Journal of Anesthesia and Clinical Research

Kampitak et al., J Anesth Clin Res 2018, 9:6
DOI: 10.4172/2155-6148.1000837

Research Article Open Access

Paramedian Spinal Anesthesia: Landmark *vs.* Ultrasound-guided Approaches

Wirinaree Kampitak[1*], Thewarug Werawatganon[2], Ketchada Uerpairojkit[2] and Banchobporn Songthamwat[1]

[1]*Department of Anesthesiology, King Chulalongkorn Memorial Hospital, The Thai Red Cross Society and Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand*

[2]*Department of Anesthesiology, King Chulalongkorn Memorial Hospital and Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand*

[*]**Corresponding author:** Wirinaree Kampitak, Department of Anesthesiology, King Chulalongkorn Memorial Hospital, The Thai Red Cross Society and Faculty of Medicine, Chulalongkorn University, 1873, Rama 4 Road, Pathumwan, Bangkok 10330, Thailand, Tel: (66) 2-256-4295; E-mail: nutong127@yahoo.com

Received date: June 06, 2018; **Accepted date:** June 20, 2018; **Published date:** June 26, 2018

Abstract

Background: Multiple attempts at needle redirection for paramedian spinal anesthesia can lead to significant complications, particularly in elderly patients. We hypothesized that ultrasound guidance may reduce the need for redirection (s), the associated discomfort, and complications in conventional landmark-guided paramedian spinal anesthesia.

Methods: A total of 70 patients >65 years of age, undergoing total knee or hip arthroplasty, were randomly assigned to pre-procedural ultrasound-guided paramedian (PP) or conventional surface landmark-guided paramedian (CP) approach groups. The paramedian approach was performed at L3-4 in the lateral decubitus position.

Results: The median number of needle redirection attempts was significantly lower in group PP (2 (interquartile range (IQR) 1-2)) than in group CP (4 (IQR 2-8.5)) (P<0.001). The median number of needle insertion attempts was also significantly lower in group PP than in group CP (P=0.003). All patients in group PP underwent successful needle insertion at the 3-4 lumbar intrathecal space, while 7 in group CP required multiple interspinous space insertions for success (P=0.006). No patient in group PP experienced significant complications related to spinal anesthesia. However, 5 (13.9%), 1 (2.8%), and 7 patients (19.4%) in group CP experienced transient radicular pain, paresthesia, and traumatic puncture, respectively.

Conclusion: Application of pre-procedural ultrasound guidance in paramedian spinal anesthesia in elderly patients resulted in a significant decrease in the number of needle redirection and insertion attempts, as well as a reduction in related complications compared with the conventional paramedian technique.

Keywords: Pre-procedural ultrasound-guided; Conventional landmark-based; Elderly; Spinal anesthesia; Paramedian approach

Introduction

Landmark-guided spinal anesthesia can be performed using midline, paramedian, or lumbosacral approaches [1]. The paramedian approach is preferred in elderly patients because of degenerative changes in the structural elements of the spine in this patient group [2]. However, this approach sometimes requires expertise, and may be associated with multiple needle redirections and attempts to reach the subarachnoid space, resulting in complications [3-7], which may lead to patient dissatisfaction and refusal to have spinal anesthesia again [8].

Real-time ultrasound guidance is now being applied to various procedures to facilitate successful blockade [9,10]. Application of ultrasound-guided spinal anesthesia is often limited by the requirement (s) for a spinal needle that is larger than 27 gauges, to make it possible to identify the needle tip by ultrasound visualization. Previous studies have reported that pre-procedural ultrasound-guided spinal anesthesia in patients with difficult surface landmarks [11], such as in elderly individuals [12,13], resulted in fewer needle redirections. This suggests that pre-procedural ultrasound-guided anesthesia appears to be feasible and easier to perform than real-time ultrasound-guided spinal anesthesia.

Pre-procedural ultrasound-guided neuraxial block can be performed using either the transverse median (TM) or parasagittal oblique (PSO) view [14]. Previous studies have indicated that the PSO view provides superior visualization of the subarachnoid space and other structures compared with the TM view [15,16]. Recent studies have reported that pre-procedural ultrasound-guided spinal anesthesia under PSO view significantly decreased the number of needle passes when compared with conventional surface landmark-guided midline approach, particularly in elderly patients [17,18]. However, we found no studies that compared pre-procedural ultrasound-guided and conventional surface-landmark paramedian approaches for spinal anesthesia in elderly subjects.

We hypothesized that the use of a pre-procedural ultrasound-guided paramedian approach under PSO view would result in fewer redirections and attempts of spinal needle insertion into the subarachnoid space and reduce complications compared with the conventional surface landmark-guided paramedian approach for spinal anesthesia in elderly patients.

Methods

This prospective, randomized, controlled study was performed from December 2016 to April 2017 at Chulalongkorn University, Bangkok, Thailand. The protocol was approved by the Institutional Review Board of the University (Ref: 610/59), and registered with Clinical trials.in.th (TCTR20161206002). Seventy subjects >65 years of age scheduled to undergo elective total knee or hip arthroplasty were enrolled. Exclusion criteria included patients with contraindications to spinal anesthesia, such as allergy to local anesthetic drugs, and those with coagulopathy, cardiac, or neurological diseases.

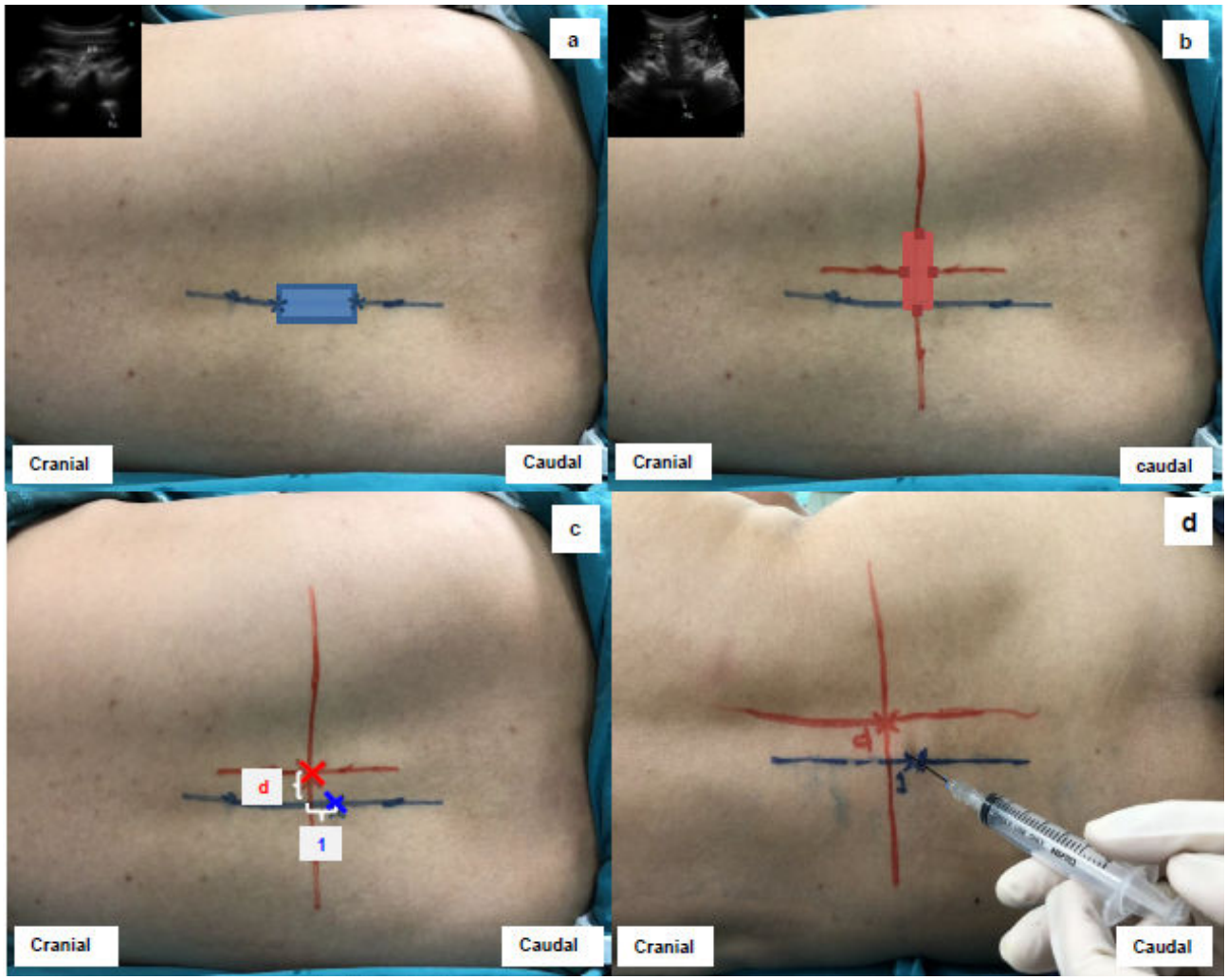

Figure 1: Illustrations demonstrating the steps of pre-procedural ultrasound-guided paramedian approach (group PP). a: An ultrasound probe (blue band) was placed at L3-4 under the parasagittal oblique (PSO) view. A point at the middle of each long border of the ultrasound probe (*) was created by a skin marker and the line drawn between those 2 points (blue line) indicated the parasagittal insertion level. b: Under the transmedian (TM) view, a point at the middle of each short and long border (.) of the ultrasound probe (red band) was created by a skin marker. Two red lines drawn between each 2 points created an intersection point of the medial angulation point (Red Cross). c: The parasagittal insertion point (blue cross) was created for paramedian spinal anesthesia by locating the point 1 cm (1) caudal from the intersection of the vertical red line and the blue line. d. Pre-procedural ultrasound-guided paramedian spinal anesthesia was performed at the parasagittal insertion point (blue cross) by approximating the optimum needle insertion angle using the Pythagorean Theorem. d: distance (cm) from midline level lateral to parasagittal insertion line.

After obtaining informed consent, a computer-generated block randomization schedule was used to allocate patients in a 1:1 ratio and in blocks of 4 to 1 to either, a pre-procedural ultrasound-guided under PSO view (group PP), or conventional surface landmark-guided (group CP), paramedian approach group for spinal anesthesia. Group allocation was concealed for the study using sealed opaque envelopes. Standard monitoring, pulse oximetry, noninvasive blood pressure measurement, electrocardiography, and intravenous access were established in all patients, who were placed in the lateral decubitus position with the operative side down and backs parallel to the edge of the table nearest to the anesthesiologist. The back was actively flexed maximally by bending flexed knees to the chest. Both groups underwent palpation of landmarks (superior aspect of the iliac crest, spinous process, interspinous gaps) followed by blinded grading of

quality for anatomical recognition (easy, moderate, difficult, or impossible) [12].

The TM and PSO views were graded as very good (both ligamentum flavum/dura complex (LFD) and posterior longitudinal ligament (PLL) clearly visible), good (both LFD and PLL visible), adequate (either LFD or PLL visible), or inadequate (both LFD and PLL not visible) at the L2-3, L3-4, and L4-5 intrathecal spaces [13]. The first anesthesiologist performed the grading of surface anatomical landmarks and pre-procedural scan under ultrasound-guidance. Spinal anesthesia was later performed by the second anesthesiologist to reduce the risk for bias.

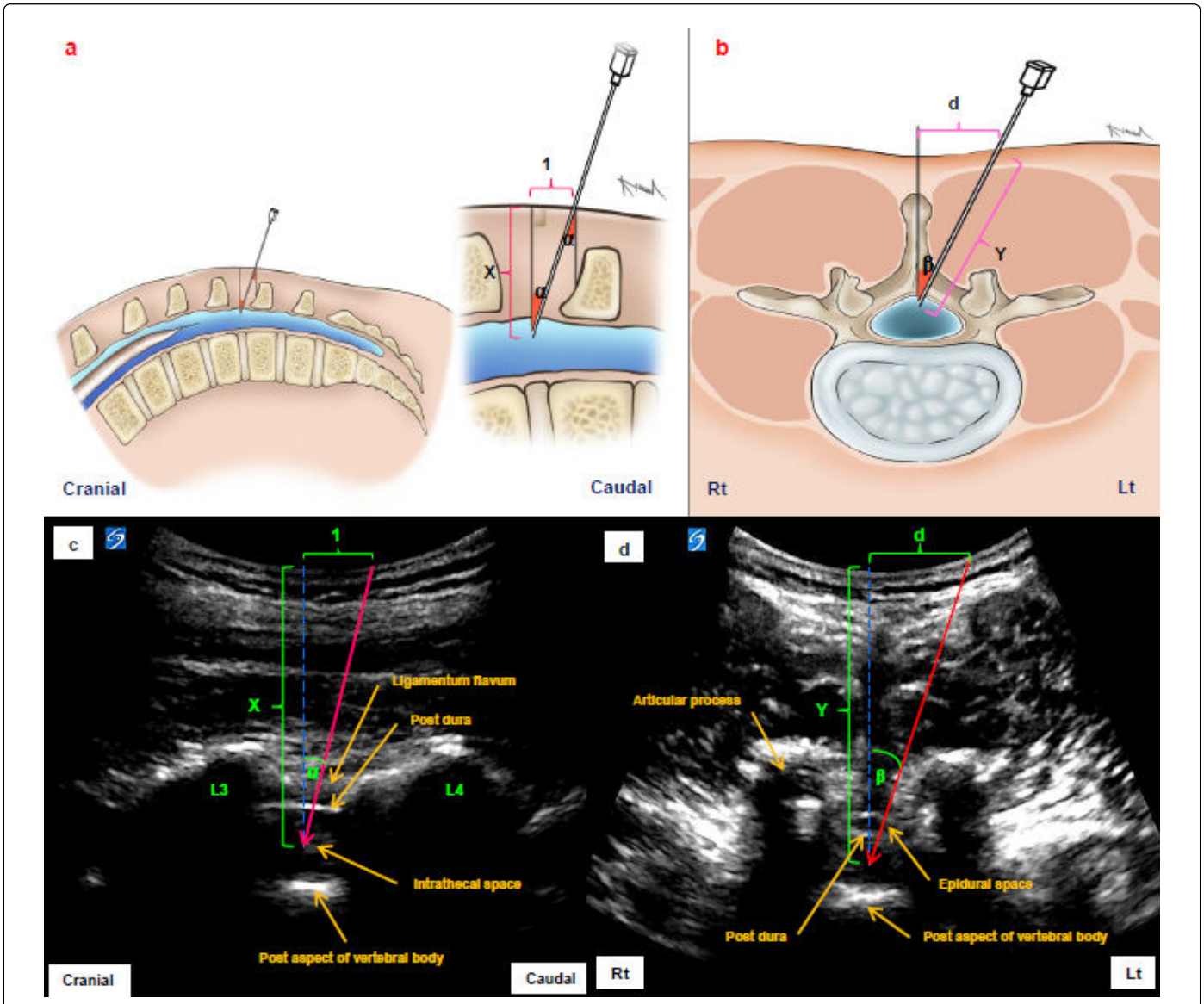

Figure 2: Illustrations demonstrating the method for calculation of the 2 optimum angles for spinal needle insertion by the Pythagorean theorem for pre-procedural ultrasound-guided paramedian spinal anesthesia in group PP. a: The optimal needle insertion angle from caudal to cranial (α)=arctan (1/X). b: The optimal needle insertion angle from sagittal to median plane (β)=arctan (d/Y). c and d: The ultrasound view of the spinal needle insertion point and direction of the needle from caudal to cranial and sagittal to midline level using the calculated needle insertion angle. 1-distance of 1 cm caudal from the intersection of vertical midline and parasagittal insertion line, X-depth (cm) from skin to intrathecal space (PSO view) by ultrasound measurement, d-distance (cm) from the midline level point of the TM view lateral to the paramedian sagittal insertion line, Y-depth from skin to the intrathecal space (TM view) by ultrasound measurement.

In group PP, after palpating for grading surface anatomical landmarks, a low-frequency (2-5 MHz), curve array ultrasound scan (Sonosite M-Turbo, Sonosite, Bothell, WA, USA) was performed for initial scan by the first anesthesiologist. The ultrasound scanning technique was applied accordingly to a previous study [14]. Under PSO view, the sacrum was identified, after which the interlaminar space between L5 and S1 was identified. Subsequent interspinous spaces were identified by counting the interlaminar spaces in the cranial direction.

In all patients, at the L3-L4 interspace with the probe positioned to obtain the clearest image of the ligamentum flavum-dura mater complex and the posterior aspect of vertebral body, the depths from skin to the ligamentum flavum-dura mater complex and the posterior aspect of vertebral body were recorded. A skin marker was applied at the midpoint of the long border of the probe, and a line was drawn between two midpoints to yield a parasagittal line for parasagittal-level insertion of the spinal needle (Figure 1a). A TM view at L3-4 was also obtained and the depth from skin to the ligamentum flavum-dura mater complex and the posterior aspect of vertebral body were recorded. A skin marker was applied at the midpoints of the short and long borders of the probe (Figure 1b). At the same vertical line of the midpoint of the long border, the midpoint of the line drawn between the two short border midpoints of the probe was used as an intersection of midline point to aid the paramedian approach for spinal block (Figure 1b). The distance (cm) from a midline point lateral to a parasagittal insertion line and 1 cm caudal were created to locate a parasagittal insertion point for the spinal needle (Figure 1c and 1d).

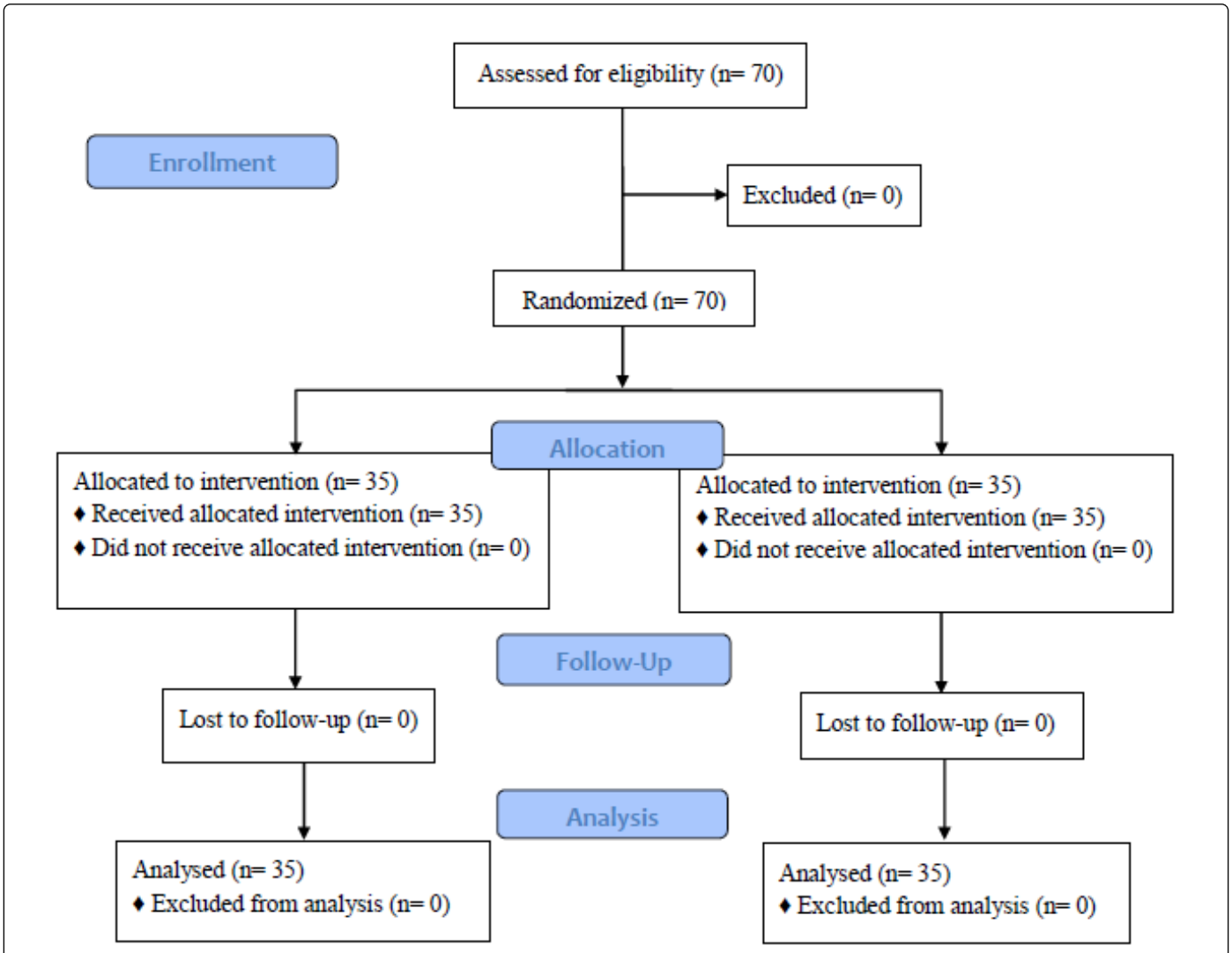

Figure 3: Consolidated Standards of Reporting Trials statement flow diagram.

The Pythagorean Theorem was used to determine the optimum needle angle for spinal anesthesia. Calculation of the optimal needle angle from caudal to cranial is: arctan (1/the depth from skin to intrathecal space (PSO view)), and the optimal needle angle from parasagittal to median level is: arctan (distance (cm) from midline level lateral to a parasagittal insertion line/the depth from skin to intrathecal space (TM view) (Figure 2) [19]. The depths from skin to intrathecal space in TM and PSO views were calculated as the depth from skin to LFD+½ (the depth from skin to PLL minus the depth from skin to LFD). After skin marking, cleaning was performed to ensure that the needle entry site was free of ultrasound gel before the needle insertion. The patients' back was scrubbed using sterile technique, and 2-3 ml of 1% lidocaine was used to infiltrate the skin. Spinal anesthesia was performed by the second anesthesiologist using the estimated of visual angle calculation and a 27-gauge, 90 mm spinal needle (BD, Franklin Lakes, NJ and USA) with Quincke bevel. Once dural puncture was achieved and confirmed by backflow of cerebrospinal fluid (CSF) from the needle hub, 0.5% hyperbaric bupivacaine 15 mg was injected.

In group CP, the first anesthesiologist palpated and graded the back for surface anatomical landmarks and performed an initial ultrasound scan in PSO view for identifying the interspinous space between L3

and L4, similar to group PP. The interspinous space between L3 and L4 is selected in all cases and a skin marker is applied away from the area of procedure. The area for ultrasound scan was cleaned of ultrasound gel before the second anesthesiologist identified the interspinous space between L3-L4. Spinal anesthesia using the paramedian approach was performed using the same technique as group PP by the second anesthesiologist. The needle was inserted 1 cm lateral and 1 cm caudal, with 10° to 15° off the sagittal plane in cephalomedial angle of approach and caudal edge of the L3 spinous process.

Pre-procedural ultrasound-guided spinal anesthesia was performed by 2 anesthesiologists (W.K., B.S), each having previously performed more than 50 pre-procedural ultrasound-guided paramedian approaches under the PSO view in soft embalmed cadavers. Anesthesiologists were offered alternative methods if 3 insertion attempts were unsuccessful. In group PP, using another interspinous space or changing to conventional landmark palpation or sitting position was considered. In group CP, using another interspinous space, real time ultrasound-guided changed to midline approach or sitting position was allowed.

Outcomes

The primary outcome was defined as the total number of needle redirections that did not involve complete withdrawal of the needle. A needle insertion attempt was defined to be complete if insertion was preceded by complete withdrawal of the needle from the patient's back after requiring more than 5 needle redirections. If a patient underwent more than one insertion attempt, a total number of needle redirection attempts continued being counted. Secondary outcomes included the following:

1. Number of insertion attempts required for successful dural puncture.

2. Time taken to identify landmarks. For group PP, it was defined as time from ultrasound probe placement on skin by the first anesthesiologist until the markings were placed. In group CP, it was defined as time from second anesthesiologist started palpating to identifying landmarks, as declared by the second anesthesiologist.

3. Performing spinal anesthesia time from insertion of the spinal needle until backflow of CSF.

4. Total time was defined as the period required identifying landmarks to complete the spinal block procedure including withdrawal of the spinal needle after injection of the local anesthetic solution into the intrathecal space, and reconfirming the position of the needle by aspiration of CSF.

5. The optimum needle insertion angle by the Pythagorean theorem from caudal to cranial and sagittal to the median plane for spinal anesthesia in group PP.

6. Level of block was tested by loss of cold sensation with ice pack after spinal anesthetic injection for 15 min.

7. Recorded incidences of radicular pain (the patient complained of pain that radiated into the lower extremity directly along the course of a spinal nerve root during spinal needle insertion), paresthesia (the patient complained of transient paresthesias during spinal needle insertion), and traumatic puncture (occurrence of a bloody tap after withdrawal of the needle stylet) during the procedure.

8. Block-associated pain score and discomfort score were rated by the patients after completion of the spinal anesthesia, on an 11-point rating scale (0-no pain or discomfort, 10-most pain or discomfort imaginable)

Outcomes were recorded by an independent observer (a nurse anesthetist). A timer was used for recording. Demographic information and data recorded included age, sex, weight, height, history of lumbar spine surgery, and history of failure with neuraxial block.

Statistical analysis

The sample size calculation was based on the primary outcome of the needle redirection attempt. Based on a pilot study in which 20 patients were randomly assigned to receive either the conventional surface-landmark guided paramedian (n=10) or pre-procedural ultrasound-guided paramedian (n=10) spinal anesthesia for orthopedic surgery. The mean (± SD) numbers of needle redirection attempts were 4 ± 4.06 and 1.6 ± 0.52, respectively. It was calculated that 31 patients would be required in each group to detect a difference at an α level of 0.05 and a β of 0.1. Considering the risk for dropouts, 35 patients were included in each group.

Statistical analysis was performed using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA). Categorical outcomes were compared using one-way analysis of variance (normal distribution data) and the chi-squared test. Pearson correlation was used to determine the correlation between the depth from skin to intrathecal space in TM and PSO views, sex, age, body weight, and height in group PP. Continuous data were tested for normality using Q-Q plots and Shapiro-Wilk statistics. Normally distributed outcomes were summarized as mean ± SD and were compared between groups using the independent-measures t test. Non-normally distributed data were summarized as median (interquartile range (IQR)) and were compared using the Mann-Whitney U test. A two-tailed P value<0.05 was considered to be statistically significant.

Results

Seventy patients were assessed for suitability. All provided informed consent to participate in the study, and 35 were randomized to each group. All patients underwent the allocated intervention and had completed follow up (Figure 3). Distribution of demographic data (sex, age, weight, height, and body mass index (BMI)), type of surgery, grading of the surface anatomical landmarks palpation, abnormalities of the lumbar spine, history of lumbar spine and intercristal line were similar between the two groups. There was no history of failure of neuraxial block in all patients (Table 1). The quality of ultrasound views (i.e., TM and PSO) at the interspinous spaces between L2-3, L3-4 and L4-5, and the depth from skin to LFD, PLL and intrathecal space in both ultrasound views (TM and PSO views), were not different between the two groups.

The median number of needle redirection attempts (i.e., primary outcome) was significantly lower in group PP (2 (IQR 1-2)) than in group CP (4 (2-8)) (P<0.001). Surprisingly, all patients in group PP required only one needle insertion attempt for successful dural puncture, and the mean number of needle insertion attempts was remarkably lower than in group CP (P=0.003). No patients in group PP required needle insertion attempts at a different intrathecal space for successful dural puncture. However, 7 patients in group CP required needle insertions at multiple intrathecal spaces for successful

dural puncture (achieved at L2-3 space in 6 patients and L4-5 interspinous space in 1 patient) (P=0.006) (Table 2).

	PP (n=35)	CP(n=35)	p-value
Sex			
Male	5 (14.3%)	3 (8.6%)	0.452
Female	30 (85.7%)	32 (91.4%)	
Age (yr)	75.06 ± 7.0	73.89 ± 7.67	0.508
BW (kg)	62.59 ± 8.75	63.54 ± 12.03	0.708
HT (cm)	155.31 ± 6.34	153.59 ± 6.76	0.274
BMI (kg/m^2)	26.03 ± 3.94	26.94 ± 4.99	0.398
Type of Sx			
THR	1 (2.9%)	1 (2.9%)	1
TKR	34 (97.1%)	34 (97.1%)	
Grading of palpated landmarks			
Easy	20 (57.1%)	19 (54.3%)	0.973
Moderate	12 (34.3%)	12 (34.3%)	
Difficult	2 (5.7%)	3 (8.6%)	
Impossible	1 (2.9%)	1 (2.9%)	
Abnormalities of the lumbar spine			
none	23 (65.7%)	29 (82.9%)	0.292
mild scoliosis	6 (17.1%)	1 (2.9%)	
moderate scoliosis	1 (2.9%)	1 (2.9%)	
kyphosis	0 (0%)	1 (2.9%)	
spinal sx	5 (14.3%)	3 (8.6%)	
Intercristal line			
L2/3	4 (11.4%)	3 (8.6%)	0.565
L3/4	31 (88.6%)	31 (88.6%)	
L4/5	0 (0%)	1 (2.9%)	

Table 1: Patient Characteristics. Values presented as mean ± SD., median (IQR) and frequency (%). P-value corresponds to (a) Independent t-test, (b) Mann-Whitney test and (c) Chi–square test.

On comparing variables for successful dural puncture (Table 2), the first successful puncture was achieved in twice as many patients in group PP than in group CP (45.7% versus 22.2%, respectively); however, the difference was not significant (P=0.08). Significantly more patients in group PP required fewer than 10 needle redirection attempts for successful dural puncture (P<0.05). Moreover, 7 patients in group CP required >10 needle redirection attempts for successful dural puncture, while there were no such patients in group PP (P<0.012). All patients in group PP (100%) underwent successful dural puncture on the first needle insertion attempt, but only 29 (80.6%) achieved that in the CP group (P=0.023).

	PP (n=35)	CP (n=35)	p-value
Total number of needle redirection attempt	2 (1-2)	4 (2-8)	<0.001*
Total number of needle insertion attempt	1 (1-1)	1(1-2)	0.003*
≥2 level of ITS space for needle insertion attempt (n)	0 (0%)	7 (19.4%)	0.006*
Time taken for identifying landmarks (s)	112 (75-148)	18.5 (13.5-23.96)	<0.001*
Time taken for performing SAB (s)	18 (13-28)	55 (23.5-94)	<0.001*
Total procedure time (s)	225 (181.4-273)	163 (126.3-211.96)	<0.001*
Success dural puncture (n),			
on 1st needle direction attempt	16 (45.7%)	8 (22.2%)	0.08
within 3 needle redirection attempt	35 (100%)	16 (44.4%)	<0.001*
within 5 needle redirection attempt	35 (100%)	23 (63.9%)	<0.001*
≥ 10 needle redirection attempt	0 (0%)	7 (19.4%)	0.012*
on 1st needle insertion attempt	35 (100%)	29 (80.6%)	0.023*
Change method or position (n)	0 (0%)	1 (2.8%)	0.321
Angle midline (degree)	12.1 ± 1.24	-	NA
Angle paramedian (degree)	19.66 ± 4.47	-	NA
Distance midline to paramedian (cm)	1.69 ± 0.36	-	NA

Table 2: Outcomes data for performance of Spinal anesthesia. Values presented as mean ± SD; median (IQR) and frequency (%). *P<0.05 compared with the PP group. ITS-Intrathecal space

Not surprisingly, significantly more time was required to identify anatomical landmarks under ultrasound guidance in group PP than with palpation of anatomical landmarks in group CP (112 s (IQR 75-148 s) *vs.* 18.5 s (IQR 13.5-23.96 s); P<0.001). Moreover, a remarkably longer time for the total procedure was required in group PP than in group CP (225 s (IQR 181.4-273 s) *vs.* 163 s (IQR 126.3-211.96 s); P<0.001). However, the time for spinal anesthesia was significantly lower in group PP than in group CP (18 s (IQR 13-28 s) *vs.* 55 s (IQR 23.5-94 s); P<0.001) (Table 2).

In group PP, a significant positive correlation was found between body weight and the depth from skin to intrathecal space on both views (TM view, r=0.489, P<0.001; PSO view, r=0.596, P<0.001). In addition, sub-group analyses based on BMI, angle of needle direction in sagittal and transverse plane, and distance from midline level lateral to a parasagittal insertion point, demonstrated that angle of needle direction in both planes and distance from midline increased with

reduced BMI, but the findings were not statistically different (P>0.05) (Table 3).

	BMI				p-value
	<20 (n=2)	20-24.9 (n=12)	25-29.9 (n=17)	>30 (n=4)	
Angle midline (degree)	13.12 ± 0.32	12.6 ± 0.95	12 ± 1.12	10.25 ± 0.29	0.113
Angle paramedian (degree)	26.87 ± 4.74	20.55 ± 4.78	19.28 ± 4.4	17.73 ± 3.07	0.075
Distance midline to paramedian (cm)	2.15 ± 0.49	1.71 ± 0.29	1.61 ± 0.38	1.78 ± 0.33	0.232

Table 3: Angle of needle direction and distance from midline to lateral for paramedian insertion in sub-group analysis. Values presented as mean ± SD, P-value corresponds to ANOVA test.

	PP (n=35)	CP (n=35)	p-value
Level of block			
T4	5 (14.3%)	9 (25%)	0.419
T5	0 (0%)	1 (2.8%)	
T6	22 (62.9%)	17 (47.2%)	
T8	8 (22.9%)	9 (25%)	
Radicular pain	0 (0%)	1 (2.8%)	0.321
Incidence paresthesia	0 (0%)	5 (13.9%)	0.022*
Blood in spinal needle	0 (0%)	7 (19.4%)	0.006*
Periprocedural pain	2 (1,2)	2 (2,5)	0.002*
Periprocedural discomfort score	6 (4,6)	6 (4,6)	0.27

Table 4: Level of block, complication and discomfort score. Values presented as mean ± SD, median (IQR) and frequency (%). *P<0.05 compared with the PP group.

No patients experienced unsuccessful spinal anesthesia (Table 2). However, an alternative technique (pre-procedural ultrasound-guided in the sitting position) was used in 1 patient in group CP; this patient required a longer time to achieve dural puncture (>10 min). Dermatome levels of loss of cold sensation after spinal block at 15 min were not significantly different between the two groups (Table 4). No patients in group PP experienced radicular pain, paresthesia during redirection or insertion, or traumatic puncture. However, in group CP, 6 patients were found to have experienced radicular pain and paresthesia. Furthermore, traumatic puncture was observed in 7 patients in group CP (P=0.006); however, none exhibited persistent symptoms or any adverse events (Table 4). There was a significant difference between the two groups in median pain score during performance of block (2 (IQR 1-2)) in group PP versus 2 (IQR 2-5) in group CP, respectively (P=0.002) (Table 4).

Discussion

The conventional paramedian approach to spinal anesthesia in the lateral position is a preferable technique for many anesthesiologists in orthopedic surgery because most patients are elderly and may have interspinous ligament calcification and an inability to achieve adequate flexion due to various factors such as osteoarthritis, kyphoscoliosis, and/or previous spinal surgery [2]. In addition, degenerative changes [20], or a fractured hip or knee, may generate pain in the sitting position [21]. The paramedian technique involves only the ligamentum flavum and, is therefore, less associated with bending of the spinal needle due to calcified bony ligaments. Previous studies have shown significantly increased success rates of the first needle insertion attempt using the paramedian approach compared with midline approach neuraxial blockade in elderly patients. However, the failure rate of the first attempt can be approximately 15% to 20% [22-24].

Previous studies have explored the advantages of pre-procedural ultrasound-guided neuraxial blockade. However, due to different populations and patient characteristics, including obstetric, obese and elderly, results were conflicting [17,18,25,26]. In elderly populations, comparative studies investigating conventional surface-landmark guided and pre-procedural ultrasound-guided spinal anesthesia have demonstrated that pre-procedural ultrasound guidance may be superior to the conventional midline approach [17,18]. In the present study, with the paramedian technique for spinal anesthesia in elderly patients, we found that the total number of needle redirection and insertion attempts were less by more than two-fold compared with the pre-procedural ultrasound-guided paramedian technique. In addition, it also saved significant time and patient discomfort from repeated needle redirection attempts.

We report fewer needle redirection and insertion attempts, and a greater success rate of dural puncture with first needle insertion/direction and attempt using a pre-procedural ultrasound-guided paramedian technique than those in previous studies [17,18]. This may be due to various reasons. First, the patient characteristics were different. Although our study subjects were older, their body size was smaller. Second, for guiding needle direction, we also measured the depth from the skin to intrathecal space in both ultrasound views (i.e., TM and PSO) and calculated the optimum angle to pierce, in contrast to previous studies in which the skin of the patients was marked as the needle insertion point. This may have led to the misalignment of the spinal needle direction, resulting in an increased number of needle redirections and attempts, and possible complications. Srinivasan et al. [18] found no incidence of radicular pain or traumatic puncture; however, 3 patients in their study experienced paresthesia during insertion of the spinal needle compared with none who underwent the pre-procedural ultrasound-guided paramedian technique (i.e., group PP) in our study.

In group CP, we used the recommended paramedian approach spinal anesthesia at 1 cm lateral and 1 cm caudal of the edge of the L3 spinous process with an angle of 10° to 15° off the sagittal plane in a cephalomedial plane [1]. However, the findings from group PP, in which we performed the pre-procedural ultrasound-guided paramedian technique using the optimal needle insertion angle determined by Pythagoras' theorem, may indicate that the optimal needle insertion angle should be individualized among different populations. Our results found that the optimum angle of needle insertion in the lateral-to-median plane was an average of 20°, and the distance from midline to paramedian insertion point was approximately 1.7 cm (Table 2). Moreover, the angle of needle

direction in the transverse plane and the distance from midline will increase in patients with lower BMI, especially those with BMI<20 kg/m^2. These findings are consistent with a previous study [19]. Therefore, the use of pre-procedural ultrasound-guided spinal anesthesia may be preferable in small, elderly patients. We also recorded grading of the ultrasound view, separated the operators performing pre-procedural guides and spinal anesthesia, and used the same interspinous space for spinal anesthesia in both groups. Therefore, any potential biases that may have been present in previous studies should have, at least, been mitigated.

There were some limitations to our study. First, the quality and technique of ultrasound may have limitations because sonograms of the lumbar spine, including the ligamentum flavum, posterior dura, spinal canal and posterior aspect of the vertebral body, may have been obscured in some patients such as the elderly [17]. Although the use of high-quality ultrasound machines may improve imaging quality, they may not be widely available. Second, skin distortion in elderly patients with mobile and loose skin may result in an inaccurate needle insertion point, particularly when performing the ultrasound scan in the PSO view. Third, the different characteristics of the ligamentum flavum/dura complex among patients (such as length) might be associated with different numbers of needle insertion attempts or redirections. However, in our study, baseline characteristics of patients, such as age, body weight, height, and grading of the ligamentum flavum/dura complex, were similar between both groups. Therefore, these factors should have had no or minimal effects on our results. Finally, the high success rate of pre-procedural ultrasound-guided spinal anesthesia may be due to the fact that we performed it in a simulation model before the study; therefore, the optimal angle of needle direction may not necessarily be achieved in all cases.

In conclusion, a pre-procedural ultrasound-guided paramedian technique for spinal anesthesia in elderly patients significantly decreased the number of needle insertion/redirection attempts and led to successful dural puncture. It may also decrease the incidence of complications compared with the conventional paramedian technique. Furthermore, pre-procedural ultrasound may be particularly advantageous in small elderly patients with BMI<20 kg/m^2.

Acknowledgements

The authors thank Professor Henry Wilde for manuscript editing, and Dr. Chananya Hokierti for the production of illustrations in this study.

Clinical Trial Registration

TCTR20161206002, Thai Clinical Trials Registry (TCTR).

Conflicts of Interest

No external funding and no other competing interests declared.

References

1. Brull R, MacFarlane AJR, Chan VWS (2015) Spinal, epidural, and caudal anesthesia: Miller's Anesthesia. (8th edn), WB Saunders Company, Philadelphia, London, Toronto.
2. Boon JM, Prinsloo E, Raath RP (2003) A paramedian approach for epidural block: an anatomic and radiologic description. Reg Anesth Pain Med 28: 221-227.
3. Brull R, McCartney CJ, Chan VW, El-Beheiry H (2007) Neurological complications after regional anesthesia: contemporary estimates of risk. Anesth Analg 104: 965-974.
4. Kent CD, Bollag L (2010) Neurological adverse events following regional anesthesia administration. Local Reg Anesth 3: 115-123.
5. Likar R, Mathiaschitz K, Spendel M, Krumpholz R, Martin E (1996) Acute spinal subdural hematoma after attempted spinal anesthesia. Anaesthesist 45: 66-69.
6. Barak M, Fischer D, Gat M, Katz Y (2004) Retroperitoneal hematoma after spinal anesthesia with the paramedian approach. Anesth Analg 98: 851-853.
7. Janik R, Dick W (1992) Post spinal headache. Its incidence following the median and paramedian techniques. Anaesthesist 41: 137-141.
8. Rhee WJ, Chung CJ, Lim YH, Lee KH, Lee SC (2010) Factors in patient dissatisfaction and refusal regarding spinal anesthesia. Korean J Anesthesiol 59: 260-264.
9. Chong SE, Mohd Nikman A, Saedah A, Wan Mohd Nazaruddin WH, Kueh YC, et al. (2017) Real-time ultrasound-guided paramedian spinal anaesthesia: evaluation of the efficacy and the success rate of single needle pass. Br J Anaesth 118: 799-801.
10. Elsharkawy H, Maheshwari A, Babazade R, Perlas A, Zaky S, et al. (2017) Real-time ultrasound-guided spinal anesthesia in patients with predicted difficult anatomy. Minerva Anestesiol 83: 465-473.
11. Chin KJ, Perlas A, Chan V (2015) The ultrasound-assisted paraspinous approach to lumbar neuraxial blockade: a simplified technique in patients with difficult anatomy. Acta Anaesthesiol Scand 59: 668-673.
12. Chin KJ, Perlas A, Singh M, Arzola C, Prasad A, et al. (2009) An ultrasound-assisted approach facilitates spinal anesthesia for total joint arthroplasty. Can J Anaesth 56: 643-650.
13. Chin KJ, Ramlogan R, Arzola C, Singh M, Chan V (2013) The utility of ultrasound imaging in predicting ease of performance of spinal anesthesia in an orthopedic patient population. Reg Anesth Pain Med 38: 34-38.
14. Chin KJ, Karmakar MK, Peng P (2011) Ultrasonography of the adult thoracic and lumbar spine for central neuraxial blockade. Anesthesiology 114: 1459-1485.
15. Borges BC, Wieczorek P, Balki M, Carvalho JC (2009) Sonoanatomy of the lumbar spine of pregnant women at term. Reg Anesth Pain Med 34: 581-585.
16. Grau T, Leipold RW, Horter J, Conradi R, Martin EO, et al. (2001) Paramedian access to the epidural space: the optimum window for ultrasound imaging. J Clin Anesth 13: 213-217.
17. Chin KJ, Perlas A, Chan V, Brown-Shreves D, Koshkin A, et al. (2011) Ultrasound imaging facilitates spinal anesthesia in adults with difficult surface anatomic landmarks. Anesthesiology 115: 94-101.
18. Kallidaikurichi Srinivasan K, Iohom G, Loughnane F, Lee PJ (2015) Conventional landmark-guided midline versus preprocedure ultrasound-guided paramedian techniques in spinal anesthesia. Anesth Analg 121: 1089-1096.
19. Puigdellívol-Sanchez A, Reina MA, Sala-Blanch X, Pomés-Talló J, Prats-Galino A (2016) Pitagoras and cosines: The skin-dural sac distance and optimal angles in paramedian spinal anesthesia. Clin Anat 29: 1046-1052.
20. Scapinelli R (1989) Morphological and functional changes of the lumbar spinous processes in the elderly. Surg Radiol Anat 11: 129-133.
21. Ahsan-ul-Haq M, Amin S, Javaid S (2005) Paramedian technique of spinal anesthesia in elderly patients for hip fracture surgery. J Coll Physicians Surg Pak 15: 160-161.
22. Muranaka K, Mizutani H, Seo K, Yoshida M, Gohara T, et al. (2001) A comparison between midline and paramedian approaches for combined spinal-epidural anesthesia. Masui 50: 1085-1088.
23. Leeda M, Stienstra R, Arbous MS, Dahan A, Th Veering B, et al. (2005) Lumbar epidural catheter insertion: the midline vs. the paramedian approach. Eur J Anaesthesiol 22: 839-842.

24. Rabinowitz A, Bourdet B, Minville V, Chassery C, Pianezza A, et al. (2007) The paramedian technique: a superior initial approach to continuous spinal anesthesia in the elderly. Anesth Analg 105: 1855-1857.

25. Ansari T, Yousef A, El Gamassy A, Fayez M (2014) Ultrasound-guided spinal anaesthesia in obstetrics: is there an advantage over the landmark technique in patients with easily palpable spines? Int J Obstet Anesth 23: 213-216.

26. Arzola C, Mikhael R, Margarido C, Carvalho JC (2015) Spinal ultrasound versus palpation for epidural catheter insertion in labour: A randomised controlled trial. Eur J Anaesthesiol 32: 499-505.