



# Relation of lumbar sympathetic chain to the open corridor of retroperitoneal oblique approach to lumbar spine: an MRI study

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## Abstract

**Background** Retroperitoneal oblique approach to lumbar spine used surgical corridor between psoas muscle and aorta for exposure to anterior part of lumbar spine. Lumbar sympathetic chain (LSC) runs in the corridor to make it a structure at risk of injury.

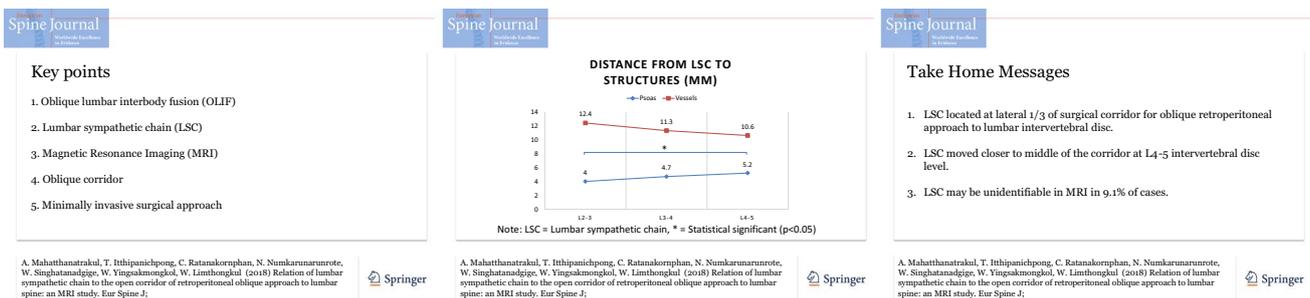
**Research question** Does LSC relationship with surgical corridor for minimally invasive retroperitoneal anterolateral oblique approach change in different intervertebral disc level?

**Methods** Left LSC was identified in axial magnetic resonance imaging images at L2–3, L3–4 and L4–5 intervertebral disc levels of 144 patients. Distances between LSC and left psoas muscle and aorta were recorded.

**Results** Mean age of the patients was 62.3 years. LSC was identifiable in 90.9% of levels. Distance between LSC and psoas muscle at L2–3, L3–4 and L4–5 was 4.0 mm, 4.7 mm and 5.2 mm. Statistical difference was found between L2–3 and L4–5 level ( $p=0.006$ ). Distance between LSC and aorta at each level was 12.4 mm, 12.3 mm and 10.6 mm without statistical difference. In non-scoliosis group distance between LSC and psoas muscle at each level was 3.1 mm, 3.3 mm and 4.0 mm. Statistical difference was found between L2–3 and L4–5 level ( $p=0.012$ ) and between L3–4 and L4–5 level ( $p=0.041$ ). Distance between LSC and aorta at each level was 11.9 mm, 11.4 mm and 10.2 mm. Statistical difference was found between L2–3 and L4–5 disc level ( $p=0.039$ ).

**Conclusion** LSC moves away from psoas muscle and becomes closer to aorta in L4–5 disc level.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.



**Keywords** Oblique lumbar interbody fusion · Lumbar sympathetic chain · Magnetic Resonance Imaging · Oblique corridor · Minimally invasive surgical approach

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s00586-018-5779-6>) contains supplementary material, which is available to authorized users.

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## Introduction

Minimally invasive retroperitoneal oblique approach to lumbar spinal fusion had gained popularity recently after Mayer described the approach to access L2 to L5 intervertebral discs in 1997 [1]. This approach used potential space between aorta and left psoas muscle as a surgical corridor [2, 3]. Minimally invasive spine surgery had a steep learning curve but can be shortened when surgeon becomes familiar to the anatomy and operative field [4, 5]. Injury to structure during the approach including, lumbar plexus, psoas muscle, segmental artery and great vessel had been reported [6–8].

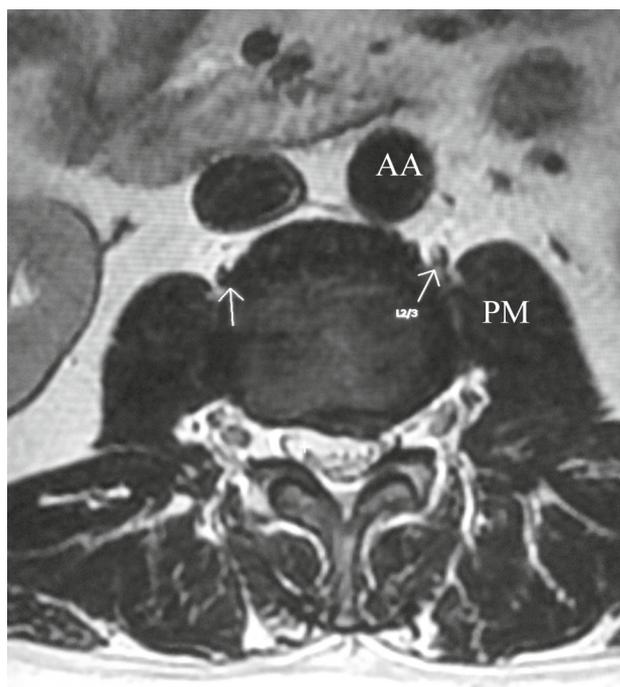
Lumbar sympathetic chain (LSC) usually runs anterolateral to vertebral body and anterior to psoas muscle [9–11] which makes it a structure at risk of injury during this approach. Accidental lumbar sympathectomy during anterior and lateral lumbar interbody fusion had been reported and associates with post-sympathectomy neuralgia and decreased quality of life [12–15].

The aim of this study was to identify relationship between LSC, psoas muscle, great vessels and intervertebral disc from L2–5 by using MRI of lumbar spine.

## Method

Patients with low back pain or radicular pain with MRI of lumbar spine were included. Exclusion criteria were patients with history of spinal injury, infection, malignancy or previous spinal instrumentation. Patients were divided into three groups, dextroscoliosis, levoscoliosis and non-scoliosis group, by measurement of Cobb angle of more than 10 degrees on right curve, left curve or less than 10 degrees retrospectively, on coronal MRI of lumbar spine. MRIs of the patients were reviewed by 2 orthopaedists and 1 musculoskeletal radiologist independently.

The measurements were taken using measurement tools in Synapse PACS (Fujifilm Medical Systems U.S.A., Stamford, CT). LSCs were identified on consecutive T1- and T2-weighted axial image without fat suppression and identified a group of low signal intensity dot, some show fascicular pattern, in linear craniocaudal orientation which was encircled by retroperitoneal fat and located between aorta or iliac artery and psoas muscle (Fig. 1). The LSCs were identified at L2–3, L3–4 and L4–5 intervertebral disc levels. Distances between the LSC and left psoas muscle, intervertebral disc, aorta or common iliac artery were recorded. If multiple LSCs were found in the same MRI image, the distance between the corresponding structure and the nearest LSC was measured. Sizes of LSC and level of common iliac artery bifurcation were also noted.



**Fig. 1** Axial cut of T2-weighted MRI shows position of lumbar sympathetic chain (white arrow) between abdominal aorta (AA) and psoas muscle (PM)

## Statistical analysis

Normal distribution of data was tested by Kolmogorov–Smirnov test. Repeated-measure *t* test was used to compare distance between sympathetic chain and nearby structures at each intervertebral level. One-way ANOVA was used to compare difference between three groups. Interrater reliabilities were calculated using intraclass correlation coefficients (ICC) based on a mean rating of three raters, consistency and two-way random effects. SPSS version 21 (IBM, Armonk, NY) was used for statistical analysis. P value of less than 0.05 was considered statistically significant.

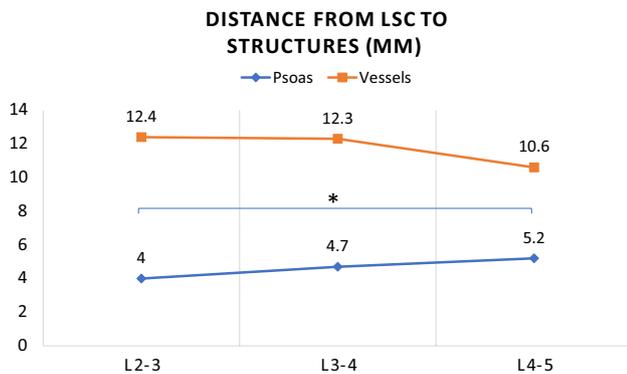
## Results

MRIs of lumbar spine of 144 patients were reviewed. One hundred and nine were female (75.7%), and 35 were male (24.3%). There were 32 patients in scoliosis group and 112 patients in non-scoliosis group. Mean age of the patients was 62.3 years old (Range 40–85 years old). LSC was identified in 90.9% of intervertebral levels. LSC was identified in 92.3% of the patients in non-scoliosis group, 91.7% in levoscoliosis group and 81.3% in dextroscoliosis group (Table 1).

**Table 1** Demographic data and identifiability of LSC according to each group of the patients

|                               | Total            | Non-scoliosis    | Levoscoliosis    | Dextroscoliosis  | <i>p</i> |
|-------------------------------|------------------|------------------|------------------|------------------|----------|
| Number                        | 144              | 112              | 16               | 16               |          |
| Age (years, 95% CI)           | 62.3 (60.5–64.1) | 60.6 (58.6–62.6) | 71.3 (66.3–76.4) | 64.8 (60.7–68.9) | 0.001*   |
| Cobb's angle (degree, 95% CI) | –                | –                | 16.6 (13.5–20.0) | 16.1 (13.6–18.7) | 0.75     |
| Female (%)                    | 109 (75.7%)      | 82 (73.2%)       | 12 (75.0%)       | 15 (93.8%)       | 0.204    |
| Identifiability of LSC        |                  |                  |                  |                  |          |
| L2–3                          | 91.4             | 93.2             | 93.8             | 77.1             | 0.010*   |
| L3–4                          | 94.7             | 95.5             | 95.8             | 87.5             | 0.630    |
| L4–5                          | 86.8             | 86.8             | 85.4             | 79.2             | 0.223    |
| Total                         | 90.9             | 92.3             | 91.7             | 81.3             | 0.000*   |

LSC lumbar sympathetic chain, CI confidential interval, \*statistically significant ( $p < 0.05$ )



**Fig. 2** Distance between LSC and psoas muscle and aorta or common iliac vessels. Note: LSC lumbar sympathetic chain, \*statistically significant ( $p < 0.05$ )

Distance between LSC and psoas muscle was 4.0 mm (95% CI 3.4–4.5) at L2–3, 4.7 mm (95% CI 4.0–5.3) at L3–4 and 5.2 mm (95% CI 4.6–5.9) at L4–5. Statistical difference

was found between L2–3 and L4–5 level ( $p = 0.006$ ). Distance between LSC and aorta or iliac artery was 12.4 mm (95% CI 11.3–13.4) at L2–3, 12.3 mm (95% CI 11.2–13.5) at L3–4, 10.6 mm (95% CI 9.2–12.0) at L4–5 without statistical difference between groups (Fig. 2). Distance between LSC and intervertebral disc was 1.3 mm (95% CI 1.0–1.5) at L2–3, 1.4 mm (95% CI 1.1–1.6) at L3–4, 1.8 mm (95% CI 1.4–2.2) at L4–5 which was different from L2–3 and L3–4 ( $p = 0.029$  and  $0.049$ ). Diameter of LSC was 2.4 mm (95% CI 2.2–2.6) at L2–3, 2.4 mm (95% CI 2.3–2.6) at L3–4, 2.3 mm (95% CI 2.1–2.4) at L4–5 without statistical difference between levels (Table 2).

In non-scoliosis group, distance between LSC and psoas muscle was 3.1 mm (95% CI 2.7–3.5) at L2–3, 3.3 mm (95% CI 3.0–3.7) at L3–4, 4.0 mm (95% CI 3.5–4.5) at L4–5. Statistical difference was found between L2–3 and L4–5 level ( $p = 0.012$ ) and between L3–4 and L4–5 level ( $p = 0.041$ ). Distance between LSC and aorta or iliac artery was 11.9 mm (95% CI 11.1–12.7) at L2–3, 11.4 mm (95% CI 10.5–12.2) at L3–4, 10.2 mm (95% CI 9.1–11.2) at

**Table 2** Distance between LSC and psoas muscle, aorta or common iliac artery and intervertebral disc

|                 | L2–3             | L3–4             | L4–5            | <i>p</i> |
|-----------------|------------------|------------------|-----------------|----------|
| LSC psoas       | 4.0 (3.4–4.5)    | 4.7(4.0–5.3)     | 5.2 (4.6–5.9)   | 0.003*   |
| Non-scoliosis   | 3.1 (2.7–3.5)    | 3.3 (3.0–3.7)    | 4.0 (3.5–4.5)   | 0.004*   |
| Levoscoliosis   | 3.7 (2.6–4.9)    | 5.2 (3.5–6.9)    | 6.8 (5.3–8.3)   | 0.001*   |
| Dextroscoliosis | 5.1 (3.4–6.7)    | 5.4 (3.1–7.8)    | 5.0 (2.9–7.90)  | 0.923    |
| LSC vessels     | 12.4 (11.3–13.4) | 12.3 (11.2–13.5) | 10.6 (9.2–12.0) | 0.058*   |
| Non-scoliosis   | 11.9 (11.1–12.7) | 11.4 (10.5–12.2) | 10.2 (9.1–11.2) | 0.020*   |
| Levoscoliosis   | 9.2 (7.4–11.0)   | 9.5 (7.4–11.5)   | 12.3 (9.4–15.1) | 0.131    |
| Dextroscoliosis | 16.0 (12.9–19.2) | 16.2 (12.3–20.0) | 9.4 (5.6–13.2)  | 0.018*   |
| LSC disc        | 1.3 (1.0–1.5)    | 1.4 (1.1–1.6)    | 1.8 (1.4–2.2)   | 0.009*   |
| Non-scoliosis   | 1.1 (0.9–1.3)    | 1.1 (0.9–1.3)    | 1.8 (1.5–2.2)   | 0.000*   |
| Levoscoliosis   | 1.4 (0.8–1.9)    | 1.7 (0.9–2.5)    | 2.1 (1.2–3.0)   | 0.123    |
| Dextroscoliosis | 1.3 (0.7–1.9)    | 1.3 (0.7–1.9)    | 1.6 (0.8–2.3)   | 0.199    |

Data are shown in millimetres (95% CI)

LSC lumbar sympathetic chain, \*statistically significant ( $p < 0.05$ )

L4–5. Statistical difference was found between L2–3 and L4–5 disc level ( $p=0.039$ ) (Fig. 3).

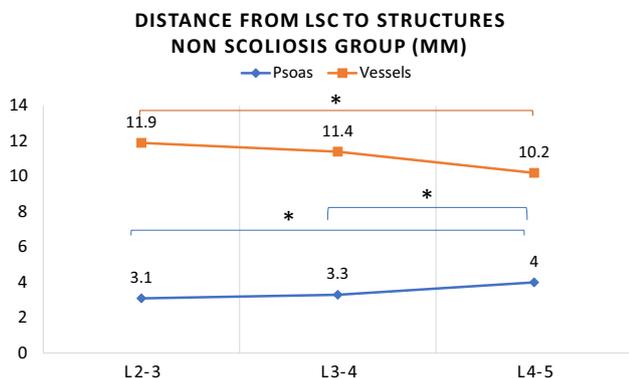
In levoscoliosis group, distance between LSC and psoas muscle was 3.7 mm (95% CI 2.6–4.9) at L2–3, 5.2 mm (95% CI 3.5–6.9) at L3–4, 6.8 mm (95% CI 5.3–8.3) at L4–5. Statistical difference was found between L2–3 VS L4–5 level ( $p=0.001$ ). Distance between LSC and aorta or iliac artery was 9.2 mm (95% CI 7.4–11.0) at L2–3, 9.5 mm (95% CI 7.4–11.5) at L3–4, 12.3 mm (95% CI 9.4–15.1) at L4–5 without statistical difference between levels (Fig. 4).

In dextroscoliosis group, distance between LSC and psoas muscle was 5.1 mm (95% CI 3.4–6.7) at L2–3, 5.4 mm (95% CI 3.1–7.8) at L3–4, 5.0 mm (95% CI 2.9–7.0) at L4–5. Distance between LSC and aorta or iliac artery was 16.0 mm (95% CI 12.9–19.2) at L2–3, 16.2 mm (95% CI 12.3–20.0) at L3–4, 9.4 mm (95% CI 5.6–13.2) at L4–5 without statistical difference between levels (Fig. 5).

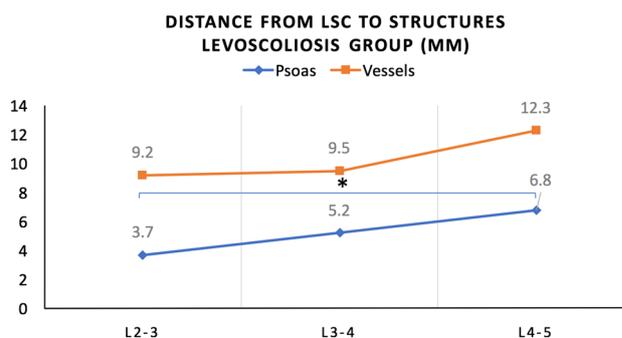
Distance between LSC and psoas muscle was statistically different between non-scoliosis, levoscoliosis and dextroscoliosis groups at L2–3, L3–4, L4–5 level ( $p=0.003$ , 0.001 and 0.001, respectively). Distance between LSC and vessels was statistically different at L2–3, L3–4 level ( $p=0.000$ , 0.000) between groups.

The aortic bifurcation was found at L3 vertebral body in 1.0%, L3–4 intervertebral disc in 13.3%, L4 vertebral body in 60.2%, L4–5 intervertebral disc in 19.4%, L5 vertebral body in 6.1%.

ICC between three observers was calculated. ICC of distance between LSC and psoas muscle was 0.574, moderate reliability (95% CI 0.413–0.696). ICC of distance between LSC and vessels was 0.867, good reliability (96% CI 0.817–0.905).



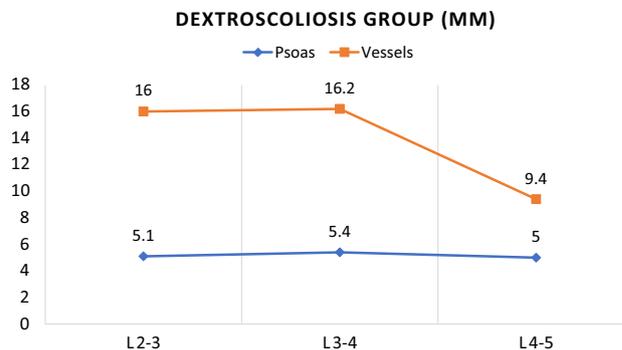
**Fig. 3** Distance between LSC and psoas muscle and aorta or common iliac vessels in non-scoliosis group. Note: LSC lumbar sympathetic chain, \*statistically significant ( $p < 0.05$ )



**Fig. 4** Distance between LSC and psoas muscle and aorta or common iliac vessels in levoscoliosis group. Note: LSC lumbar sympathetic chain, \*statistically significant ( $p < 0.05$ )

## Discussion

Minimally invasive retroperitoneal oblique approach to intervertebral body fusion uses surgical corridor between aorta and psoas muscle. The procedure uses psoas muscle as a landmark and was dissected from the lateral circumference of the disc space [1, 2, 7]. Advantage of lateral lumbar interbody fusion in degenerative scoliosis correction is that it gives a better correction of Cobb's angle than posterior spinal fusion alone [16]. However, surgical corridor in this group of patients had not been thoroughly studied. Davis et al. had measured retroperitoneal oblique corridor in 20 cadavers and found that from L2–L5 the corridor was narrowest at L4–5 level. Molinares et al. also found that the corridor was narrowest at L4–5 level by using MRI. Lieu et al. had reported that the actual operative windows for retroperitoneal oblique approach were smaller than 1 cm in 6.7% of L4–5 level by computed tomography angiography [2, 3, 17]. Similar result was found in our study. However, we found that spinal curve has the effect to the corridor and LSC distances. Unlike non-scoliosis and dextroscoliosis groups, surgical corridor in levoscoliosis group is wider from L2/3



**Fig. 5** Distance between LSC and psoas muscle and aorta or common iliac vessels in dextroscoliosis group. Note: LSC lumbar sympathetic chain, no statistical significance ( $p > 0.05$ )

to L4/5. Widest corridor was found in non-scoliosis, dextroscoliosis group at L2/3 and L3/4 and levoscoliosis group at L4/5. Collapsed disc at concave site leading to relaxation of the structure may explain this finding.

Inadvertent injury to LSC during anterolateral approach to spinal column is a known complication which may be underdiagnosed [13, 18]. Hrabalek et al. [14] reported 28 cases of post-anterior or lateral lumbar interbody fusion with post-sympathectomy syndrome. Sixteen cases (57%) can only be diagnosed by skin thermography without any other sign or symptom. However, 32% of the patients had the symptom of post-sympathectomy syndrome. At L1 to L5 approach, LSC is usually identified and was recommended to be cauterized if necessary [7]. Symptoms of post-sympathectomy syndrome including cold sensation on contralateral side of the injury due to vasodilatation of the affected side, anhidrosis, dysesthesia, discoloration and swelling of limb were reported [13, 14, 18–20]. Rajaraman et al. [18] have reported sympathetic chain injury in 6 from 60 patients (10%) in whom anterior lumbar interbody fusion (ALIF) by retroperitoneal approach was performed. They have found that 4 patients have lower-extremity temperature changed and the symptoms resolved within 4 months. One patient has intermittent swelling and discoloration of lower limb for 6 months, and another patient experiences persistent dysesthesia of left foot and burning paraesthesia of left thigh. Kim et al. [6] have reported that from 29 patients who had undergone OLIF, 4 patients (13.9%) had evidence of sympathetic injury from physical examination and digital infrared thermal imaging. Hrabalek et al. [14] reported 28 cases of lumbar sympathetic chain injury after ALIF and extreme lumbar interbody fusion. Ten patients (35.7%) have persistent symptoms more than 6 months. Two from 28 cases (7.1%) have severe symptoms that decrease their quality of life. Woo et al. [19] reported a case with persistent severe sympathetic pain after anterior spine surgery who need lumbar sympathetic block to relieve the symptoms. Our study showed that LSC runs closer to aorta and away from psoas muscle from L2/3 to L4/5. However, different tracking was found in dextroscoliosis due to the narrower corridor.

Effects of vertebral rotation to retroperitoneal structure were reported Makaanji et al. [21] found a significant increase of per cent overlapping of inferior vena cava over cephalad and apex vertebral endplate in left-side curve of degenerative scoliosis patient comparing to right-side curve. Regev et al. [22] reported 22.8% overlapping of right nerve root to vertebral endplate in dextroscoliosis and 21.4% overlapping of left nerve root in levoscoliosis comparing to 9.7 and 14.7% overlapping in contralateral side retrospectively. Reduction of safe zone from 70% in non-scoliosis spine to 61 and 43.9% in dextroscoliosis and levoscoliosis retrospectively, due to migration of nerves and vessels, was also found. Vertebral body rotation resulted in a relative change

in position of nerves and vessels was mentioned. Our study showed that LSC moved closer to vessel in dextroscoliosis and away from vessel in levoscoliosis. Unlike to other structures, this may be resulted from adhesion of LSC to the vertebral body. These may increase the risk of structural injury during OLIF approach. Similar to previous study, the aortic bifurcation was most common at L4 vertebral body study [3]. Level of the bifurcation may contribute to reduced distance between LSC and the artery at L4–5 level compared to L2–3 and L3–4.

Surgeons need to study their patient's surgical corridor in each case to correctly identify the location of the LSC. Because of the LSC located closer to psoas muscle in L4/5, surgeons should be aware of injury to LSC in such level in dextroscoliosis patient.

The disadvantages of an MRI study compared to cadaveric dissection are that the patients were in supine position and psoas muscle was not retracted which may affect the corridor and correlation of the LSC to vessels and psoas muscle [2, 23, 24]. LSC also could not be identified in 9.1% of levels, but they can be identified in all specimen of cadaveric study [11]. Interrater reliabilities were calculated in our study, the distance between LSC and psoas muscle had lesser reliability than the distance between LSC and vessels, and this may be because the shape of psoas muscles was not as round as the vessels. The observers may select a different point on psoas muscle for measurement.

## Conclusion

LSC was located at lateral 1/3 of surgical corridor for oblique retroperitoneal approach to lumbar intervertebral disc. LSC also moved closer to middle of the corridor in L4–5 intervertebral disc level. In scoliosis patients, LSC location might not be rotated in concordance with vertebral rotation and was more likely to be unidentifiable in MRI.

## Compliance with ethical standards

**Conflict of interest** W. Limthongkul is a consultant for Medtronic. There is no funding or grants related to this research.

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