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Real-Time Ultrasound–Guided Versus Ultrasound-Assisted Spinal Anesthesia in Elderly Patients With Hip Fractures: A Randomized Controlled Trial

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BACKGROUND: Traditional landmark-guided spinal anesthesia can be challenging in elderly patients with hip fractures. Ultrasound assistance (US_{AS}) and real-time ultrasound guidance (US_{RTG}) techniques can facilitate lumbar neuraxial blocks. However, it remains undetermined which method is optimal for use in elderly patients. This study aimed to evaluate which technique was associated with a higher success rate of spinal anesthesia in elderly patients with hip fractures: US_{AS} or US_{RTG} technique.

METHODS: A total of 114 elderly patients (≥70 years of age) with hip fractures were randomly assigned to receive spinal anesthesia using either the US_{AS} or US_{RTG} technique. The primary outcome was the first-attempt success rate, analyzed using the χ^2 test. Secondary outcomes included first-pass success rate, the number of needle attempts and passes, locating time, procedure time, total time, adverse reactions and complications, patient satisfaction, and procedural difficulty score.

RESULTS: The first-attempt success rate (80.7% vs 52.6%; 95% confidence interval [CI], for the difference, 11.6–44.6) and first-pass success rate (63.2% vs 31.6%; 95% CI for the difference, 14.2–49) were both significantly higher in the US_{AS} compared with the US_{RTG} group (both $P = .001$). The number of attempts (1 [1–1] vs 1 [1–3]; $P = .001$) and median passes (1 vs 3; $P < .001$) were both significantly lower in the US_{AS} group than in the US_{RTG} group. The US_{RTG} group had a shorter locating time (175 seconds [129–234 seconds] vs 315 seconds [250–390 seconds]; $P < .001$) but a longer procedure time (488 seconds [260–972 seconds] vs 200 seconds [127–328 seconds]; $P < .001$) and total time (694 seconds [421–1133 seconds] vs 540 seconds [432–641 seconds]; $P = .036$). There were no significant differences between the 2 groups with regard to the adverse reactions and complications. More patients in the US_{AS} group had a high satisfaction score of 3 to 5 ($P = .008$). Overall, anesthesiologists rated the US_{RTG} group procedure as "more difficult" ($P = .008$).

CONCLUSIONS: In elderly patients with hip fractures, spinal anesthesia with the US_{RTG} technique is not superior to the US_{AS} technique since it has a lower success rate, longer procedure time, lower satisfaction score, and is more difficult to perform. So US_{AS} technique may be more suitable for elderly patients. (Anesth Analg 2022;134:400–9)

KEY POINTS

- **Question:** Which technique is associated with a higher success rate of spinal anesthesia in elderly patients with hip fractures: ultrasound assistance, or real-time ultrasound guidance technique?
- **Findings:** In elderly patients with hip fractures, real-time ultrasound–guided spinal anesthesia presented a lower first-attempt success rate and first-pass success rate than ultrasound assistance.
- **Meaning:** Ultrasound-assisted spinal anesthesia can be more suitable for elderly patients than real-time ultrasound guidance.

GLOSSARY

AC = anterior complex; **ASA** = American Society of Anesthesiologists; **BMI** = body mass index; **CI** = confidence interval; **CONSORT** = Consolidated Standards of Reporting Trials; **CSF** = cerebrospinal fluid; **IQR** = interquartile range; **PC** = posterior complex; **PMSI** = paramedian sagittal in-plane; **PMSO** = paramedian sagittal out-plane; **PMTI** = paramedian transverse in-plane; **PSO** = parasagittal oblique; **SD** = standard deviation; **TM** = transverse midline; **US_{AS}** = ultrasound assistance; **US_{RTG}** = real-time ultrasound guidance

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Spinal anesthesia has a number of advantages, including quick onset, complete blockade, few complications, and little effect on cardiopulmonary function, that make it suitable for use in elderly patients. However, performing spinal anesthesia using a traditional landmark-guided approach can be considerably challenging in elderly patients with hip fracture due to lumbar degeneration, coupled with limitations on positioning due to pain.[1–4] Multiple needle attempts may lead to a higher incidence of complications (eg, postdural puncture headache, paresthesia, hematoma, and infection) and increase patient discomfort and dissatisfaction.[5–7] Therefore, novel techniques are needed to improve the success rate of spinal anesthesia for such patients.

Recently, ultrasound has emerged as a way to facilitate lumbar neuraxial blocks, namely, the ultrasound assistance (US_{AS}) technique and the real-time ultrasound guidance (US_{RTG}) technique. The US_{AS} technique is beneficial for lumbar neuraxial anesthesia, improving technique performance by providing reliable anatomical information.[8–10] Previous studies have shown that prepuncture ultrasound scanning can improve puncture success rates, shorten puncture time, reduce needle passes, and increase the efficacy and safety of lumbar neuraxial blocks.[2,11–13] However, a problem with the US_{AS} approach is that the needle is advanced blindly and seldom achieves an ideal trajectory. One possible remedy, reported in recent studies, is the US_{RTG} technique, which provides real-time observation of the trajectory of the needle during the puncture process.[14–17] However, the US_{RTG} technique is uncommon due to its technical difficulty and complexity. Since few randomized studies comparing the 2 techniques have been done to date, no clear indication exists of which ultrasound technique is more suitable for use in elderly patients with hip fractures.

Therefore, this study aimed to compare the first-attempt success rate of both the US_{AS} and US_{RTG} techniques in elderly patients with hip fractures. The first-pass success rate, procedure time, adverse reactions and complications, patient satisfaction, and procedural difficulty score were also compared between the 2 techniques.

Reprints will not be available from the authors.

Clinical trial number and registry URL: ChiCTR2000034268, http://www.chictr.org.cn/.

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METHODS

Study Design and Patient Population

This study was approved by the institutional review board of the First Affiliated Hospital of Guangzhou University of Chinese Medicine (No: JY [2019]075; date of approval: January 6, 2020), and written informed consent was obtained from all patients participating in the trial. The trial was registered before patient enrollment in the Chinese Clinical Trial Register at http://www.chictr.org.cn (ChiCTR2000034268; principal investigator: Yuhui Li, date of registration: June 30, 2020). The study was conducted in the First Affiliated Hospital of Guangzhou University of Chinese Medicine from July 2020 to December 2020. This article adhered to the applicable Consolidated Standards of Reporting Trials (CONSORT) guidelines.[18]

A total of 114 patients were enrolled in the study. The inclusion criteria were as follows: patients scheduled for elective hip fracture surgery with spinal anesthesia, ≥70 years of age, American Society of Anesthesiologists (ASA) physical status I to III. Patients with severe cardiopulmonary diseases, contraindications of spinal anesthesia (eg, coagulopathy, puncture site infection, or local anesthetics allergy), or the inability to communicate and cooperate were excluded.

Randomization and Operator

The patients were randomly assigned to receive spinal anesthesia using either the US_{AS} technique (n = 57) or US_{RTG} technique (n = 57) based on a computer-generated random number table. The allocation of patients was concealed with sequentially numbered and sealed opaque envelopes that could only be opened by the attending anesthesiologist performing the procedure once the patients were in the operating room. Patients were blinded to the group assignment. Neither the intraprocedural parameters collector nor anesthesiologist performing the procedure could be blinded to group assignment. However, the investigator measuring postprocedural outcomes after completion of spinal anesthesia was blinded to the group allocation.

All spinal blocks were a single-operator technique and were performed by 1 of 3 attending anesthesiologists skilled in ultrasound-guided peripheral nerve blocks (200 blocks per year), each having performed >30 ultrasound-assisted and real-time ultrasound–guided lumbar neuraxial blocks, respectively.

Study Procedures

An oxygen facemask (1–2 L/min) was applied to the patient, and peripheral venous access was established. Under routine monitoring (electrocardiogram, pulse oximetry, and noninvasive blood pressure), a real-time ultrasound–guided fascia iliaca compartment block was conducted with 20 mL of 0.375% ropivacaine to relieve pain caused by positioning changes.[19]

After 15 minutes, the patient was maneuvered into a lateral position, fracture side up, for spinal anesthesia. No sedatives were administered before or during the puncture procedure. A portable ultrasound system (Huasheng, Inc) equipped with a curved array probe (2–5 MHz frequency) was used.

In the US_{AS} group, spinal anesthesia with a paramedian approach was performed based on the optimum puncture point, suggested puncture angles, and puncture depth, as mentioned in our previous study.[20] The probe was placed for the parasagittal oblique (PSO) view and slid gently to obtain the optimal ultrasound image. Subsequently, the upper edge of the inferior laminar of the selected interlaminar space was moved to the center of the ultrasound screen. The midpoint of the probe was considered as the optimum puncture point. The suggested puncture angles included the cephalad angle measured by the built-in angle program of the ultrasound and the medial angle measured by a 180° protractor (Deli). The puncture depth, the distance from the skin to the posterior complex, was measured utilizing the ultrasound clipper tool.

In the US_{RTG} group, the systematic procedure was performed according to the following steps.

1. Identification of the midline: the transducer was placed on the spine in the transverse midline (TM) plane and slid gently until the acoustic shadow of the spinous processes was observed. The midpoint of the long axis of the transducer corresponded to the midline of the spine.
2. Identification of the laminar interspace: the probe was placed for the PSO view, 1 to 2 cm lateral to the midline. A flat hyperechoic sacrum was identified, and then the L5-S1 to L2-L3 laminar interspaces were counted upwards. The level with the widest intervertebral space and the clearest anterior/posterior complex was the first choice for puncture.
3. Skin marking: at the PSO view, the preferred interlaminar space was moved to the center of the ultrasound screen. Then, the midpoint of the long axis of the probe was marked on the skin, without the requirement to precisely obtain the best image.
4. Spinal anesthesia: after disinfection and draping were complete, the probe was covered with ultrasound gel and a medical sterile protective sheath. The iodophor served as a coupling agent between the skin and the probe. The iodophor at the puncture site was wiped off with sterile gauze before puncture. The probe was held in the nondominant hand, while the needle was manipulated using the dominant hand. One of the following 3 approaches was utilized for real-time ultrasound–guided spinal anesthesia.

- Paramedian sagittal in-plane (PMSI) approach: In the PSO plane, the transducer was positioned on the previously marked interlaminar space. The image of the interlaminar space was moved to the right of the ultrasound screen. The transducer was adjusted to obtain the optimal ultrasound image so that the posterior and anterior complexes were displayed as clearly as possible. Two to 3 mL of 1% lidocaine was injected at 1 cm caudal to the transducer for local infiltration. Under the in-plane guidance, a spinal needle was advanced toward the posterior complex in a caudad-to-cephalad direction until the dura was penetrated (Figure 1A).
- Paramedian sagittal out-plane (PMSO) approach: In the PSO plane, the transducer was placed on the marked interlaminar space. The interlaminar space was adjusted to achieve a clear image of the posterior and anterior complexes, keeping them centered on the ultrasound screen. Two to 3 mL of 1% lidocaine was injected at the midpoint of the probe edge for local infiltration. Under the out-plane guidance, a spinal needle was advanced toward the posterior complex until the dura was penetrated. The needle tip was visible on the ultrasound image as a bright spot (Figure 1B).
- Paramedian transverse in-plane (PMTI) approach: The transducer was positioned on the marked interlaminar space in a transverse orientation. The image of the interlaminar space was moved to the left of the ultrasound screen, and the transducer was adjusted to obtain an optimal image of the posterior and anterior complexes. Two to 3 mL of 1% lidocaine was infiltrated into the skin 1 cm lateral to the probe's footprint. The spinal needle was advanced toward the target posterior complex with the in-plane technique in a lateral-to-medial direction until the dura was penetrated (Figure 1C).

The operators in this study were all right-handed. In the US_{RTG} group, if the quality of the POS image was superior to the TM image and the patient was placed in the right lateral position, the PMSO technique was preferred; however, if the patient was placed in the left lateral position, the PMSO or PMSI technique could be selected at the operator's discretion. If the TM image quality was better than that of the POS, the PMTI technique was preferred. If there was little difference in quality between the POS and TM images and the patient was placed in the right lateral position, the operator could select either the PMSO or PMTI technique; if the patient was placed in the left lateral position, the operator could choose any of the 3

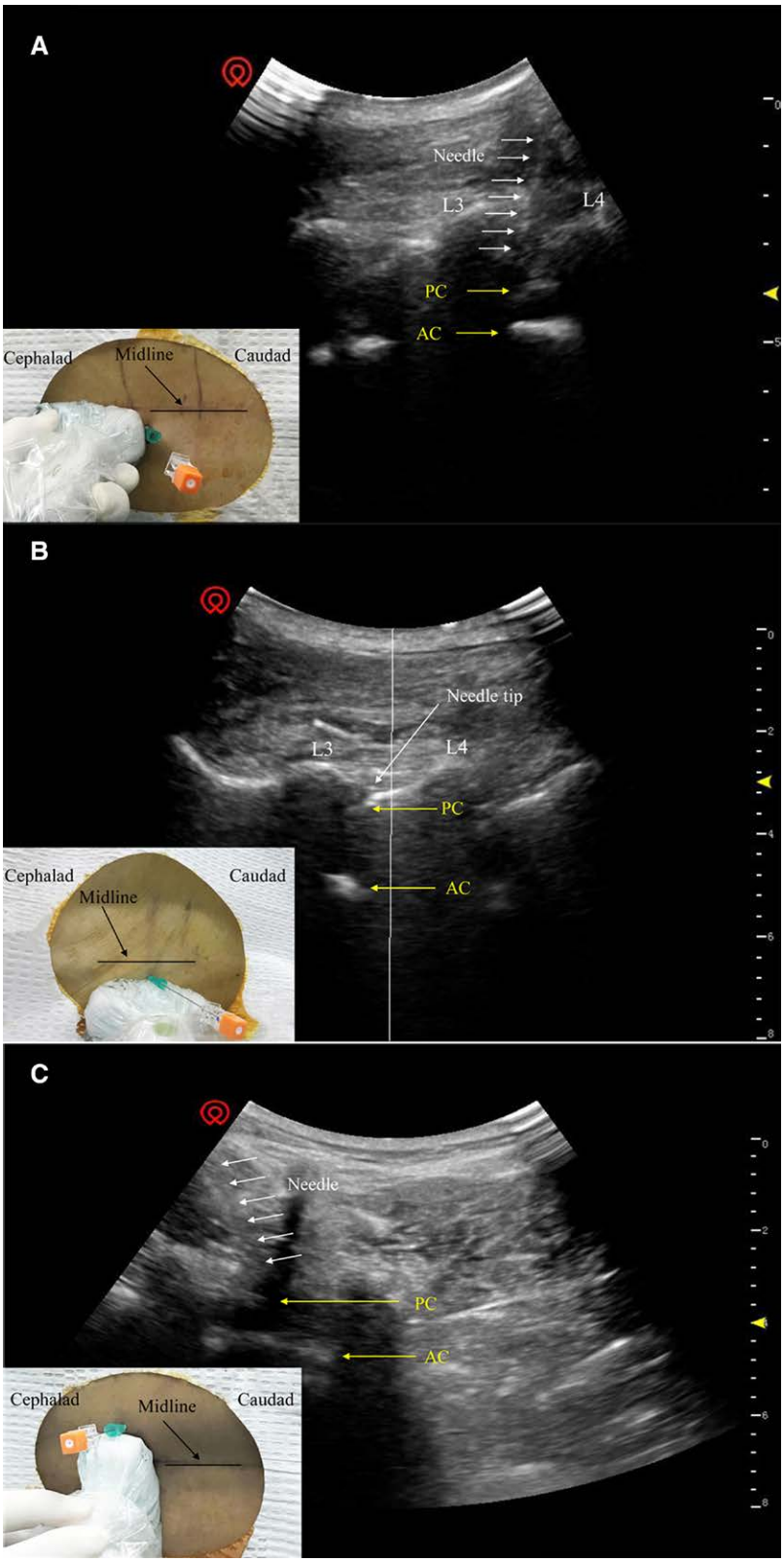

Figure 1. A sonogram of the lumbar spine and the trajectory of the spinal needle (white arrows) or needle tip (a bright dot) during the process of real-time ultrasound–guided spinal anesthesia. The photo in the lower left corner shows the position of the transducer and spinal needle. A, The PMSI approach. B, The PMSO approach. C, The PMTI approach. AC indicates anterior complex; PC, posterior complex; L3, lamina of L3 vertebra; L4, lamina of L4 vertebra; PMSI, paramedian sagittal in-plane; PMSO, paramedian sagittal out-plane; PMTI, paramedian transverse in-plane.

approaches. During the procedure, tissue movements or the needle shaft could help to identify the needle trajectory. When the needle tip (a bright spot) was not visible, a feeling of "give" could be helpful to identify dura penetration.

In both groups, the whole puncture process adopted the aseptic technique. For better 1-hand manipulation, a 25-gauge spinal needle (Kindao Interventional Medical Co, Ltd) inserted through an introducer needle (21-gauge syringe needle) was used

for spinal puncture. After successful dural puncture was confirmed by the outflow of cerebrospinal fluid (CSF), 0.5% ropivacaine (9.75–12.75 mg) was injected. A maximum of 6 attempts (needle completely withdrawn from the skin's surface and then reinserted) was allowed in 1 intervertebral space, and a maximum of 6 needle passes (needle redirections without entire withdrawal from the skin) was allowed for each attempt. If 6 attempts failed to achieve dural puncture, the operator would switch to an alternative technique (palpation, US_{AS}, US_{RTG}, another interlevel, or another anesthetist).[20] If the alternatives were unsuccessful, general anesthesia would be performed. If both the anterior and posterior complexes were invisible from L4-5 to L2-3 in the POS and TM views, the operator could choose to perform a traditional landmark-based technique or use general anesthesia.

The quality of the POS and TM images was evaluated as good (both posterior and anterior complexes visible), moderate (either posterior or anterior complex visible), or poor (neither posterior nor anterior complexes visible). The width of the posterior and anterior complexes in the better quality image was measured using the ultrasound clipper tool. A follow-up was performed within 48 hours after surgery.

Outcomes

The primary outcome was the first-attempt success rate of spinal anesthesia, with "first-attempt" defined as the needle achieving successful dural puncture through a single attempt.

Secondary outcomes included the following:

- First-pass success rate: defined as the needle achieving successful dural puncture through a single attempt without redirection.
- Number of attempts: defined as the number of skin punctures.
- Number of passes: needle attempts + needle redirections.
- Locating time: the time from when the probe was placed on the skin until the skin marking was complete.
- Procedure time: recorded from the needle insertion into the skin until observation of the outflow of CSF using the allocated technique (or if needed, the alternative technique decided by the operator).
- Total time: defined as the sum of the locating time and procedure time.
- Adverse reactions and complications: including radicular pain, bloody tap, postdural puncture headache, paresthesia, and back pain.
- Patient satisfaction score: patients were asked to assess their satisfaction on a 5-point numeric rating scale (1, extremely unsatisfied; 5, extremely satisfied).
- Procedural difficulty score: operators were asked to rate the difficulty of the procedure on a 5-point numeric scale after completion of the spinal block (1, extremely easy; 5, extremely difficult).

Statistical Analysis

SPSS V17.0 software (SPSS Inc) was used for data analysis. The Kolmogorov-Smirnov test was used to evaluate whether the data were normally distributed. Normally distributed data were described as mean ± standard deviation (SD), compared using the Student *t* test. Non-normally distributed data were presented as median and interquartile range (IQR), compared using the Mann-Whitney *U* test (2 groups) or the Kruskal-Wallis test (3 groups). The variables including the number of attempts/passes, time variables, patient satisfaction, and procedural difficulty were analyzed using the Mann-Whitney *U* test or the Kruskal-Wallis test. Categorical variables, including the success rate, adverse reactions and complications, and the quality in the POS/TM view, were expressed as number and percentage, compared using the χ^2 test or Fisher exact test. Analysis of correlation between the number of needle attempts, passes, and the width of the anterior and posterior complex was used Spearman correlation coefficients. A subgroup analysis about puncture-related variables among 3 approaches in the US_{RTG} group was conducted after the completion of the study. A $P < .05$ (2 sides) was considered statistically significant.

Sample Size Calculation

PASS V15.0.5 software (2017; NCSS LLC) was utilized to calculate the study sample size. Based on our pilot study, the first-attempt success rates with the US_{AS} and US_{RTG} techniques were 76% and 43%, respectively. Calculations determined that 45 patients were required for each group at the 0.05 significance level ($\alpha = .05$) and 90% power ($\beta = .1$). Accounting for possible patient dropouts, the sample size was increased to 57 patients per group.

RESULTS

A total of 130 patients were assessed for eligibility, of whom 114 patients were randomly allocated to either the US_{AS} (n = 57) or US_{RTG} (n = 57) group. The remaining 16 patients were excluded, including 3 patients who declined to participate and 13 patients whose surgeries were canceled (Figure 2). The patient demographics were comparable between the 2 groups (Table 1).

The first-attempt success rate (80.7% vs 52.6%; 95% confidence interval [CI] for the difference, 11.6–44.6) and first-pass success rate (63.2% vs 31.6%; 95% CI for the difference, 14.2–49) were both significantly higher in the US_{AS} group than in the US_{RTG} group ($P = .001$ in both; Table 2). The number of attempts (1 [1–1] vs 1 [1–3]) and median passes (1 vs 3) required to achieve

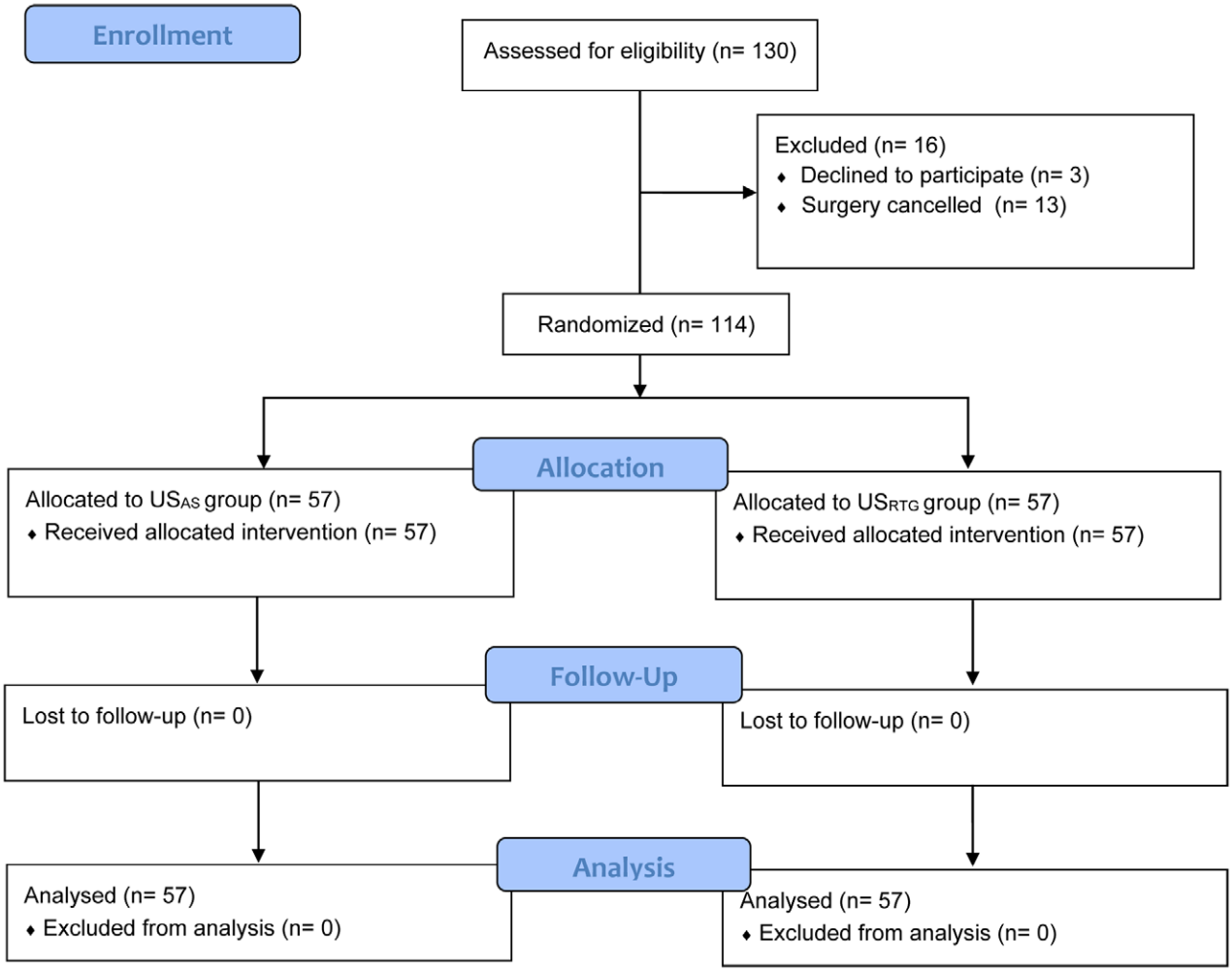

Figure 2. Patient recruitment flow diagram following the CONSORT. CONSORT indicates Consolidated Standards of Reporting Trials; US_{AS}, ultrasound assistance; US_{RTG}, real-time ultrasound guidance.

Table 1. Patient Demographics

	US_{AS} group n = 57	US_{RTG} group n = 57	Standardized differences (%)
Age (y)	84.5 ± 6.2	82.7 ± 6.6	28
Sex, male/female	15/42	20/37	—
Height (cm)	157.1 ± 7.8	158.6 ± 5.9	22
Weight (kg)	53.0 ± 10.2	55.5 ± 8.6	26
BMI (kg/m^2)	21.3 ± 3.4	21.9 ± 3.1	18
ASA physical status			
I	0 (0%)	0 (0%)	—
II	27 (47%)	33 (58%)	22
III	30 (53%)	24 (42%)	22
Abnormalities of the lumbar spine			
Previous spinal surgery	1 (1.8%)	2 (3.5%)	11
Scoliosis	2 (3.5%)	3 (5.3%)	9
None	54 (94.7%)	52 (91.2%)	14
Site of surgery			
Left hip	31 (54.4%)	24 (42.1%)	25
Right hip	26 (45.6%)	33 (57.9%)	25

Values are presented as mean ± SD or numbers (percentages).

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation; US_{AS}, ultrasound assistance; US_{RTG}, real-time ultrasound guidance.

Table 2. Comparison of Outcomes Between the 2 Groups

Outcomes	US_{AS} group n = 57	US_{RTG} group n = 57	*P* value	95% CI of differences (%)
First-attempt success, n (%)	46 (80.7)	30 (52.6)	.001[a]	11.6–44.6
First-pass success, n (%)	36 (63.2)	18 (31.6)	.001[a]	14.2–49
Number of attempts	1 [1–1]	1 [1–3]	.001[b]	
≤2	52 (91.2%)	41 (71.9%)	.008[a]	
≥3	5 (8.8%)	16 (28.1%)		
Number of passes	1 [1–2]	3 [1–6]	<.001[b]	
≤2	45 (78.9%)	25 (43.9%)	<.001[a]	
≥3	12 (21.1%)	32 (56.1%)		
Locating time (s)	315 [250–390]	175 [129–234]	<.001[b]	
Procedure time (s)	200 [127–328]	488 [260–972]	<.001[b]	
Total time (s)	540 [432–641]	694 [421–1133]	.036[b]	
Aseptic preparation time of the probe (s)	–	70 (62–89)	–	
Patient satisfaction: 3–5	55 (96%)	46 (81%)	.008[a]	3.6–26.4
Procedural difficulty	2 [2–3]	3 [2–4]	.008[b]	

Values are presented as median (interquartile range) or number (percentage).
Abbreviations: US_{AS}, ultrasound assistance; US_{RTG}, real-time ultrasound guidance; CI, confidence interval.
[a]Obtained from χ^2 test.
[b]Obtained from Mann-Whitney *U* test.

successful dural puncture were both significantly lower in the US_{AS} group than in the US_{RTG} group ($P = .001$ and $P < .001$, respectively; Table 2). In the US_{RTG} group, 56.1% of patients required >2 needle insertion passes to achieve dural puncture (Table 2).

Compared with the US_{AS} group, the US_{RTG} group required less locating time overall but took substantially longer for both procedure time and total time. In addition, the median time for aseptic preparation of the probe in the US_{RTG} group was 70 seconds. More patients in the US_{AS} group rated their satisfaction score of the spinal anesthesia as 3 to 5 (96% vs 81%, $P = .008$, Table 2). The procedural difficulty was rated significantly higher in the US_{RTG} group ($P = .008$, Table 2).

The intervertebral level of successful puncture was not significantly different between the groups ($P = .707$, Table 3). The peak dermatome level could reach T6-T10 in all cases, so there was no significant difference between the 2 groups in that regard ($P = .486$, Table 3). Similarly, there was no significant difference observed in the adverse reactions and complications between the 2 groups. No patients in either group experienced postdural puncture headache, paresthesia, or back pain (Table 3). In the US_{AS} group, no patients switched to an alternative technique. However, 8 patients required conversion to an alternative technique (US_{AS} technique) to acquire CSF in the US_{RTG} group, amounting to a significant difference between the 2 groups ($P = .006$, Table 3). In both groups, none of the patients required a switch to general anesthesia, and each spinal block was sufficient for the surgery.

There was no significant difference in the quality of ultrasound views and the width of the posterior and anterior complex between the 2 groups (Supplemental Digital Content 1, Table 1, http://links.lww.com/AA/D708). The number of needle attempts and insertion passes appeared to have a certain correlation with the width of the anterior and posterior complex in the US_{RTG} group (Supplemental Digital Content 1, Table 2, http://links.lww.com/AA/D708).

A subgroup analysis was performed for the 3 US_{RTG} techniques, and no significant difference was found in the procedure-related data between the 3 groups. As previously mentioned, 3 patients in the PMSI group, and 5 patients in the PMSO group, required conversion to an alternative technique (US_{AS} technique) (Supplemental Digital Content 1, Table 3, http://links.lww.com/AA/D708).

Table 3. Block Characteristics and Adverse Reactions

	US_{AS} group n = 57	US_{RTG} group n = 57	*P* value
Intervertebral level of successful puncture			.707[a]
L2-3	27 (47.4%)	25 (43.9%)	
L3-4	30 (52.6%)	32 (56.1%)	
Peak dermatome level			.486[a]
T6	4 (7%)	7 (12.3%)	
T8	25 (43.9%)	20 (35.1%)	
T10	28 (49.1%)	30 (52.6%)	
Adverse reactions and complications			
Radicular pain	3 (5.3%)	1 (1.8%)	.618[b]
Bloody tap	2 (3.5%)	1 (1.8%)	1[b]
Postdural puncture headache	0 (0%)	0 (0%)	–
Paresthesia	0 (0%)	0 (0%)	–
Back pain	0 (0%)	0 (0%)	–
Alternative technique	0 (0%)	8 (14%)	.006[b]
Conversion to general anesthesia	0 (0%)	0 (0%)	–

Data are presented as number (percentage).
Abbreviations: US_{AS}, ultrasound assistance; US_{RTG}, real-time ultrasound guidance.
[a]Obtained from χ^2 test.
[b]Obtained from Fisher exact test.

DISCUSSION

The study indicated that for elderly patients with hip fractures, the US_{RTG} technique had lower first-attempt and first-pass success rates, required more needle attempts and passes, had a longer overall puncture time and total time, and was more difficult to perform than the US_{AS} technique.

In contrast to the current study, Grau et al[21] previously found that the first-attempt success rate in the US_{RTG} group (100%) was higher than in the US_{AS} group (70%). Different from Grau et al,[21] who used a midline approach, watching needles advance through interspinous ligaments in real-time, our study adopted the paramedian technique, a superior approach in the elderly.[22,23] The first-attempt success rate of the US_{RTG} group was 52.6% in the current study, which was lower than in previous research by Chong et al[15] (87%, 18 to 75 years of age), Liu et al[17] (95.2%, mean age 33.0 ± 5.2 years), Brinkmann et al[24] (85%, <80 years of age), Conroy et al[16] (65%, mean age 66 ± 11 years), and Niazi et al[25] (71%, mean age 67 ± 10 years). There are 3 possible explanations for this outcome. One, the subjects in this study were much older (mean age 82.7 ± 6.6 years) and could not achieve good lumbar curvature due to hip fracture. Therefore, performing dural puncture was relatively difficult. Second, elderly patients are associated with ligament calcification and bone hyperplasia, which impedes the penetration of the ultrasound beam. Muscle atrophy, osteoproliferation, and calcification of ligaments in the elderly can make ultrasound images appear hyperechoic.[26,27] As a result, the ultrasound images in this study were of suboptimal quality, and it was observed that the posterior complex was generally either not clear or completely invisible. Finally, the operator experience and usual practice were undoubtedly essential factors resulting in different results.

The lower first-attempt success rate in the US_{RTG} group may result from technical difficulty and complexity. First, in contrast with traditional 2-handed puncture, the US_{RTG} technique requires one hand to hold the probe while the other hand coordinates the probe for puncture. Second, the intraspinal structure is surrounded by bone, which may prevent the ultrasound beam and needle from penetrating. Finally, the subarachnoid space is deep, and so the needle visibility was poor.

The US_{RTG} technique required less locating time (175 vs 315 seconds), which could be attributed to marking the skin without precisely obtaining the optimal image. However, the procedure time was longer (488 vs 200 seconds), which may be due to obtaining an optimal acoustic window and maintaining needle-beam alignment, resulting in longer total time. The procedure time of the US_{RTG} group in the current study was longer than in previous studies.[15,28] This could possibly be because the subjects in this study were all elderly patients, which necessitated more time to obtain and maintain a satisfactory acoustic window. The US_{RTG} group required more insertion attempts, passes and more time for punctures, which may reduce patient satisfaction.

The ligamentum flavum, epidural space, and the posterior dura mater show a hyperechoic linear structure, collectively referred to as the posterior complex. Anterior dura mater, posterior longitudinal ligament, and posterior vertebral body usually present a hyperechoic linear structure, collectively referred to as the anterior complex.[10] The width of the anterior and posterior complexes could estimate the dimensions of interlaminar space and predict the technical difficulty of central neuraxial blockade.[29] A certain correlation was found between the number of needle attempts, passes, and the width of the anterior and posterior complex in the US_{RTG} group, indicating that the wider the anterior and posterior complex, the lower the number of needle attempts and insertion passes. This finding is consistent with that of Liu et al,[17] who found that if the articular processes and anterior and posterior complexes were clearly visible, the first-attempt success rate was high.

In the US_{RTG} group, 8 patients had no outflow of CSF and were switched to an alternative technique (US_{AS}) for successful dural puncture. Possible mechanisms include spinal needle blockage, insufficient rigidity, entering anterior epidural space, lower CSF pressure, too lateral of an insertion point, and axial deviation during needle advancement.[30] In addition, for elderly patients with hip fractures, puncture failure in the US_{RTG} group may have resulted from poor ultrasound image quality, as well as poor needle visibility.

Unlike the previous study using a single approach for real-time ultrasound–guided spinal anesthesia,[15,28] we selected 1 of the 3 approaches based on the patient's position and the quality of the ultrasound images. The reason was that for right-handed operators, it is difficult to perform the PMSI technique for patients with the right lateral position. The needle body is invisible during puncture when adopted the PMSO technique, and the PMTI technique was not suitable for all elderly patients because the visibility of the anterior and posterior complexes is suboptimal in most elderly patients for the transverse scan.[10]

In this study, the image of the target interlaminar space was located in the right side of the ultrasound screen when adopting the PMSI technique for punctures, while it was located in the center for previous studies.[14,31] There are 2 advantages to the current technique. First, there is a large space for puncture and decreased obstruction of needle advancement by the lamina, which is more suitable for patients with narrowing of intervertebral space. Second, the needle trajectory is shorter. However, it requires a relatively steep puncture angle, and it is not easy to visualize the whole needle during the process (Figure 3).

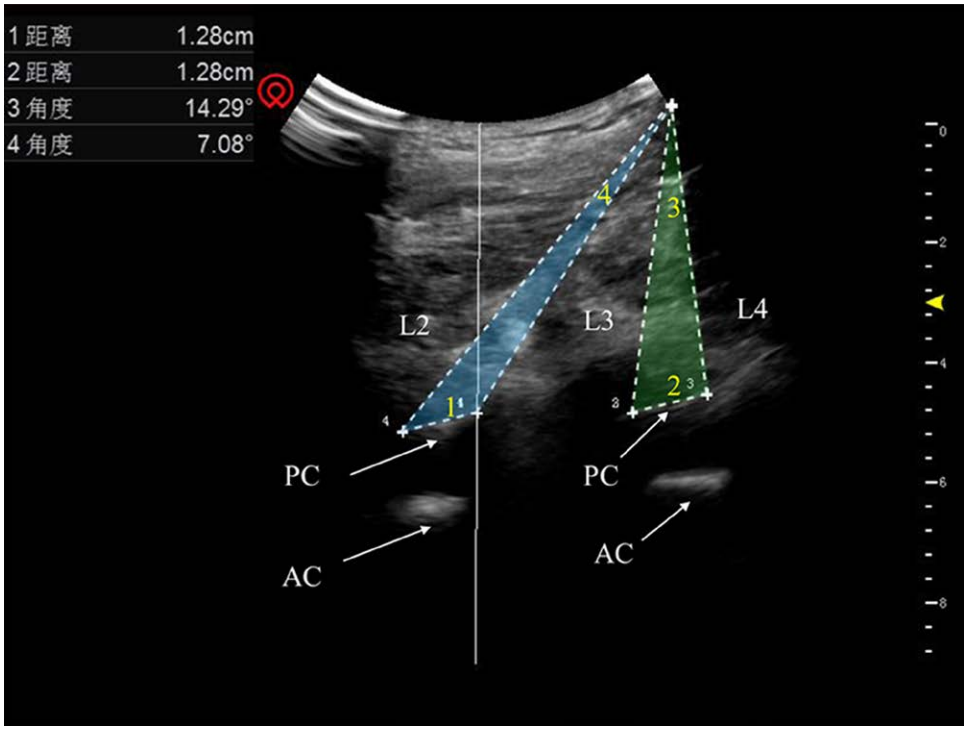

Figure 3. Comparison of puncture spaces. The ultrasound image shows the L2-L4 interlaminar space, AC, and PC in the PSO view. When the width of the PC is equal (1 = 2), moving the target interlaminar space to the right of the screen can increase the puncture space (∠3 > ∠4). AC indicates anterior complex; PC, posterior complex; PSO, parasagittal oblique.

In our experience, we found that it is easy to touch the lamina when the PMSI technique is used in patients with stenosis of intervertebral space, and the PMSO approach may be a better option for such patients. Regardless of the selected approach, the insertion site should not be too lateral. A low-frequency probe with a smaller footprint would be easier to manipulate and improve contact with the skin.

This study had some limitations. First, the intraprocedural outcome assessors and performers were not blinded to group allocation due to the nature of the study. Second, since the study participants had relatively suboptimal ultrasound image quality due to age-related factors, these study results could be less generalizable. In addition, the BMI of elderly patient might not be similar to other populations, which might reduce generalizability. Third, a direct comparison was unable to be made as to the quality of surface landmarks between the 2 groups, as the anesthesiologists did not palpate the surface landmark in both groups.

In conclusion, the US_{RTG} technique is not recommended for patients with poor quality of sonoanatomy, especially those with unclear posterior and anterior complexes. In elderly patients with hip fractures, the US_{RTG} technique presented a lower success rate, longer procedure time, and more difficult procedure, which suggests that the US_{AS} technique is more useful for such patients in clinical practice.

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