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A morphometric study of the thoracolumbar spine spinous process and lamina space in the Chinese

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Abstract

Background: To analyze the anatomical parameters of the thoracolumbar spine spinous process and lamina space for Chinese anatomic study, and provide an anatomical reference for its clinical operation.

Materials and methods: Samples from 24 adult autopsy subjects were obtained from the thoracolumbar spine spinous process and lamina space at levels T1 through L5. Direct measurements were made for the spinous process spacing distance, spinous process length, width, thickness and inclination angle, and the lamina space width, height.

Results: 1. Distance of the spine spinous process spacing: Thoracic part: The maximum tip distance was observed at T4~T5 level, and the minimum tip distance
was observed at T9~T10 level. The maximum center distance and root distance were observed at T11~T12 level, and the minimum were observed at T5~T6 level separately. Lumbar part: distance of spinous process spacing in lumbar part showed an decreasing pattern from L1 ~ L2 to L5 ~ S1. 2.Length, width, thickness of the spine spinous process: 1) The length of the spinous process: The upper border gradually increased from T1 to T6 and then decreased till T12 region. The center region is T8 maximum, T11 minimum. The lower border length showed a decreasing trend from T1 to T12. Lumbar part: The length increased from L1 and reached maximum value at L3. Then, the length decreased gradually to reach minimum value at L5. 2) The width of the spinous process: The width showed a increasing trend from T1 to T12. Lumbar part: Maximum width was seen at L3 and a minimum L5. 3) The thickness of the spinous process: Tip thickness > center thickness > Root thickness in each thoracic and lumbar vertebra. Thoracic part: the maximum tip thickness is T1, T7 minimum, The maximum center thickness is T12, T7 minimum. The maximum root height is T6, T9 minimum. Lumbar part: Maximum tip thickness was seen at L1, and a minimum L3. Maximum center thickness was seen at L5, and a minimum L2. Maximum root thickness was seen at L2, and a minimum L1. 3. Inclination angle of the spine spinous process: The inclination angle gradually decreased from T1 to T7 to minimum value at T7 and then increased till T12 region. 4. Width and height of lamina space: 1) The width of lamina space: For thoracic part, the data became shorter gradually from T1~T2 to T5~T6, and then increased till to T11~T12. For lumbar part, the width of lamina space increased from T12~L1 to L5~S1. 2) The height of lamina space: In the thoracic vertebrae, the maximum height of center region was observed at T11~T12 and the minimum mean value was observed at T3~T4. In the lumbar vertebrae, the height of the lamina space was gradually increased from T12~L1 to L5~S1.

Conclusion: This study reports morphometric data of the thoracolumbar spine spinous process and lamina space in the Chinese population, which provides an anatomic basis for thoracolumbar spine design of internal fixation, posterior surgery, puncture and epidural anaesthesia.

Key words: thoracolumbar spinous process, lamina space, anatomy, morphology
INTRODUCTION

Lumbar spinous processes (SPs) are an appealing target for applications in spine surgery, which are relatively superficial and easy to access anatomically. Currently, a number of devices and techniques use lumbar SPs or the lamina space for instrumentation[1-7]. Thoracic part of vertebral column is even more complex [8-11]. Knowledge of morphology of the thoracic spine is essential for the anaesthetic and surgical procedures carried out in this part of the vertebral column, to achieve desired results and to avoid complications. Thoracic epidural anaesthesia(TEA) and pedicle screw fixation of thoracic spine have made the morphometric analysis of the thoracic pedicle a clinical necessity for all the surgeons practicing this procedure[12-13]. Recently, the anatomical parameters of lumbar spine process have been well described[14-16], and previously studies have provided information regarding thoracic spinous processes[17-21]. There are only few reports on the measurement of lamina space. However, a comprehensive description of the related parameters of the thoracolumbar spinous process and lamina space has not been reported. Meanwhile, to our knowledge, spine morphology varies across different races [22]. There have been few reports of spinous process morphometry in the Chinese population.

Therefore, it is essential to understand the precise anatomy of the SP and lamina space. The purpose of this study was to determine the morphometric parameters of the thoracolumbar SP and lamina space, and to provide an anatomic basis for lamina space stabilization devices, other posterior surgery, puncture and epidural anaesthesia for the Chinese population.

MATERIALS AND METHODS

Materials

Twenty-four formalin-fixed intact adult male cadavers from the Department of Anatomy of North China University of Science and Technology ages ranged from 35 to 69 years, with a mean of 47 years. And height ranged from 160 to 175 cm, with a mean of 168 cm. There were no malformations and local pathological changes of the
Measurement instruments consist of electronic vernier caliper and compass.

Measuring parameters

The cadavers were placed in a prone position for numbering the vertebra. The posterior lumbar spine (T1-T12) (S1-S5) was exposed, and the spinous process, vertebral plate, and articular process were revealed (Figure 1). Symmetric structures were measured bilaterally. Measurements were made using an electronic vernier caliper accurate to 0.01 mm and a compass. After each measurement, compass and electronic vernier caliper were restored to the initial state of zero. All data were measured three times to take its average value. Statistical analysis was used to determine the average (mean), standard deviation (SD) and minimum and maximum values. The main measuring parameters were as follows:

Distance of the spine spinous process spacing, which is between the lower border of the upper adjacent spinous process and the upper border of the lower adjacent spinous process. The tip distance (TD), center distance (CD) and root distance (RD) between the adjacent spinous processes were measured respectively (Figure 2 and Figure 3). The TD in this article has the same meaning as DB (distance between the two adjacent spinous processes) in other articles [14, 15].

Length, width, thickness of the spine spinous process: 1) the length of the spinous process was evaluated in the upper border (UL), center region (CL) and lower border (LL) (Figure 2 and Figure 3). 2) the width of the spinous process was measured in the tip border (TW), center region (CW) and root border (RW). 3) the thickness of the spinous process was evaluated in the tip border (TT), center region (CT) and root border (RT).

Inclination angle of the spine spinous process: The inclination angle of spinous process was measured by measuring the angles between the straight line of the upper edge (UI), the center (CI) and the lower edge (LI) of spinous process and the tangent line of the spines, which is in the state of natural bending.

Width and height of lamina space: After removed all the spinous process and the surrounding connective tissue, the lamina space were fully exposed (Figure 4).
Two feet of a compass were put into the lamina space to measure the width of lamina space (WI), and the height between the upper and lower lamina from the left side (LHI), center region (CHI) and right side (RHI) (Figure 5).

Collected data were analyzed and compared with other studies. The schematic diagram of relevant anatomical indicators of spinous process was shown at Figure 6.

Ethics statement: This study was conducted in accordance with the Declaration of Helsinki (Edinburgh 2000 revised). The Institutional Review Board of North China University of Science and Technology approved this study, confirm that the study was performed in accordance with relevant guidelines/regulations and informed consent was obtained from family members or their legal guardian/s.

RESULTS

Distance of the spine spinous process spacing (Table 1)

The tip distance (TD) > the center distance (CD) > the root distance (RD) in each thoracic vertebra. The tip distance: The maximum was observed at T4~T5 (16.80±2.34mm) level, and the minimum was observed at T9~T10 (9.82±1.93mm) level. The center distance: The maximum was observed at T11~T12 (10.98±1.91mm) level, and the minimum was observed at T5~T6 (7.56±2.44mm) level. The root distance: The maximum was observed at T11~T12 (9.14±2.80mm) level, and the minimum was observed at T5~T6 (4.94±1.92mm) level.

The center distance > the tip distance > the root distance in L1~L2 and L2~L3 levels. The center distance > the root distance > the tip distance in L3~L4, L4~L5 and L5~S1 levels. The tip distance is L2~L3 maximum (11.94±2.01mm), L5~S1 minimum (6.51±1.47mm). The center distance is L1~L2 maximum (12.48±1.21mm), L5~S1 minimum (7.74±1.82mm). The root distance is L2~L3 maximum (10.69±2.02mm), L4~L5 minimum (7.46±2.26mm). Distance of spinous process spacing in lumbar part showed an decreasing pattern from L1~L2 to L5~S1.

Table 1. Distance of the spine spinous process spacing (mean±SD, mm)
Length, width, thickness of the spine spinous process (Table 2)

The length of the spinous process

Thoracic part: the upper border (UL) > the center region (CL) > the lower border (LL) in each thoracic spinous process. The upper border gradually increased from T1 to T6 to maximum value at T6 with mean of 33.38±2.94mm and then decreased till T12 region with mean of 25.25±2.36mm. The center region is T8(30.75±2.59mm) maximum, T11 (22.52±2.12mm) minimum. The lower border length showed a decreasing trend from T1 to T12. Maximum LL was seen at T1(29.82±2.54mm) and a minimum T12(20.35±1.57mm). Lumbar part: the upper border > the center region > the lower border in each lumbar spinous process. The length increased from L1 and reached maximum value at L3 with mean of 29.17±2.35mm(UL), 27.23±2.23mm(CL), 24.89±2.04mm(LL). Then, the length decreased gradually to reach minimum value at L5 with the mean of 25.12±2.37mm(UL), 23.76±2.82mm(CL), 20.80±2.75mm(LL). Upper border length of the lower spine > lower border length of the upper adjacent spine.
The width of the spinous process

Thoracic part: Root width (RW) > center width (CW) > tip width (TW) in each thoracic vertebra approximately, and the width mentioned showed an increasing trend from T1 with the mean of 11.38±0.99mm (TW), 10.99±0.80mm (CW), 15.81±1.42mm (RW) to T12 with the mean of 20.28±1.57mm (TW), 19.88±1.53mm (CW), 23.80±0.81mm (RW). Lumbar part: Maximum width was seen at L3 with the mean of 23.68±1.41mm (TW), 23.56±1.36mm (CW), 25.83±0.96mm (RW) and a minimum L5 with the mean of 19.54±0.78mm (TW), 17.91±1.85mm (CW), 17.20±1.72mm (RW).

The thickness of the spinous process

Tip thickness (TT) > center thickness (CT) > root thickness (RT) in each thoracic and lumbar vertebra. Thoracic part: the maximum tip thickness is T1(7.57±1.03mm), T7 minimum(4.41±0.77mm), The maximum center thickness is T12(8.50±0.98mm), T7 minimum(5.73±0.99mm). The maximum root thickness is T6(13.67±1.52mm), T9 minimum(7.87±1.69mm). Lumbar part: Maximum TT was seen at L1 with the mean of 7.70±1.26mm, and a minimum L3 with the mean of 7.12±1.14mm. Maximum CT was seen at L5 with the mean of 8.11±0.83mm, and a minimum L2 with the mean of 7.28±0.95mm. Maximum RT was seen at L2 with the mean of 11.43±1.76mm, and a minimum L1 with the mean of 9.74±1.51mm.

Table 2. Length, width and thickness of spine spinous process (mean ± SD, mm)

| T1 ~ L5 | Length  | Width  | Thickness |
|---------|---------|--------|-----------|
|         | Upper   | Center | Lower     | Tip     | Center | Root   | Tip     | Center | Root   |
|         | (UL)    | (CL)   | (LL)      | (TW)    | (CW)   | (RW)   | (TT)    | (CT)   | (RT)   |
| T1      | 32.48±3 | 29.69±2| 29.82±2   | 11.38±0 | 10.99±0| 15.82±1| 7.57±1  | 7.68±1 | 9.76±1 |
|         | .28     | 61     | 54        | 99      | .80    | 42     | 03      | 00     | 3      |
| T2      | 31.53±2 | 29.86±2| 28.67±2   | 11.72±1| 12.95±1| 16.12±1| 6.52±0  | 7.38±0 | 12.14±1|
|         | .96     | 60     | 50        | 10      | .38    | 53     | 94      | 97     | 00     |
| T3      | 33.03±3 | 30.35±2| 28.47±2   | 13.30±0| 14.11±1| 17.92±1| 5.47±0  | 6.88±0 | 12.77±1|
|         | .74     | 68     | 38        | 84      | .42    | 55     | 77      | 93     | 22     |
|   | T4       | T5       | T6       | T7       | T8       | T9       | T10      | T11      | T12      | L1       | L2       | L3       | L4       | L5       |
|---|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|   | 31.43±3  | 32.98±2  | 33.38±2  | 31.55±2  | 32.65±2  | 31.50±2  | 29.62±2  | 25.49±2  | 25.25±2  | 25.59±2  | 27.09±2  | 29.17±2  | 27.88±2  | 25.12±2  |
|   | 29.51±2  | 27.50±2  | 29.94±2  | 29.64±2  | 30.75±2  | 23.07±2  | 23.09±2  | 22.51±2  | 23.13±2  | 25.52±2  | 25.78±2  | 24.89±2  | 26.33±2  | 23.76±2  |
|   | 13.83±0  | 28.39±2  | 28.24±2  | 27.80±3  | 25.15±2  | 22.90±2  | 21.53±2  | 20.77±2  | 20.35±1  | 21.66±2  | 24.05±2  | 24.36±1  | 23.59±1  | 22.68±2  |
|   | 15.05±0  | 15.73±0  | 17.37±0  | 18.56±0  | 20.42±1  | 16.93±0  | 17.30±1  | 18.56±0  | 20.35±1  | 21.99±1  | 22.48±1  | 23.56±1  | 23.59±1  | 22.68±2  |
|   | 5.18±0.  | 19.80±1  | 22.56±1  | 22.60±1  | 20.42±1  | 22.18±1  | 16.03±1  | 22.60±1  | 21.30±1  | 24.94±1  | 25.19±1  | 25.83±0  | 23.35±1  | 25.83±0  |
|   | 6.41±0.  | 6.79±1.  | 6.93±0.  | 6.50±0.  | 5.95±0.  | 6.22±0.  | 6.03±1.  | 6.60±0.  | 8.50±0.  | 7.70±1.  | 7.28±0.  | 7.75±0.  | 7.39±0.  | 7.25±0.  |
|   | 12.69±1. | 12.05±1. | 13.67±1. | 10.13±2. | 8.43±0.  | 7.87±1.  | 10.27±1. | 9.74±1.  | 12.14±1. | 9.74±1.  | 11.43±1. | 9.93±1.  | 11.43±0. | 10.69±1. |
|   | .21      | .44      | .94      | .77      | .74      | .92      | .80      | .90      | .36      | .13      | .10      | .35      | .44      | .37      |
|   | 75       | 46       | 86       | 42       | 59       | 33       | 52       | 12       | 44       | 85       | 52       | 23       | 32       | 82       |
|   | 40       | 53       | 40       | 08       | 60       | 69       | 87       | 15       | 57       | 34       | 22       | 04       | 84       | 75       |
|   | 91       | 53       | 40       | 08       | 60       | 69       | 87       | 15       | 57       | 17       | 72       | 41       | 44       | 78       |
|   | .86      | .80      | .84      | .90      | .21      | .91      | .84      | .90      | .53      | .10      | .49      | .36      | .91      | .85      |
|   | 28       | 50       | 50       | 30       | 56       | 52       | 50       | 30       | 81       | 48       | 30       | 96       | 71       | 72       |
|   | 73       | 85       | 10       | 80       | 67       | 74       | 85       | 86       | 11       | 26       | 32       | 14       | 19       | 72       |
|   | 92       | 52       | 85       | 86       | 84       | 73       | 50       | 86       | 98       | 74       | 95       | 51       | 67       | 92       |
|   | 58       | 42       | 70       | 28       | 84       | 49       | 70       | 28       | 45       | 1         | 4           | 1           | 1           | 1           |

**Inclination angle of the spine spinous process (Table 3)**

The inclination angle gradually decreased from T1 to T7 to minimum value at T7 with mean of 37.25±3.15°(UI), 38.14±2.48°(CI) and 86.50±2.38°(LI) and then increased till T12 region with mean of 74.29±3.50°(UI), 78.20±3.70°(CI) and 39.50±3.70°(LI). And the lower edge inclination angle(LI) > the center edge inclination angle(CI) > the upper edge inclination angle(UI) in each thoracic
vertebra. Generally, the inclination angle of lumbar spine is basic 90 degrees, which is of little significance. Thus we did not measure the inclination angle of lumbar spine.

Table 3. The inclination angle of spinous process (mean ± SD, °)

| T1~T12 | Upper edge inclination angle(UI) | Center edge inclination angle(CI) | Lower edge inclination angle(LI) |
|--------|----------------------------------|----------------------------------|---------------------------------|
| T1     | 61.20±2.17                       | 62.63±3.38                       | 67.70±3.50                      |
| T2     | 58.33±3.50                       | 60.50±3.12                       | 64.80±3.77                      |
| T3     | 54.30±4.14                       | 57.38±3.46                       | 59.20±3.03                      |
| T4     | 49.40±1.95                       | 52.50±3.78                       | 55.00±3.16                      |
| T5     | 40.57±3.74                       | 45.83±3.66                       | 48.40±2.70                      |
| T6     | 38.29±3.25                       | 41.50±3.82                       | 43.67±3.43                      |
| T7     | 37.25±3.15                       | 38.14±2.48                       | 39.50±3.70                      |
| T8     | 40.89±2.57                       | 41.44±3.28                       | 42.14±3.34                      |
| T9     | 42.63±3.89                       | 45.38±3.93                       | 52.88±1.96                      |
| T10    | 51.67±3.93                       | 57.44±2.46                       | 61.11±2.67                      |
| T11    | 59.50±2.33                       | 71.38±3.50                       | 78.00±2.65                      |
| T12    | 74.29±3.50                       | 78.20±3.70                       | 86.50±2.38                      |

Width and height of lamina space (Table 4)

The width of lamina space: For thoracic part, the data became shorter gradually from T1~T2 (11.73±2.51mm) to T5~T6 (9.63±3.63mm), and then increased till to T11~T12 (10.70±4.67mm). For lumbar part, the width of lamina space increased from T12~L1(12.18±1.43mm) to L5~S1(15.64±1.73mm). Among them, the increment of L5~S1 width was the largest, and larger about 2mm than L4~L5 width.

The height of lamina space: In the thoracic vertebrae, the maximum height of center region was observed at T11~T12(7.47±2.78mm) and the minimum mean value was observed at T3~T4(5.20±1.77mm). Since the thoracic space height is small, the left and right sides are difficult to measure, so this study did not measure this two indicators. In the lumbar vertebrae, the height of the lamina space was gradually increased from T12~L1 to L5~S1. The height of the center region was greater than the height of the left and right sides, and there was no significant difference between the heights of the left and right sides. The center height increased from (9.68±1.76)mm to
(11.88±1.78)mm, the left height increased from (6.91±1.16)mm to (7.79±1.19)mm, and the right height increased from (7.04±0.92)mm to (7.79±1.06)mm.

### Table 4. The width and height of lamina space (mean ± SD, mm)

| Lamina space (WI) | Width (WI) | Height Center region (CHI) | Height Left side (LHI) | Height Right side (RHI) |
|-------------------|------------|----------------------------|------------------------|------------------------|
| T1 ~ T2           | 11.73±2.51 | 6.20±2.49                  | —                      | —                      |
| T2 ~ T3           | 11.53±2.87 | 6.01±2.25                  | —                      | —                      |
| T3 ~ T4           | 10.20±3.44 | 5.20±1.77                  | —                      | —                      |
| T4 ~ T5           | 10.62±3.84 | 5.49±2.10                  | —                      | —                      |
| T5 ~ T6           | 9.63±3.63  | 5.65±2.03                  | —                      | —                      |
| T6 ~ T7           | 10.92±4.95 | 5.32±2.14                  | —                      | —                      |
| T7 ~ T8           | 10.80±4.94 | 5.91±2.67                  | —                      | —                      |
| T8 ~ T9           | 10.33±4.28 | 5.52±2.17                  | —                      | —                      |
| T9 ~ T10          | 10.20±4.54 | 6.00±2.57                  | —                      | —                      |
| T10 ~ T11         | 9.72±5.12  | 6.92±4.28                  | —                      | —                      |
| T11 ~ T12         | 10.70±4.67 | 7.47±2.78                  | —                      | —                      |
| T12 ~ L1          | 12.18±1.43 | 9.68±1.76                  | 6.91±1.16              | 7.04±0.92              |
| L1 ~ L2           | 12.81±2.12 | 10.24±0.91                 | 7.06±0.66              | 7.18±0.66              |
| L2 ~ L3           | 12.92±1.80 | 11.19±0.83                 | 7.30±0.77              | 7.29±0.56              |
| L3 ~ L4           | 13.10±1.91 | 11.20±1.37                 | 7.43±0.57              | 7.44±0.84              |
| L4 ~ L5           | 13.71±1.37 | 11.32±0.77                 | 7.60±0.87              | 7.56±0.88              |
| L5 ~ S1           | 15.64±1.73 | 11.88±1.78                 | 7.79±1.19              | 7.79±1.06              |

### DISCUSSION

At present, lumbar spine process related indicators have been reported[14-16], and there are a few reports on the measurement of thoracic spinous processes[17-21]. There are also some studies that report measurements of thoracic and lumbar spine-related indicators separately, which are not comprehensive enough. In the morphology of lumbar spine processes studied by B. Cai et al[14], only the distance, height, thickness of the upper, middle and lower borders of the lumbar spine were studied. Bo Ran et al[15] performed lumbar spine morphology in Chinese population by three-dimensional CT reconstruction. Kiranpreet Kaur M.D.[17] only reported the inclination angle of the thoracic spine. Jeremy D.Shaw et al[16] analyzed the length,
width, height, slope and tail morphology of lumbar spine, but did not measure the
distance between spinous processes spacing. In our study, more relevant indicators of
thoracolumbar spine and lamina space were measured based on intact corpses, which
include distance of spinous processes spacing, spinous process length, width,
 thickness, and inclination angle of the spinous process, and width, height(center, left
and right) of the lamina space.

The experimental results of the spinous process spacing distance in each thoracic
vertebra show that the tip distance > the center distance > the root distance. The
maximum of the tip distance was observed at T4~ T5, and the minimum was T9~ T10.
The maximum of the center distance was observed at T11~ T12, and the minimum
was T5~ T6. The maximum of the root distance was observed at T11~ T12, and the
minimum was T5~ T6. Thus, the thoracic spine process spacing distance is
wedge-shaped. In the sagittal plane, the front is high and the back is low. To avoid
damage caused by stress concentration of the implant, the internal fixation device
should have a wedge-shaped structure, which is high in front and low in back. The
maximum tip distance of lumbar spinous process spacing was noted at L2~L3, while
the minimum tip distance was L5~S1. The maximum center distance of lumbar
spinous process spacing was noted at L1~L2, then it gradually decreased to the
minimum root distance(L5~S1). The maximum root distance of lumbar spinous
process spacing was noted at L2~L3, while the minimum root distance was L4~L5.
The above results are different from the data of B.Cai et al[14], which considered that
distance between lumbar spines was gradually decreased from L1~L2 to L5~S1.
And our results deffer from Bo Ran[15] and others opinion, which hold that the
distance between lumbar spines was gradually decreased from L1~L2 to L4~L5,
and then increased from L4~L5 to L5~S1. B. Cai[14], Bo Ran et al[15] measured
the above parameter at only one point, while our study performed it at three points(tip,
center and root), which is more comprehensive and detailed. Recently, numerous
lamina space implants have been introduced and have shown favorable outcomes in
the treatment of degenerative disc disease, herniated nucleus pulposus, lumbar spinal
stenosis, lumbar instability, and degenerative lumbar spondylolisthesis [23-27].
Nevertheless, there are still complications with lamina space implants. Therefore, choosing optimal sizes of implants is important to avoid unnecessary complications and the size of the device should be carefully evaluated [28, 29]. The data in this study can help clinicians grasp the optimal size of the implant, which is one way to reduce complications.

By measuring the length of the spine spinous process, we can learn that the upper border > the center region > the lower border in each thoracic and lumbar spinous process. In the lumbar part, L3 is the maximum and L5 is the minimum, which is consistent with the conclusions drawn by B. Cai [14], Bo Ran et al. [15]. Usually, spinal lesions are treated with a posterior approach, where surgeons can remove the posterior part of the spine in order to expand the field of vision. In this process, the knowledge of the length, width and thickness of the spine spinous processes provides a comprehensive reference for the type of instrument chosen and the location of the occlusal site. With known length, width, and thickness, we can estimate the size of the spinous processes of the spine, which is important for lumbar interbody fusion [30]. In addition, the designing of spinous process internal fixation provides an equivalent pain/function improvement compared to conventional posterior-lumbar-interbody-fusion (PLIF) pedicle screw fixation, reducing the number of hospitalizations and operations [31]. So the above indicators are also important reference indicators for the design of spinous process internal fixation devices.

The spinous process of the thoracic spine is obliquely posteriorly downward, but the specific values of the inclination angle are rare. Kiranpreet Kaur M.D. et al. [17] used the scanner software to measure the spinous process angle of volunteers, showing that the spinous process angle increased from T1 and reached maximum value at T6 level, then decreased gradually and reached minimum value at T12 level. In our study, the intact cadaver specimens were used to expose the spinous processes of the thoracic spine. The inclination angle of spinous process was measured by measuring the angles between the straight line of the upper edge, the center and the lower edge of spinous process and the tangent line of the spines, which is in the state of natural bending. The inclination angle gradually decreased from T1 to T7 to
minimum value and then increased till T12 region, which is slightly different from result of the above document. In clinical application, the setting of the inclination angle of the upper and lower edges of the spinous process internal fixation needs to refer to the inclination angle of the spinous process to be inserted into the internal fixation.

Laminar space plays an important role in spinal surgery. Clinically, most of the procedures such as disc herniation, spinal stenosis, and intraspinal schwannomas need to be taken from the lamina space. Therefore, the study of anatomical parameters of the laminar space can provide a basis for relevant clinical operations. For example, in the treatment of disc herniation, percutaneous endoscopic laser-assisted discectom (PELD) has been widely used in clinical practice in recent years[32-34]. The outer diameter of the required endoscope is 7.5 mm, and the working channel is at the center of the lamina space. According to the data obtained in this experiment, it is not difficult to implement PELD in L4~L5 and L5~S1. For another example, spinal stenosis is also a common disease in the spinal region, which is due to a cascade of degenerative processes starting with degeneration of posterior annulus to disc herniation and dehydration, then to loss of disc height, overriding of the facets, and/or infolding of ligamentum flavum, and ultimately stenosis. This condition occurs as a result of age-related spinal degeneration, particularly in the lamina space disc and ligamentum flavum. Common symptoms include radicular pain and neurogenic claudication, which is mainly treated by surgical intervention[35-37]. This requires some anatomical parameters of the lamina space to guide the operation. In addition, the removal of schwannomas in the spinal canal also requires from lamina space[38,39], whose anatomical parameters are particularly important. In addition to the surgical approach, the measurement of the width and height of the lamina space provides an anatomical basis for the intraspinal puncture approach. According to reports in the literature, emergency doctors can quickly obtain lumbar anatomical markers by ultrasound[40]. These data can also provide reference and experience for clinicians to help clinical first aid and other treatments.
CONCLUSIONS

More related indicators of the thoracolumbar spine spinous process and intervertebral space were measured based on intact cadavers in our study, including the distance, length, width, thickness, inclination angle of the spinous process and the width, height of the intervertebral space, to provide comprehensive anatomic basis for thoracolumbar spine design of internal fixation, posterior surgery, puncture and epidural anaesthesia for the Chinese population.

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**Figure 1:** Picture showing the thoracic and lumbar vertebral lamina and articular process after removed all muscles and ligaments.
**Figure 2:** Picture showing the distance, length, width, height of the spine spinous process in the thoracic part.

**Figure 3:** Picture showing the distance, length, height of the spine spinous process in the lumbar part.

**Figure 4:** Picture showing the lamina space after removed all the spinous process and the surrounding connective tissue.

**Figure 5:** Picture showing the height of the center region of lamina space measured with compasses.
Figure 6: The schematic diagram of relevant anatomical indicators of spinous process.

① The tip distance (TD) of the spine spinous process spacing; ② The center distance (CD) of the spine spinous process spacing; ③ The root distance (RD) of the spine spinous process spacing; ④ The upper length (UL) of the spine spinous process; ⑤ The center length (CL) of the spine spinous process; ⑥ The lower length (LL) of the spine spinous process; ⑦ The tip width (TW) of the spinous process; ⑧ The center width (CW) of the spinous process; ⑨ The root width (RW) of the spinous process.

A The inclination angle of spinous process upper edge (UI);
B The inclination angle of spinous process center edge (CI);
C The inclination angle of spinous process lower edge (LI).