

ORIGINAL ARTICLE

Comparison Between Pre-Procedural Ultrasound Assisted Midline Approach and Landmark Technique in Obese Surgical Patients under Lumbar Subarachnoid Block

Sharmeela E.M.

HOW TO CITE THIS ARTICLE:

Sharmeela E.M. Comparison Between Pre-Procedural Ultrasound Assisted Midline Approach and Landmark Technique in Obese Surgical Patients under Lumbar Subarachnoid Block. *Ind J Anesth Analg.* 2025; 12(2): 97-105.

ABSTRACT

Background and Objectives: Obesity presents significant challenges in neuraxial anesthesia due to difficult surface anatomical landmarks, leading to increased failure rates and complications. Since Bier first described spinal anesthesia in 1899, the traditional method for identifying the subarachnoid space has been through anatomical landmarks. Conventional palpation techniques often prove unreliable in these patients. Neuraxial ultrasound aims to enhance accuracy by visualizing sonoanatomy, potentially improving success rates and patient outcomes. This study was done to evaluate the effectiveness of preprocedural ultrasound-assisted midline approach compared to the traditional landmark-guided technique in obese patients undergoing lumbar subarachnoid block.

Methods: A prospective observational study was conducted in 90 obese patients (BMI > 25 kg/m²) aged between 18 and 80 years scheduled for elective surgery under spinal anesthesia at Travancore Medical College, Kollam. Patients were divided into two groups: ultrasound-assisted (USG) and surface landmark-guided (SLG). Detailed history, physical examination, and informed consent were obtained. A portable USG machine with curved array probe was utilised for pre procedure marking. Key variables measured included first-attempt success rate, number of needle passes, time for space identification, and total procedure time. Data was analysed using statistical package for social sciences version 25.

Results: The first-attempt success rate was significantly higher in the USG group (51.1%) compared to the SLG group (15.6%). The mean time for space identification was longer in the USG group (119.64 ± 48.69 seconds) than in the SLG group (28.56 ± 15.65 seconds), but the total procedure time was shorter in the USG group (281 ± 85.657 seconds) compared to the SLG group (414.44 ± 218.835 seconds). Patient satisfaction and reduced number of needle passes were also better in the USG group.

AUTHOR'S AFFILIATION:

Third Year Postgraduate Student, Department of Anaesthesia, Travancore Medical College, Kollam, Kerala, India.

CORRESPONDING AUTHOR:

Sharmeela E.M., Third-Year Postgraduate Student, Department of Anaesthesia, Travancore Medical College, Kollam, Kerala, India.

E-mail: sharmeelaem@gmail.com

➤ Received: 23-12-2024 ➤ Accepted: 01-02-2025



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution NonCommercial 4.0 License (<http://www.creativecommons.org/licenses/by-nc/4.0/>) which permits non-Commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the Red Flower Publication and Open Access pages (<https://www.rfppl.co.in>)

Conclusion: This study demonstrates that the ultrasound-guided technique significantly improves the first attempt success rate of spinal anesthesia and enhances patient satisfaction in obese patients. Despite the longer time required for space identification, the overall procedure time is reduced with ultrasound guidance. These findings suggest that incorporating ultrasound guidance into clinical practice could enhance the efficacy of spinal anesthesia in obese patients, highlighting its potential as a valuable tool in modern anesthetic practice.

KEYWORDS

- Ultrasound-guided • Spinal anesthesia • Obese patients • Landmark-guided
- Lumbar subarachnoid block

INTRODUCTION

Central neuraxial blockade (CNB) involves the injection of local anesthetics and sometimes adjuvants into the epidural or subarachnoid space around the spinal cord for achieving blockade of sympatho-somatic outflow. It encompasses spinal, epidural, combined spinal epidural and caudal epidural injections. These methods are commonly employed during the perioperative period for anesthesia and analgesia, as well as for chronic pain management. Intrathecal or subarachnoid block is commonly referred to as spinal anesthesia. A small dose of local anesthetic administered via subarachnoid injection can quickly induce dense surgical anesthesia which is nearly always performed in the lumbar region, below the termination of spinal cord. It creates optimal surgical conditions for procedures involving the lower abdomen, pelvis and lower extremities. Therefore, mastering the technique of neuraxial puncture is essential for every anesthesiologist. Neuraxial punctures are traditionally carried out by identifying anatomical landmarks known as Tuffier or Jacoby lines through palpation. Achieving successful subarachnoid space localization on the initial attempt hinges on the clarity of patient's anatomical landmarks, effectiveness of patient positioning and the proficiency of the provider. Surface landmarks may be absent, indistinct or distorted in patients who are obese, have edema, with underlying spinal deformity, or a previous spine surgery. Multiple needle insertion attempts can result in patient discomfort, prolonged procedure durations, post-dural puncture headache,^{1,2} and potential neural tissue trauma.³

Even in the absence of spine abnormalities, accurately estimating a specific intervertebral level can be challenging, often resulting in needle placement one or two spinal levels

higher than intended and this difficulty is magnified in patients with obesity.⁴ Obesity has now reached epidemic proportions globally. The frequency of surgical procedures performed on obese and morbidly obese patients has also increased.

Ultrasound imaging of the spine has emerged recently as a valuable technique to address many limitations associated with surface landmark-guided approach to performing CNBs. It is non-invasive, easy to use, can be performed quickly at the point of care, offers real-time imaging, and carries no risk of radiation exposure.⁵ Despite its benefits, the adoption of ultrasound for CNBs in clinical practice is still at an early stage. This study is an attempt to evaluate the effectiveness of ultrasound imaging in obese patients, examining its influence on first attempt success rate, patient satisfaction and procedure duration in comparison to traditional landmark-guided technique.

METHODS AND MATERIAL

This prospective observational study included patients aged 18–80 years with a BMI >25 kg/m², scheduled for elective surgery under lumbar subarachnoid block at Travancore Medical College, Kollam. Ethical approval and written informed consent were obtained.

Participants were randomly assigned to two groups:

- **Ultrasound-Assisted Group (USG):** Preprocedural marking of the L3-L4 interspinous space was done in the preoperative room using a curvilinear ultrasound probe (3–6 MHz) in a sitting position. The midpoint of the interspinous space was identified using sagittal and transverse views, and markings were made using a sterile skin marker.

- **Surface Landmark Guided Group (SLG):** Space identification was done in the operating room using traditional palpation techniques after positioning.

Procedure

- A detailed history, physical, and systemic examination were conducted the day before surgery. Patients were instructed to fast for 8 hours prior to the procedure.
- On the day of surgery, patients were positioned in a sitting posture with monitors attached, baseline parameters recorded, and intravenous access established.
- Space identification times were recorded for both groups:
 - **USG:** Time from placing the ultrasound probe to marking completion.
 - **SLG:** Time from palpation to space identification.

Spinal anesthesia was administered under strict aseptic precautions using a 25-G Quincke-Babcock needle. A maximum of 6 needle passes per skin puncture and 3 punctures per patient were allowed. If CSF was not acquired, the block was considered a failure and converted to general anesthesia.

Data Collected

- **Primary Variable:** First-pass success rate of CSF acquisition.
- **Secondary Variables:**
 - Number of needle passes and skin punctures.
 - Time for space identification and the complete procedure.
 - Patient-reported pain (0-10 scale) during spinal anesthesia.
 - Periprocedural discomfort (0-10 scale) related to positioning, anxiety, or fear.

Sensory block was assessed using an alcohol swab for loss of cold sensation. Both preprocedural scans and spinal anesthesia were performed by a senior anesthesiologist to ensure consistency.

RESULTS

A prospective observational study was done to measure and compare the first attempt success

rate of CSF acquisition in L3-L4 subarachnoid space in USG and Landmark approaches.

Data was collected from a total of 90 patients who fulfilled the inclusion criteria.

The results of the study are discussed as following:

1. General profile of the study subjects
2. Comparison between USG and landmark approaches

General profile of the study subjects

General profile includes:

1. Age
2. Gender
3. BMI
4. Type of surgery

Age

Table 1: Distribution of study subjects based on age groups

Age group (in years)	Frequency	Percentage (%)
< or = 30	19	21.1
31-60	50	55.6
>60	21	23.3
Total	90	100

Majority of the study subjects belonged to age group 31-60 years (55.6 %) followed by > 60 years and < or = 30 years (23.3% and 21.1 % respectively)

Mean age was 47.28 ± 17.52 years and it ranges from 21 to 78 years.

Gender

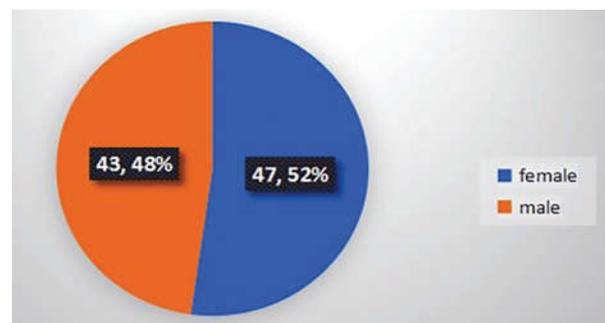


Figure 1: Distribution of study subjects based on gender

Out of the 90-study subject’s majority belonged to female gender (52%). 48% of the study subjects were male.

Type of surgery

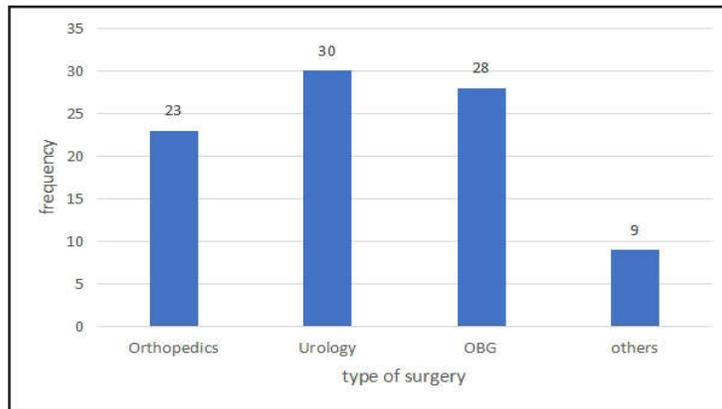


Figure 2: Distribution of study subjects based on type of surgery

Majority of the patients underwent urology surgery (33.3%), followed by OBG (31.1%) and Orthopaedic procedures (25.6%).

Table 2: Distribution of study subjects based on BMI

BMI (kg/m ²)	USG		SLG		Total	Percentage (%)
	Frequency	Percentage (%)	Frequency	Percentage (%)		
30-34.9	26	57.8	35	77.8	61	67.8
35-39.9	17	37.8	6	13.3	23	25.6
>or = 40	2	4.4	4	8.9	6	6.7
Total	45		45		90	100

Majority belonged to BMI category 30-34.9 kg/m² in both the groups (77.8 % in landmark and 57.8 in USG approach).

Mean BMI of all study subjects was 34.12 ± 3.62 kg/m²

Mean BMI in USG approach – 34.92 ± 2.84 kg/m² (30.4-42.6)

Mean BMI in landmark approach – 33.32 ± 4.14 kg/m² (30.0-49.8)

Mean Height – 160.48 ± 7.65 cm

Mean Weight – 88.46 ± 13.6 kg

Table 3: Age distribution of study subjects categorized by the type of procedures

Surgery	Age group			Total
	< or = 30	31-60	>60	
Orthopedics	5 (21.7%)	11 (47.8%)	7 (30.4%)	23 (100%)
Urology	2 (6.7%)	15 (50.0%)	13 (43.3%)	30 (100%)
OBG	11 (39.3%)	17 (60.7%)	0	28 (100%)
Others	1 (11.1%)	7 (77.8%)	1 (11.1%)	9 (100%)
Total	19 (21.1%)	50 (55.6%)	21 (23.3%)	45 (100%)

Majority of elderly patients underwent urologic procedures.

Comparison between USG and SLG groups

First attempt success rate

Table 4: Association between first attempt success rate and approach

Test	First attempt		Total
	Success N (%)	Failed N (%)	
USG	23 (51.1 %)	22 (48.9 %)	45 (100 %)
SLG	7 (15.6 %)	38 (84.4 %)	45 (100 %)
Total	30 (33.3 %)	60 (66.7 %)	90 (100 %)

Chisquare = 12.8, df = 1, p value < 0.001

It was found that 33.3% of subjects had success at first attempt. The success rate was significantly higher in the ultrasound guided (USG) group at 51.1% compared to 15.6% in the landmark-guided (SLG) group. This difference was statistically significant ($p < 0.001$) as determined by the chi-square test.

Skin puncture

Table 5: Association between number of skin punctures and approach

Test	Skin punctures		Total
	One puncture N (%)	>1 puncture N (%)	
USG	38 (84.4%)	7 (15.6%)	45 (100%)
Landmark approach	19 (42.2%)	26 (57.8%)	45 (100%)
Total	57 (63.3%)	33 (36.7%)	90 (100%)

Chisquare =17.273, df = 1, p value < 0.001

63.3% of the study subjects required only one skin puncture. The proportion of one skin puncture was higher in subjects using ultrasound-guided (USG) approaches (84.4%) compared to those using the landmark approach (42.2%). This difference, tested using the chi-square test, was found to be statistically significant ($p < 0.001$).

Needle passes

Table 6: Association between number of needles passes and approach

Test	Needle passes			Total
	1 N (%)	2-3 N (%)	>3 N (%)	
USG	23 (51.1 %)	14 (31.1 %)	8 (17.8 %)	45 (100 %)
SLG	7 (15.6 %)	13 (28.9 %)	25 (55.6 %)	45 (100 %)
Total	30 (33.3 %)	27 (30.0 %)	33 (36.7 %)	90 (100 %)

Chisquare =17.328, df = 1, p value < 0.001

The proportion of subjects requiring only one needle pass was significantly higher in the USG group (51.1%) compared to the landmark group (15.6%). The proportion of subjects requiring more than three needle passes was higher in the landmark group (55.6%) compared to the

USG group (17.8%). These differences were statistically significant ($p < 0.001$).

Time for space identification

Table 7: Association between time taken for space identification and approach

Test	N	Mean time for space identification (in seconds)	t value	p value
USG	45	119.64 ± 48.69	11.945	< 0.001
SLG	45	28.56 ± 15.65		

The mean time for space identification was significantly higher in the USG group (119.64 ± 48.69 seconds) compared to the landmark group (28.56 ± 15.65 seconds). This difference in mean time was tested using the independent t-test and found to be statistically significant ($p < 0.001$).

Time for total procedure

Table 8: Association between time taken for total procedure and approach

Test	N	Mean time for total procedure (in seconds)	t value	p value
USG	45	281 ± 85.657	3.809	< 0.001
SLG	45	414.44 ± 218.835		

The total procedure time was notably longer in the landmark approach group (414.44 ± 218.84 seconds) compared to the USG group (281.00 ± 85.66 seconds). This difference was statistically significant ($p < 0.001$).

Periprocedural pain score

Table 9: Association between periprocedural pain score and approach

Test	N	Mean periprocedural pain score	t value	p value
USG	45	1.29 ± 0.458	6.663	< 0.001
SLG	45	3.69 ± 2.372		

The mean periprocedural pain score in the landmark approach group (3.69 ± 2.372) was significantly higher than in the USG approach group (1.29 ± 0.458), with a statistically significant difference ($p < 0.001$).

Periprocedural discomfort score

Table 10: Association between periprocedural discomfort score and approach

Test	N	Mean periprocedural discomfort score	t value	p value
USG	45	3.67 ± 1.398	1.918	0.058
Landmark approach	45	4.56 ± 2.776		

The mean periprocedural pain score was higher in the landmark approach group (4.56 ± 2.776) compared to the USG approach group (3.67 ± 1.398). However, this difference was not statistically significant ($p > 0.05$).

Table 11: Association between BMI and number of needle passes in USG group

	1		2-3		>3		
	N	%	N	%	N	%	
30-34.9	15	57.7	8	30.8	3	11.5	26
35-39.9	8	47.1	4	23.5	5	29.4	17
>or = 40	0	0	2	100	0	0	2
Total	23	51.1	14	31.1	8	17.8	45

Patients with a BMI of 30-34.9 kg/m² had a significantly lower proportion of needle passes, with 57.7% requiring only one needle pass. In contrast, those with a BMI of 35-39.9 kg/m² experienced the highest number of needle passes, with 29.4% requiring more than three needle passes

Table 12 Association between BMI and number of needle passes in SLG group.

BMI	Needle Passes						Total
	1		2-3		>3		
	N	%	N	%	N	%	
30-34.9	7	20	11	31.4	17	48.6	35
35-39.9	0	0	2	33.3	4	66.7	6
>or = 40	0	0	0	0	4	100	4
Total	7	15.6	13	28.9	25	55.6	45

All patients with a BMI of 40 or above required more than three needle passes, while 66.7% of patients with a BMI of 35-39.9 kg/m² also required more than three needle passes in the SLG group.

DISCUSSION

The study compared ultrasound-guided

(USG) and surface landmark-guided (SLG) techniques for lumbar subarachnoid block in 90 obese patients and found that the first-pass success rate was significantly higher in the USG group (51.1%) compared to the SLG group (15.6%). A higher proportion of SLG patients required more than three needle passes (55.6% vs. 17.8% in the USG group), and the mean total procedure time was shorter in the USG group (281 ± 85.6 seconds) than in the SLG group (414 ± 218.8 seconds), despite longer space identification times in the USG group (119.64 ± 48.69 seconds vs. 28.56 ± 15.65 seconds for SLG). The mean periprocedural pain score was significantly lower in the USG group (3.31 ± 1.32) compared to the SLG group (5.18 ± 2.46), though the difference in discomfort scores was not statistically significant. Patients with BMI ≥35 kg/m² or aged ≥60 years experienced higher success rates and fewer needle redirections with the USG technique. Among parturients, 70% of USG cases required only one pass, while 30% of SLG cases achieved first-pass success.

CONCLUSION

In conclusion, preprocedural ultrasound imaging greatly enhances the conduct of spinal anesthesia in obese patients. Given the growing prevalence of obesity among surgical patients, we believe that this is a valuable skill to acquire.

Conflict of Interest: Nil

REFERENCES

- Harrison D.A., Langham B.T. Spinal anaesthesia for urological surgery: A survey of failure rate, postdural puncture headache and patient satisfaction. *Anaesthesia*. 1992 Oct; 47(10): 902-3.
- Flaatten H., Felthaus J., Larsen R., Bernhardsen S., Klausen H. Postural post-dural puncture headache after spinal and epidural anaesthesia. A randomised, double-blind study. *Acta anaesthesiologica scandinavica*. 1998 Aug; 42(7): 759-64.
- 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. *The Journal of the American Society of Anesthesiologists*. 1997 Sep 1; 87(3): 479-86.

4. Broadbent C.R., Maxwell W.B., Ferrie R., Wilson D.J., Gawne-Cain M, Russell R. Ability of anaesthetists to identify a marked lumbar interspace. *Anaesthesia*. 2000 Nov; 55(11): 1122-6.
5. Khan M.A., Gupta M., Sharma S., Kasaudhan S. A comparative study of ultrasound assisted versus landmark technique for combined spinal-epidural anaesthesia in patients undergoing lower limb orthopaedic surgery. *Indian Journal of Anaesthesia*. 2022 Apr 1; 66(4): 272-7.
6. Chin K.J., Karmakar M.K., Peng P.: Ultrasonography of the adult thoracic and lumbar spine for central neuraxial blockade. *Anesthesiology* 2011; 114: 1459-1485.
7. Karmakar M.K., Li X., Ho. A.M., Kwok W.H., Chui P.T.: Real-time ultrasound-guided paramedian epidural access: evaluation of a novel in-plane technique. *Br J Anaesth* 2009; 102: 845-854.
8. Karmakar M.K.: Ultrasound for central neuraxial blocks. *Tech Reg Anesth Pain Manag* 2009; 13: 161-170.
9. Bogin I.N., Stulin I.D.: Application of the method of 2-dimensional echospondylography for determining landmarks in lumbar punctures. *Zh Nevropatol Psikhiatr Im S S Korsakova* 1971; 71: 1810-1
10. Porter R.W., Wicks M., Ottewell D.: Measurement of the spinal canal by diagnostic ultrasound. *J Bone Joint Surg Br* 1978; 60-B:481-484
11. Cork R.C., Kryc J.J., Vaughan R.W: Ultrasonic localization of the lumbar epidural space. *Anesthesiology* 1980; 52: 513-516.
12. Currie J.M.: Measurement of the depth to the extradural space using ultrasound. *Br J Anaesth* 1984; 56: 345-347.
13. Grau T., Leipold R.W., Conradi R., Martin E.: Ultrasound control for presumed difficult epidural puncture. *Acta Anaesthesiol Scand* 2001; 45: 766-771.
14. Grau T., Leipold R.W., Conradi R., Martin E., Motsch J.: Ultrasound imaging facilitates localization of the epidural space during combined spinal and epidural anesthesia. *Reg Anesth Pain Med* 2001; 26: 64-67.
15. Grau T., Leipold R.W., Conradi R., Martin E., Motsch J.: Efficacy of ultrasound imaging in obstetric epidural anesthesia. *J Clin Anesth* 2002; 14: 169-175.
16. Grau T., Leipold R.W., Fatehi S., Martin E., Motsch J.: Real-time ultrasonic observation of combined spinal-epidural anaesthesia. *Eur J Anaesthesiol* 2004; 21: 25-31.
17. Chin K.J., Ramlogan R., Arzola C., Singh M., Chan V.: The utility of ultrasound imaging in predicting ease of performance of spinal anesthesia in an orthopedic patient population. *Reg Anesth Pain Med* 2013; 38: 34-38.
18. Chin K.J., Perlas A., Singh M., Arzola C., Prasad A., Chan V., Brull R. An ultrasound-assisted approach facilitates spinal anesthesia for total joint arthroplasty. *Can J Anaesth*. 2009 Sep; 56(9): 643-50. doi: 10.1007/s12630-009-9132-8. Epub 2009 Jun 23. PMID: 19548051.
19. Chin K.J., 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. doi: 10.1097/ALN.0b013e31821a8ad4. PMID: 21572316.
20. Furness G., Reilly M.P., Kuchi S.: An evaluation of ultrasound imaging for identification of lumbar intervertebral level. *Anaesthesia* 2002; 57: 277-280.
21. Locks G.F., Almeida M.C., Pereira A.A.: Use of the ultrasound to determine the level of lumbar puncture in pregnant women. *Rev Bras Anesthesiol* 2010; 60: 13-19.
22. Pula R., Gooty S., Thakur N., Sharathchandra B. Dural sac cross-sectional area measured using ultrasound to modify the dosage of local anaesthetic in spinal anaesthesia for transurethral resection of prostate surgery: A prospective, double blind, randomised controlled study. *Indian J Anaesth*. 2022 Oct; 66(10): 719-723. doi: 10.4103/ija.ija_244_22. Epub 2022 Oct 19. PMID: 36437974; PMCID: PMC9698297.
23. Gnaho A., Nguyen V., Villevielle T., Frota M., Marret E., Gentili M.E.: Assessing the depth of the subarachnoid space by ultrasound. *Rev Bras Anesthesiol* 2012; 62: 520-530.
24. Weed J.T., Taenzer A.H., Finkel K.J., Sites B.D.: Evaluation of pre-procedure ultrasound examination as a screening tool for difficult spinal anaesthesia*. *Anaesthesia* 2011; 66: 925-930.
25. Margarido C.B., Arzola C., Balki M., Carvalho J.C.: Anesthesiologists' learning curves for ultrasound assessment of the lumbar spine. *Can J Anaesth* 2010; 57: 120-126.

26. Vallejo M.C., Phelps A.L., Singh S., Orebaugh S.L., Sah N.: Ultrasound decreases the failed labor epidural rate in resident trainees. *Int J Obstet Anesth* 2010; 19: 373-378
27. Rizk M.S., Zeeni C.A., Bouez J.N., Bteich N.J., Sayyid S.K., Alfahel W.S., Siddik-Sayyid S.M. Preprocedural ultrasound versus landmark techniques for spinal anesthesia performed by novice residents in elderly: a randomized controlled trial. *BMC anesthesiology*. 2019 Dec; 19: 1-8.
28. Chitrabika P., Madhu Gupta, Mohd Anas Khan. Comparative study of ultrasound assisted versus conventional surface landmark guided technique for combined spinal epidural anaesthesia in patients with increased body mass index and difficult surface anatomy of lower back and spinal deformity. *Indian journal of clinical anesthesia*. 2022; 9(2): 247-253.
29. Bhardwaj D., Thakur L., Sharma S., Rana S., Gupta B., Sharma C. Comparative evaluation of three techniques for paramedian subarachnoid block: point-of-care preprocedural ultrasound assisted, real-time ultrasound guided and landmark based. *Indian Journal of Anaesthesia*. 2022 Mar 1; 66 (Suppl 2): S102-7.
30. Onwochei, Desire; Nair, Ganeshkrishna; Young, Bruce; Desai, Neel. Conventional landmark palpation versus preprocedural ultrasound for neuraxial procedures in nonobstetric patients: A systematic review with meta-analysis and trial sequential analysis of randomised controlled trials. *European Journal of Anaesthesiology* 38(): pp. S73-S86, August 2021.
31. Jiang, L., Zhang, F., Wei, N. *et al.* Could preprocedural ultrasound increase the first-pass success rate of neuraxial anesthesia in obstetrics? A systematic review and meta-analysis of randomized controlled trials. *J Anesth* 34, 434-444 (2020).
32. Chen, Luying M.D.*; Huang, Jieling M.D.*; Zhang, Yuling M.D.*; Qu, Bo M.D.†; Wu, Xinyuan M.D.‡; Ma, Wuhua M.D., PhD‡; Li, Yuhui M.D.‡. Real-Time Ultrasound-Guided Versus Ultrasound-Assisted Spinal Anesthesia in Elderly Patients With Hip Fractures: A Randomized Controlled Trial. *Anesthesia & Analgesia* 134(2): pp. 400-409, February 2022.
33. Srinivasan K.K., Iohom G., Loughnane F., Lee P.J. Conventional landmark-guided midline versus preprocedure ultrasound-guided paramedian techniques in spinal anesthesia. *Anesthesia & Analgesia*. 2015 Oct 1; 121(4): 1089-96.
34. Sahin, T., Balaban, O., Sahin, L. *et al.* A randomized controlled trial of preinsertion ultrasound guidance for spinal anaesthesia in pregnancy: outcomes among obese and lean parturients. *J Anesth* 28, 413-419 (2014).
35. 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. *International journal of obstetric anaesthesia*. 2016 Dec 1; 28: 12-6.
36. Li, Mengzhu M.D.; Ni, Xiu M.D.; Xu, Zhendong PhD; Shen, Fuyi M.D.; Song, Yingcai M.D.; Li, Qian M.D.; Liu, Zhiqiang PhD. Ultrasound-Assisted Technology Versus the Conventional Landmark Location Method in Spinal Anesthesia for Cesarean Delivery in Obese Parturients: A Randomized Controlled Trial. *Anesthesia & Analgesia* 129(1): pp. 155-161, July 2019.
37. Ravi, Parli Raghavan; Naik, Sudarshan; Joshi, Mukund C1; Singh, Seema2. Real-time ultrasound-guided spinal anaesthesia vs pre-procedural ultrasound-guided spinal anaesthesia in obese patients. *Indian Journal of Anaesthesia* 65(5): pp. 356-361, May 2021.
38. Tawfik M.M., Atallah M.M., Elkhaboutly W.S., Allakkany N.S., Abdelkhalek M. Does preprocedural ultrasound increase the first-pass success rate of epidural catheterization before Cesarean delivery? A randomized controlled trial. *Anesth Analg* 2017; 124: 851e6
39. Park S.K., Cheun H., Kim Y.W., Bae J., Yoo S., Kim W.H., Lim Y.J., Kim J.T. Ultrasound-assisted spinal anesthesia: A randomized comparison between midline and paramedian approaches. *Journal of Clinical Anesthesia*. 2022 Sep 1; 80: 110823.
40. Lee P.J., Tang R., Sawka A., Krebs C., Vaghadia H. Brief report: real-time ultrasound-guided spinal anesthesia using Taylor's approach. *Anesth Analg*. 2011 May; 112(5): 1236-8. doi: 10.1213/ANE.0b013e31820ec53c. Epub 2011 Mar 3.
41. Sidiropoulou T., Christodoulaki K., Siristatidis C. Pre-Procedure Lumbar Neuraxial Ultrasound-A Systematic Review of Randomized Controlled Trials and Meta-Analysis. *Healthcare (Basel)*. 2021 Apr 17; 9(4): 479

42. Bae J., Park S.K., Yoo S., Lim Y.J., Kim J.T. Influence of age, laterality, patient position, and spinal level on the interlamina space for spinal puncture. *Regional Anesthesia & Pain Medicine*. 2020 Jan 1; 45(1): 27-31.
43. Ghisi D., Tomasi M., Giannone S., *et al.* A randomized comparison between Accuro and palpation-guided spinal anesthesia for obese patients undergoing orthopedic surgery. *Reg Anesth Pain Med* 2020; 45: 63e6
44. Weiniger C.F., Carvalho B., Ronel I., *et al.* A randomized trial to investigate needle redirections/re-insertions using a handheld ultrasound device versus traditional palpation for spinal anesthesia in obese women undergoing cesarean delivery. *Int J Obstet Anesth* 2022; 49, 103229
45. Kamimura Y., Yamamoto N., Shiroshita A., Miura T., Tsuji T., Someko H., Imai E., Kimura R., Sobue K. Comparative efficacy of ultrasound guidance or conventional anatomical landmarks for neuraxial puncture in adult patients: a systematic review and network meta-analysis. *British Journal of Anaesthesia*. 2023 Oct 6.
46. Carvalho J.C. Ultrasound-facilitated epidurals and spinals in obstetrics. *Anesthesiology clinics*. 2008 Mar 1; 26(1): 145-58.

