Preprocedural Ultrasound Guidance for Combined Spinal-Epidural Anesthesia Results in Better Success Rates in Elderly Patients with Hip Fracture: A Randomized Controlled Trial

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Abstract

Background: Combined spinal-epidural (CSE) anesthesia is considerably challenging for elderly patients with hip fractures. This study aimed to investigate the ability of a modified preprocedural ultrasound-guided technique to improve the success rate and efficacy of CSE anesthesia for elderly patients with hip fractures.

Methods: This prospective, single-blind, parallel-group randomized controlled trial included 80 patients (aged ≥ 65 years) who were scheduled for elective hip fracture surgery with CSE anesthesia. Patients were randomly allocated into either the landmark group (n = 40) or the ultrasound group (n = 40). The primary outcome was first-pass success rate. Secondary outcomes included first-attempt success rate; number of needle insertion attempts; number of needle passes; locating, puncture, and total time; level of block; procedural adverse reactions and postoperative complications; and patient satisfaction score. Patients were blinded to group allocation.

Results: All patients, 40 in each group, completed the study and were included in the final analysis. The first-pass success rates for the landmark and ultrasound groups were 20% and 70%, respectively ($P < 0.001$). The first-attempt success rates in the landmark and ultrasound groups were 42.5% and 85%, respectively ($P < 0.001$). The number of needle insertion attempts and passes in the landmark group were 2 (1, 2) and 3 (2, 4), respectively; values of 1 (1, 1) and 1 (1, 2) were documented for the ultrasound group (median [interquartile range], all $P < 0.001$). The locating time ($P < 0.001$) and total time ($P = 0.001$) were longer in the ultrasound group, while puncture time was shorter ($P = 0.003$). No significant difference was found regarding the incidence of adverse reactions and complications. More patients in the ultrasound group had a satisfaction score of 4–5 ($P = 0.007$). Subgroup analysis demonstrated benefits for ultrasound in patients with scoliosis.

Conclusions: Modified ultrasound-assisted CSE anesthesia increases first-pass and first-attempt success rates, and reduces needle insertion attempts, passes, and puncture time for elderly patients with hip fracture, especially those with scoliosis. This technique improves patient satisfaction and warrants consideration for application in clinical practice.

Trial registration: Chinese Clinical Trial Register, ChiCTR1900020819. Registered January 20, 2019, http://www.chictr.org.cn/showprojen.aspx?proj=34634

Background

Hip fracture is the second leading cause of hospitalization in the elderly population, its incidence increasing with age [1–3]. Compared with general anesthesia, patients who receive combined spinal-epidural (CSE) anesthesia for hip surgery have a lower 30-day mortality [4, 5] and shorter hospital stays [1, 4, 6]. Traditional CSE anesthesia has relied on the palpation of surface landmarks to identify the intervertebral levels; however, this procedure may be challenging in elderly patients with hip fracture due to spinal degeneration [7–10] and limitations in positioning [11, 12].
The ultrasound-assisted CSE anesthesia technique provides improved precision and efficacy, overcoming the technical difficulties of performing neuraxial blocks [13–16] for obese [17, 18], obstetric [19–22], and aged patients [12, 23, 24], as well as patients with difficult-to-detect and abnormal anatomical surface landmarks [9, 25]. However, few studies have focused on ultrasound-assisted CSE anesthesia in elderly patients who have difficulty achieving optimal body positioning. The paramedian technique is the preferred choice of CSE anesthesia for the elderly, and its success requires proper cephalad [26] and medial needle angulation [27]. Previous studies have determined the optimal needle insertion point and depth via ultrasonography; however, the ideal needle angulation has not been investigated to date [23, 28]. Furthermore, while the ultrasound-assisted central neuraxial block has been conventionally applied in spinal anesthesia with either a midline [21] or paramedian approach [23, 28, 29], and in CSE anesthesia with a midline approach [22], few studies have investigated the use of a paramedian approach in CSE anesthesia.

Thus, there is a need for the validation of a modified ultrasound-assisted CSE anesthesia technique using a paramedian approach with suggested needle angulations, among elderly patients with hip fractures. We hypothesized that this technique would contribute to a higher first-pass success rate, fewer needle passes, and improved patient satisfaction, compared to a traditional landmark-guided technique.

**Methods**

**Study Design and Participants**

This prospective, randomized controlled trial was approved by the hospital’s Institutional Review Board (Ethics Committee of The First Affiliated Hospital of Guangzhou University of Chinese Medicine; Y [2019]042; February 11, 2019) and written informed consent was obtained from all patients participating in the trial. This study was registered prior to patient enrolment at the Chinese Clinical Trial Register (identifier, ChiCTR1900020819; principal investigator, Y.L.; date of registration, January 20, 2019). The trial was performed from February 2019 to September 2019 in The First Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, China, and adhered to the applicable Consolidated Standards of Reporting Trials (CONSORT) guidelines (Fig. 1).

A total of 80 patients were recruited. The inclusion criteria comprised (1) patients who were scheduled to receive CSE anesthesia for elective hip fracture surgery; (2) age ≥ 65 years; (3) body mass index (BMI) ≤ 30 kg/m²; and (4) an American Society of Anesthesiologists (ASA) classification of I to III. Exclusion criteria included the following: (1) severe cardiopulmonary diseases; (2) a contraindication to CSE anesthesia (e.g., coagulopathy, hypovolemia, raised intracranial pressure, infection in puncture area, allergy to local anesthetics, or lack of cooperativity); and (3) a history of lumbar surgery.

**Randomization**

The patients were randomized (using a computer-generated randomized number table) to receive CSE anesthesia using either a landmark-guided technique (n = 40) or an ultrasound-assisted technique (n =
The allocation of patients was determined by sequentially numbered, sealed envelopes after the patients were moved into the operating room. During the procedure, only patients were blinded to group allocation.

**Procedures**

Three anesthetists conducted the trial, and each had previously performed more than 40 ultrasound-assisted neuraxial blocks. In the landmark group, ultrasound and CSE anesthesia were performed by distinct operators, while the whole procedure in the ultrasound group was performed by the same operator.

After the patients were moved to the operating room, routine monitoring (non-invasive blood pressure, 3-lead electrocardiogram, oximetry) and face mask oxygen at a flow rate of 1–2 L/min were applied, and peripheral intravenous access was established. An ultrasound-guided fascia iliaca compartment block was performed with 20 mL of 0.375% ropivacaine to reduce pain [30, 31]. After 15 minutes, the patient was assisted in assuming a lateral decubitus position with the fracture side up. In both groups, the anesthetists palpated the surface landmark and graded the ease of palpation using a 3-point scale (easy, moderate, and difficult) as described in a previous study [24].

For the landmark group, the procedure included three steps.

- Identification of the needle insertion point. The needle insertion point was marked on the skin by traditional palpation. The first anesthetist subsequently left the operating room.
- Ultrasound scan. A portable ultrasound machine (Konica Minolta, SONIMAGE HS1, Japan) with a low frequency (2–5 MHz) curved array probe with a depth of 8 cm was used. Due to safety concerns, a second anesthetist conducted an ultrasound to check if the skin mark was above the L1-L2 interlaminar space; if so, the anesthetist was required to perform CSE anesthesia at a lower interlaminar space [22]. Ultrasound images were saved.
- Administration of CSE anesthesia. CSE anesthesia was performed by the first anesthetist, using the paramedian approach.

For the ultrasound group, the entire procedure included six steps.

- Marking of the midline. The probe was placed at the transverse midline (TM) plane for the evaluation of spine anatomy. The probe was tilted to obtain optimal ultrasound images. Midpoints of the long edge of the ultrasound probe were marked as the midline of the spine.
- Identification of the interlaminar space. The probe was placed at the parasagittal oblique (PSO) plane, 1–2 cm to the midline. The scan was performed upwards from the sacrum; the L5-S1 to L2-L3 interlaminar spaces were identified successively by the “counting-up” approach. The primary and secondary choice of interlaminar space for puncture were determined by the ultrasound image quality and the length of the anterior/posterior complex.
Identification of the needle insertion point. The probe was adjusted to achieve the best ultrasound image at the determined interlaminar space. Then, the upper edge of the inferior laminar was placed at the center of the ultrasound screen. Skin marks were made at the midpoints of the long and short borders of the probe. The intersection of two connecting lines indicated the needle insertion point.

Measurement of the suggested insertion angles. The built-in tool in the ultrasound unit was used to measure the maximum cephalad angle (\(\angle \alpha\)) in Fig. 2a) between (1) the connecting line from the insertion point to the far end of the posterior complex and (2) the midline of the ultrasound screen; \(1/2 \angle \alpha\) was the suggested cephalad angle. The angle of the probe to the median plane indicated the medial angle (\(\angle \beta\)), and was measured using a 180° protractor (Deli, Shanghai, China) (Fig. 2b).

Measurement of the needle insertion depth. The distance from the insertion point to the posterior complex, which was the presumed minimum insertion depth, was measured using the ultrasound clipper tool (Fig. 2a).

Administration of CSE anesthesia. CSE anesthesia was conducted using the paramedian technique according to the marked insertion point, suggested insertion angles, and presumed depth. After the needle reached the subcutaneous tissue and became stable, a low temperature plasma sterilized protractor (Deli, Shanghai, China) was used to correct the needle insertion angle (Fig. 2c). When the puncture was successful, the actual needle insertion angles (cephalad and medial) were measured (Fig. 2d).

In both groups, an aseptic technique was strictly applied throughout the entire process. CSE anesthesia was performed using a needle-through-needle approach, with a 25/16-gauge CSE kit (Kindao Interventional Medical Co., Ltd., Guangzhou, China). When the backflow of clear cerebrospinal fluid was observed, 0.5% ropivacaine (9.75–12.75 mg) was injected. Then, a 20-gauge multi-orifice epidural catheter (Kindao Interventional Medical Co., Ltd., Guangzhou, China) was inserted through the Touhy needle, up to 5 cm into the epidural space. If three attempts failed, the secondary interlaminar space was used. If attempts at two different interlaminar spaces failed, an alternative technique was allowed (palpation, ultrasound guidance, midline approach, another anesthetist). In the event that the alternative technique failed, general anesthesia was induced.

The block level was tested by loss of cold sensation, 15 minutes after anesthesia. The patient satisfaction score was rated using a 5-point scale (from 1: completely dissatisfied to 5: completely satisfied) after the surgery [22]. The quality of the ultrasound image was assessed as good (the posterior complex and anterior complex were both visible), moderate (either the posterior complex or anterior complex was visible), or poor (neither the posterior nor anterior complex was visible) [23, 28, 32]. The discrepancy (\(\Delta\)) between the suggested and actual angle was classified as accurate (\(0^\circ \leq \Delta \leq 5^\circ\)), acceptable (\(5^\circ < \Delta \leq 10^\circ\)), or inaccurate (\(\Delta > 10^\circ\)). During the entire procedure, data were recorded by a research assistant; for all measurements, the mean of three readings was calculated. A postoperative follow-up was conducted within 48 hours after the surgery.

**Study Outcomes**
The primary outcome in this study was the first-pass success rate of CSE anesthesia. A first-pass success was defined as the needle reaching the subarachnoid space within a single insertion attempt, without redirection.

Secondary outcomes were as follows:

- **First-attempt success rate**: defined as the needle reaching the subarachnoid space within a single insertion attempt and allowing redirection.
- **Number of needle insertion attempts**: each skin puncture was considered as a separate attempt.
- **Number of needle passes**: total number of insertion attempts and needle redirections.
- **Locating time**: the time from when the operator touched the patient's skin to the marking of the insertion point on the skin (landmark group), and the time from when the probe was placed on the skin to the marking of the insertion point (ultrasound group).
- **Puncture time**: interval between the contact of the skin with the Touhy needle, and the observation of cerebrospinal fluid from the spinal needle.
- **Total time**: the sum of the locating time and puncture time.
- **Level of block**: measured by testing the loss of cold sensation.
- **Procedural adverse reactions**: radicular pain, bloody tap, unintentional dural puncture.
- **Postoperative complications**: including paresthesia, backache, and post-dural puncture headache.
- **Patient satisfaction score**: 1 (completely dissatisfied), 2 (dissatisfied), 3 (moderate), 4 (satisfied), 5 (completely satisfied).

### Statistical Analysis

Data were analyzed using SPSS 25.0 (IBM Corporation, NY, USA). Continuous data were tested for normality using the Kolmogorov-Smirnov test. Normally distributed data (mean ± standard deviation [SD]) were compared using the Student's t-test. Non-normally distributed data (median [interquartile range]) were compared using the Mann-Whitney U test. Categorical variables were presented as n (%) and were compared using the χ² test or Fisher's exact test. The primary outcome (first-pass success rate) was compared using the χ² test, while Fisher exact test was used in subgroup analyses for subgroups with < 40 patients. Spearman's rank correlation was used to determine the relationship between the presumed minimum needle insertion depth and actual insertion depth. For the differences in success rates for a selected number of passes and attempts between two groups, 95% confidence intervals (CI) were calculated. A two-tailed \( P < 0.05 \) was considered statistically significant.

The sample size was calculated using PASS software Version 15.0 (NCSS, Kaysville, USA). Based on our pilot study, the first-pass success rates in patients using the conventional palpation and ultrasound-assisted technique were 22% and 59%, respectively. With an α error of 5% and a β error of 10% (90% power), a sample size of 35 patients per group was required. We increased the target sample size to 40 patients per group to allow for dropouts.
Results

From February to September 2019, 92 elderly patients were recruited and assessed for eligibility. Eighty patients, aged 82.8 ± 6.8 years, were included for random allocation to the landmark (n = 40) or ultrasound (n = 40) group (Fig. 1). No data were missing, and no patients were lost to follow-up. The reasons for the 12 exclusions were that patients did not meet the inclusion criteria (n = 2), or surgery was canceled by the surgical department (n = 10).(Fig. 1)

There were no significant differences between the groups for age, height, weight, BMI, sex, ASA classification, scoliosis, degree of back curvature, and ease of landmark palpation (Table 1). Data related to the CSE anesthesia procedures performed in both groups are presented in Table 2. A significantly higher first-pass success rate (70% vs. 20%) and success rate within two passes (82.5% vs. 40%) were achieved in the ultrasound group vs. the landmark group (both $P < 0.001$; Table 2). The success rate for the first attempt in the ultrasound group was twice that in the landmark group (85% vs. 42.5%, $P < 0.001$). However, no difference between the two groups was found for the success rate within two attempts (85% vs. 95%, $P = 0.264$). A significantly lower median number of needle attempts (1 vs. 2) and passes (1 vs. 3) were achieved in the ultrasound group (both $P < 0.001$; Table 2).
|                          | Landmark-guided group | Ultrasound-assisted group | Statistical value | P value |
|--------------------------|-----------------------|---------------------------|-------------------|---------|
| Age (y)                  | 82.3 ± 7.1            | 83.3 ± 6.7                | t = -0.602        | 0.549   |
| Height (cm)              | 156.7 ± 7.0           | 156.9 ± 7.2               | t = -0.094        | 0.925   |
| Weight (kg)              | 50.6 ± 8.4            | 53.2 ± 10.1               | t = -1.284        | 0.203   |
| BMI (kg/m²)              | 20.6 ± 3.0            | 21.6 ± 3.6                | t = -1.366        | 0.176   |
| Sex (male/female)        | 7/33                  | 10/30                     |                   |         |
| ASA Classification       |                       |                           | $x^2 = 0.672$     | 0.412   |
| I                        | 0 (0%)                | 0 (0%)                    |                   |         |
| II                       | 22 (55%)              | 19 (47.5%)                |                   |         |
| III                      | 18 (45%)              | 21 (52.5%)                |                   |         |
| Degree of back curvature |                       |                           | 0.635$^a$         |         |
| Backward                 | 4 (10%)               | 2 (5%)                    |                   |         |
| None                     | 33 (82.5%)            | 36 (90%)                  |                   |         |
| Forward                  | 3 (7.5%)              | 2 (5%)                    |                   |         |
| Scoliosis                |                       |                           | $x^2 = 0.000$     | 1.000   |
| Positive                 | 6 (15%)               | 6 (15%)                   |                   |         |
| Negative                 | 34 (85%)              | 34 (85%)                  |                   |         |
| Ease of landmark palpation|                      |                           | 0.654$^a$         |         |
| Easy                     | 34 (85%)              | 31 (77.5%)                |                   |         |
| Moderate                 | 5 (12.5%)             | 7 (17.5%)                 |                   |         |
| Difficult                | 1 (2.5%)              | 2 (5%)                    |                   |         |

Data are presented as mean ± SD or n (%)

Abbreviations: BMI, Body mass index; SD, Standard deviation; ASA, American Society of Anesthesiologists

$^a$Fisher’s exact test
Table 2
Comparison of procedure related data

|                          | Landmark-guided group n = 40 | Ultrasound-assisted group n = 40 | Statistical value | P value  | 95% CI of differences (%) |
|--------------------------|-----------------------------|---------------------------------|-------------------|----------|---------------------------|
| First pass success, n (%) | 8 (20)                      | 28 (70)                         | $\chi^2 = 20.202$ | $< 0.001$ | (31.1 to 68.9)            |
| Success within 2 passes, n (%) | 16 (40)                  | 33 (82.5)                       | $\chi^2 = 15.221$ | $< 0.001$ | (23.3 to 61.7)            |
| First attempt success, n (%) | 17 (42.5)                | 34 (85)                         | $\chi^2 = 15.632$ | $< 0.001$ | (23.6 to 61.4)            |
| Success in 2 attempts, n (%) | 34 (85)                   | 38 (95)                         | $\chi^2 = 1.250$  | 0.264$^a$ | (−3 to 23)                |
| Number of attempts       | 2 [1 to 2] (1, 7)          | 1 [1 to 1] (1, 3)               | z = -3.848        | $< 0.001$ |                           |
| Number of passes         | 3 [2 to 4] (1, 17)         | 1 [1 to 2] (1, 9)               | z = -4.559        | $< 0.001$ |                           |
| Locating time            | 32.5 [21.3 to 40.8] (10.0, 60.0) | 337.5 [300.0 to 403.8] (120.0, 505.0) | z = -7.710        | $< 0.001$ |                           |
| Puncture time            | 320.0 [223.3 to 583.0] (110.0, 1130.0) | 227.5 [170.0 to 340.0] (94.0, 740.0) | z = -2.935        | 0.003    |                           |
| Time to reach epidural space | 240.0 [165.3 to 377.5] (75.0, 1070.0) | 143.5 [101.3 to 197.0] (48.0, 640.0) | z = -3.436        | 0.001    |                           |
| Time to reach subarachnoid space | 275.0 [187.5 to 472.5] (90.0, 1115.0) | 193.0 [138.8 to 283.8] (72.0, 710.0) | z = -2.762        | 0.006    |                           |
| Total time               | 440.3 ± 240.1              | 608.2 ± 196.9                   | t = -3.419        | 0.001    |                           |
| Patients’ satisfaction;4–5 | 26 (65.0%)                | 36 (90.0%)                      | $\chi^2 = 7.618$  | 0.007    | (7.5 to 42.5)             |

Data are presented as mean ± SD, median [interquartile range] (min, max) or n (%)

Abbreviations: SD, standard deviation; CI, confidence interval

$^a$Continuity correction
Compared with the landmark group, the time taken to locate the needle insertion point was much longer in the ultrasound group (337.5 s vs. 32.5 s, \( P < 0.001 \)). During the puncture, less time was required for the needle to reach the epidural space (143.5 s vs. 240.0 s, \( P = 0.001 \)) and the subarachnoid space (193.0 s vs. 275.0 s, \( P = 0.006 \)) in the ultrasound group. The puncture time was shorter in the ultrasound group (227.5 s vs. 320.0 s, \( P = 0.003 \)). A longer total time for CSE anesthesia was required in the ultrasound group (608.2 s ± 196.9 vs. 440.3 s ± 240.1, \( P = 0.001 \)). More patients rated their satisfaction of the CSE anesthesia as 4 or 5 in the ultrasound group (90% vs. 65%, \( P = 0.007 \)).

Discrepancies between suggested and actual angles are presented in Table 3. In terms of the cephalad angle, the actual cephalad angle exceeded the measured maximum angle in five cases. A total of 28 (70%) cases reached the “accurate” level. For the medial angle, 32 (80%) cases reached the “accurate” level.

| Comparison between actual and maximum cephalad angle | Number of views |
|-----------------------------------------------------|-----------------|
| actual angle ≤ maximum angle                        | 35 (87.5%)      |
| actual angle > maximum angle                        | 5 (12.5%)       |

| Cephalad angle discrepancy                          | Number of views |
|-----------------------------------------------------|-----------------|
| accurate 0° ≤ Δ \( \leq \) 5° n (%)                 | 28 (70%)        |
| acceptable 5° < Δ ≤ 10° n (%)                       | 7 (17.5%)       |
| inaccurate Δ > 10° n (%)                            | 5 (12.5%)       |

| Medial angle discrepancy                            | Number of views |
|-----------------------------------------------------|-----------------|
| accurate 0° ≤ Δ ≤ 5° n (%)                          | 32 (80%)        |
| acceptable 5° < Δ ≤ 10° n (%)                       | 6 (15%)         |
| inaccurate Δ > 10° n (%)                            | 2 (25%)         |

\( ^a \Delta \) indicates the discrepancy between the suggested and actual angles

In all cases, the width of the posterior complex was 0.94 ± 0.22 cm, and that of the anterior complex was 1.24 ± 0.31 cm. The minimum needle insertion depth (from the skin to epidural space, measured through ultrasound imaging) had a certain correlation with the actual insertion depth (\( r = 0.514, P < 0.001 \)).

A significant difference was found in the interspace level of the puncture between the two groups (\( P = 0.036 \); Table 4). The T8 or T10 dermatome level could be reached in all cases, and no significant difference was found between the two groups (\( P = 0.251 \); Table 4). In terms of procedural adverse
reactions and postoperative complications, no significant differences were found in the incidence of radicular pain \( (P = 1.0) \), bloody tap \( (P = 0.615) \), or unintentional dural puncture \( (P = 1.0) \) (Table 5). There were no occurrences of paresthesia, backache, or post-dural puncture headache. No patients were converted to general anesthesia in either group. In the landmark group, two patients were converted to alternative techniques, in order to achieve a successful dural puncture; however, the difference was not significant between the two groups \( (P = 0.494) \).

### Table 4
Interspinous level of successful puncture and block level

|                          | Landmark-guided group n = 40 | Ultrasound-assisted group n = 40 | Statistical value | \( P \) value |
|--------------------------|------------------------------|---------------------------------|-------------------|-------------|
| Interspace level of successful puncture n (%) |                          |                                 | \( x^2 = 4.381 \) | 0.036       |
| L2/L3                    | 10 (25%)                     | 19 (47.5%)                      |                   |             |
| L3/L4                    | 30 (75%)                     | 21 (52.5%)                      |                   |             |
| Peak dermatome level n (%) |                          |                                 | \( x^2 = 1.317 \) | 0.251       |
| T8                       | 13 (32.5%)                   | 18 (45%)                        |                   |             |
| T10                      | 27 (67.5%)                   | 22 (55%)                        |                   |             |
| Data are presented as n (%) |                          |                                 |                   |             |
Table 5
Procedural adverse reactions and postoperative complications

|                          | Landmark group (n = 40) | Ultrasound group (n = 40) | P value<sup>a</sup> |
|--------------------------|-------------------------|--------------------------|---------------------|
| Radicular pain           | 2 (5.0%)                | 2 (5.0%)                 | 1                   |
| Bloody tap               | 3 (7.5%)                | 1 (2.5%)                 | 0.615               |
| Unintentional dural puncture | 2 (5.0%)            | 1 (2.5%)                 | 1                   |
| Backache                 | 0 (0%)                  | 0 (0%)                   | -                   |
| Post-dural puncture headache | 0 (0%)              | 0 (0%)                   | -                   |
| Paresthesia              | 0 (0%)                  | 0 (0%)                   | -                   |
| Alternative technique    | 2 (5.0%)                | 0 (0%)                   | 0.494               |
| Conversion to general anesthesia | 0 (0%)            | 0 (0%)                   | -                   |

Data are presented as n (%)

<sup>a</sup>Fisher’s exact test

In terms of the quality of the ultrasound images, more images of good quality were obtained in PSO views (82.5% vs. 12.5%) than in TM views (Table 6). In the TM views, a large portion (87.5%) of the images were of moderate (43.75%) and poor (43.75%) quality.

Table 6
Distribution of ultrasound image quality in both groups

| Number of views | Parasagittal oblique view | Good | 66 (82.5%) |
|-----------------|---------------------------|------|------------|
|                 |                           | Moderate | 14 (17.5%) |
|                 |                           | Poor    | 0 (0%)     |
| Transverse midline view | Good | 10 (12.5%) |
|                 |                           | Moderate | 35 (43.75%) |
|                 |                           | Poor    | 35 (43.75%) |

Data are presented as n (%)

A subgroup analysis was conducted for 12 patients with scoliosis (Table 7). The first-pass success rate was 83.8% in the ultrasound group, and 0% in the landmark group (P = 0.015). Fewer attempts (P = 0.022)
and needle passes ($P = 0.016$) were achieved in the ultrasound group. The locating time was longer (405.0 s vs. 40.0 s, $P = 0.004$) in the ultrasound group, while the puncture time was shorter (272.5 s vs. 535.3 s, $P = 0.043$). The total time ($P = 0.659$) and patient satisfaction score ($P = 0.061$) were not significantly different between the two groups.

### Table 7
Subgroup analysis for patients with scoliosis

|                      | Landmark-guided group | Ultrasound-assisted group | Statistical value | $P$ value | 95% CI of differences (%) |
|----------------------|-----------------------|---------------------------|-------------------|-----------|--------------------------|
| First pass success, n (%) | 0 (0.0%)              | 5 (83.3%)                 |                   | 0.015$^a$ | (71.7, 94.9)             |
| Number of attempts   | 2 [1 to 5]            | 1 [1 to 1]                | $z = -2.292$      | 0.022     |
| Number of passes     | 3.5 [2.75 to 12.5]    | 1 [1 to 1.75]             | $z = -2.417$      | 0.016     |
| Locating time        | 40.0 [33.75 to 45.75] | 405.0 [256.75 to 466.25]  | $z = -2.887$      | 0.004     |
| Puncture Time        | 535.33 ± 185.24       | 272.50 ± 206.80           | $t = 2.319$       | 0.043     |
| Total time           | 576.33 ± 180.21       | 641.17 ± 298.78           | $t = -0.455$      | 0.659     |
| Satisfaction; 4–5    | 2 (33.3%)             | 6 (100.0%)                |                   | 0.061$^a$ | (52.1, 81.3)             |

Data are presented as mean ± SD, median [interquartile range] (min, max) or n (%)

Abbreviations: SD, standard deviation; CI, confidence interval

$^a$Fisher’s exact test

### Discussion

The current study attempted to validate a modified preprocedural ultrasound-assisted technique by suggesting needle insertion angles in elderly patients with hip fractures. In comparison with the landmark-guided technique, the ultrasound-assisted technique had a higher first-pass and first-attempt success rate, fewer needle passes and insertion attempts, and a shorter puncture time; this improved the efficacy of CSE anesthesia, as well as patient satisfaction.
CSE anesthesia was applied to reduce the dose of local anesthetic in spinal anesthesia; this lowered the risk of unstable hemodynamic conditions among the elderly patients, who had a high prevalence of underlying diseases. Epidural cathetering was applied to ensure an adequate block level during the surgery, and maintenance of postoperative analgesia [33]. No differences in patient baseline characteristics were found between the two study groups. Compared with previous studies [23, 24], the subjects in the current study had a higher mean age and lower lumbar curvature ability; furthermore, patients with scoliosis were also included. Thus, puncture was relatively more difficult in the present study.

The results observed in the ultrasound group can be attributed to several reasons. First, accurately measured insertion angles provided a better needle trajectory. Previous studies have suggested 10–15° medial and cephalad angles during the puncture [27]. However, in practice, these angulations are estimated based on personal judgment. The present study provided personalized insertion angles and used an aseptic protractor to guide the puncture. The results (Table 3) showed that for most cases (70%), the actual cephalad angle discrepancies were within 5°. Indeed, the first pass was also achieved in these cases. For the medial angle, 80% of the cases showed a discrepancy within 5°. These results demonstrated that the suggested angles could provide reasonable guidance. Second, for elderly patients with hip fractures, limitations associated with patient positioning may have led to a narrow interlaminar space. Previous studies have often placed the posterior and anterior complex at the center of the screen, and identified the needle insertion point by skin-marking the midpoint of the probe at that time [23, 28], thereby resulting in a relatively limited operating space (Fig. 3). The current study placed the upper edge of the inferior lamina at the center of the screen to obtain a lower needle insertion point and a larger cephalad angle, resulting in a wider operating space for the puncture (Fig. 3). Third, ultrasonography could have indicated the most suitable interlaminar space for puncture, based upon the variation in individual anatomic characteristics.

In the current study, a successful first pass was not always accomplished. In most circumstances, this was because of bony contact, most frequently with the inferior laminar. Therefore, needle redirection and more needle passes were needed for a successful puncture. In five cases, the actual cephalad angle exceeded the maximum suggested angle (\( \angle \alpha \)) measured by the ultrasound image; this may have been explained by the deviation of the insertion point. If the marked needle insertion point was lower than the ideal point, the needle encountered the inferior laminar, and a larger cephalad angle was needed.

Relative to similar studies involving elderly patients [23, 24], the first-pass success rate in the ultrasound group was higher than that reported in a study conducted by Park et al. [23], and a higher first-attempt rate was achieved compared with that reported in a study conducted by Geng et al. [24]. These results may have been possibly due to the use of the modified ultrasound-assisted technique, which provided a more accurate guidance for the needle trajectory, resulting in a lower number of needle redirections. However, an undesirable result was a lower first-attempt success rate relative to values reported in previous studies [23]. This was possibly due to the patients in the current study having a higher average age, as well as the difficulties experienced with positioning as a result of their hip fracture.
Although the differences in adverse reactions and postoperative complications were not statistically significant between the two groups, unintentional dural puncture occurred in three cases, possibly because the degenerative disc disease, ligament calcification, and stenosis of the spinal canal in elderly patients made it difficult to identify the tissue layer and control the force to perform the procedure [34]. Two cases in the landmark group required the use of alternative techniques, indicating that the variability of performance in the landmark group was relatively large compared with the ultrasound group. No patients in either group required conversion to general anesthesia; this may have been due to the high level of experience of the senior anesthetists, who were able to achieve success with two different interlaminar spaces or an alternative technique, in the event of initial failure.

Compared to PSO views, fewer ultrasound images of good quality were obtained from the TM views; this concurred with the results of previous studies [24, 28]. The moderate and poor images may have been due to the calcification of the supraspinous and interspinous ligaments, as well as facet joint hypertrophy [8, 15, 28].

While there has been an increasing trend in the use of real-time ultrasound guidance [35–38], this technique may not have been suitable for the current study, due to the limitations in the operator’s dominant hand in the PSO view [38], and the poor quality of the ultrasound image in the TM view [36].

The current study had some limitations. First, due to the nature of the study design, only the patients were blinded during the CSE anesthesia procedure. Second, measurement error was inevitable, even though the suggested cephalad and medial angles were measured by the same operator. Finally, in some cases, inaccuracy in the needle insertion point was unavoidable, as elderly patients often have loose and mobile skin.

Conclusions

In conclusion, the modified preprocedural ultrasound-assisted CSE anesthesia technique can increase both the first-pass success rate and the first-attempt success rate in elderly patients with hip fractures. It also reduces puncture time, and the number of needle passes and needle insertion attempts, especially in patients with scoliosis. This technique improves patient satisfaction, and we believe that it has clinical benefits for elderly patients with hip fractures; its application in other difficult conditions requires further validation.

List Of Abbreviations

AC, Anterior complex; ASA, American Society of Anesthesiologists; BMI, Body Mass Index; CI, Confidence Interval; CSE, Combined spinal-epidural; PC, Posterior complex; PSO, Paramedian sagittal oblique; SD, Standard deviation; TM, Transverse midline.

Declarations
Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Ethics Committee of The First Affiliated Hospital of Guangzhou University of Chinese Medicine (Y [2019]042; February 11, 2019). All patients provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

BQ designed the study, analyzed the data, and wrote the manuscript. LC, YZ, and MJ collected and analyzed the data. CW conducted the trial and wrote the manuscript. WM and YL designed the study and conducted the trial. YL is the guarantor of the paper. All authors have read and approved the manuscript.

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Figures
Figure 1

Consolidated Standards of Reporting Trials diagram showing the progress of patients through the study.
Figure 2

Measurement and application of the needle angle. (a) An ultrasound image from the paramedian sagittal oblique (PSO) view, which shows the L2-L3 interlaminar space, posterior complex (PC), and anterior complex (AC). $\angle \alpha$ is the measured maximum cephalad angle of the needle. A to B is the distance from the skin to the posterior complex. (b) Measuring the medial angle with a 180° protractor during the paramedian approach, which is the tilting angle of the probe to the median plane. (c) An aseptic 180°
protractor was used to assist the cephalad needle insertion angle. (d) After a successful puncture, the actual medial angle was measured with an aseptic 180° protractor.

Figure 3

Comparison of operating spaces. The ultrasound image shows the L2-L3 interlaminar space in the parasagittal oblique (PSO) view. The posterior complex (PC) and anterior complex (AC) are shown at the same time. The modified preprocedural ultrasound-guided technique placed the upper edge of the inferior laminar at the center of the ultrasound screen and suggested a lower needle insertion point, which provided a larger cephalad angle ($\angle \alpha$), and a wider operation space (S2) than the previous technique which placed the PC and AC at the center of the screen ($\angle \alpha'$ and S1).

Supplementary Files

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- CONSORT2010Checklist.doc