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Research of thoracolumbar spine lateral vascular anatomy and imaging

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This study introduces an anatomical basis for surgeries such as thoracoscope-assisted thoracolumbar spinal anterior interbody fusion in terms of image observing and corpse specimen anatomising. The observation of the 3-dimensional computed tomography (CT) image indicates that segmental arteries are visible and run in the central supersulcus of the corresponding vertebral body's side, while the branches are invisible. The distances between adjacent segmental arteries in $T_{10/11}$, $T_{11/12}$, T_{12}/L_1, $L_{1/2}$, and $L_{2/3}$ are 23.35 ± 1.48, 25.61 ± 2.08, 29.12 ± 2.30, 32.53 ± 2.18, and 33.73 ± 2.29 (mm), respectively. And the observation by the thoracolumbar spine side of the adult corpse specimens shows that segmental arteries and veins constantly exist and run in the central supersulcus of the corresponding vertebral body's side; each segmental artery has some small branches; the zone between the upper and lower segmental arteries form a relatively non-vascular nerve safe zone, where the intervertebral space (disc) locates. The distances between adjacent segmental arteries in $T_{10/11}$, $T_{11/12}$, T_{12}/L_1, $L_{1/2}$, $L_{2/3}$ are 23.34 ± 0.78, 25.54 ± 0.85, 29.11 ± 1.01, 32.82 ± ± 1.28, and 33.71 ± 1.42 (mm), respectively. The safe zone, with the intervertebral disc as the reference mark, can provide enough operation space for surgeries like thoracoscope-assisted anterior interbody fusion and reducing damage to blood vessels as well as surgical complications. Additionally, the arrangement and distribution of segmental arteries can be clearly displayed on the 3-dimensional CT image and the result is basically consistent with that of corpse specimens. Therefore, the 3-dimensional CT image can be regarded as the reference for video-assisted thoracoscopic surgery plans. (Folia Morphol 2010; 69, 3: 128–133)

Key words: thoracolumbar spine, image, anatomy, safe zone

INTRODUCTION

The thoracolumbar spine section refers to the T_{11}–L_2 section, which is an important structural transition zone at the junction of thoracolumbar. This section has a deeper anterior approach position, complex anatomical structure, and high risk for larger trauma and complications during traditional surgeries.

Since Mack applied video-assisted thoracoscopic surgery (VATS) to treat the prolapse of an intervertebral disc for the first time in 1993, it has been widely used in the treatment of various thoracic and lumbar spine diseases. Compared with conventional open surgery, it has the following advantages: fewer traumas, less bleeding, and faster recovery; less interference for old and weak patients, or those with poor heart and lung function; and extended surgical indications. However, one of the keys to VATS is how properly to deal with the segment blood

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vessels. However, at present, few application-oriented anatomical studies have been done on the thoracolumbar lateral vascular, especially those combined with image technology.

This study focuses on the research of the arrangement, distribution, and adjacent relationship of the thoracolumbar spinal lateral vascular by corpse specimen anatomy and image technology. The study results prove that the 3-dimensional computed tomography (CT) image can be utilised as a reference for video-assisted thoracoscopic surgery (VATS) plans.

MATERIAL AND METHODS

The materials in this study included 29 adult corpse specimens (female 13, male 16, height 156–177 cm: female average height 161 cm, male average height 172 cm). All specimens, provided by the Southern Medical University, Human Anatomy Department, had no local vascular disease or other pathological changes.

CT scans were conducted on 29 adult corpse specimens after opacification and the 3-dimensional reconstruction at a CT workstation. The arrangement of the segmental blood vessels was observed, and the distance between two adjacent segmental arteries at the mean line of the lateral thoracolumbar spine was measured (Figs.1, 2).

After the image data processing, corpse specimen processing was conducted as follows:

1) The cadaveric specimens were put into a 10% formalin solution to fix after perfusing with red latex solution. Then the fixed cadaveric specimens were perfused with red emulsion through the femoral artery within two or three weeks.
2) The internal organs of the thoracic cavity and abdominal cavity of each specimen were removed, as well as the parietal pleura and parietal peritoneum in the thoracolumbar spine segments; diaphragm and psoas major muscle were separated and removed, fully displaying structures such as the lateral blood vessels and nerves.
3) The arrangement and adjacent relation of segmental blood vessels, sympathetic trunks, greater splanchnic nerves, aortas, azygos veins, and hemiazygos veins were observed.
4) The distance between the upper and lower segmental arteries at the mean line of the lateral thoracolumbar spine was measured (using vernier calipers, gauged to 0.01 mm) (Figs. 3, 4).

Statistical analysis

Comparisons between the specimens and images were performed using the paired sample T-test on both sides and the independent sample T-test in terms of gender. The statistics were calculated using the SPSS for Windows software package (version 13, SPSS Inc., Chicago, Ill), and $p < 0.05$ was accepted as the level of statistical significance.

RESULTS

Results by observation of reconstructed 3-dimensional images

Firstly, observing the 3-dimensional images provided information about the arrangement and distribution of segmental vessels.

The segmental arteries constantly exist in the supersulcus of the corresponding vertebral centre with occasional absence (2/58). The segmental arteries originate from the posterior wall of the aorta, having a lower starting position than the corresponding vertebral height, and running backward and upward with the corresponding vertebral body, then to the central supersulcus of the corresponding vertebral body's side. The segmental arteries are at almost equal distances from the upper and lower discs. Many bilateral same sequence segmental arteries' starting points are in the same horizontal plane, and bilaterally symmetrical (27/29). It is hard to see that the segmental arteries have branches on the side of the vertebral body in the images. The reconstructed image can show the relationship between the artery and the vertebral body, but cannot show the organisations such as the nervus splanchnicus major, hemiazygos vein, and sympathetic trunk (Figs. 1, 2).

Results by observing corpse specimens

The arrangement and distribution of segmental vessels were visible through observing corpse specimens:

1) On the side of thoracolumbar spine, the segmental arteries and veins constantly exist in the corresponding vertebral body central supersulcus, and the veins run on the top of the arteries with occasional absence (2/58).
2) The segmental arteries are from the posterior wall of the aorta with starting positions lower than the height of the corresponding vertebra. Most bilateral same sequence segmental arteries' starting points are in the same horizontal plane, and

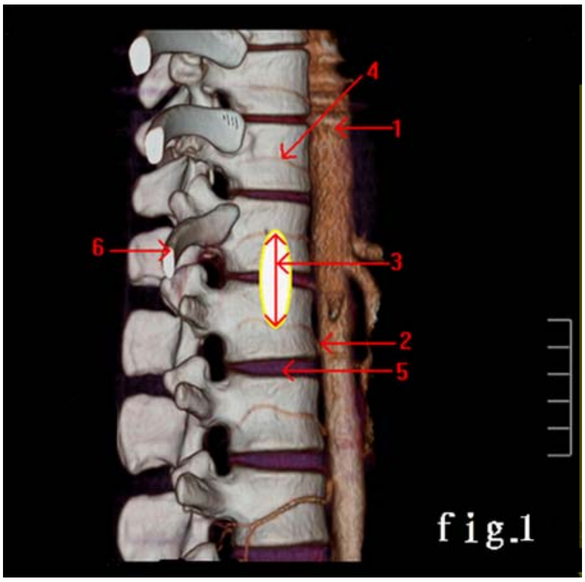

Figure 1. Right view: 1 — aorta; 2 — starting point of segmental arteries; 3 — distance between segmental arteries; 4 — segmental artery; 5 — intervertebral place; 6 — T_{12} rib.

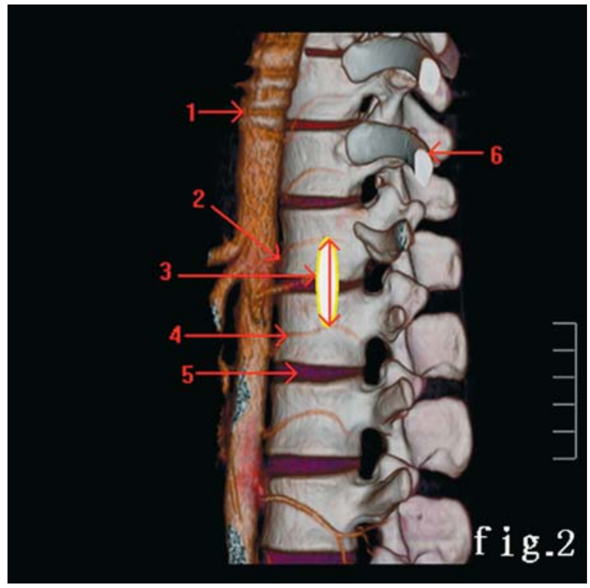

Figure 2. Left view: 1 — aorta; 2 — starting point of segmental arteries; 3 — distance between segmental arteries; 4 — segmental artery; 5 — intervertebral place; 6 — T_{12} rib.

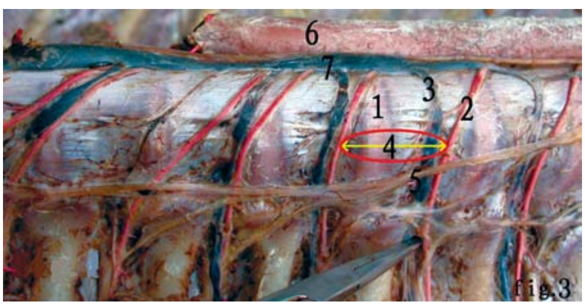

Figure 3. Right view: 1 — T_{12}/L_1 intervertebral disc; 2 — segmental artery; 3 — segmental vein; 4 — distance between both segmental arteries; 5 — sympathetic nerve; 6 — aorta; 7 — azygos vein.

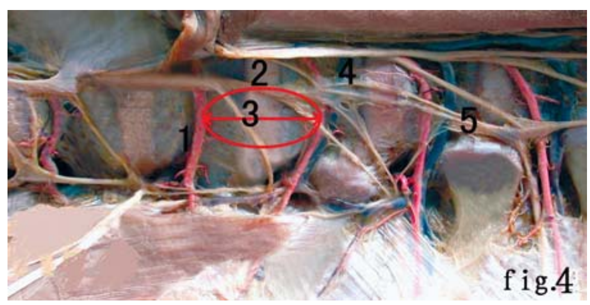

Figure 4. Left view: 1 — segmental artery; 2 — T_{12}/L_1 intervertebral disc; 3 — distance between both segmental arteries; 4 — segmental vein; 5 — sympathetic nerve.

are bilaterally symmetrical (27/29). The segmental artery in the anterior aspect of the vertebra sends out the small branches — the central anterior branches — which in general pass through the vertebral body cortical bone directly into the cancellous bone. When near the transverse process, it splits into the dorsal branch and the lateral branch. The dorsal branch enters the intervertebral foramen, and the lateral branch moves directly into the intercostal artery or lumbar artery. In the right side of the spine, the T_{11}, T_{12} segmental arteries run successively in the rear of the thoracic duct, azygos vein, greater splanchnic nerve, and sympathetic trunk from anterior to posterior direction, and in the left side of the spine they run in the rear of the hemiazygos vein, greater splanchnic nerve, and sympathetic trunk. The L_1, L_2 segmental arteries run in the rear of crura diaphragmatis, with the right running through the rear of the inferior vena cava and the sympathetic trunk, and the left by the rear of the sympathetic trunk.

3) The segmental vein is the convergence of two branches at the intervertebral foramen, and runs above the segmental artery of the same name; it is hard to see that the segmental vein has branches on the side of the vertebral body. The T_{11}, T_{12} segmental veins cross by the rear of the sympathetic trunk and greater splanchnic nerve, converge into the azygos vein in the right side, and into the hemiazygos vein in the left side. The L_1, L_2 veins converge into the inferior vena cava by

Table 1. The distance between segmental arteries (mean ± SD, mm)

Items	Male		Female		Total	
	Specimen	Image	Specimen	Image	Specimen	Image
T_{10}–T_{11}	23.67 ± 0.43	23.69 ± 1.52	23.01 ± 0.93 #	23.02 ± 1.36*	23.34 ± 0.78	23.35 ± 1.48**
T_{11}–T_{12}	26.02 ± 0.67	26.03 ± 1.93	25.06 ± 0.75 #	25.09 ± 2.19*	25.54 ± 0.85	25.61 ± 2.08**
T_{12}–L_1	29.60 ± 0.78	29.61 ± 2.99	28.52 ± 1.00 #	28.48 ± 1.05*	29.11 ± 1.01	29.12 ± 2.30**
L_1–L_2	32.92 ± 1.68	32.95 ± 2.22	32.13 ± 0.74 #	32.11 ± 2.11*	32.82 ± 1.28	32.53 ± 2.18**
L_2–L_3	33.99 ± 1.85	34.01 ± 3.50	33.53 ± 0.82 #	33.46 ± 1.93*	33.71 ± 1.42	33.73 ± 2.29**

Comparison with male $^{*}p < 0.05$, $^{\#}p < 0.05$; comparison with total specimen $^{**}p > 0.05$

the rear of the sympathetic trunk in the right side, and into the inferior vena cava by the rear of the abdominal aorta and sympathetic trunk in the left side.

However, the converging points of the segmental veins are not constant and can be in the upper half of the same sequence vertebral body or the lower half part, even in the upper or lower flat disc plane.

The intervertebral disc locates between the upper segmental artery and the lower segmental vein; each segmental artery has some small branches (Figs. 3, 4).

In the midline of the vertebral body side, the distance between adjacent segmental arteries in $T_{10/11}$, $T_{11/12}$, T_{12}/L_1, $L_{1/2}$, and $L_{2/3}$ gradually increases (see Table 1 for detailed information) for the corpse specimens and images, i.e. 23.34 ± 0.78 mm, 25.54 ± ± 0.85 mm, 29.11 ± 1.01 mm, 32.82 ± 1.28 mm, 33.71 ± 1.42 mm, and 23.35 ± 1.48 mm, 25.61 ± ± 2.08 mm, 29.12 ± 2.30 mm, 32.53 ± 2.18 mm, and 33.73 ± 2.29 mm, respectively. The blood vessel space increases gradually from top to bottom.

DISCUSSION

The significance of conducting segmental blood vessel anatomy research

As we know, some peritoneal approaches can easily cause damage to the great vessels [1], and the retroperitoneal approach induces complications such as postoperative pain because of the traditional interbody fusion [2]. In order to overcome the limitations and drawbacks of previous treatment, a number of new technologies, surgical approaches, and ideas have been introduced into clinical applications. At present, endoscopic treatment for thoracolumbar disease has been gradually extended, and is mostly used in anterior aspect exposition [8]. The study of retroperitoneal endoscopic operation approaches has also been carried out, and is expected to be applied in lateral interbody fusion and anterolateral decompression such as a video-assisted mi-nimally invasive procedure for interbody fusion for the treatment of painful degenerative discopathy in young adults. Moreover, some scholars proposed that the retroperitoneal approaches be carried out via the video-assisted interbody fusion from the side.

The video-assisted thoracoscope thoracolumbar anterior approach is a new minimally invasive technique. The indications for VATS are: interbody fusion, prolapse of intervertebral disc, vertebral tuberculosis, vertebral tumours, vertebral fractures, scoliosis, etc. Properly dealing with the segmental artery is one of the keys to the success of the VATS. The segmental artery, which directly originates from the aorta, has high blood vessel pressure, and bleeds more after injury. It is even more difficult to control when bleeding.

At present, a study has been reported in the literature on spinal cord anaemic damage occurring after blockage of the anterolateral segmental artery in the anterior approach, and the long-term impact of bone fusion.

Yuan et al. [9] suggested that with the increasing number of segmental blood vessel ligations, the risk of corresponding spinal cord ischaemia would be higher. Li et al. [4], from animal experiments, indicated that the ligation of segmental blood vessels would affect anterior approach bone fusion, reduce the hardness of fused bone, and have an obvious impact on the occurrence of intervertebral disc degeneration. It was also reported that the risk of having spinal cord ischaemic damage caused by the blockage of many segmental blood vessels would greatly increase [7].

The anterior radicular artery is a branch of the dorsal branch. The most important branch of the anterior radicular artery is the Adamkiewicz artery, which is an important source of thoracolumbar spinal cord blood supply. Damage during surgery can lead to spinal anterior artery syndrome and can eventually cause paraplegia [6]. The results of the Adamkiewicz artery autopsy by Koshino et al. [3] showed that 72% of Adamkiewicz arteries originated from the left intercostal arteries or lumbar arteries, 91% in the T_8–L_1 level. Consequently, we should fully prepare during surgery for Adamkiewicz artery protection.

In short, in order to adapt to the development of VATS, it is necessary to conduct research on this vascular section. Therefore, more specific anatomy research in this field is needed for clinical application.

However, the related basic anatomic research is lagging behind. There is little literature for specific research about the thoracolumbar spine lateral segmental vasculature, especially regarding thoracoscope anatomy. Few scholars have conducted specific research of corpse specimens and images of the thoracolumbar spine lateral segmental vasculature. Moreover, the study on the related image of segmental vascular is extremely inadequate.

Based on these conditions, we have made a preliminary discussion on the related segmental artery anatomy.

The influence of the safe zone to the anterior approach

Mirovsky et al. [5] believed that there was sufficient space between the adjacent segmental arteries on the side of the thoracolumbar to place a screw or implant fusion cage, thus reducing the risk of spinal cord ischaemic injury caused by blocking the blood vessels.

We believe that it is entirely possible to have an operation (such as interbody fusion and disk replacement) in the zone between the adjacent segmental arteries without the need of ligation for segmental arteries. Regarding the fact that the segmental vein is thin and bleeds easily after being stretched, it should be blocked properly and impose no impact on blood supply to the spinal cord during surgery.

If simply for discectomy, or carrying out an operation between two adjacent vertebral bodies (such as interbody fusion), ligation of segmental arteries is not needed. As for interbody fusion, the disc can be inserted first with a Kirschner wire, the target disc can be identified by C-arm X-ray machine, and the operation carried out upward and downward around the intervertebral disc, then discectomy, intervertebral expansion, intervertebral cartilage removal, and intervertebral Cage placement can be carried out. If only one vertebral body or two adjacent vertebral bodies fracture without segmental arterial injury, the operation can be carried out in the safe zone without ligation of the segmental arteries. As long as the segmental artery damage or the screw for anterior spinal osteosynthesis has to be placed on the equatorial line of the vertebral body, the segmental arteries must be ligated. For multi-segment operation, segmental artery ligation should be kept to a minimum. Meanwhile, if the branches of the segmental artery (such as the central anterior branches) are near the operation zone, we should ligate these branches.

Therefore, we believe that the position of the safe zone on both sides of the thoracolumbar sufficiently ensures that surgeries of this section can be successfully completed using a thoracoscope. With the intervertebral disc as the surgical reference mark (because the intervertebral disc locates well in the middle of the upper and lower segmental arteries), operating up and down separately using the pre-operative image data can avoid or reduce injury to blood vessels, and reduce surgical complications (because there is no significant difference between specimens and images by the paired samples T-test, $p > 0.05$). However, differences exist between individuals. Therefore, to make an individual surgery plan, preoperative CT imaging should be conducted for the patients by observing the 3-dimensional reconstruction images, the anatomical features, and the relationship of adjacent segmental vessels. The distance between two adjacent segmental arteries should also be measured.

When conducting other operations, accurately localisation should also be carried out with a C-shape arm X-ray machine to ensure that the operation is conducted on the intervertebral disc level.

During the operation the aorta is of good elasticity, so artery-related complications seldom appear. During surgeries in the right side, the influence of diaphragm should be considered and the fact that it is near the vena cava inferior. In addition, the vein pipe wall is thin, it has bad elasticity, and it is easily damaged; therefore, the surgery should be conducted on the left side. Because the segmental veins do not produce impact to the blood supply, we can tie up the related segmental veins first.

Finally, it must be pointed out that significant differences exist in terms of gender between the two samples' T-tests. In the same segments, the male's blood vessel space is bigger than that of the female; this is possibly caused by the factor of height.

CONCLUSIONS

By comparing observation results between specimens and images, we can give specific anatomical parameters to provide a reference for the operation. There are no important blood vessel nerves between the upper and lower segmental arteries on the side of the thoracolumbar spine. The intervertebral disc locates well in this zone, which makes it a relatively safe zone of the blood vessel for anterior approaches. Taking into account the fact that the segmental veins can be ligated without affecting the blood supply, and segmental veins constantly run on the top of the adjacent arteries (or absence), we can take the distance between the two segmental arteries as the maximum range of operation. The segmental artery arrangement and the adjacent relations can also be clearly displayed by reconstructed CT 3-dimensional images. Comparing the corpse specimens with the images, we can find that the arrangement and distribution rules of segmental arteries are basically consistent, and there are few differences in distance between both the samples by comparison. Therefore, we can conduct VATS in this zone without damage to the blood vessels, and the 3-dimensional image can be provided a reference for surgery plans before operation.

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