e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(9); 141-151

Original Research Article

Comparison between the Efficacy of Preprocedural Ultrasound-Guided Paramedian Approach & Conventional Landmark Guided Paramedian Approach in an Obese Patient

Seema Singh[1], Parli Raghavan Ravi[2], Anushree Mishra[3], Abhishek Mishra[4]

[1]MBBS, MD Anesthesiology & Junior Consultant, Manipal Hospital, Dwarka, New Delhi, India
[2]MBBS, MD Anesthesiology & Senior Consultant, Sultan Qaboos Comprehensive Cancer Care and Research Centre, Muscat, Oman
[3]MBBS, MS & Graded Specialist, Ophthalmology, Command Hospital, Udhampur, India
[4]MBBS, MD & Classified Specialist, Radiology, Command Hospital, Udhampur, India

Received: 20-06-2023 / Revised: 21-07-2023 / Accepted: 25-08-2023
Corresponding author: Dr. Abhishek Mishra
Conflict of interest: Nil

Abstract:

Background: The use of ultrasound imaging techniques in regional anaesthesia is rapidly becoming an area of increasing interest. It represents one of the largest changes that the field of regional anaesthesia has seen. Earlier electrical stimulation or paraesthesia, both of which relied on surface landmark identification, was used for regional anaesthesia. However, landmark techniques have limitations; variations in anatomy and nerve physiology as well as equipment accuracy, have had an effect on success rates and complications. The introduction of ultrasound may go some way towards changing this.

Aim: To evaluate the efficacy of two modalities of spinal anaesthesia preprocedural ultrasound-guided paramedian approach and conventional landmark-guided paramedian approach in an obese patient undergoing lower abdomen, perenial and lower limb surgeries.

Methods and Materials: The study was a randomized single blinded controlled study. A total of 80 subjects were included in the final study, with 40 subjects in each of the study groups.

Group 1 (US group) participants received Preprocedural USG guided paramedian spinal anaesthesia and Group 2 (LM group) received landmark-guided Conventional midline spinal anaesthesia. Following variables were compared between the two groups, number of attempts, number of passes, time taken for identifying landmark (sec), time for a successful lumbar puncture (sec), number of attempts, number of passes, time taken for performing successful lumbar puncture defined as the time taken from insertion of the introducer needle to completion of the injection.

Results: Among the people in landmark (LM) group, the median number of passes was 5.50 (IQR 4 to 7) and it was 4 (IQR 3 to 4) in people with ultrasound-guided (US) spinal anaesthesia. The difference in the number of passes between the group was statistically significant (P Value <0.001). Among the people in landmark (LM) group, the median time for identifying space was 38.19 sec (IQR 25.05 to 57.95) and it was 78.35 sec (IQR 60.20, 90.67) in ultrasound-guided (US) group. The difference in the identifying space (sec) between groups was statistically significant (P Value <0.001). Among landmark (LM) group, 2 (5%) people were converted to GA. Among the ultrasound-guided (US) group, 3 (7.5%) people were converted to GA. Among the people with landmark (LM), the median spinal injection was 88.31 sec (IQR 51.74 to 120.19) and it was 64.32 sec (IQR 51.46 to 88.31) in people with ultrasound-guided (US). The difference in the time for a successful lumbar puncture (sec)between the group was statistically significant (P Value 0.048).

Conclusion: Ultrasonography can be a useful adjunct to safe spinal anaesthesia and also it facilitates the performance of spinal anaesthesia in the non-obstetric patient population with difficult anatomic landmarks, like obese patients.

Keywords: Efficacy, preprocedural ultrasound-guided paramedian approach, conventional landmark guided paramedian approach, obese patient

Introduction

Spinal anaesthesia is widely performed using a surface landmark-based "blind" technique. Multiple passes and attempts while administering spinal anaesthesia are associated with a greater incidence of post-dural puncture headache, paraesthesia and spinal hematoma.[1,2]

Real-time and preprocedural neuraxial ultrasound techniques have been used successfully to perform spinal anaesthesia. Information on the use of real-time ultrasound-guided spinal anaesthesia has, to date, been limited to case series and case reports.[3-5] Its use may be limited by the requirement for wide-bore needles and the technical difficulties associated with simultaneous ultrasound scanning and needle advancement.[6] The use of preprocedural ultrasound has been shown to increase the first-pass success rate for spinal anaesthesia only in patients with difficult surface anatomic landmarks.[7]

Studies on preprocedural ultrasound-guided spinal techniques have focused on a midline approach using a transverse median (TM) view. The parasagittal oblique (PSO) view consistently offers a better ultrasound view of the neuraxis compared with TM views.[8,9] However, very few studies have been conducted to assess whether these superior PSO views translate into easier paramedian needle insertion.[10,11]

The use of ultrasound imaging techniques in regional anaesthesia is rapidly becoming an area of increasing interest. It represents one of the largest changes that the field of regional anaesthesia has seen. Earlier electrical stimulation or paraesthesia, both of which relied on surface landmark identification, was used for regional anaesthesia. However, landmark techniques have limitations; variations in anatomy and nerve physiology, as well as equipment accuracy, have had an effect on success rates and complications. The introduction of ultrasound may go some way towards changing this.[12,13]

If we want the use of ultrasound to become more widespread amongst anaesthetists, then it must be shown to be clinically effective, practical and cost-effective[10]. The use of ultrasound guidance in daily clinical practice requires a degree of training and understanding of the equipment and technology.

US-guided Central Neuraxial block is a promising alternative to traditional landmark-based techniques6. It is non-invasive, safe, simple to use, can be quickly performed, does not involve exposure to radiation, provides real-time images and is free from adverse effects. US guidance may also allow the use of central neuraxial block in patients who in the past may have been considered unsuitable for such procedures due to abnormal spinal anatomy.[14,15]

Spinal anaesthesia may be challenging in patients with poorly palpable surface landmarks or abnormal spinal anatomy. Pre-procedural ultrasound of the lumbar spine can help by providing additional anatomical information, thus permitting more accurate estimation of the appropriate needle insertion site and trajectory.[16]

Hence present study is aimed at evaluating the efficacy of two modalities of spinal anaesthesia preprocedural ultrasound-guided paramedian approach and conventional landmark-guided paramedian approach in an obese patient undergoing lower abdomen, perenial and lower limb surgeries.

Methods and materials

The study was a randomized single blinded controlled study. A total of 80 subjects were included in the final study, with 40 subjects in each of the study groups.

Group 1 (US group) participants received Preprocedural USG guided paramedian spinal anaesthesia and Group 2 (LM group) received landmark-guided Conventional midline spinal anaesthesia. The study population included all subjects scheduled for the elective lower abdomen, perineal and lower limb surgeries under spinal anaesthesia were included. Randomization was done using computer generated random number sequence.Allocation concealment was done using serially number opaque envelop method. Investigator blinding was not possible, considering the nature of the intervention.

Institutional ethical committee approval was obtained. Informed written consent was obtained from participating patients. Confidentiality of the study participants was maintained throughout the study.

As with other uses of ultrasound, specific training is required to identify correctly the landmarks and interspaces necessary for neuraxial blockade. Therefore 25 scout scans were performed on healthy individuals before performing on patients in study group.

Inclusion Criteria

1. Patient aged between 20-85 yrs,
2. ASA grade II or III Obese with BMI > 30kg/Sqm
3. Patients giving valid informed consent
4. Patient scheduled for the elective lower abdomen, perineal and lower limb surgeries under spinal anaesthesia.

Exclusion Criteria

1. Contraindications to Neuraxial block.
2. Pregnant patient
3. Patient refusal for spinal anaesthesia

Study procedure

All patients were visited on the day prior to the surgery and explained in detail about the anaesthetic procedure in detail in their vernacular language and written and informed consent was obtained.

All patients were kept nil orally from 12 O'clock midnight prior to the day of surgery. Before spinal anaesthesia, all the patients were preloaded with 500ml of lactated Ringer's solutions 15 minutes before surgery. Patients with oxygen saturation, blood pressure (systolic, diastolic, mean arterial pressure), electrocardiogram were monitored. Basal values were recorded. The patients were placed in a sitting position and the dural puncture was performed at L3-L4, L4-L5 interspace. Hyperbaric bupivacaine 0.5% was injected intrathecally (2.5-3 ml). The volume of the local anaesthetic, the volume of preloading fluid, use of vasopressors were determined by the attending anesthesiologists and was not affected by inclusion in the study.

The patient was positioned sitting on a level trolley with feet resting on a footrest. They were given a pillow to hug and requested to maintain an arched back posture with an assistant holding the patient to aid positioning. No sedation was given prior to or during the administration of spinal anaesthesia.

Under strict asepsis local infiltration of 2% lignocaine was done. Using paramedian approach dural puncture was carried out at the L3-L4/L4-L5 level. About 2.5-3.5 ml of Hyperbaric Bupivacaine 0.5% was injected intrathecal in both the group.

In US group L3-L4, L4-L5 subarachnoid space was located by the use of Mind ray USG machine using 2 to 5 MHz linear probe. In group1 US, a portable ultrasound machine (Mindray) was used for initial pre-procedural marking. The L3-L4, L4-L5, interspinous space with the best image of the anterior complex (ligamentum flavum dura complex- LFD) and posterior complex (posterior longitudinal ligament- PLL) was obtained. At these selected interspaces and with the probe positioned to obtain the clearest ultrasound image, a skin marker was used to mark the midpoint of the long border of the probe and the midpoints of the short borders of the probe. At the same horizontal level as the midpoint of the long border of the probe, the mid-point of the line drawn between the two short border mid-points of the probe was used as a paramedian insertion point for the spinal needle. Spinal anaesthesia is then administered based on these landmarks. In LM group L3-L4, L4-L5 interspinous space was identified by using the conventional technique by palpation of iliac crests and dorsal spinous processes. A standard blanket was used to cover the chest and upper limb of the patients. All the preloading fluids & drugs were given at room temperature. The ambient temperature of operation theatre was kept between 23-25^{o}C.

Patient's vital parameters were monitored throughout the procedure. Patients were assessed for the feeling of nausea, dizziness and purities and observed for vomiting. If reqd was treated with Metoclopramide 10 mg I.V. Hypotension (SBP < 100 or fall > 20% baseline values) was treated with Inj Ephedrine 6 mg I.V. and heart rate less than 50 bpm was considered as bradycardia and treated with Inj. Atropine 0.6 mg I.V.

Following variables were compared between the two groups:-

1. Number of attempts
2. Number of passes
3. Time is taken for identifying landmark (sec)
4. Time for a successful lumbar puncture (sec)
5. A number of attempts - defined as the number of times the spinal needle was withdrawn from the skin and reinserted.
6. Number of passes - defined as the number of forwarding advancements of the spinal needle in a given interspinous space (i.e. withdrawal and redirection of the spinal needle without exiting the skin)
7. Time for identifying landmarks in group1 (US) it was defined as the time from which the ultrasound probe was placed on the skin to the anesthesiologist declaring that the markings are completed. In group2 (LM) it was defined as the time from which the anesthesiologist started palpating to identify the landmarks to completion of the process as declared by the anesthesiologist.
8. Time taken for performing successful lumbar puncture defined as the time taken from insertion of the introducer needle to completion of the injection.

Results

A total of 80 subjects were included in the final analysis. Among the study population, 40 (50%) was a landmark (LM) and the remaining 40 (50%) were ultrasound guided (US). (Table 3). Among the people with, landmark (LM), the median age was 59.50 (IQR 52.25 to 65.75) and it was 58.50 (IQR 50.25 to 65.75) in people with ultrasound-guided (US). The difference in the age between the group was statistically not significant (P Value 0.965). (Table 1 & Figure 1). In landmark (LM) group 15 (37.5%) were in male and the remaining 25 (62.5%) were in the female. In ultrasound-guided (US) group 12 (30%) were in male and the remaining 28 (70%) were female. The difference in the proportion of group between genders was statistically not significant (P value 0.478). (Table 2 & figure 2). Among the people with a landmark (LM), the median BMI was 34.9 (IQR 33.1 to 36.40) and it was 34.9 (IQR 33.1 to 36.35) in people with ultrasound-guided (US). The difference in the BMI between the group was statistically not significant

(P Value 0.958). (Table 3 & Figure 3). Among the people in landmark (LM) group, the median number of attempts was 3 (IQR 2 to 4) and it was 2 (IQR 1 to 2) in ultrasound-guided (US) group. The difference in the number of attempts between the group was statistically significant (P Value <0.001) (Table 4 & Figure 4).

Among the people in landmark (LM) group, the median number of passes was 5.50 (IQR 4 to 7) and it was 4 (IQR 3 to 4) in people with ultrasound-guided (US) spinal anaesthesia. The difference in the number of passes between the group was statistically significant (P Value <0.001). (Table 5 & Figure 5). Among the people in landmark (LM) group, the median time for identifying space was 38.19 sec (IQR 25.05 to 57.95) and it was 78.35 sec (IQR 60.20, 90.67) in ultrasound-guided (US) group. The difference in the identifying space (sec) between groups was statistically significant (P Value <0.001). (Table 6 & Figure 6). Among landmark (LM) group, 2 (5%) people were converted to GA. Among the ultrasound-guided (US) group, 3 (7.5%) people were converted to GA. (table 7). Among the people with landmark (LM), the median spinal injection was 88.31 sec (IQR 51.74 to 120.19) and it was 64.32 sec (IQR 51.46 to 88.31) in people with ultrasound-guided (US). The difference in the time for a successful lumbar puncture (sec)between the group was statistically significant (P Value 0.048). (Table 8 & Figure 7).

Table 1: Descriptive analysis of group in the study population (N=80)

Group	Frequency	Percentages
Landmark (LM)	40	50.00%
Ultrasound Guided (US)	40	50.00%

Table 2: Comparison of median value in age between study group (N=80)

Group	Age(yrs) Median (IQR)	Mann Whitney U test (P value)
Landmark (LM)	59.50 (52.25, 65.75)	0.965
Ultrasound guided (US)	58.50 (50.25, 65.75)	

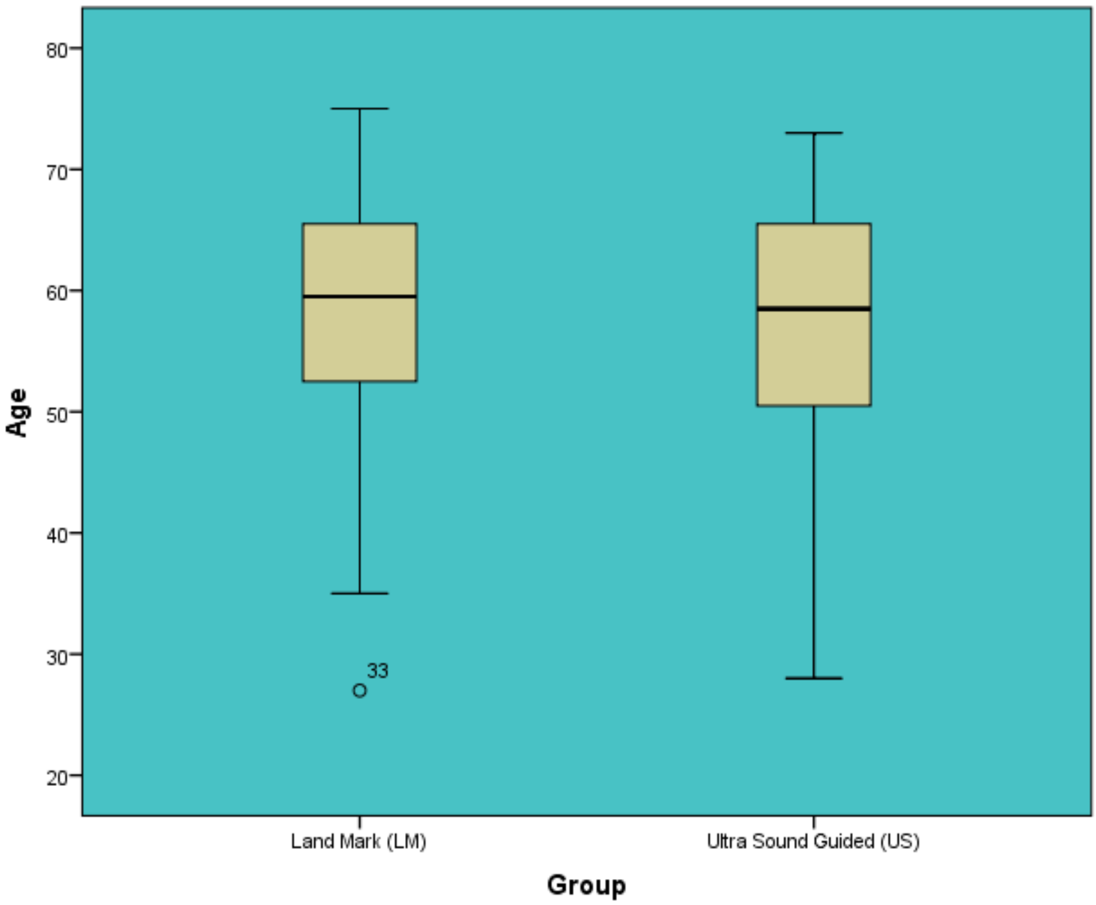

Figure 1: Box plots of comparison of median value in age between study group (N=80)

Table 2: Comparison of the group with the gender of the study population (N=80)

Gender	Group		Chi square	P-value
	LM(N=40)	US (N=40)		
Male	15 (37.5%)	12 (30%)	0.503	0.478
Female	25 (62.5%)	28 (70%)		

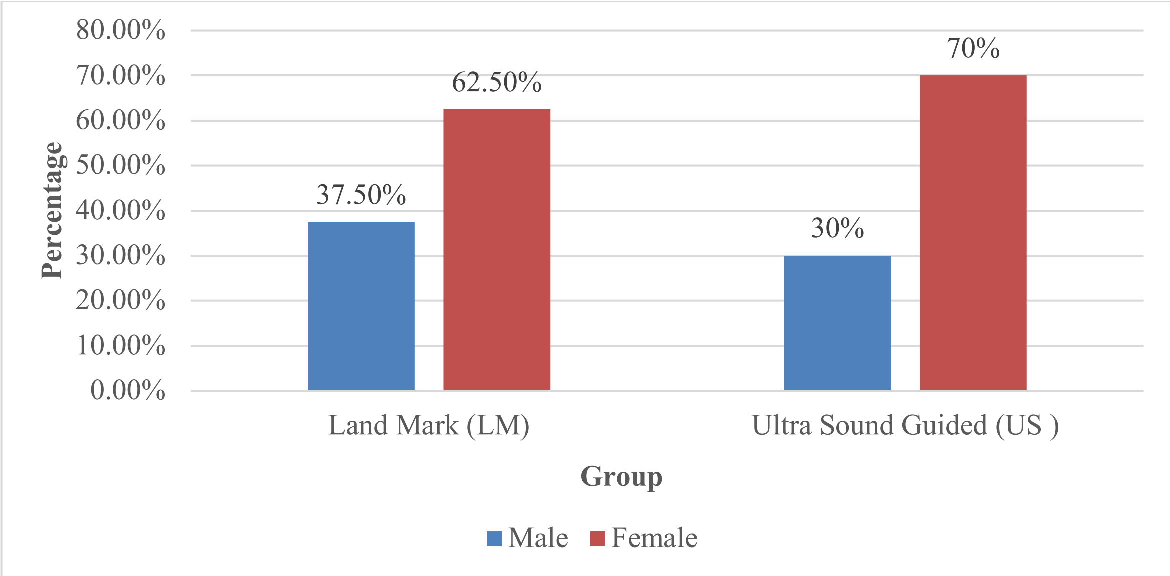

Figure 2: Cluster bar chart of comparison of group with the gender of the study population (N=80)

Table 3: Comparison of median value in BMI between study group (N=80)

Group	BMI Median (IQR)	Mann Whitney U test (P value)
Land mark (LM)	34.9 (33.1, 36.40)	0.958
Ultrasound guided (US)	34.9 (33.1, 36.35)	

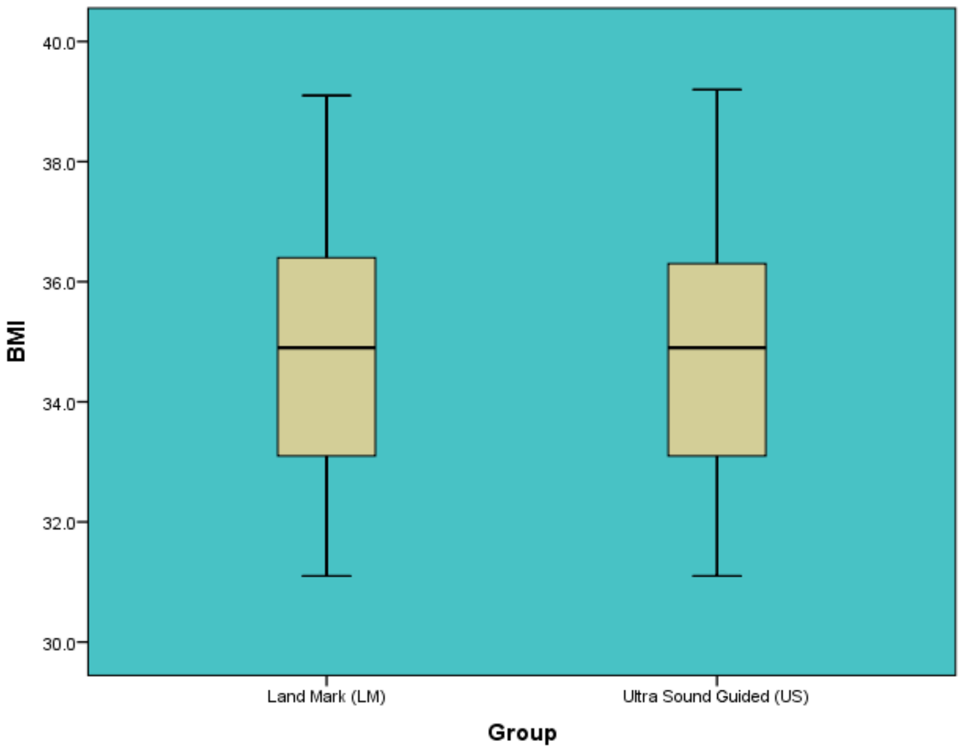

Figure 3: Box plots of comparison of median value in BMI between study group (N=80)

Table 4: Comparison of median value in a number of attempts between the study groups

Group	Number of Attempts Median (IQR)	Mann Whitney U test (P value)
Landmark (LM)(N=40)	3 (2,4)	<0.001
Ultrasound guided (US)(N=40)	2 (1,2)	

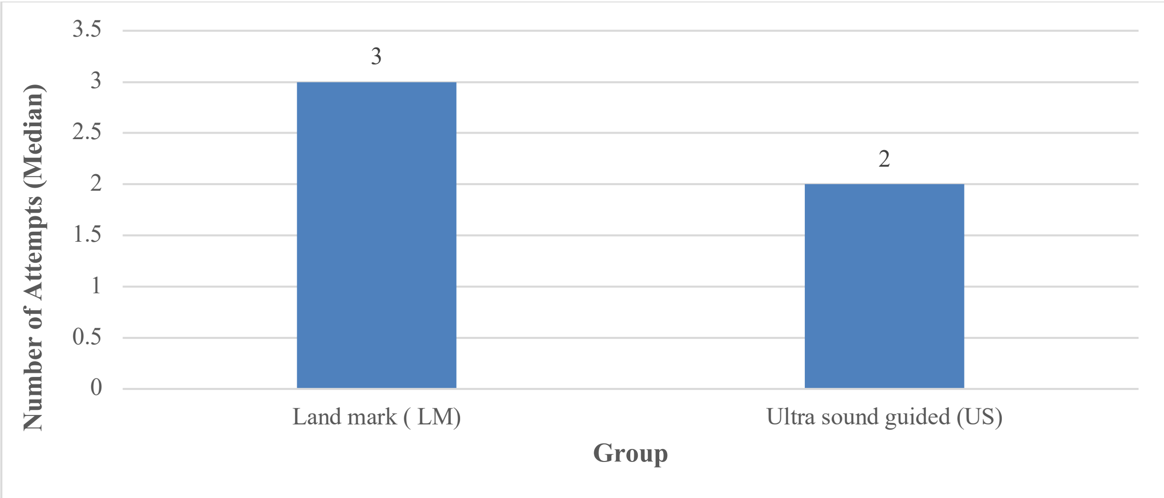

Figure 4: Bar chart of comparison of median value in a number of attempts between study groups

Table 5: Comparison of median value of number of passes between the study groups

Group	Number of Passes Median (IQR)	Mann Whitney U test (P value)
Land mark (LM) (N=40)	5.50 (4, 7)	<0.001
Ultrasound-guided (US) (N=40)	4 (3,4)	

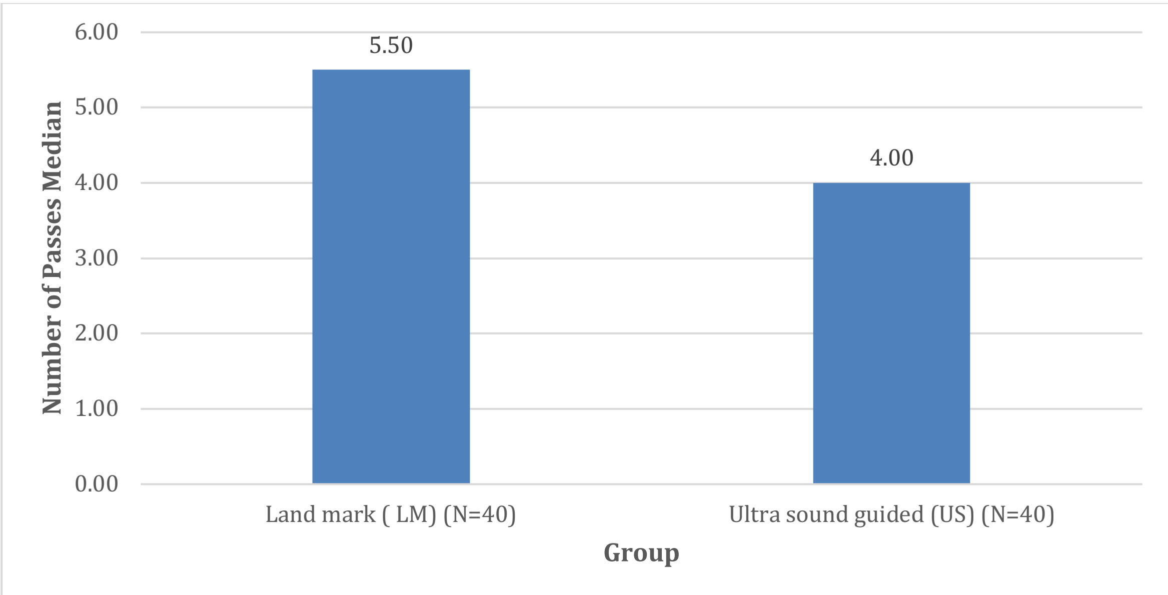

Figure 5: Bar chart of Comparison of median value in a number of passes between the study groups

Table 6: Comparison of the median value in the time taken for identifying space (sec) between the study groups

Group	Time is taken for Identifying Space (sec) Median (IQR)	Mann Whitney U test (P value)
Land mark (LM) (N=40)	38.19 (25.05, 57.95)	<0.001
Ultra sound guided (US) (N=40)	78.35 (60.20, 90.67)	

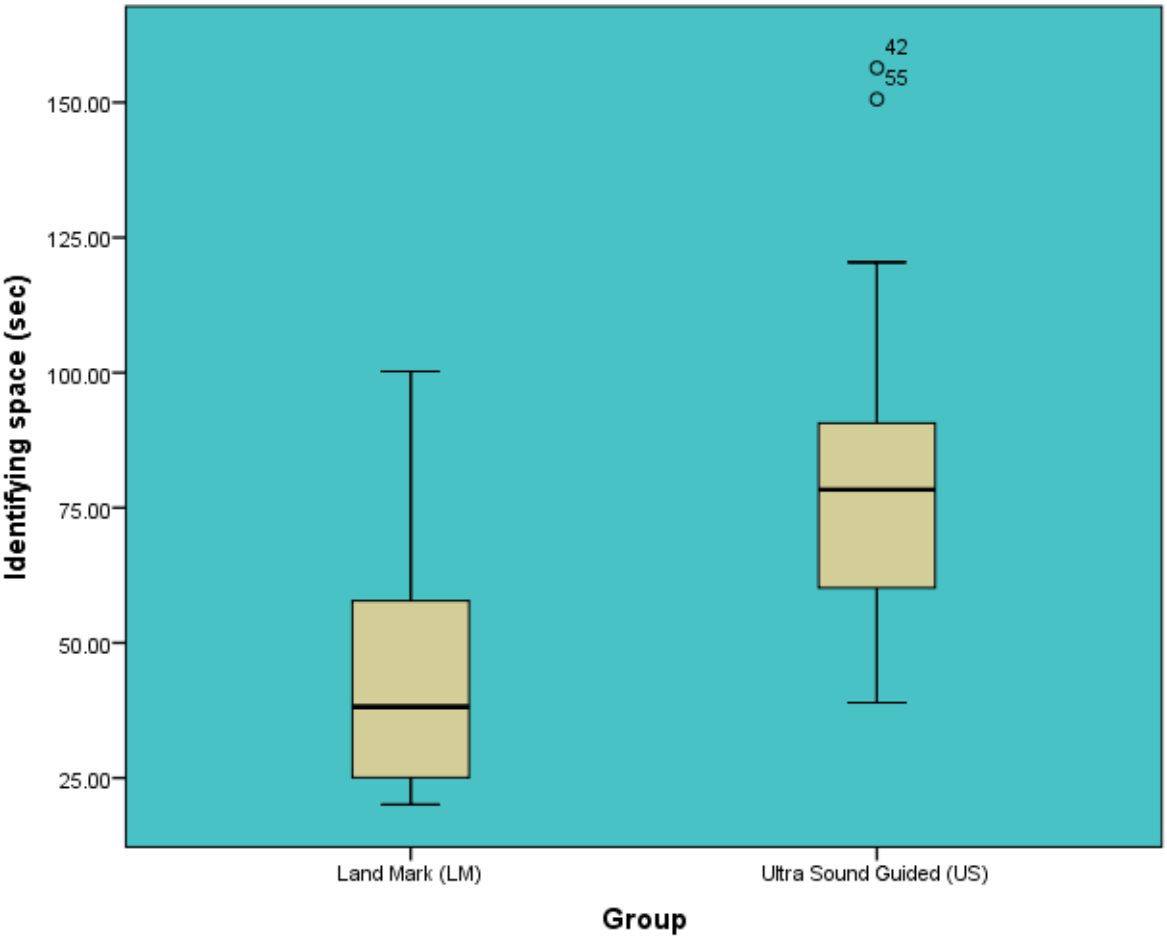

Figure 6: Box plots of comparison of median value in the time taken for identifying space (sec) between the study groups.

Table 7: Comparison of the group with success (N=80)

Success	Group		Chi square	P-value
	Landmark (LM)	Ultrasound Guided (US)		
Success	38 (95%)	37 (92.5%)	0.213	0.644
Converted to GA	2 (5%)	3 (7.5%)		

Table 8: Comparison of median value in time for a successful lumbar puncture (sec) between study groups

Group	Time for a successful lumbar puncture (sec) Median (IQR)	Mann Whitney U test (P value)
Landmark (LM) (N=38)	88.31 (51.74, 120.19)	0.048
Ultrasound guided (US) (N=37)	64.32 (51.46, 88.31)	

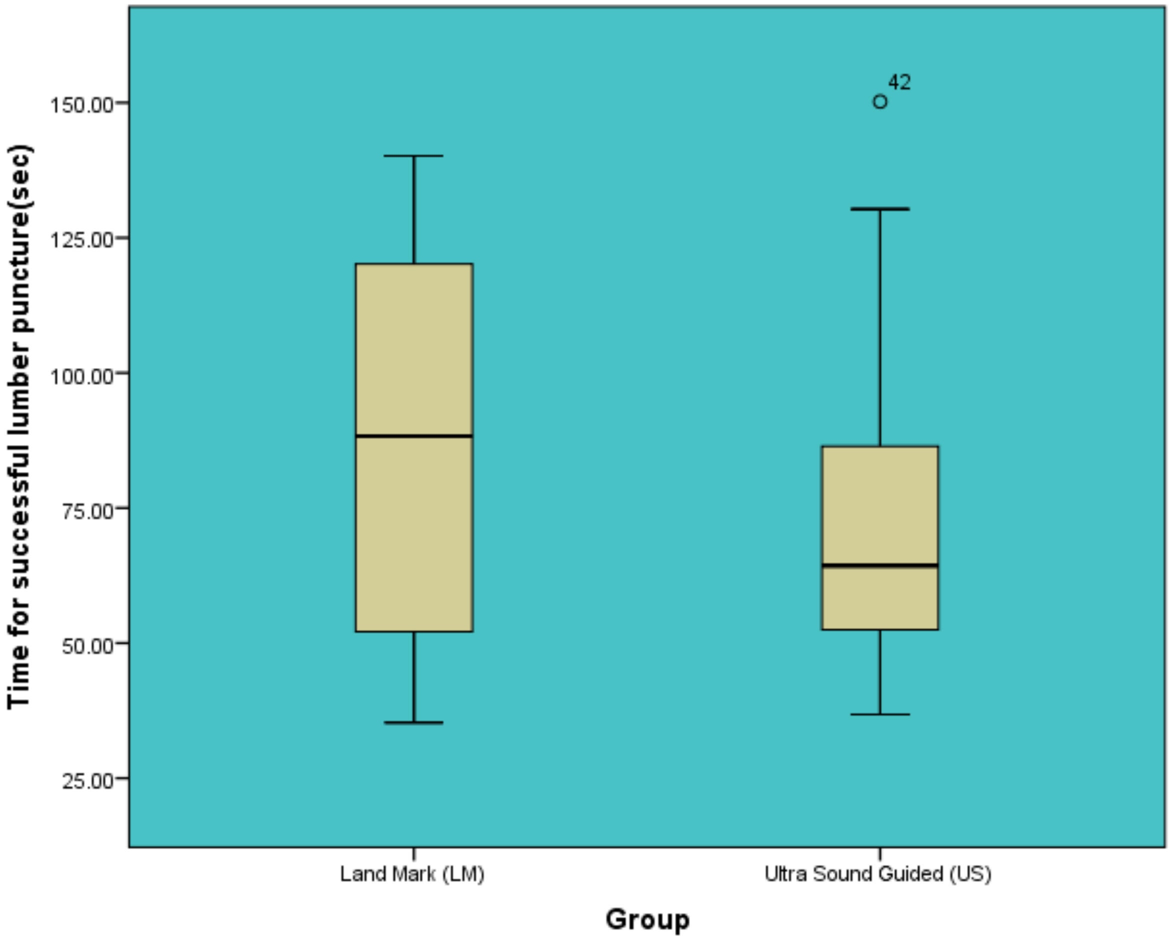

Figure 7: Box plots of comparison of median value in time for successful lumbar puncture between the study groups

Discussion

For the identification of a safe lumbar interspace, clinicians often rely on three beliefs. Firstly, an imaginary line (defined by Tuffier) joining the iliac crests is assumed to be close to the fourth lumbar spine, but it may cross higher or lower.[17] Secondly, classical teaching is that of spinal cord ends at L1–2, but it has been known for over half a centurythat this is the mean position of a normal distribution. Several series describe the spinal cord extending to the body of L3 in 1–3% of cases and to L2 or lower in almost 50% of cases, with increased variability in women.[18] Thirdly, reliance may be placed on a lack of paraesthesia, but this confidence may be misplaced if the latter does not happen during cordotomy with a 22G needle until electrical stimulation is applied.[19] A technique to improve the localization of a lumbar interspace would be an advantage.

Neuraxial ultrasound is a recent development in the field of regional anaesthesia. This technique allows the operator to preview spinal anatomy, identify midline and determine the inter-space for needle insertion. A “pre-procedural” ultrasound examination of the spine accurately delineates the underlying relevant anatomy, thus aiding in successful insertion of a spinal or epidural needle; this has also been termed “ultrasound-assisted” neuraxial blockade.[20,21]

Of the total 80 patients included in the study, an equal proportion of (40 each) belonged to a landmark (LM) guided and US-guided spinal anaesthesia groups. Comparatively all studies have included more patients. In their randomized controlled trial, Abdelhamid et al.[20] studied 90 patients; it was 1007 and 12022 in two separate studies by Srinivasan et al [7]. while Lim et al.[2] studied 170 patients. However, Chin et al.[1] in their clinical trial studied lesser (60) patients undergoing lower limb orthopaedic surgery.

Regarding the number of attempts for successful anaesthesia, Srinivasan et al.[22] noted equal attempts in both groups (2 in the LM group and 2.07 in the US-guided group. In comparison, the number of attempts was similar in the study among the US-guided group (2), which was, however, significantly (P Value <0.001) lesser when compared to the LM group (3). However, in their previous study Srinivasan et al. 7 reported US method required significantly (P=0.0021) lesser attempts (1.28) compared to the LM method (1.98). Chin et al.[1] also found the US-guided method requiring significantly (P Value <0.001) lesser attempts (1) compared to the LM method (2).

The number of passes was significantly (P Value <0.001) more in the LM group (5.50) compared to the US-guided group (4). A similar finding of 4 passes was observed in the study by Srinivasan et al.[7] for the latter method. However, the former required considerably more passes (8.2) and the difference was statistically significant (P=0.01) indicating the inaccuracies in locating the landmarks. Chin et al. in their study on orthopaedic patients also found US-guided method requiring significantly (P Value <0.001) lesser passes (6) than the LM method (13).Though, the average number of passes similar in both groups reported by Srinivasan et al.[22] (6.13 in LM group and 6.95 in the US-guided group), the latter method required a number of passes in relation to the present study.

The number of passes was more in the LM group could be due to many reasons. First, the patient population was different. Mean age and body mass index in our study was 59 years and 34.9 kg/m^2, respectively, versus 63-68 years and 28.5-30.5 kg/m^2 in the referenced studies.[7,22] Second, in the study by Kim et al.[23] ,the number of passes was self-reported, whereas, in our study, it was recorded by an independent observer. This is important because it has been shown that the self-reported number of passes is always lower than the actual number of passes.[7]

We note a reduction in a number of passes required to enter the subarachnoid space because of the following probable reasons. First, the age of our population group was, on average, 64.3 years (SD = 12.8) and spinal anaesthesia has been shown to be more difficult in an older population compared with a general adult population.[16] Second, we used a paramedian approach to the neuraxis (guided by ultrasound), which has not been studied so far. In the presence of interspinous ligament calcification and an inability to achieve adequate flexion (both of which are common in the elderly), this paramedian approach might be valuable. It has also been shown that both the length and the width of the lumbar spinous process increase significantly with ageing, which further narrows the interspinous space available for a midline approach.[24] The interlaminar space is least affected by changes attributable to ageing and offers a potential window for spinal anaesthesia.

When the median time taken for identifying space for each group was compared, it was 38. 19 seconds for the LM group, while it was twice as high (78.35 seconds) for the US-guided group which was statistically significant (P Value <0.001). The average time taken in the study by Srinivasan et al.[22] was very less (12.3 seconds) for LM group than that of US-guided group (105.1 seconds), which were, in turn, were in line with their earlier study findings (14.6 seconds for the former method, 96.1 seconds for the latter) and this finding was statistically significant (P=0.0002).7In a study by Chin et al.[1] ,using similar endpoints, this process in the ultrasound group took 240 seconds longer. The difference might be because of the fact that in their study, scanning was done in patients with difficult surface landmarks and it involved marking 3 interspinous spaces.

The technical difficulty of the neuraxial blockade is measured using two main parameters: the number of needle manipulations required for success and the time taken to perform the block.[24] Of the two, the previous is more important because multiple needle insertions are an independent predictor of complications, such as inadvertent dural puncture, vascular puncture and paresthesia1.Elicitation of paresthesia, in turn, is a significant risk factor for persistent neurologic deficit after spinal anesthesia.[25,26]

Regarding the time taken for successful lumbar puncture between the groups, the US-guided method took significantly (P Value =0.048) less time (64.32 seconds) compared to LM method (88.31 seconds). A similar finding was seen in the study by Srinivasan et al.[7] with the former method requiring less time (97.8 seconds) for successful procedure compared to the latter method (169.9 seconds). However, the overall time taken by both the procedures was higher in the study of Srinivasan et al.[22] [US-guided procedure took more time (137.2 seconds) than LM group (127.4 seconds)], which was contrasting to our study findings.

The successfulness of both the methods was comparable (95% in LM group; 92.5% in US-guided group) with only 2 (5%) cases converted to GA in the LM group and 3 (7.5%) of them needed the same in a US-guided group. Similarly, Srinivasan et al. [22] noted slightly more cases in the US-guided group (3) requiring GA in relation to LM group (2). Also using a midline approach of US-guided spinal anaesthesia Abdelhamid et al. [20] reported significantly improved success rate (the subjects were younger). However, Lim et al. [2] who studied elderly subjects like the present study found no difference between the LM group and US-guided paramedian approach.

There are consistent data to suggest that neuraxial ultrasound identifies lumbar intervertebral levels, with greater accuracy than palpation of surface anatomical landmarks.[27] Using plain X-ray of the lumbar spine as a reference standard, Furness et al. [3] demonstrated that ultrasound correctly identified individual interspaces (from L2-3 to L4-5) 71% of the time, whereas palpation was only correct 29% of the time. Furthermore, the margin of error never exceeded one level with ultrasound but was up to 2 spaces higher or lower in 27% of palpation assessments. These findings are consistent with those reported by Watson et al.[28] who, using MRI as their reference standard, found that ultrasound accurately identified the L3-4 interspace in 76% of cases with a margin of error that did not exceed one level.

Conclusion

Pre-procedural Ultrasound-guided method of needle insertion needed a significantly lesser number of attempts compared to the landmark-guided method for successful spinal anaesthesia. The US-guided method needed significantly less number of passes in relation to the LM methods. The landmark-guided method took significantly less time of identifying space, while the US-guided method took twice of the time. The US-guided method took significantly less time for successful lumbar puncture compared to LM method. Ultrasonography can be a useful adjunct to safe spinal anaesthesia and also it facilitates the performance of spinal anaesthesia in the non-obstetric patient population with difficult anatomic landmarks, like obese patients.

References

1. Chin KJ, Perlas A, Chan V, Brown-Shreves D, Koshkin A, Vaishnav V. Ultrasound -imaging facilitates spinal anesthesia in adults with difficult surface anatomic landmarks. Anesthesiology. 2011 Jul;115(1):94-101.
2. Lim YC CC, Tan KT. A randomised controlled trial of ultrasound-assisted spinal anaesthesia. Anaesth Intensive Care. 2014 Mar;42(2):191–8.
3. Furness G, Reilly MP, Kuchi S. An evaluation of ultrasound imaging for identification of lumbar intervertebral level. Anaesthesia. 2002 Mar;57(3):277–80.
4. Nomura JT, Leech SJ SS, Sierzenski PR, O'Connor RE, M. B. A randomized controlled trial of ultrasound-assisted lumbar puncture. J Ultrasound Med. 2007 Oct;26(10):1341-8.
5. Chin KJ, Chan VW, Ramlogan R, Perlas A. Real-time ultrasound-guided spinal anesthesia in patients with a challenging spinal anatomy: two case reports. Acta Anaesthesiol Scand. 2010 Feb;54(2):252-5.
6. Arzola C, Mikhael R, Margarido C, Carvalho JC. Spinal ultrasound versus palpation for epidural catheter insertion in labour: A randomised controlled trial. Eur J Anaesthesiol. 2015 Jul;32(7):499-505.
7. Kallidaikurichi Srinivasan K, Iohom G, Loughnane F, Lee PJ. Conventional Landmark-Guided Midline Versus Preprocedure Ultrasound-Guided Paramedian Techniques in Spinal Anesthesia. Anesth Analg. 2015 Oct;121(4):1089-96.
8. Weed JT, Taenzer AH, Finkel KJ, Sites BD. Evaluation of pre-procedure ultrasound examination as a screening tool for difficult spinal anaesthesia*. Anaesthesia. 2011 Oct;66(10):925-30.
9. Creaney M, Mullane D, Casby C, Tan T. Ultrasound to identify the lumbar space in women with impalpable bony landmarks presenting for elective caesarean delivery under spinal anaesthesia: a randomised trial. Int J Obstet Anesth. 2016 Dec; 28:12-6.
10. Chin KJ, Perlas A, Singh M, Arzola C, Prasad A, Chan V, et al. An ultrasound-assisted approach facilitates spinal anesthesia for total joint arthroplasty. Can J Anaesth. 2009 Sep;56(9):643-50.
11. Brinkmann S, Tang R, Sawka A, Vaghadia H. Single-operator real-time ultrasound-guided spinal injection using SonixGPS: a case series. Can J Anaesth. 2013 Sep;60(9):896-901.
12. Soni NJ, Franco-Sadud R SD, Dancel R, Tierney DM, al. SGe. Ultrasound guidance for lumbar puncture. Neurol Clin Pract. 2016;6(4):358-68.
13. Corp I. IBM SPSS statistics for windows, version 22.0. Armonk, (NY): IBM Corp. 2013.
14. Bier A. Versuche über cocainisirung des rückenmarkes. Deutsche Zeitschrift für Chirurgie. 1899;51(3-4):361-9.
15. Broadbent CR, Maxwell WB, Ferrie R, Wilson DJ, Gawne-Cain M, Russell R. Ability of anaesthetists to identify a marked lumbar interspace. Anaesthesia. 2000 Nov;55(11):1122-6.
16. Puolakka R, Haasio J, Pitkänen MT, Kallio M, Rosenberg PH. Technical aspects and postoperative sequelae of spinal and epidural anesthesia: a prospective study of 3,230 orthopedic patients. Reg Anesth Pain Med. 2000 Sep-Oct;25(5):488–97.
17. CA. R. The reproducibility of the iliac crest as a marker of lumbar spine level. Anaesthesia. 1996 Nov;51(11):1070-1.
18. Reimann AF, Anson BJ. Vertebral level of termination of the spinal cord with report of a case of sacral cord. Anat Rec. 1944;88(1):127-38.
19. Pounder D, Elliott S. An awake patient may not detect spinal cord puncture. Anaesthesia. 2000 Feb;55(2):194-.
20. Abdelhamid SA, Mansour MA. Ultrasound-guided intrathecal anesthesia: does scanning help? Egypt J Anaesth. 2013;29(4):389-94.
21. Gnaho A, Nguyen V, Villevielle T, Frota M, Marret E, Gentili ME. Assessing the depth of the subarachnoid space by ultrasound. Rev Bras Anestesiol. 2012 Jul;62(4):525-30.
22. Srinivasan KK, Leo AM, Iohom G, Loughnane F, Lee PJ. Pre-procedure ultrasound-guided paramedian spinal anaesthesia at L5-S1: Is this

better than landmark-guided midline approach? A randomised controlled trial. Indian J Anaesth. 2018 Jan;62(1):53-60.
23. Kim JH, Song SY, Kim BJ. Predicting the difficulty in performing a neuraxial blockade. Korean J Anesthesiol. 2011 Nov;61(5):377-81.
24. Aylott CE, Puna R, Robertson PA, C. W. Spinous process morphology: the effect of ageing through adulthood on spinous process size and relationship to sagittal alignment. Eur Spine J. 2012 May;21(5):1007-12.
25. Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K. Serious complications related to regional anesthesia: results of a prospective survey in France. Anesthesiology. 1997 Sep;87(3):479-86.
26. Horlocker TT, McGregor DG, Matsushige DK, Schroeder DR, Besse JA. Perioperative Outcomes Group. A retrospective review of 4767 consecutive spinal anesthetics: central nervous system complications. Anesth Analg. 1997 Mar;84(3):578-84.
27. Perlas A, Chaparro LE, Chin KJ. Lumbar Neuraxial Ultrasound for Spinal and Epidural Anesthesia: A Systematic Review and Meta-Analysis. Reg Anesth Pain Med. 2016 Mar-Apr Mar-Apr;41(2):251-60.
28. Watson MJ, Evans S, JM. T. Could ultrasonography be used by an anaesthetist to identify a specified lumbar interspace before spinal anaesthesia? Br J Anaesth. 2003 Apr;90(4):509-11.