

A study on the puncture method of extrapedicular infiltration anesthesia applied during lumbar percutaneous vertebroplasty or percutaneous kyphoplasty

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Abstract

Extrapedicular infiltration anesthesia (EPIA) was reported for percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) and provided good local anesthetic effects. Because of differences in anatomical morphology at each lumbar level, the puncture method of EPIA is not uniform in each lumbar vertebrae. To accurately insert the anesthetic needle into the extrapedicular region, we researched the puncture method of EPIA at each lumbar level.

We retrospectively analyzed computed tomography (CT) images in 230 patients with lumbar osteoporotic fractures, including 59 L1 fractures, 54 L2 fractures, 50 L3 fractures, 36 L4 fractures, and 31 L5 fractures. The puncture of EPIA was simulated in every fractured vertebrae through CT, and the skin puncture point, puncture direction, and puncture depth of the anesthetic needle were observed. These specific parameters were the distance from the skin puncture point to the superior border of the pedicle projection on the skin (distance AD), distance from the skin puncture point to the lateral border of the pedicle projection on the skin (distance BC), sagittal section angle (SSA), transverse section angle (TSA), and depth of EPIA.

As the lumbar ordinal number increased, the SSA, distance AD, TSA, and distance BC for each lumbar level gradually increased, and the puncture depth gradually decreased, all these parameters showed significant differences among the 5 lumbar levels ($P < .001$). The recommended puncture methods for EPIA at each lumbar level, including distance AD, distance BC, SSA, and TSA, were as follows: in L1, 4 mm, 8 mm, 9° and 8°; in L2, 6 mm, 10 mm, 11° and 10°; in L3, 9 mm, 13 mm, 12° and 12°; in L4, 12 mm, 18 mm, 16° and 18°; and in L5, 20 mm, 26 mm, 24° and 24°. The depth of EPIA was 13 mm in L1-L3 and 11 mm in L4-L5.

By confirming the skin puncture point and puncture direction of the anesthetic needle, from an anatomical perspective, EPIA is feasible for lumbar PVP (PKP).

Abbreviations: CT = computed tomography, EPIA = extrapedicular infiltration anesthesia, PKP = percutaneous kyphoplasty, PVP = percutaneous vertebroplasty, SSA = sagittal section angle, TSA = transverse section angle.

Keywords: extrapedicular infiltration anesthesia, percutaneous kyphoplasty, percutaneous vertebroplasty, puncture method

1. Introduction

Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) have been widely applied to osteoporotic vertebral compression fractures, Kümmell diseases and vertebral tumors.^[1-4] With progress in the puncture technique, unilateral puncture has been gradually applied to PVP and PKP.^[5,6] Some

studies have confirmed that the clinical effects of unilateral puncture are similar to those of bilateral puncture.^[7,8]

In the superior lumbar vertebrae, the width of the pedicle is confining. Lien et al^[9] measured the width of the pedicle in L1-L3, which was 6, 7, and 9 mm, respectively, and the transverse angle of the pedicle in L1-L3, which was 8.3°, 11.5°, and 14.1°.

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LL and HW contributed equally to this work.

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respectively. The diameter of the work channel in PVP and PKP is usually 4.2 and 5 mm, respectively, and the medial wall and lateral wall of the pedicle have 1 to 2 mm cortical bone.^[9] Therefore, the adjustment of the transpedicular puncture needle is very limited. For simultaneously satisfying the ideal position of the unilateral puncture to reach the anterior-middle 1/3 of the vertebral body and not breaking the medial wall of the pedicle, the transverse angle of the puncture needle in L1-L3 reaches up to 29.08°, 33.06°, and 39.88°, respectively.^[6] The transverse angle of the puncture needle is much larger than the transverse angle of the pedicle itself. Therefore, in the unilateral puncture process, a part of the puncture needle actually passes through the lateral region of the pedicle, especially in the thoracic vertebrae and the superior lumbar, which was termed the unilateral extrapedicular approach.^[10,11] According to these anatomical parameters, an illustration is shown in Figure 1, which demonstrates that the puncture needle passed through the lateral region of the pedicle in L1 (Fig. 1A), a large proportion of the lateral region of the pedicle in L2 (Fig. 1B), and a small part of the lateral region of the pedicle

in L3 (Fig. 1C). In L4 or L5, due to a large inner diameter of the pedicle (12 mm in L4, 18 mm in L5) and a sufficient transverse angle (20° in L4, 25° in L5),^[10,11] the transpedicular puncture was easily accomplished, and the extrapedicular puncture was not necessarily required (Fig. 1D). This information was the author's theoretical basis for extrapedicular infiltration anesthesia (EPIA).

Local infiltration anesthesia is usually selected for PVP (PKP), and the anesthetic range is from the skin to the vertebral lamina surface.^[12] However, due to the screen of the transverse process, the extrapedicular region is not anesthetized. When the puncture needle passed through the extrapedicular region, the patient complained of severe pain. In 2016, our research team reported EPIA for PVP (PKP), which provided good local anesthetic effects and had no complications.^[13] During EPIA, the anesthetic needle was maintained at a certain transverse section angle (TSA), from the outside to the inside, and at a certain sagittal section angle (SSA), from the upward side to the downward side, along the lateral surface of the superior articular process and the superior border of the transverse process entering into the extrapedicular

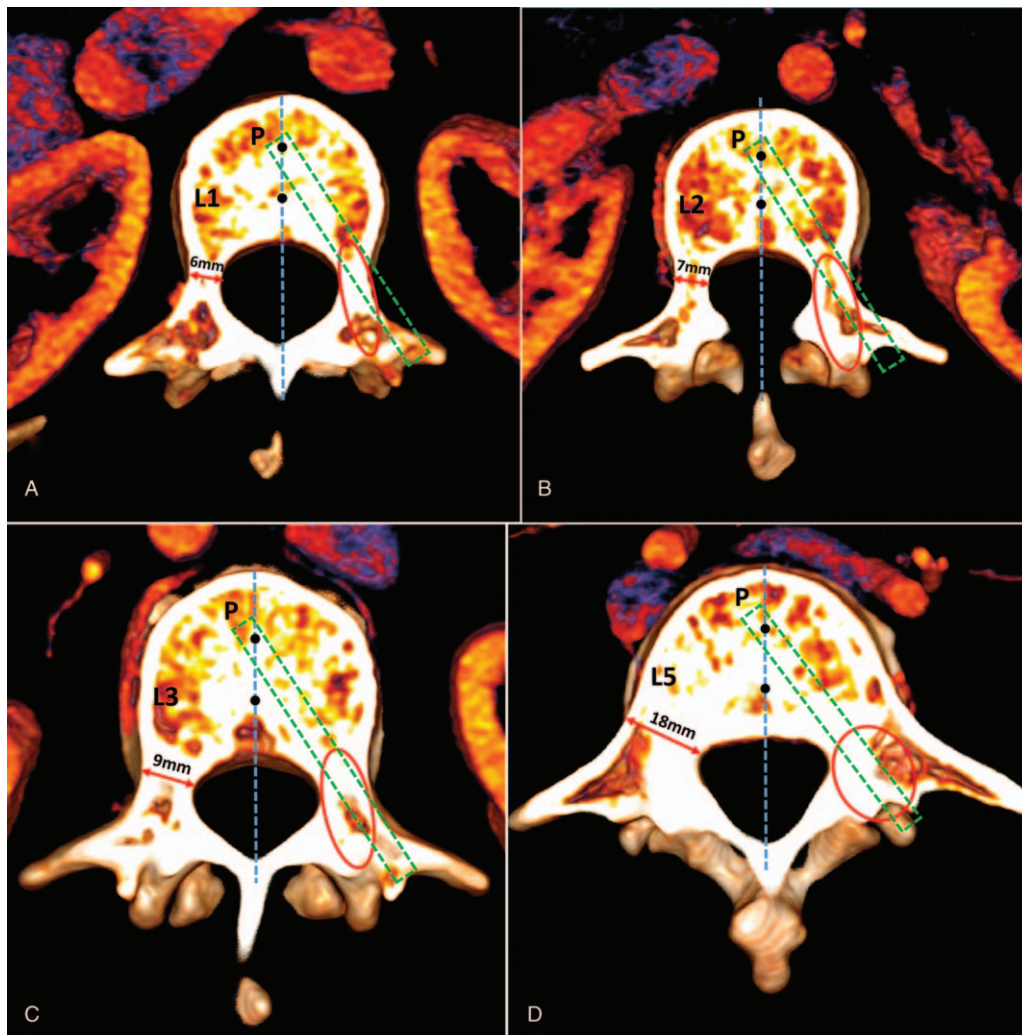


Figure 1. An illustration of the unilateral puncture approach in L1, L2, L3, and L5. P = ideal unilateral puncture point, the anterior-middle 1/3 of the vertebral body. Blue dotted line = median sagittal section. Green dotted line = puncture pathway. Red ellipse = pedicle projection. (A) The puncture needle passed through the lateral region of the pedicle in L1. (B) The puncture needle passed through the posterior 1/2 lateral region of the pedicle in L2. (C) The puncture needle passed through the posterior 1/3 lateral region of the pedicle in L3. (D) The transpedicular puncture in L5.

region.^[13] However, not every lumbar had consistent SSAs and TSAs because of differences in anatomical morphology.^[6,9,14,15] For accurate insertion of the anesthetic needle into the extrapedicular region, researching the puncture method of EPIA at each lumbar level was necessary.

Therefore, we observed the puncture parameters related to EPIA for lumbar PVP (PKP) and analyzed their clinical significance through 3-dimensional computed tomography (CT) reconstruction, recommending the puncture method of EPIA for lumbar PVP (PKP).

2. Materials and methods

2.1. General Information

We retrospectively analyzed CT images in patients with lumbar osteoporotic fractures who received dual-source spiral CT examination (SIEMENS Corporation, Munich, Germany) in a prone position before PVP (PKP) surgery. The inclusion criteria were as follows: fresh, single lumbar osteoporotic compression fracture; anterior vertebral height compression within 1/2; no nerve damage, such as radiation pain and numbness in lower limbs and sphincter dysfunction. The exclusion criteria included lumbar deformity, lumbar vertebrae tumor, lumbar intervertebral infections, and lumbar surgery history. All the methods in this experiment were performed in accordance with the Helsinki Declaration's relevant guidelines and regulations. All the experimental protocols were approved by the Scientific Research Ethics Committee of Ningxia Medical University General Hospital. Written informed consent was obtained from all the enrolled participants.

2.2. Methods

The measurement process was mainly divided into 3 steps. First, according to the inclusion criteria and exclusion criteria, 230 patients with lumbar osteoporotic fractures were included, with 59 L1 fractures, 54 L2 fractures, 50 L3 fractures, 36 L4 fractures, and 31 L5 fractures.

Second, the puncture of EPIA in every fractured vertebrae was simulated in the postprocessing workstation of the SIEMENS dual-source spiral CT (Fig. 2). The puncture path of the anesthetic needle could be passed through 2 points. Point T was the puncture target point, which was defined as the intersection between 2 lines in the sagittal section (Fig. 2A). One line was the posterior border of the vertebral body, and the other line passed through the middle-upper 1/3 of the lateral wall of the pedicle and was parallel to the horizontal line. Point O was the junction between the lateral surface of the superior articular process and the superior border of the transverse process (Fig. 2A, B). In the sagittal and transverse planes, we connected Point T to Point O, which was the puncture path of the anesthetic needle.

Third, puncture parameters were easily measured as follows:

1. Distance AD was measured from the skin puncture point to the superior border of the pedicle projection on the skin (Fig. 2C).
2. Distance BC was measured from the skin puncture point to the lateral border of the pedicle projection on the skin (Fig. 2D). Distance AD and BC contributed to determination of the puncture point of the anesthetic needle on the skin.
3. The SSA, or the α -angle, was formed between the anesthetic needle and the sagittal section (Fig. 2C).

4. The TSA, or β -angle, was formed between the anesthetic needle and the transverse section (Fig. 2D). The SSA and TSA contributed to determination of the puncture direction of the anesthetic needle.

5. Distance T_1O_1 was the puncture depth on the lateral wall of the pedicle in the sagittal section (Fig. 2C), and distance T_2O_2 was the puncture depth on the lateral wall of the pedicle in the transverse section (Fig. 2D). The depth of EPIA = (distance T_1O_1 + distance T_2O_2)/2.

The measurements were performed independently by 2 professional orthopedic surgeons, and the averaged values were used. If the same angle differed by more than 5° or the same distance differed by >5 mm, the measurement was repeated.

2.3. Statistical analysis

SPSS19 software was employed for statistical analyses. The anatomical parameters are presented as $\bar{x} \pm S$. Unpaired *t* test was used to analyze the differences between males and females, as well as between left sides and right sides. One-way analysis of variance was used to analyze the differences within the same parameter among the 5 lumbar levels. $P < .05$ indicated a significant difference.

3. Results

In total, there were 230 patients aged 66.8 ± 5.5 (ranging from 53 to 78) years. There were no significant differences between the left and right sides for each parameter ($P > .05$). The puncture parameters in L1-L5 are shown in Table 1. The SSA in L2, distance BC in L4, and depth in L1 were not significantly different between males and females ($P > .05$); the remaining parameters were significantly different between males and females ($P < .05$). Compared to the female SSA and TSA, the male SSA and TSA were increased by up to 4° , and the skin puncture point was increased by up to 5 mm in males compared to that in females.

As the lumbar ordinal number increased, the SSA, distance AD, TSA, and distance BC in each lumbar level gradually increased. Each of these parameters had significant differences among the 5 lumbar levels ($P < .001$). Each of these parameters, when compared between any 2 lumbar levels, also had significant differences ($P < .001$). As the lumbar ordinal number increased, the depth of EPIA on the lateral wall of the pedicle gradually decreased, and the depth of EPIA was significantly different among the 5 lumbar levels ($P = .000$). However, there were no significant differences in the depth of EPIA between L1 and L2, between L1 and L3, between L2 and L3, or between L4 and L5 ($P > .05$).

To facilitate clinical use, we simplified the recommended puncture method of EPIA for lumbar PVP (PKP) as follows (Fig. 3): The respective parameters for distance AD, distance BC, SSA and TSA in L1 were 4 mm, 8 mm, 9° and 8° ; in L2, 6 mm, 10 mm, 11° and 10° ; in L3, 9 mm, 13 mm, 12° and 12° ; in L4, 12 mm, 18 mm, 16° and 18° ; and in L5, 20 mm, 26 mm, 24° and 24° . The depth of EPIA was approximately 13 mm in L1-L3, and 11 mm in L4-L5.

4. Discussion

Extrapedicular PVP (PKP) was 1st used in the upper and midthoracic vertebrae and was gradually applied to the lower thoracic and lumbar vertebrae.^[16-18] The primary advantages of

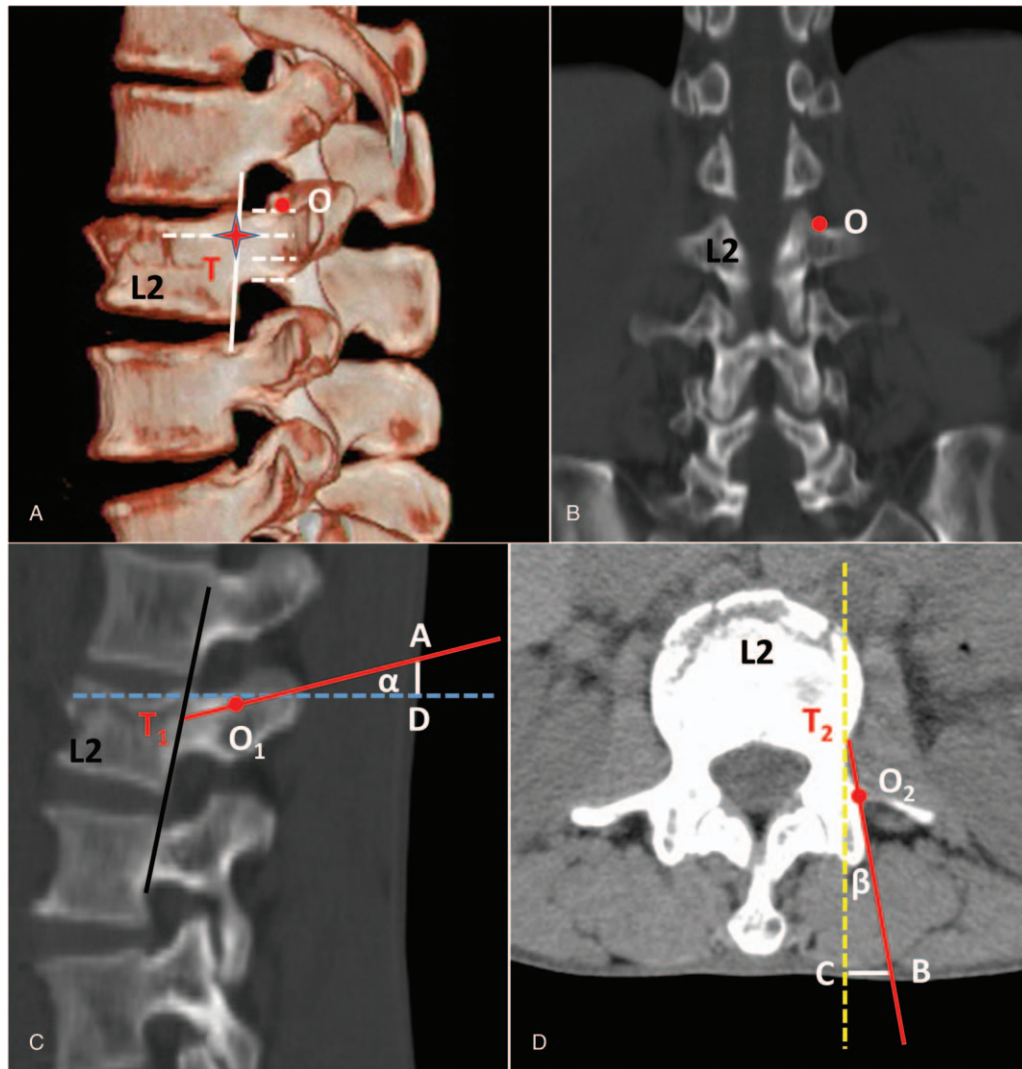


Figure 2. Puncture parameters of the anesthesia needle in extrapedicular infiltration anesthesia. (A) Sagittal view: solid line = posterior border of L4 vertebral body, dotted lines = these lines divided the lateral wall of the pedicle into 3 equal parts in the sagittal view, Point T = the puncture target point was the intersection of one line, which was represented by the posterior border of the vertebral body, and another line, which passed through the middle-upper 1/3 of the lateral wall of the pedicle, Point O = the junction between the lateral surface of the superior articular process and the superior border of the transverse process. (B) Point O in the coronal section. (C) Sagittal section: dotted line = the line paralleled the horizontal line and passed through the superior border of the pedicle, AT_1 = the puncture direction of the anesthetic needle in the sagittal section, α -angle = sagittal section angle (SSA). Distance T_1O_1 = the puncture depth on the lateral wall of the pedicle in the sagittal section, distance AD = from the skin puncture point to the superior border of the pedicle projection on the skin. (D) Transverse section: dotted line = the line paralleled the midsagittal plane and passed through the lateral border of the pedicle, BT_2 = the puncture direction of the anesthetic needle in the transverse section, β -angle = transverse section angle, distance T_2O_2 = the puncture depth on the lateral wall of the pedicle in the transverse section, distance BC = from the skin puncture point to the lateral border of the pedicle projection on the skin.

extrapedicular PVP (PKP) are that the puncture needle can easily reach the anterior-middle 1/3 point on the middle line of the vertebral body for PVP and easily reach the middle point on the middle line of the vertebral body for PKP. Additionally, bilateral puncture is not required, reducing the operative time and decreasing the radiation frequency. Furthermore, the integrity of the pedicle cortex is maintained, avoiding iatrogenic pedicle fracture and preventing the destruction of the axial or lateral biomechanical stability of the spine.^[19]

At present, local infiltration anesthesia is the most commonly used anesthetic method for PVP (PKP),^[20–22] avoiding some of the risks of intravenous anesthesia and general anesthesia.^[23] In conventional local infiltration anesthesia, a narcotic is injected into

the skin, subcutaneous tissue, and erector spinae. However, the narcotic does not diffuse to the extrapedicular region because of the obstruction of the superior articular process and the transverse process. In extrapedicular PVP (PKP), the puncture needle stimulates the extrapedicular periosteum and the soft tissue, causing severe pain. According some research, the pain caused by puncture was more severe than the pain caused by local skin anesthesia and bone cement injection in PVP surgery.^[24] Therefore, by confirming the skin puncture point and the puncture direction of the anesthesia needle, the needle could be inserted into the extrapedicular region of the pedicle, minimizing patient pain.

Heo and Cho^[25] indicated that the safe puncture area for extrapedicular PVP should be slightly higher than the midline of

Table 1
The puncture parameters related to EPIA at each lumbar level.

	SSA, °	Distance AD, mm	TSA, °	Distance BC, mm	Depth, mm
L1 (n=59)					
Male (n=27)	9.3±2.4	4.3±1.7	8.3±2.1	8.8±2.0	14.3±2.6
Female (n=32)	8.4±1.9	3.7±1.4	7.4±1.7	7.7±1.6	13.4±2.5*
Male + female	8.8±2.2	4.0±1.6	7.8±1.9	8.2±1.9	13.8±2.5
L2 (n=54)					
Male (n=25)	11.0±2.9	7.0±1.6	10.6±1.6	11.1±2.0	14.3±2.9
Female (n=29)	10.8±2.5*	5.9±2.2	9.7±1.9	9.9±2.0	13.0±3.1
Male + female	10.7±2.6	6.1±2.1	9.7±1.9	10.0±2.0	13.2±3.1
L3 (n=50)					
Male (n=22)	13.2±3.1	10.0±2.2	12.6±1.8	13.8±2.5	14.6±3.3
Female (n=28)	11.0±3.2	7.8±2.3	10.9±1.9	11.5±1.9	12.1±3.0
Male + female	12.0±3.3	8.8±2.5	11.6±2.0	12.5±2.5	13.2±3.4
L4 (n=36)					
Male (n=16)	17.5±3.4	13.7±2.6	19.0±3.4	18.9±3.5	12.4±1.4
Female (n=20)	14.3±3.8	11.2±3.2	16.9±3.2	17.8±3.1*	10.8±2.2
Male + female	15.7±3.9	12.3±3.2	17.8±3.4	18.3±3.3	11.5±2.0
L5 (n=31)					
Male (n=14)	26.0±4.6	23.0±5.1	25.6±1.9	27.2±3.9	12.8±2.2
Female (n=17)	21.9±3.7	17.9±5.3	23.4±2.2	24.1±3.6	10.1±1.5
Male + female	23.8±4.6	20.2±5.8	24.4±2.4	25.5±4.0	11.0±2.3

Distance AD = from the skin puncture point to the superior border of the pedicle projection on the skin, Distance BC = from the skin puncture point to the lateral border of the pedicle projection on the skin, EPIA = extrapedicular infiltration anesthesia, SSA = sagittal section angle, TSA = transverse section angle.

* No significant difference between males and females ($P > .05$); the remaining parameters were significantly different between males and females ($P < .05$).

the pedicle to avoid damaging the segmental artery. According to our experience, we thought that the target point (T point) of the anesthetic needle should be located at the middle-upper 1/3 of lateral wall of the pedicle, which is connected to the vertebral

body. The junction (O point) between the lateral surface of the superior articular process and the superior border of the transverse process is where the anesthetic needle must be passed through. By connecting these 2 points in the sagittal and

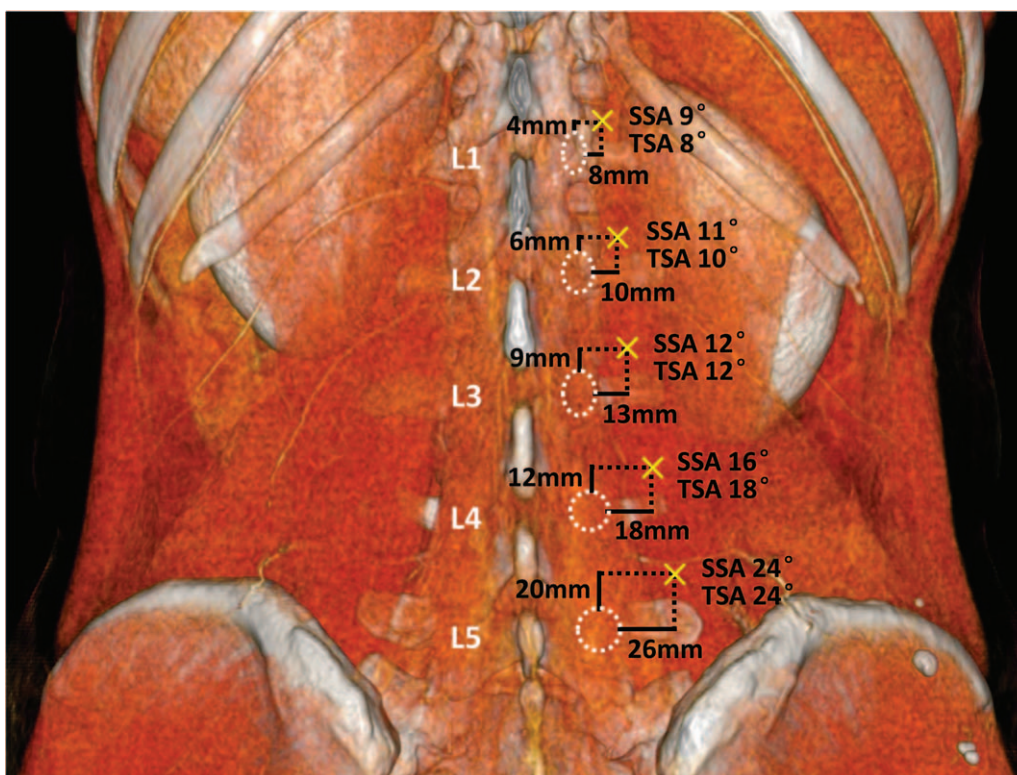


Figure 3. The puncture method for extrapedicular infiltration anesthesia in each lumbar level. Dotted circle = the body surface pedicle projection, x = skin puncture point, SSA = sagittal section angle, TSA = transverse section angle.

transverse planes, and lengthening the 2 lines to intersect with the skin, we easily measured the parameters related to the anesthetic needle.

In this study, as the lumbar ordinal number increased, the TSA in each lumbar level gradually increased, which was related to the morphology of the pedicle.^[14] Due to the limited pedicle height in the sagittal view and the presence of the upper and lower nerve root, it was very important to ensure the SSA of the anesthetic needle. This angle is related to the sagittal pedicle angle, the morphology of the transverse process, etc. We studied the skin puncture point because it is very difficult to adjust the direction of the anesthetic needle once a needle with a small diameter penetrates the strong erector spinae. We chose a No 7 epidural needle as the anesthetic needle for EPIA, which has a diameter of only 1 mm.^[13] Therefore, it was very important to confirm the skin puncture point.

Of course, this study also had some limitations, such as a small sample size and some inevitable measurement errors. In addition, we did not consider the differences in physique and subcutaneous fat between each patient. Therefore, the results of this study may provide a reference for EPIA. In the actual clinical application, the principle of individualization is the basis, and measuring the relevant parameters on the patient's CT image is recommended before surgery. Furthermore, assisted by C-arm X-ray machine monitoring, the puncture of EPIA was entirely feasible.

5. Conclusion

By confirming the skin puncture point and puncture direction of the anesthetic needle, from an anatomical perspective, we have shown that EPIA is feasible for lumbar PVP (PKP).

Author contributions

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Validation: Weidong Jin.

Writing – original draft: Liehua Liu, Haoming Wang.

Writing – review & editing: Liehua Liu, Haoming Wang, Yuan Xu, Weidong Jin.

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