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ORIGINAL STUDY

Study on the anatomy of the lumbosacral anterior great vessels pertinent to L5/S1 anterior interbody surgery with computer tomography angiography

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We investigate the anatomy of the lumbosacral anterior great vessels using computer tomography (CT) angiography before L5/S1 anterior interbody surgery. Sixty-two adult patients were selected. The location of the abdominal aortic bifurcation and common iliac venous confluence in the lumbar vertebrae and the anatomic parameters of the iliac vascular space (e.g., distances from the included angle vertex of the iliac vascular space to the median sagittal plane and to the inferior boundary of L5 and distances between the left and right iliac vessels on the inferior boundary of L5 and on the superior boundary of S1) were analysed. Overall, 67.73% of the 62 cases had an abdominal aortic bifurcation located at L4 and L4/5 intervertebral disc ; 61.29%, the common iliac venous confluence located at L5. The four distances mentioned above were 0.98 cm ± 0.38 cm, 2.01 cm ± 1.26 cm, 3.11 cm ± 1.35 cm and 4.34 cm ± 1.10 cm, respectively. A classification system of types A, B and C was developed. The calculated L5/S1 intervertebral space exposure percentages of types A, B and C were 32.21%, 82.58% and 54.68%, respectively. During L5/S1 anterior interbody surgery, type B intervertebral discs can be exposed conveniently, preventing injury of the iliac vessels, which was also observed in 54.68% and 32.21% of the type C and type A discs, respectively. Because the type A intervertebral disc has minimal exposure, the risk of iliac vascular injury is relatively high in these patients.

Keywords : anatomy ; lumbosacral great vessel ; anterior interbody surgery ; CT angiography.

INTRODUCTION

Anterior lumbar surgery has been performed for more than eighty years. In 1932, Capenter reported the application of an anterior lumbar interbody fusion (ALIF) to treat lumbar spondylolisthesis (*4*). In 1934, Ito treated Pott's disease with anterior lumbar surgery (*11*). At present, the popular laparoscopic anterior lumbar surgery, which is usually performed with a lower abdominal median incision or a paramedian incision (*5*), is a good choice for lumbar

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interbody fusion and lumbar intervertebral disc replacement.

As minimally invasive spinal surgery becomes recognised, mini-open or laparoscopic anterior lumbar surgery (*13*) is the preferable choice of both surgeons and patients, but its complications have also attracted more attention, such as vascular injury, especially venous bleeding (*9,10,24,25*). To minimise the risk of vascular complications during the operation, the evaluation of the anatomy of the lumbar anterior great vessels preoperatively in those patients who receive elective anterior lumbar surgery is essential.

In front of the L5/S1 intervertebral disc, the iliac vessels are routed towards the bilateral sacroiliac joint, and thus theoretically the L5/S1 intervertebral space can be well exposed, which provides a good anatomic condition for L5/S1 anterior interbody surgery. In the present study, we investigated the anatomy of the L5/S1 anterior great vessels using lumbar CT 3D reconstruction and abdominal CT angiography. Our study findings provide a reference for the determination of the vascular anatomy before L5/S1 anterior interbody surgery.

MATERIALS AND METHODS

General data

A total of 62 patients who underwent lumbar CT 3D reconstruction and abdominal CT angiography in the Department of Radiology, Southwest Hospital, Third Military Medical University from March to June 2012 were included in this study. There were 32 males aged 43.7 (19-68) years and 30 females aged 44.2 (14-67) years. All patients had no lumbar vertebra deformation, no abnormality of the lumbar anterior great vessels, no vascular disorders, and no history of retroperitoneal surgery and lumbar surgery.

Methods

The SIEMENS Somatom Definition dual-source spiral CT scanner was used for T12-S1 and the lumbosacral anterior great vessels. The following parameters were employed : slice thickness for scanning, 5 mm ; pitch, 1.15 mm ; slice thickness for reconstruction, 1.0 mm ; and overlapping rate, 30%. The contrast agent (100 ml, 37 gI) was intravenously injected via the right median cubital vein at a speed of 4 ml/s. The scan program was triggered automatically by a high-pressure syringe. The scanning time was 25-30 s for the arterial phase and 60-70 s for the venous phase. All images were subjected to the maximum intensity projection (MIP), volume rendering technique (VRT) and multiplanar reformation (MPR) to ensure that the lumbosacral anterior great vessels were displayed clearly. The SIEMENS dual-source spiral CT post-processing workstation was used to observe the anatomy of the L5/S1 anterior great vessels. The anatomic parameters included the following (Fig. 1) : (1) the location of the abdominal aortic bifurcation and the common iliac venous confluence in the lumbar

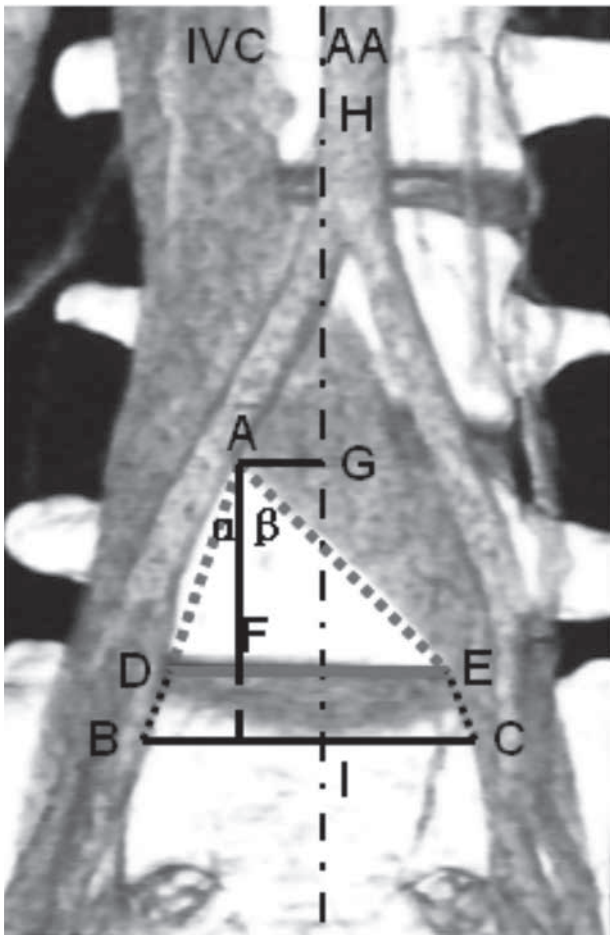

Fig. 1. — AA : Abdominal aorta ; IVC : Inferior vena cava ; ∠α+∠β : Included angle of the iliac vascular space ; HI : Median sagittal plane ; AG : Distance from the included angle vertex of the iliac vascular space to the median sagittal plane ; AF : Distance from the included angle vertex of the iliac vascular space to the inferior boundary of L5 ; DE : Distance between the left and right iliac vessels on the inferior boundary of L5 ; BC : Distance between the left and right iliac vessels on the superior boundary of S1 ; △ADE : Interiliac triangle.

vertebrae ; (2) the bifurcation angle of the abdominal aorta, confluence angle of the common iliac vein, and included angle of the iliac vascular space (α and β) ; (3) the classification of types A, B and C according to the location of the abdominal aortic bifurcation and common iliac venous confluence in front of the lumbar vertebrae and with the inferior boundary of the L4 vertebral body (*14*) ; and (4) the iliac vascular space, with respect to the height and width in front of the L5/S1 intervertebral space, distances from the included angle vertex of the iliac vascular space to the median sagittal plane and to the inferior boundary of L5, and distances between the left and right iliac vessels on the inferior boundary of L5 and on the superior boundary of S1. All angle and distance measurements were performed using the computer software in the SIEMENS dual-source spiral CT post-processing workstation. The angle measurement results were reserved as integers, and the distance measurement results were reserved to two decimal places and presented in the units of centimetres.

Statistical analysis

SPSS16 software was employed for the statistical analysis. The experimental data were presented as $\bar{x} \pm S$. The *t* test was used for analysing the differences between males and females. $P < 0.05$ suggested a significant difference.

RESULTS

Location of the abdominal aortic bifurcation and common iliac venous confluence in the lumbar vertebrae

On the cross-sectional view, the abdominal aortic bifurcation was mainly located at the upper, middle and lower 1/3 sections of the L4 and at the L4/L5 intervertebral disc (8 cases [12.90%], 12 cases [19.35%], 22 cases [35.48%], and 8 cases [12.90%], respectively), whereas on the sagittal view, it was mostly in the middle 1/3 section of the spine (54 cases [87.10%]). The common iliac venous confluence was mainly located at the upper, middle and lower 1/3 sections of L5 on the cross-sectional view (16 cases [25.81%], 15 cases [24.19%], and 7 cases [11.29%], respectively), whereas it was located in the right 1/3 section of the spine on the sagittal view in all patients.

Bifurcation angle of the abdominal aorta, confluence angle of the common iliac vein, and included angle of the iliac vascular space (Table I)

The included angle of the iliac vascular space was separated into left and right sub-angles by the sagittal plane, which were 45.81° ± 11.57° and 31.37° ± 11.87°, respectively. At the level of the superior boundary of the L5/S1 intervertebral space, the iliac vascular space was composed of the left iliac vein and right iliac artery in 54 cases (87%), the iliac arteries in 4 cases (6.45%), the iliac veins in 2 cases (3.23%), and the left iliac artery and right iliac vein in 2 cases (3.23%).

Classification System

In this study, a classification system was developed in accordance with the abdominal aortic bifurcation and common iliac venous confluence related to the inferior boundary of the L4 vertebral body. Type A indicated cases in whom the abdominal aortic bifurcation and common iliac venous confluence were both below the inferior boundary of the L4 vertebral body. Type B indicated cases in whom the abdominal aortic bifurcation and common iliac venous confluence were both above the inferior boundary of the L4 vertebral body. Type C indicated cases in whom the abdominal aortic bifurcation and common iliac venous confluence were above and below, respectively, the inferior boundary of the L4 vertebral body.

Iliac vascular space

The anatomic parameters of the iliac vascular space are shown in Table II. According to the classification system, there were 13 cases (21%) of Type A, 19 cases (31%) of Type B, and 30 cases (48%) of Type C. The anatomic parameters of each type are shown in Table III (Figs. 2, 3 and 4).

DISCUSSION

With deeper research into lumbar anterior anatomy and the development of various interbody fu-

Table I. — Bifurcation angle of the abdominal aorta, confluence angle of the common iliac vein, and included angle of the iliac vascular space ($\bar{x} \pm S$, °)

	Bifurcation angle of the abdominal aorta	Confluence angle of the common iliac vein	Included angle of the iliac vascular space
Male	45.37 ± 9.25	63.57 ± 12.12	73.37 ± 19.84
Female	47.06 ± 9.19	63.44 ± 14.62	79.69 ± 14.15
P	0.472	0.970	0.152
Male + female	46.24 ± 9.18	63.50 ± 13.36	76.63 ± 17.29

Table II. — Anatomic parameters of the iliac vascular space ($\bar{x} \pm S$, cm)

	Height in front of the L5/S1 intervertebral space	Width in front of the L5/S1 intervertebral space	Distance from the included angle vertex of the iliac vascular space to the median sagittal plane	Distance from the included angle vertex of the iliac vascular space to the inferior boundary of L5	Distance between the left and right iliac vessels on the inferior boundary of L5	Distance between the left and right iliac vessels on the superior boundary of S1
Male	1.56 ± 0.33	5.64 ± 0.60	1.09 ± 0.41	1.69 ± 1.25	2.76 ± 1.47	3.95 ± 1.23
Female	1.42 ± 0.24	5.06 ± 0.46	0.88 ± 0.32	2.30 ± 1.23	3.42 ± 1.17	4.70 ± 0.82
P	0.062	0.000	0.034	0.060	0.057	0.006
Male + female	1.49 ± 0.30	5.34 ± 0.60	0.98 ± 0.38	2.01 ± 1.26	3.11 ± 1.35	4.34 ± 1.10

Table III. — Anatomic parameters of the iliac vascular space by type (A, B and C)

Iliac vascular space	A (n = 13)	B (n = 19)	C (n = 30)	P△
Included angle (α+β) (Fig. 1) (°)	81.54 ± 17.26	71.47 ± 12.34	77.77 ± 19.53	0.068
Left sub-angle (β) (°)	46.08 ± 16.45	39.50 ± 6.87	49.67 ± 10.03	0.009
Distance from the included angle vertex of the iliac vascular space to the inferior boundary of L5 (cm)	0.89 ± 0.92	3.35 ± 0.72	1.64 ± 0.90	0.000
Distance from the included angle vertex of the iliac vascular space to the median sagittal plane (cm)	0.88 ± 0.37	1.06 ± 0.37	0.98 ± 0.40	0.412
Distance between the left and right iliac vessels on the inferior boundary of L5 (cm)	1.72 ± 0.96	4.28 ± 0.71	2.92 ± 1.18	0.000

△: One-way analysis of variance.

sion cages and internal fixators, anterior lumbar surgery has been widely applied in the treatment of lumbar degenerative diseases, infections, and tumours and also in artificial lumbar vertebral disc replacement. Anterior lumbar surgery has advantages such as minimal invasion, low bleeding, convenient operation, and rapid postoperative recovery (*2,16,18*). Long-standing developments have been made in, for example, mini-invasive anterior lumbar surgery (*8,14,19*). As reported, however, the occurrence rate of vascular injury during anterior lumbar surgery is 1.2-15.6%, which is higher than that during posterior lumbar surgery (*1,17,22*). Baker *et al* (*1*) found in a retrospective study of 102 cases who underwent anterior lumbar surgery, 15 (15.6%) cases experienced venous injury without arterial injury, 4 experienced injury of the inferior vena cava, 11 experienced injury of the common iliac vein, and

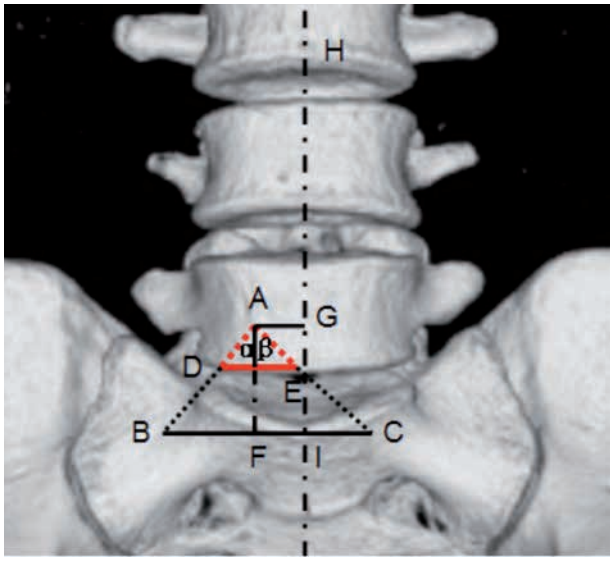

Fig. 2. — Interiliac triangle of type A

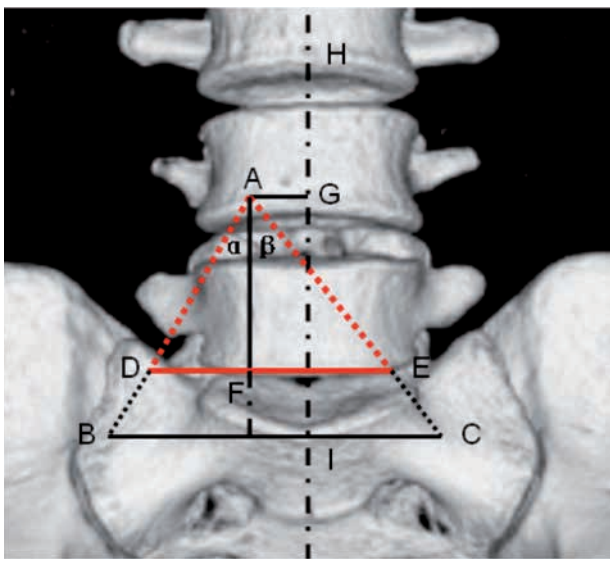

Fig. 3 — Interiliac triangle of type B

1 experienced injury of the iliolumbar vein. In addition, vascular complications were observed in 2/26 (7.7%) cases with an anterolateral retroperitoneal approach and 14/76 (18.4%) cases with a paramedian extraperitoneal approach. Garg *et al* (*7*) reviewed vascular complications in 212 cases who received anterior lumbar surgery at Scripps Green Hospital from August 2004 to June 2009. The results showed a total of 13 cases experienced vascular injury without death : 1 case with a major arterial injury underwent partial resection and repair of the artery, and the remaining 12 cases with venous injury underwent venous repair. Clinically, the iliac vessels are bifurcated in front of the L5/S1 intervertebral disc and indicated for surgical operation ; thus, L5/S1 anterior interbody surgery is commonly performed, but its complication of vascular injury cannot be ignored. There is clinical variability in the anatomy of the lumbosacral anterior vessels among different races and among different individuals. To provide a reliable basis for the development of surgical strategies, accurately evaluating the vascular anatomy before L5/S1 anterior interbody surgery is essential. In the present study, the anatomy of the L5/S1 anterior great vessels in Chinese adults was evaluated, which builds a foundation for the evaluation of vascular anatomy before L5/S1 anterior interbody surgery.

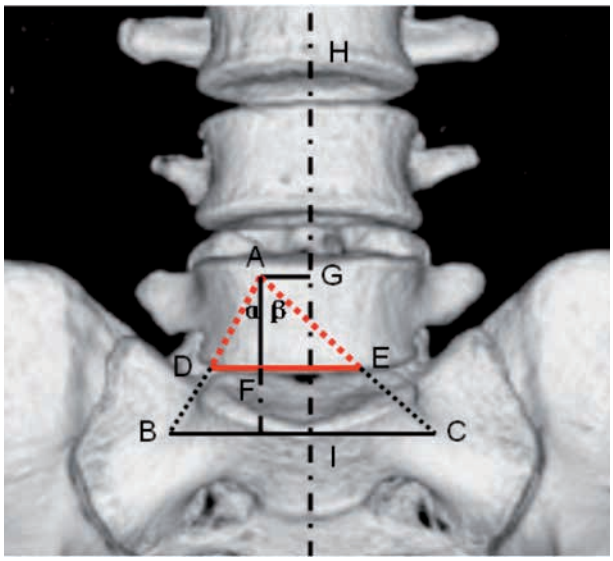

Fig. 4. — Interiliac triangle of type C

The abdominal aortic bifurcation and common iliac venous confluence are the major vascular anatomic structures in front of the lumbosacral vertebrae, which limits the sufficient exposure of the lumbosacral anterior region. In the anatomy monograph, abdominal aortic bifurcation was shown to be located in front of the lower 1/3 section of the L4, and the common iliac venous confluence was at the right front of the median L5. Khamanarong *et al* (*12*)

Table IV. — Included angle of the iliac vascular space ($\bar{x} \pm S$, °)

Study	Type of study	Mean	Range
Capellades *et al* (*3*)	Anatomical (n = 134)	73 ± 13	35-115
Pirro *et al* (*213*)	Anatomical (n = 42)	69 ± 21	28-107
Ouiminga *et al* (*20*)	Radiological	72	45-110
Present study	Radiological (n = 62)	76.63 ± 17.29	37-109

found that the abdominal aorta ended at the level of the L4 in 70.1% of the cases and the level of the L5 in 17.6% of the cases. These findings are similar to the results of the present study.

The bifurcation angle of the abdominal aorta and the confluence angle of the common iliac vein were 54° ± 16° and 71° ± 15°, as measured by Kajorn Lakchayapakorn (*15*) using cadavers. Our results are lower than his findings, which may be due to our measurements being performed with CT angiography rather than cadavers. At the level of the superior boundary of the L5/S1 intervertebral space, the iliac vascular space is widely believed to consist of the left iliac vein and right iliac artery. However, our observations showed that the iliac vascular space, composed of the left iliac vein and right iliac artery, accounted for only 87%, which was not reported previously. There is little difference in the included angle of the iliac vascular space compared with that in previous reports (see Table IV). We measured the left and right sub-angles on the sagittal plane. Obviously, the left sub-angle is larger. Furthermore, most of the included angle vertex is located at 1 cm on the right side of the median sagittal plane, and thus the majority of the left iliac vessel pass obliquely through the L5/S1 intervertebral disc. This positioning represents the anatomic cause for the L5/S1 anterior interbody surgery easily injuring the left iliac vessels.

As reported, the height of the iliac vascular confluence is 18-28 mm (*3,20,23*). There are three measurement methods reported in the literature, i.e., measuring the distance from the iliac vascular confluence to the cochlear of sacral bone (*23*), to the superior boundary of the L5/S1 intervertebral disc (*6*) or to the centre of the L5/S1 intervertebral disc (*3*). We suggest measuring the distance from the included angle vertex of the iliac vascular space to the inferior boundary of the L5 because the extent of the exposure of the L5 vertebral body can be used as a reference to place internal fixation devices. Based on this study, we also conclude that the median anatomic location of the L5/S1 intervertebral space corresponding to the included angle was at 1 cm from its left side, which can be used as a reference to place the implant in the centre during intervertebral disc replacement or interbody cage implantation. The surgical operability of the L5/S1 intervertebral disc depends on the measured distance between the left and right iliac vessels, which has been reported by Tribus (*23*). Tribus measured the distance between the left and right iliac vessels on the inferior boundary of the L5 vertebral body as 33.5 mm. In that study, he used cadavers and a smaller sample size of likely not more than 35 cases, leading to a certain amount of error. Importantly, our measurements were performed in vivo, and thus our measurement results are closer to those in a human being under operation. Therefore, our findings are more reliable.

The left and right iliac vessels form a triangle with the L5/S1 intervertebral disc on the coronal plane. Using the measurements of angle α, angle β, and the distances from the included angle vertex of the iliac vascular space to the superior boundary of L5 and to the median sagittal plane, the interiliac triangles for types A, B and C were plotted separately (see Figs. 2, 3 and 4). The exposure percentage was defined as the exposure area of the superior boundary of the L5/S1 intervertebral space/total width of the intervertebral space ×100%. According to our measurements, the calculated exposure percentages of types A, B and C are 32.21%, 82.58% and 54.68%, respectively. This finding is of great significance in clinical practice. During L5/S1 anterior interbody surgery, the L5/S1 intervertebral disc of type B can be exposed without separating the great vessels, which ensures a convenient operation

and prevents injury of the iliac vessels, followed by type C. With respect to type A cases, because the left iliac vessels pass through the median sagittal plane of the L5/S1 intervertebral disc and the iliac vessels need to be pulled left upward during the operation, the iliac vessels are likely to be injured. This possibility reminds surgeons that the risk is relatively high in these patients, and cooperation from the vascular surgeons may ensure that the operation is performed with higher safety.

Abdominal CT angiography can be used to accurately evaluate the anatomy of the great vessels before L5/S1 anterior interbody surgery, which can provide a reference for safe surgical procedures and minimise the risk of vascular complications during the operation.

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