and the center of the aorta was defined as the left pedicle-aorta (LtP-Ao) angle and length of a line connecting the origin and the edge of the aorta as the LtP-Ao distance. Two parameters and the X- and Y-units of the LtP-Ao distance at 240 vertebral bodies were measured pre- and postsurgery after excluding vertebrae with incomplete data. From the repeatability test from our previous study,[7] interclass corre-

Table 1. Aorta Parameters Before and After Surgery

		LtAo-Angle (deg)			LtAo-Distance (mm)			
Level	n	Preop	Postop	Change	Preop	Postop	Change	Movement (mm)
T4	6	22.3 ± 30.9 (−6 to 65)	16.2 ± 24.6 (−18 to 55)	−4.1 ± 13.0 (−28 to 9)	22.0 ± 8.4 (11 to 32)	25.8 ± 8.3 (14 to 39)	3.6 ± 3.1* (−1 to 8)	5.9 ± 4.2 (1 to 12)
T5	20	30.8 ± 21.0 (−1 to 78)	23.8 ± 18.0 (−10 to 67)	−7.2 ± 8.9* (−23 to 12)	19.9 ± 4.7 (12 to 32)	23.6 ± 6.0 (14 to 37)	4.3 ± 3.7* (−1 to 14)	5.4 ± 2.9 (1 to 13)
T6	22	37.3 ± 16.8 (9 to 74)	30.2 ± 14.2 (3 to 59)	−7.1 ± 9.1* (−22 to 8)	18.1 ± 3.7 (13 to 28)	20.7 ± 5.0 (11 to 33)	2.6 ± 2.7* (−2 to 9)	4.6 ± 2.7 (1 to 13)
T7	22	42.3 ± 14.0 (17 to 74)	32.6 ± 11.4 (12 to 59)	−10.0 ± 7.7* (−22 to 3)	17.9 ± 3.7 (12 to 26)	19.7 ± 4.5 (12 to 33)	1.9 ± 2.6* (−3 to 7)	4.1 ± 2.6 (0 to 9)
T8	22	42.4 ± 11.1 (16 to 65)	34.5 ± 8.5 (20 to 55)	−7.9 ± 7.1* (−20 to 4)	19.2 ± 4.3 (13 to 30)	20.2 ± 3.7 (14 to 29)	1.0 ± 2.6 (−6 to 4)	3.9 ± 2.1 (1 to 8)
T9	22	39.2 ± 11.5 (13 to 53)	32.5 ± 8.8 (9 to 46)	−6.8 ± 7.0* (−23 to 7)	20.8 ± 4.9 (14 to 32)	21.8 ± 4.2 (16 to 31)	1.0 ± 2.4 (−6 to 5)	3.8 ± 2.2 (1 to 9)
T10	22	29.9 ± 14.1 (−13 to 51)	27.1 ± 10.3 (0 to 49)	−2.7 ± 7.5 (−15 to 13)	24.1 ± 6.3 (15 to 36)	25.0 ± 5.2 (17 to 34)	0.9 ± 3.2 (−5 to 6)	4.3 ± 2.8 (0 to 10)
T11	22	13.0 ± 20.4 (−46 to 44)	13.9 ± 13.6 (−21 to 37)	0.8 ± 10.0 (−17 to 25)	31.8 ± 8.0 (19 to 46)	31.3 ± 6.7 (20 to 43)	−0.5 ± 3.1 (−7 to 4)	5.1 ± 4.4 (0 to 19)
T12	21	0.4 ± 16.2 (−26 to 28)	3.7 ± 13.2 (−18 to 34)	3.3 ± 6.4* (−10 to 13)	39.4 ± 8.1 (25 to 52)	38.2 ± 7.4 (25 to 55)	−1.0 ± 2.5 (−7 to 4)	5.0 ± 3.0 (1 to 10)
L1	21	−12.6 ± 14.1 (−36 to 13)	−8.0 ± 10.6 (−29 to 9)	4.8 ± 5.5* (−8 to 12)	50.3 ± 6.8 (36 to 63)	49.0 ± 6.2 (39 to 59)	−1.5 ± 3.3* (−7 to 6)	6.0 ± 3.1 (1 to 13)
L2	21	−16.0 ± 10.3 (−38 to 2)	−12.0 ± 8.8 (−28 to 3)	4.1 ± 4.6* (−3 to 14)	54.5 ± 4.5 (44 to 61)	52.8 ± 4.4 (44 to 61)	−1.6 ± 1.5* (−7 to 2)	5.2 ± 3.2 (2 to 14)
L3	14	−17.6 ± 5.2 (−27 to −10)	−14.0 ± 5.3 (−23 to −5)	2.6 ± 4.0* (−4 to 8)	55.4 ± 4.5 (47 to 63)	54.4 ± 4.3 (48 to 62)	−1.0 ± 2.9 (−5 to 4)	4.4 ± 2.6 (1 to 8)
L4	5	−19.6 ± 5.9 (−28 to −12)	−17.0 ± 4.6 (−25 to −13)	2.4 ± 3.0 (−1 to 7)	53.2 ± 3.3 (48 to 57)	53.2 ± 4.7 (48 to 59)	0.0 ± 3.1 (−3 to 4)	3.9 ± 2.0 (2 to 7)
Total	240	17.9 ± 27.4 (−46 to 78)	15.4 ± 21.6 (−29 to 67)	−2.5 ± 9.1 (−28 to 25)	31.3 ± 15.3 (11 to 63)	31.9 ± 13.9 (11 to 62)	0.7 ± 3.3 (−7 to 14)	4.8 ± 3.2 (0 to 20)

*$P < 0.01$.

LtAo-Angle indicates left pedicle-aorta angle; LtAo-Distance, left pedicle-aorta distance; Preop, preoperative; Postop, postoperative.

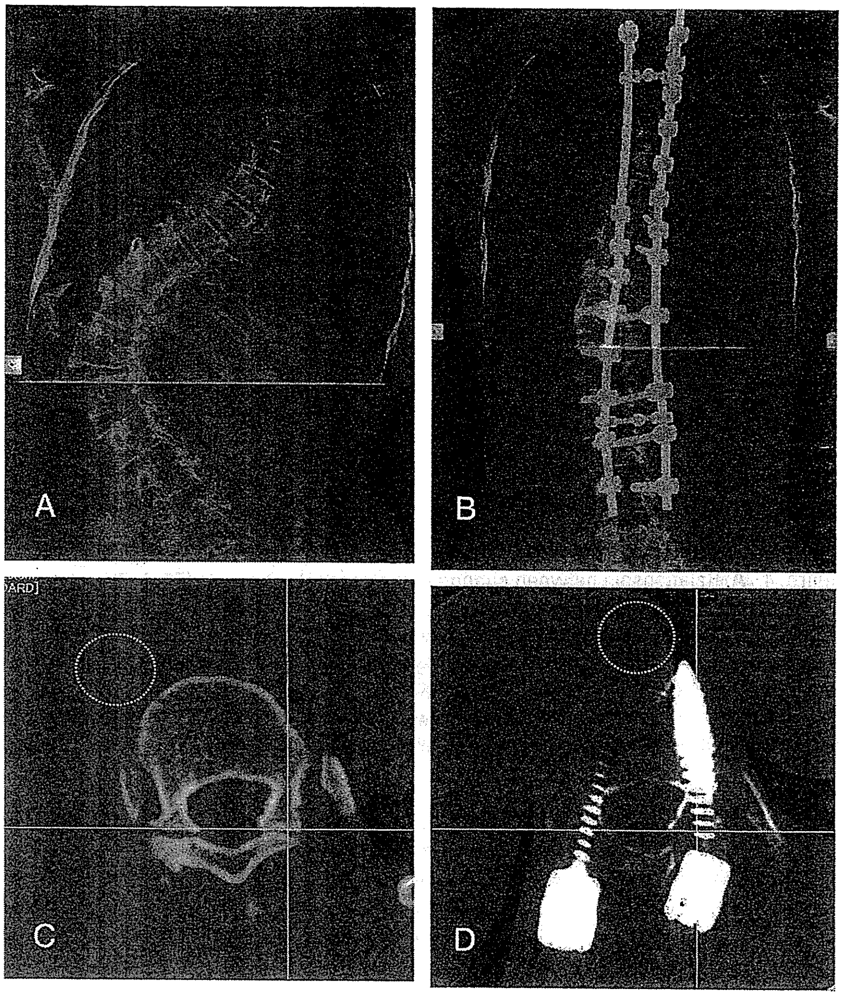


Figure 3. **A**, Standing anteroposterior spinal radiograph of a 14-year-old girl with a 69° right thoracic curve and 88° left lumbar curve. She had only 11 thoracic vertebrae (no T12) and the apical vertebral translation was 69.5 mm. She had had foraminal magnum decompression and duroplasty 16 months before spinal surgery. **B**, Standing coronal radiograph 2 weeks after segmental pedicle screw instrumentation from T2 to L4 demonstrating thoracic curve correction to 19° and lumbar curve correction to 25°. The apical vertebral translation decreased to 30.1 mm. **C**, Preoperative computed tomography by multiplanar reconstruction at T11. The aorta (dotted circle) located in front of the right side of the vertebral body. **D**, Postoperative computed tomography adjusted by multiplanar reconstruction to match the preoperative imaging. The aorta (dotted circle) had moved 19.5 mm to the bicortical pedicle screw of the left side.

lation coefficients were 0.922 to 0.957 in the intraobserver measurement and 0.896 to 0.929 (0.864–0.961) in the interobserver measurement.

We analyzed the movement of the aorta relative to the spine in each level. To determine the relationship between the thoracic main curve and thoracic coronal/sagittal alignment, we selected patients who had their main curve in the thoracic spine. In the 17 selected patients, we measured the Cobb angle and the apical vertebral translations (AVT) of the main curve, and the sagittal alignment (the Cobb angle at T5–T12) before and after surgery. These deformity parameters were examined for their correlation, with the maximum movement of the aorta in the main thoracic curve. Statistical analysis was performed by SPSS 17.0 (SPSS Inc., Chicago, IL).

We simulated placement of the pedicle screw with a direction different from the ideal trajectory. Sensitivity analysis was performed by varying the direction error and the length of the screw independently. The direction error started from 10° up to 30° with 10° increments (3 scenarios). The length of the screw started from 25 to 40 mm with increments of 5 mm (4 scenarios). Therefore, we set up total of 24 scenarios in the preoperative or postoperative state. We defined a warning pedicle as being when the aorta enters the expected area of the screw. Ratio between the number of warning pedicles and the number of the examined pedicles at 1 spine level was calculated from T4 to L4 in every scenario.

Results

The LtP-Ao angle changed significantly from T5 to T9 and from T12 to L3 (*t* test, $P < 0.01$) (Table 1), whereas the LtP-Ao distance changed significantly from T4–T7, L1 and L2. The average of the aorta movement in the examined 240 vertebrae was 4.7 ± 3.0 mm. The aorta moved more than 10 mm in 14 vertebrae (5.8%), and had a tendency to migrate in the anteromedial direction (Figure 2). A representative case is shown in Figure 3.

In the 17 patients who had the main curve in the thoracic spine, the maximum movement of the aorta in the main thoracic curve was 8.9 ± 3.5 mm (range, 3.9–14.9). Level of the maximum movement was T4 in 1 case, T5 in 1, T6 in 1, T7 in 2, T9 in 1, T10 in 3, T11 in 1, T12 in 1, L1 in 3, L2 in 2, L3 in 0, and L4 in 1. Level of the maximum movement was periapical (±1 vertebra of the apex) in 8 cases. The maximum movement of the aorta correlated with the preoperative AVT (Pearson correlation coefficient, −0.55; $P = 0.02$), preoperative sagittal alignment (−0.52, $P = 0.03$), and change of the sagittal alignment (0.57, $P = 0.02$) (Figure 4).

Sensitivity analysis (Tables 2–4) revealed that long pedicle screw (40 mm) with moderate direction error

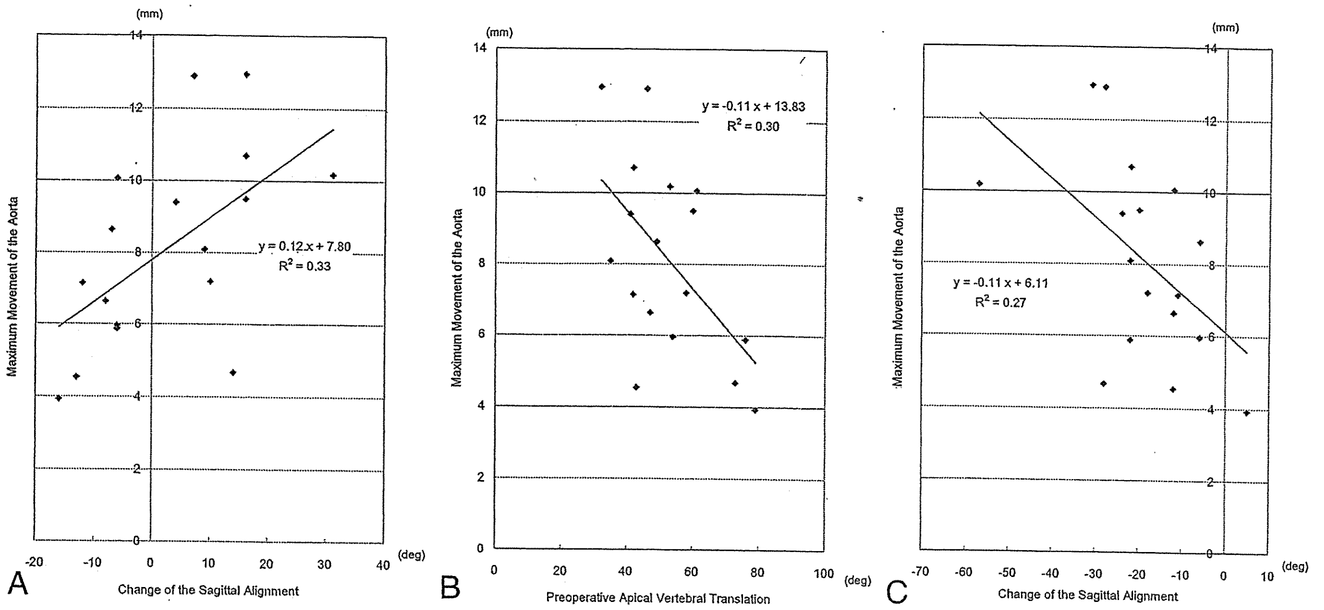


Figure 4. **A**, Relationship between change of the sagittal alignment (T5–T12) and the maximum aorta movement in the main thoracic curve of 17 patients. Positive change denotes more kyphotic change. Pearson correlative coefficient was 0.571 ($P = 0.017$); *i.e.*, more correction of the main curve meant greater aorta movement. **B**, Relationship between the postoperative apical vertebral translation and the maximum aorta movement. Pearson correlative coefficient was −0.550 ($P = 0.022$); *i.e.*, lower apical vertebral translation after surgery meant greater aorta movement. **C**, Relationship between the preoperative sagittal alignment (T5–T12) and the maximum aorta movement in the main thoracic curve of 17 patients. Positive change denotes more kyphotic change. Pearson correlative coefficient was −0.521 ($P = 0.032$); *i.e.*, more correction of the main curve meant larger aorta movement.

imposed risk on the aorta, but a large direction error (30°) by itself put the aorta at a high risk in any spine level regardless of the length of the pedicle screw.

There were only 5 warning pedicles in 96 examined lumbar spine and all were first lumbar spine. Therefore, further analysis was limited only in the thoracic spine. The distribution of the warning pedicles revealed 3 groups. The middle thoracic level (T7–T9) had a low ratio of warning pedicles before surgery, and the ratio increased statistically significantly after deformity correction. The upper thoracic level (T4–T6) as well as the lower thoracic level (T10–T12) had a moderate ratio of warning pedicles before surgery, and did not change considerably after deformity correction.

Discussion

The present study revealed that the aorta moved more than 10 mm in 17 of the examined 240 spines (5.8%), with a shift to the anterior and medial positions after posterior surgery. From our previous study,[8] the aorta may be at risk at left concave pedicle at T4, T5, and T10–T12 before surgery, and there was a relative safety of the aorta for pedicle screw placement at the apical level. The present study showed that the dangerous pedicle ratio increased at the midthoracic level after surgery. At the apical level, the aorta often resides far lateral of the vertebral body which is far from the axis of the trunk. Surgeons assume from the preoperative imaging that the

Table 2. Warning Pedicles—Direction Error Within 10°

		Preoperative			Postoperative			
Screw Length	Level	Warning (+)*	Warning (−)†	Ratio	Warning (+)*	Warning (−)†	Ratio	Difference
25 mm	T4–T6	2	46	4.2%	0	48	0.0%	−4.2%
25 mm	T7–T9	0	66	0.0%	0	66	0.0%	0
25 mm	T10–T12	0	65	0.0%	0	65	0.0%	0
30 mm	T4–T6	5	43	10.4%	2	46	4.2%	−6.2%
30 mm	T7–T9	0	66	0.0%	1	65	1.5%	+1.5%
30 mm	T10–T12	0	65	0.0%	1	64	1.5%	+1.5%
35 mm	T4–T6	7	41	14.6%	5	43	10.4%	−4.2%
35 mm	T7–T9	0	66	0.0%	1	65	1.5%	+1.5%
35 mm	T10–T12	4	61	6.2%	6	59	9.2%	+3.0%
40 mm	T4–T6	7	41	14.6%	5	43	10.4%	−4.2%
40 mm	T7–T9	0	66	0.0%	1	65	1.5%	+1.5%
40 mm	T10–T12	8	57	12.3%	11	54	16.9%	+4.6%

*Number of the warning pedicles.
†Number of the nonwarning pedicles.

Table 3. Warning Pedicles—Direction Error Within 20°

		Preoperative			Postoperative			
Screw Length	Level	Warning (+)*	Warning (−)†	Ratio	Warning (+)*	Warning (−)†	Ratio	Difference
25 mm	T4–T6	7	41	14.6%	5	43	10.4%	−4.2%
25 mm	T7–T9	1	65	1.5%	0	66	0.0%	−1.5%
25 mm	T10–T12	1	64	1.5%	1	64	1.5%	0
30 mm	T4–T6	11	37	22.9%	12	36	25.0%	+2.1%
30 mm	T7–T9	2	64	3.0%	1	65	1.5%	−1.5%
30 mm	T10–T12	1	64	1.5%	5	60	7.7%	+6.2%
35 mm	T4–T6	13	35	27.1%	16	32	33.3%	+6.2%
35 mm	T7–T9	4	62	6.1%	2	64	3.0%	−3.1%
35 mm	T10–T12	10	55	15.4%	14	51	21.5%	+6.1%
40 mm	T4–T6	13	35	27.1%	18	30	37.5%	+10.4%
40 mm	T7–T9	4	62	6.1%	2	64	3.0%	−3.1%
40 mm	T10–T12	19	46	29.2%	21	44	32.3%	+3.1%

*Number of the warning pedicles.
†Number of the nonwarning pedicles.

aorta stays out of the spine and become less careful of this organ during screw placement. In fact, after correction of the scoliosis in some cases, the vertebrae return to a more physiologic position, which is the center of the body: this movement of the spine results in the medialization of the aorta relative to the spine and the risk of the aorta by a pedicle screw increased by correction of the deformity at the middle thoracic spine. Accordingly, all left pedicles have substantial risk of indenting the aorta indentation if a pedicle screw breaches outside the pedicle.

Few authors have reported change of the aorta position after deformity surgery. The first analysis was reported by Bullmann *et al.*[9] They analyzed the aorta movement in their experience of anterior surgery and found that the aorta migrates from a more posterolateral to a more anteromedial position in relation to the thoracic vertebrae. However, patients were scanned in supine position for preoperative CT and in a lateral decubitous position for postoperative magnetic resonance imaging. As the aorta location depends on the patient position at examination especially in the midthoracic level as clearly shown by the study of Huitema *et al*,[10] the aorta movement in Bullman's report may come from a difference in the patient's position in the 2 examinations.

Recently, Wang *et al*[11] analyzed the change of the position of the aorta after anterior or posterior instrumentation of type I Lenke curve and concluded that the aorta moved more in anterior surgery than in posterior surgery. They measured by 2 methods: one was from the aorta to the closest point of the cortex of the vertebral body and the other was from the posterior wall of the aorta to the anterior edge of the left rib head, neither of which was associated with the pedicle screw impingement. They measured 2 angles which were not suitable to describe the aorta position as for pedicle screw placement. Accordingly, parameters they adopted could not clarify the aorta movement relative to the spine, as do our results.

The present analysis indicated that the aorta position has a relationship with the curve characteristics of spinal deformity. The aorta movement highly correlated with the deformity characteristics: change of the sagittal alignment, preoperative AVT and sagittal alignment. Therefore, the

Table 4. Warning Pedicles—Direction Error Within 30°

		Preoperative			Postoperative			
Screw Length	Level	Warning (+)*	Warning (−)†	Ratio	Warning (+)*	Warning (−)†	Ratio	Difference
25 mm	T4–T6	15	33	31.3%	15	33	31.3%	0
25 mm	T7–T9	3	63	4.5%	15	51	22.7%	+18.2%‡
25 mm	T10–T12	6	59	9.2%	8	57	12.3%	+3.1%
30 mm	T4–T6	19	29	39.6%	23	25	47.9%	+8.3%
30 mm	T7–T9	9	57	13.6%	22	44	33.3%	+19.7%§
30 mm	T10–T12	14	51	21.5%	18	47	27.7%	+6.2%
35 mm	T4–T6	21	27	43.8%	27	21	56.3%	+12.5%
35 mm	T7–T9	11	55	16.7%	23	43	34.8%	+18.1%§
35 mm	T10–T12	24	41	36.9%	30	35	46.2%	+9.3%
40 mm	T4–T6	21	27	43.8%	29	19	60.4%	+16.6%
40 mm	T7–T9	11	55	16.7%	23	43	34.8%	+18.1%§
40 mm	T10–T12	33	32	50.8%	38	27	58.5%	+7.7%

*Number of the warning pedicles.
†Number of the nonwarning pedicles.
‡$P < 0.01$ (Fisher exact test).
§$P < 0.05$.

degree of the aorta movement may be estimated from preoperative deformity and the degree of correction.

We did not measure and analyze the rotation of the spine as most CT did not include the pelvis because of the retrospective nature of this study. Accordingly, we could not estimate the effect of derotation.

In summary, the aorta moved anteromedially relative to the spine after the posterior correction and the risk of the aorta by a pedicle screw increased by correction of the deformity at the middle thoracic spine. Surgeons are recommended to anticipate the aorta movement in the surgical planning.

■ Key Points

- We evaluated the aorta positions before and after scoliosis surgery by multiplanar reconstruction of computed tomography.
- The aorta had a tendency to migrate to the anteromedial direction after corrective surgery of the scoliosis.
- The risk of the aorta by a pedicle screw increases by correction of the deformity at the middle thoracic spine.

References

1. Kakkos SK, Shepard AD. Delayed presentation of aortic injury by pedicle screws: report of two cases and review of the literature. *J Vasc Surg* 2008;47:1074–82.
2. Minor ME, Morrissey NJ, Peress R, et al. Endovascular treatment of an iatrogenic thoracic aortic injury after spinal instrumentation: case report. *J Vasc Surg* 2004;39:893–6.
3. Wegener B, Birkenmaier C, Fottner A, et al. Delayed perforation of the aorta by a thoracic pedicle screw. *Eur Spine J* 2008;17(suppl 2):S351–4.
4. Cheung KM, Luk KD. Prediction of correction of scoliosis with use of the fulcrum bending radiograph. *J Bone Joint Surg Am* 1997;79:1144–50.
5. Vora V, Crawford A, Babekhir N, et al. A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: myth or reality. *Spine* 2007;32:1869–74.
6. Luk KD, Cheung KM, Lu DS, et al. Assessment of scoliosis correction in relation to flexibility using the fulcrum bending correction index. *Spine* 1998;23:2303–7.
7. Takeshita K, Maruyama T, Chikuda H, et al. Diameter, length, and direction of pedicle screws for scoliotic spine- analysis by multiplanar reconstruction of computed tomography. *Spine* 2009 59 34:798–803.
8. Takeshita K, Maruyama T, Chikuda H, et al. New parameters to represent the position of the aorta relative to the spine for pedicle screw placement. Paper presented at: The Scoliosis Research Society Annual Meeting; 2008; Salt Lake City, UT.
9. Bullmann V, Fallenberg EM, Meier N, et al. The position of the aorta relative to the spine before and after anterior instrumentation in right thoracic scoliosis. *Spine* 2006;31:1706–13.
10. Huitema GC, Cornips EM, Castelijns MH, et al. The position of the aorta relative to the spine: is it mobile or not? *Spine* 2007 20;32:1259–64.
11. Wang W, Zhu Z, Zhu F, et al. The changes of relative position of the thoracic aorta after anterior or posterior instrumentation of type I Lenke curve in adolescent idiopathic thoracic scoliosis. *Eur Spine J* 2008;17:1019–26.

創意と工夫

日本語版 Zurich claudication questionnaire（ZCQ）の開発

── 言語的妥当性を担保した翻訳版の作成*

原　慶宏　松平　浩　寺山　星　竹下克志　磯村達也
中村耕三**

[整形外科 61 巻 2 号：159～165，2010]

はじめに

腰部脊柱管狭窄症（lumbar canal stenosis：LCS）は主に腰椎の退行性変化に起因するもので，高齢社会に伴いその患者は急増している．長総の疫学調査では，LCS の症状を有している地域住民は 50 歳代から急増し，70 歳以上では約 30～40％にも及ぶとされている[1]．本症の主症状は，下肢の痛みやしびれに伴う神経性間欠跛行であり[2]，歩行障害を生じるため生活の質（QOL）に与える影響はきわめて大きい[3]．LCS の疾患の重症度や治療の評価においては適切な評価尺度を使用し，QOL を含めた総合的な評価をすることが重要であるといえる．

Zurich claudication questionnaire（ZCQ）は，LCS の重症度・身体機能および満足度を多面的にとらえ，総合的に評価するために開発された，18 項目の質問から構成される自記式の英語版の質問票で，LCS に疾患特異的な評価尺度である．英語版の開発は Stucki らにより行われ，1996 年に計量心理学的な妥当性が確認された第 1 版が『Spine』に公表された[4]．ZCQ はいくつかの名称をもち，Swiss spinal stenosis measure または Brigham spinal stenosis questionnaire という名称でも使用されている．

ZCQ は英語版のほかにすでにノルウェー語などで言語的妥当性が確認された翻訳版が作成されており[5]，これまでに多数の論文中に使用されている．また 2007 年に North American Spine Society から刊行された LCS 臨床ガイドラインにおいて，ZCQ は LCS の治療アウトカム評価に適切な評価法の一つとして推奨されている[6]．しかしわが国においては，言語的な妥当性が確認された翻訳版はないのが現状である．

わが国においても ZCQ を重症度評価・治療評価に導入すべく，英語の原作版を日本語に翻訳し，その言語的妥当性を検討したので報告する．

対象および方法

日本語版の開発は，言語的に妥当な翻訳版を作成する際に標準的に用いられる手順に従って行われた[7,8]（図 1）．言語的な妥当性を担保するために，原作版との内容的な整合性を保ちつつ，日本人患者にも違和感なく受け入れられる表現をめざすことが必要である．そのため，すべての段階において原作者である Dr. Stucki（Munich, Germany）に各質問の意図を確認しながら検討をすすめた．

1．日本語版案の作成（順翻訳と逆翻訳）

最初に，日本語を母国語とする 2 名の翻訳者が英語版質問票（原作版）をそれぞれ日本語に翻訳した．それぞれの翻訳案を検討し，日本語翻訳第 1 案として一つの翻訳案にまとめた．その後 2 名の LCS の治療経験を有する臨床医との協議を経て，日本語翻訳第 2 案を作成した（順翻訳）．次に，英語を母国語とする翻訳者が日本語翻

Key words：lumbar canal stenosis, outcome measure, Zurich claudication questionnaire, Japanese version, linguistic validation

---

* Development of the Japanese version of the Zurich claudication questionnaire（ZCQ）; translation and linguistic validation

** N. Hara：東京大学整形外科・脊椎外科（Dept. of Orthop. Surg. and Spinal Surg., Faculty of Medicine, The University of Tokyo, Tokyo）; K. Matsudaira（センター長）：関東労災病院勤労者筋・骨格系疾患研究センター；S. Terayama, K. Takeshita（講師）：東京大学整形外科・脊椎外科；T. Isomura：（株）Clinical Study Support；K. Nakamura（教授）：東京大学整形外科・脊椎外科．

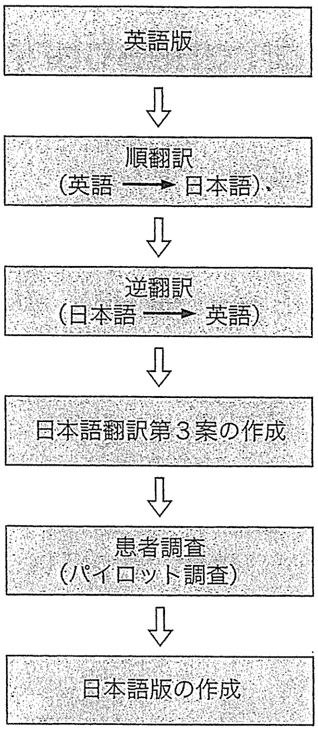


図 1．日本語版作成の手順

訳第2案を英語に翻訳し（逆翻訳），その内容について原作者（Dr. Stucki）に検討を依頼した．原作者の指摘事項を含め再度検討を行い，日本語翻訳第3案とした．

2．患者調査

日本語翻訳第3案の文章表現や質問内容の妥当性を検討するため，当科で2008年3月に個別面談方式による患者調査を実施した．患者調査の実施に際しては，当該施設における倫理委員会で承認を受けた後に実施し，調査では患者の個人情報を一切収集しないなど，患者のプライバシー保護には十分に配慮した．

個別面談は，文書による同意を得た5名のLCS患者に対し，Clinical Study Support社（名古屋）の心理学トレーニングを受けたインタビュー担当者によって実施した．インタビュー担当者は，調査目的を調査参加者に十分説明した後，自己記入で質問票に回答するように求めた．回答終了後，①質問票の全体的な印象（質問票は明瞭で理解しやすく回答しやすいか，回答に要する時間や質問数は適当か，説明文はわかりやすいか），②各質問文に関する印象（質問文は簡単に理解できるか，どのような意味であると理解したか，質問は内容的に回答しやすいか），および③回答肢についての印象（回答肢は明瞭で質問に対応しているか）について患者に意見を求めた．原作者と患者調査の結果を協議し，日本語翻訳

表 1．英語版ZCQ（原作版）と日本語版ZCQの対比表

名 称	英語版：Zurich claudication questionnaire	日本語版：チューリヒ跛行質問票(ZCQ)
前 書	In the last month, how would you describe：	最近1ヵ月の状態について回答して下さい
質問文	The pain you have had on average including pain in your back, buttocks, as well as pain that goes down the legs?	痛みは平均してどの程度でしたか？（腰やおしりの痛み，またそこから脚（あし）にまで及ぶ痛みを含みます）
回答肢	none	痛みはまったくなかった
	mild	弱い痛みであった
	moderate	中程度の痛みであった
	severe	強い痛みであった
	very severe	非常に強い痛みであった
質問文	How often have you had back, buttock, or leg pain?	どのくらいの頻度で腰，おしり，あるいは脚（あし）の痛みがありましたか？
回答肢	less than once a week	1週間に1回未満
	at least once a week	1週間に少なくとも1回
	every day, for at least a few minutes	少なくとも1日1回
	every day, for most of the day	1日の大半
	every minute of the day	四六時中痛みがある
質問文	The pain in your back or buttocks?	腰あるいはおしりの痛みはどうでしたか？
回答肢	none	痛みはまったくなかった
	mild	弱い痛みであった
	moderate	中程度の痛みであった
	severe	強い痛みであった
	very severe	非常に強い痛みであった
質問文	The pain in your legs or feet?	脚（あし）や足部の痛みはどうでしたか？
回答肢	none	痛みはまったくなかった
	mild	弱い痛みであった
	moderate	中程度の痛みであった
	severe	強い痛みであった
	very severe	非常に強い痛みであった
質問文	Numbness or tingling in your legs or feet?	脚（あし）や足部のしびれやうずきはどうでしたか？
回答肢	none	しびれやうずきはまったくなかった
	mild	弱いしびれやうずきであった
	moderate	中程度のしびれやうずきであった
	severe	強いしびれやうずきであった
	very severe	非常に強いしびれやうずきであった
質問文	Weakness in your legs or feet?	脚（あし）や足部の衰え具合はどうでしたか？
回答肢	none	衰えはまったくなかった
	mild	軽い衰えであった
	moderate	中程度の衰えであった
	severe	激しい衰えであった
	very severe	非常に激しい衰えであった
質問文	Problems with your balance?	バランス（安定感）に問題はありましたか？
回答肢	No, I've had no problems with my balance	いいえ，バランスをとることにまったく問題はなかった
	Yes, sometimes I feel my balance is off, or that I am not sure-footed	はい，バランスを崩したり足元がしっかりしていなかったりすると，ときどき感じた
	Yes, often I feel my balance is off, or I am not sure-footed	はい，バランスを崩したり足元がしっかりしていなかったりすると，しばしば感じた