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SYSTEMATIC REVIEW

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Does preprocedural ultrasound prior to lumbar neuraxial anesthesia or analgesia increase first-pass success in adults with obesity? A systematic review

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Abstract

Background and Aims: Preprocedural ultrasound (PPU) reduces the risk of technical failure in non-obese patients and when technical difficulty is predicted. We conducted this review to determine if PPU improves first-pass needle insertion success for neuraxial anesthesia in patients with obesity.

Methods: We conducted a systematic review without meta-analysis, due to the small number of included studies. The study protocol was registered (PROSPERO: CRD42022368271). We conducted searches in MEDLINE, Embase, PubMed, and Cochrane Library from January 1, 1980 to October 1, 2022 for peer-reviewed randomized controlled or observational studies comparing PPU versus landmark techniques in patients with body mass index >30 kg/m^2. The quality of evidence was assessed using the revised Cochrane risk-of-bias tool for randomized trials and Grading of Recommendations Assessment, Development, and Evaluation approach.

Results: There were nine randomized controlled studies, comprising 866 patients having lumbo-sacral neuraxial techniques. Three studies utilized a small handheld ultrasound device called Accuro™ and six utilized non-handheld ultrasound devices. Certainty of evidence was low for improving the first-pass success rate. There was evidence (moderate certainty) that PPU decreased number of passes, increased first insertion attempt success, and reduced number of insertion attempts. There was no evidence that PPU affected identifying time, needling time, or overall procedural time. There was no evidence that PPU influenced procedural failure rate (very low certainty evidence) and insufficient evidence to suggest that artificial intelligence-supported handheld devices were superior to conventional ultrasound devices.

Conclusions: In patients with obesity, there is evidence of very-low to moderate certainty that PPU improves markers of insertion success, with no indication of increased adverse effects. PPU should be used to reduce attempts. Further studies adhering to standardized outcome definitions are required for definitive recommendations.

Registration: The study protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO: CRD42022368271).

KEYWORDS

body mass index, neuraxial, obesity, preprocedural, palpation, spinal, ultrasound

1 | INTRODUCTION

Neuraxial blocks used for lumbar anesthesia or analgesia include spinal, epidural, and combined spinal epidural (CSE).[1] These are traditionally performed by palpating surface landmarks to identify the location of both the neuraxial midline and the intended interspinous space.[2] The use of bony landmarks to identify spinal levels is notoriously inaccurate.[3] Ultrasound localization of the epidural space has been reported since the 1980s.[4] Correct identification is essential for clinical efficacy and to avoid multiple attempts. Multiple needle insertions, particularly at an inappropriate level may be unpleasant for the patient and increase the risk of inadvertent dural puncture, postdural puncture headache, and nerve injury.[5] Multiple factors affect insertion success rate, including the ease of palpating anatomical landmarks, patient positioning, and the proceduralist's level of experience.[6] More patients are living with obesity worldwide and obesity is associated with technical difficulties when inserting neuraxial blocks. This is due to increased difficulty when palpating landmarks and an increased depth to the epidural space.[7] For this systematic review, obesity was defined according to the World Health Organization definition as body mass index (BMI) >30 kg/m^2.[8]

In non-obese patients, there is evidence that preprocedural ultrasound (PPU) increases the success rate and decreases complications without increasing the procedural time.[9,10] The systematic review and meta-analysis of 32 trials by Sidiropoulou et al. examined the use of PPU in patients having obstetric and non-obstetric procedures as well as diagnostic lumbar puncture. They performed a subgroup analysis of patients with obesity and/or difficult spinal anatomy, demonstrating an increased first-attempt success rate in the PPU group. The evidence of benefit was stronger in this subgroup compared to the wider population; however, these results may not be generalizable to patients with obesity.[9] Young et al. performed a systematic review, meta-analysis and trial sequential analysis in 22 trials evaluating PPU use in obstetric neuraxial anesthesia and analgesia.[10] They identified an increase in first-pass success in the PPU group, with greater benefit observed in those with anticipated difficult neuraxial technique. However the quality of the evidence was low to very-low, due to performance and detection biases.[10] In patients with obesity, the degree of adipose and soft tissue increases, resulting in reduced quality of the ultrasound image. This may reduce the utility of PPU and prolong the associated procedure in patients with obesity. Knowing the specific demonstrated benefits has implications for resource and training provision in institutions providing neuraxial blocks for patients with obesity.

We performed this systematic review to determine if PPU increased first-pass success rate in comparison to the landmark technique (LM), when neuraxial anesthesia and analgesia were performed in patients with obesity. Our secondary aims were to examine other markers of success, time and adverse events.

2 | METHODS

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (Registration number: CRD42022368271). We adhered to the reporting framework set by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[11] Studies were selected if they were peer-reviewed randomized controlled trials or observational studies published between January 1, 1980 to October 1, 2022. We included articles with the full text available in the English language and excluded case reports and conference abstracts. Eligible studies included participants aged ≥16 years and BMI >30 kg/m^2, with the intervention of interest being PPU before neuraxial anesthesia or analgesia. Studies were excluded if participants received real-time ultrasound and those who underwent diagnostic lumbar punctures. The comparator was the LM technique, using palpation of bony landmarks to identify the site of needle insertion.

The primary outcome was the first-pass success rate, which was defined as the rate of successful neuraxial anesthesia or analgesia on the first needle insertion, with no redirections. There is some variation in the literature regarding the nomenclature of insertion,[12] so we prospectively applied the following definitions: an insertion attempt was defined as each time the needle was inserted through the patient's skin; a redirection was defined as any withdrawal and re-advancement of the needle without removal of the needle from skin; the number of passes was defined as the sum of every needle insertion attempt and every needle redirection.[12]

Additional outcomes included number of passes, first insertion attempt success (success on first needle insertion attempt irrespective of the number of redirections), number of insertion attempts, number of redirections, number of puncture levels (number of interspaces with needle insertion), identifying time (time taken to identify interspace before first needle insertion),[13] needling time (time taken from needle touching skin until successful placement of the block),[13] overall procedural time (identifying time plus procedural time), procedural failure and adverse events. While these definitions were identified prospectively, when present, variation from these definitions was to be described in full.

Searches were conducted through the databases MEDLINE, EMBASE, PubMed, and Cochrane Library (reviews and trials) with a time period from January 1, 1980 to October 1, 2022. The following search terms and their Boolean combinations were included: "obesity," "neuraxial," "spinal," "epidural," "combined spinal epidural," and "ultrasound" (see Supporting Information S1: Material 1 for full search strategy). Results from the searches were compiled using the reference manager Zotero (Corporation for Digital Scholarship), and duplicates were removed manually. Title and abstracts were assessed for suitability and compiled. The full text of each article was then independently screened by separate reviewers (AK and AH) and any discrepancies were settled through discussion until consensus was achieved. Reference lists of included studies were then searched for further eligible studies.

The included studies were assessed independently using the Cochrane risk-of-bias tool for randomized trials (RoB 2) as all studies were randomized controlled trials with no observational studies meeting inclusion criteria.[14] The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system was then used to assess the overall quality of the body of evidence for each outcome of interest.[15]

Data points extracted included year of publication, country of origin, BMI cutoff for inclusion of participants, the type of surgery undertaken, sample size, participant positioning for neuraxial block, type of neuraxial block, proceduralist level of experience and the primary and additional outcomes. A meta-analysis was planned if included studies were homogeneous and number of included studies with available outcomes was ≥10.

3 | RESULTS

In this systematic review, 1142 primary studies were initially included, then 316 duplicates were removed (Figure 1). After screening the titles and abstracts, full-text review, and final reconciliation, nine papers were included in the review. The results were synthesized qualitatively due to the number of primary outcomes assessed in the studies, which resulted in a small number of included studies for each outcome and precluded meta-analysis.

The nine included studies were all randomized controlled trials, with a total of 866 participants and individual study sample sizes ranging from 40 to 210 (Table 1).[13,16–23] One study[20] applied an inclusion threshold of BMI >35 kg/m^2 and the remainder used an inclusion threshold of BMI >30 kg/m^2.[13,16–19,21–23] One study included spinals performed between L3 and S1,[21] whereas the remainder evaluated lumbar neuraxial techniques.[13,16–20,22,23] Spinal anesthesia was performed in five studies,[13,18,19,21,23] CSEs in three,[16,17,22] and epidurals in one.[20] Six utilized the sitting position,[16,18–20,22,23] two in the lateral position,[13,17] and one a combination of both.[21] Three studies used Accuro™ (Rivanna Medical), a small handheld battery-operated ultrasound device that enhances bone-to-tissue contrast and uses automatic recognition to aid the proceduralist.[21–23] As the Accuro device applies artificial intelligence-enabled image guidance to aid identification of the midline and interlaminar space, the outcomes of these studies were considered separately from those utilizing conventional ultrasound. The included studies were assessed for risk of bias using RoB 2, with eight deemed "Some concerns" and one deemed "High" (Figure 2).[24] The primary source of bias was due to inadequate blinding of patients or proceduralists and lack of protocol registration.

3.1 | Primary outcome and outcomes related to needle insertion

3.1.1 | First-pass success

Four studies examined first-pass success as a marker of procedural success (Table 2). Only one study found evidence that first-pass success was significantly improved with PPU.[22] That study used Accuro in the seated position for CSE in 80 patients undergoing elective cesarean delivery. The three other studies failed to identify a statistically significant difference between PPU and LM; however, all reported a higher percentage of success for PPU.[16–18]

3.1.2 | Number of passes

Five studies recorded number of passes, with four finding statistical evidence that PPU decreased number of passes. The studies that identified a statistically significant difference between PPU and LM all used standard ultrasound rather than Accuro and evaluated participants having spinal, epidural, CSE, in the seated and lateral position.[13,16,19,20]

3.1.3 | First insertion attempt success

Similarly, first insertion attempt success was shown to be increased when PPU was used in three out of four studies.[13,16,18] In a study utilizing the Accuro device, Weiniger et al.[23] reported no statistically significant increase in first insertion attempt success rates when using Accuro compared with the LM technique.

3.1.4 | Number of insertion attempts

Number of insertion attempts was reduced with PPU in the five studies reporting this outcome. Although Sahin et al.[18] reported a lower median number of insertion attempts 1 versus 2 (PPU vs. LM), their statistical analysis included nonobese subgroups and it is unclear if that significance applies to patients with obesity. The remaining four studies found a statistically significant reduction in the number of insertion attempts when PPU was used,[13,16,19,21] one of which used the Accuro device.[21] *Number of needle redirections:* Number of redirections was reported in four studies. Three studies

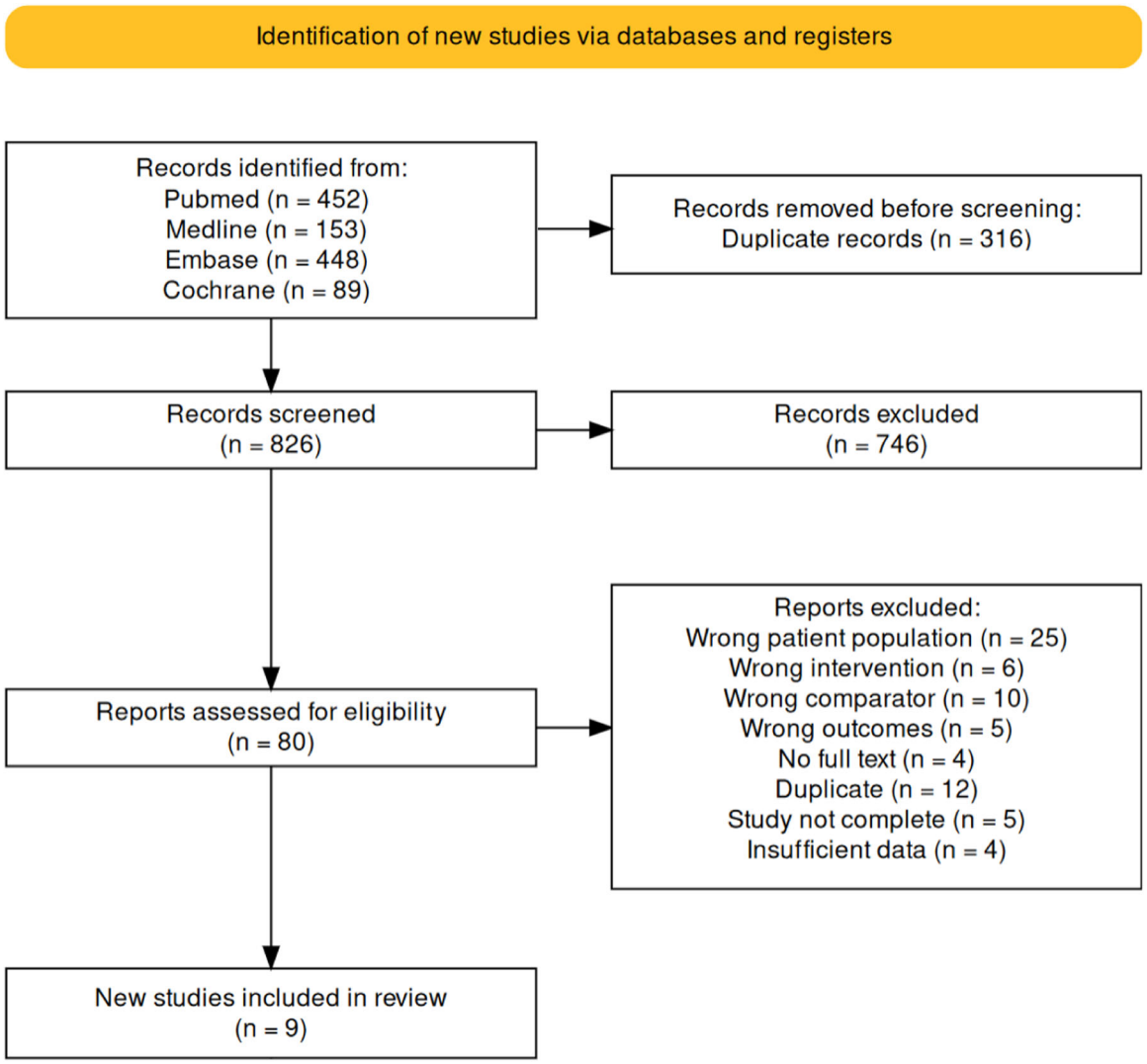

FIGURE 1 PRISMA flow diagram of search strategy and article selection.

utilized Accuro with one[23] finding no reduction in the median number of redirections, the second[21] finding a decrease in median number of redirections, and the third[22] found a decreased rate of patients requiring redirections when PPU was used. The remaining study using standard ultrasound identified no difference in number of redirections, with the analysis including nonobese patients.[18] *Number of skin puncture levels*: The effect of PPU on the number of puncture levels was reported in five studies.[13,17,18,22,23] Two studies that evaluated conventional ultrasound found evidence of a decrease in skin punctures,[13,17] whereas three (including two utilizing Accuro)[22,23] found no reduction in skin punctures.[13,17,18,22,23]

3.2 | Outcomes related to procedural time

Eight studies recorded some measure of procedural time, with the study by Jain et al.[16] being the exception. A variety of duration-related measures were reported. *Identifying time*: Identifying time was measured in four studies.[13,17,20,22] Two studies, including one utilizing the Accuro device,[22] defined identifying time as time from palpation or ultrasound probe touching skin until the needle insertion site was marked.[13,22] Ni et al., using the Accuro device, found that the use of PPU reduced identifying time,[22] whereas Li et al. found no difference when conventional ultrasound was used.[13] Wang et al.[17] measured the time from the patient being placed in the right lateral position until the site of needle insertion was identified, finding PPU increased identifying time. One study performed an abbreviated PPU, using the ultrasound to identify midline, marking it with a pen, and then using palpation to locate the correct spinal level, with identifying time increased by PPU.[20]

3.2.1 | Needling time

Five studies measured needling time, with three finding needling time decreased by PPU and two finding no effect. Two studies measured

TABLE 1 Study characteristics of nine studies (three evaluating the use of Accuro™ are identified).

Author, Year; Country	Patient population	Technique, interspace, position	Method of ultrasound localization	Primary outcome	Secondary outcomes
Jain,[16] 2019; India	BMI >30 kg/m^2, elective orthopedic lower limb joint replacements	CSE L2–L5 (PPU vs. LM); Seated	Longitudinal and transverse	First insertion attempt success	Number of passes, number of insertion attempts, adverse events, depth to epidural space, patient satisfaction
Wang,[17] 2012; China	BMI >30 kg/m^2, elective cesarean delivery	CSE L2–L4 (PPU vs. LM); Lateral	Longitudinal and transverse	First-pass success	Identifying time, needling time, adverse events
Sahin,[18] 2014; Turkey	BMI <30 kg/m^2 (n = 50), BMI >30 kg/m^2 (n = 50), elective cesarean delivery	Spinal L4–L5 (PPU vs. LM vs. nonobese PPU vs. nonobese LM); Seated	Longitudinal and transverse	First insertion attempt success	Identification of correct level, depth to ligamentum flavum on ultrasound vs actual, adverse events
Urfalioğlu,[19] 2017; Turkey	BMI >30 kg/m^2, elective cesarean delivery	Spinal L3–L5 (PPU vs. LM); Seated	Longitudinal and transverse	Overall procedure time, duration of block, number of skin punctures, needle passes, adverse effects	
Li,[13] 2019; China	BMI >30 kg/m^2, elective cesarean delivery	Spinal L2–L4 (PPU vs. LM); Lateral	Longitudinal and transverse	First insertion attempt success	Number of insertion attempts, needle passes, identifying time, needling time, adverse effects
Tubinis,[20] 2019; USA	BMI >35 kg/m^2, labor analgesia	Lumbar epidural (PPU vs. LM); Seated	Transverse	Time for epidural placement	Number of passes, failures, overall procedural time
Ghisi,[21] 2020; Italy; **Accuro**	BMI >30 kg/m^2, orthopedic lower limb surgery, aged 18–75 years	Spinal L3–S1 (Accuro vs. LM); Seated or lateral	Interspace identified using device pattern recognition software	Number of redirections	Number of passes, performance time, adverse events, number of redirections, failure
Ni,[22] 2021; China; **Accuro**	BMI >30 kg/m^2, elective cesarean delivery	CSE L2–L4 (Accuro vs. LM); Seated	Interspace identified using device pattern recognition software	First-pass success	Number of redirections, number of passes, adverse events, identifying time
Weiniger,[23] 2022; Israel; **Accuro**	BMI >30 kg/m^2, elective cesarean delivery	Spinal L3–L5 (Accuro vs. LM); Seated[a]	Interspace identified using device pattern recognition software	Number of passes	Needling time, number of intervertebral spaces, comfort level

[a]C. Weiniger, personal communication.

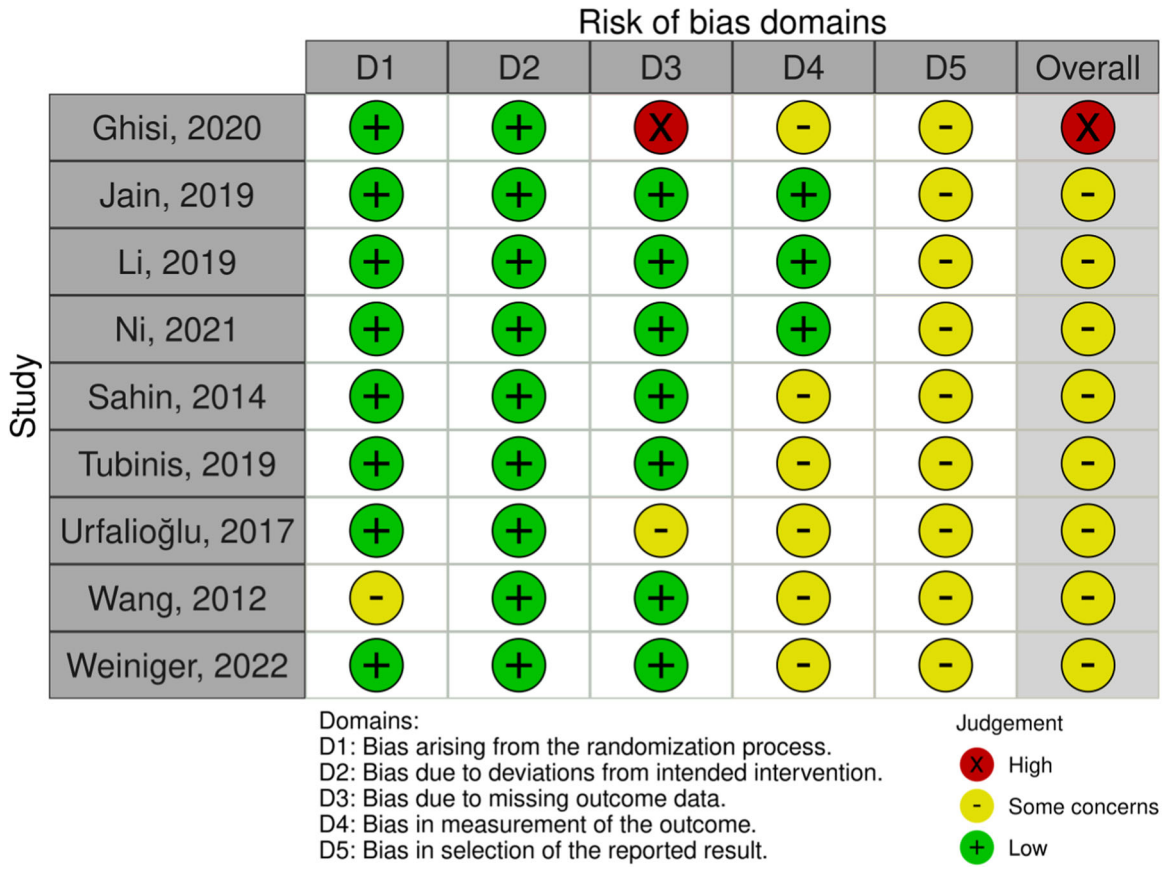

FIGURE 2 Risk of Bias Table. Generated using robvis.

needling time as the time taken from initial subcutaneous local anesthetic infiltration until successful cerebrospinal fluid (CSF) flow. Ni et al., using the Accuro device, found no difference in needling time,[22] whereas Li et al. found that needling time was decreased with PPU applying conventional ultrasound.[13,22] Sahin et al.[18] measured needling time as the time taken from holding the spinal needle until the free flow of CSF, finding PPU faster than LM (22 s vs. 52 s); however, their statistical analysis once again included nonobese subjects. Another study found needling time decreased by PPU, recording needling time from subcutaneous local anesthetic infiltration until the administration of epidural test dose.[20] Weiniger et al. measured the time from insertion of the introducer needle until CSF flow, with no statistically significant difference identified between the groups with the use of Accuro.[23]

3.2.2 | Overall procedural time

The effect of PPU on overall procedural time was mixed, with two studies finding overall procedural time decreased,[13,20] both using conventional ultrasound. Three studies found a significant increase in overall procedural time with PPU (all using conventional ultrasound),[17,19,21] and one study that used the Accuro device found no difference.[22] Defining overall procedural time as the sum of the identifying time and needling time, two studies found that PPU decreased the overall procedural time.[13,20] Ni et al. (using Accuro) used the same definition of overall procedure time but found no significant difference between the groups.[22] One study measured procedural time as time taken from the opening of sterile gloves until spinal injection, with time increased when PPU was used.[21] Another study measured overall procedural time from start of palpation or ultrasound until spinal injection,[19] whereas another measured from right lateral positioning until epidural catheter being fixed,[17] with both also finding overall procedural time increased with PPU.

3.3 | Outcomes related to block failure and adverse events

Neuraxial block failure was assessed using different definitions, depending on the neuraxial technique used and the indication for the block, with none showing a significant reduction in failure rate when PPU was used. Two studies evaluating spinal anesthesia defined block failure as the need to convert to general anesthesia and one of these used Accuro.[18,21] One study utilizing CSE defined failure as inadequate analgesia despite repeated redosing with local anesthetic,[16] and another study evaluating labor analgesia defined failure as inadequate T10 analgesia following epidural infusion and

TABLE 2 Outcomes from included studies.

Author, Year	Sample size	Mean BMI	Proceduralists	First-pass success	Number of passes	First insertion attempt success	Number of insertion attempts	Redirections	Number of puncture levels	Identifying time (s)	Needling time (s)	Overall procedural time (s)	Failed block	Adverse events
Jain,[16] 2019	105 vs. 105	32.9 (±2.3) vs. 32.5 (±2.4)[a]	PPU identification by single operator, CSE performed by anesthesiologists (2–30 years experience)	64 (60.9%) vs. 52 (49.5%) [$p = 0.095$][b]	1.8 (±1.2) vs 2.2 (±1.7) [$p = 0.02$][a]	90 (85.7%) vs. 78 (74.3%) [$p = 0.04$][b]	1.2 (±0.6) vs. 1.5 (±0.9) [$p = 0.013$][a]						0 (0%) vs. 2 (1.9%) [$p = 0.498$][b]	0 (0%) vs. 6 (5.7%) [$p = 0.01$],[b,c]
Wang,[17] 2012	30 vs. 30	34.9 (±2.5) vs. 34.1 (±2.4)[a]	All proceduralists >10 years of experience	19 (63.3%) vs. 13 (43.3%) [$p = 0.12$][b]					Success at first level 30 (100%) vs. 21 (70%) [$p = 0.004$][b]	156 (±36.6) vs. 18 (±7.2) [$p < 0.001$][a]		562 (±81) vs. 460 (±91.2) [$p < 0.001$][a]		Puncture site hemorrhage 2 (6.7%) vs. 6 (20%) [$p = 0.26$][b]
Sahin,[18] 2014	25 vs. 25	34.1 (±3.5) vs. 37.3 (±5.8)[a]	PPU identification by single operator (>150 PPU), LM identification performed by single anesthesiologist (>5 years experience), spinal by single anesthesiologist (>4 years experience)	8 (32%) vs. 7 (28%)[b]		23 (92%) vs. 11 (44%) [$p = 0.001$][b]	1 vs. 2[d]	1 vs. 1[d]	1 vs. 1[d]		22 (±30) vs. 52 (±184)[e]		2 (8%) vs. 2 (8%)[a]	
Urfalioğlu,[19] 2017	48 vs. 49	39.1 (±3.29) vs. 39.4 (±3.42)[a]	All procedures (PPU and LM) performed by single anesthesiologist (>100 US-guided blocks; >5 years experience)		1 (0–2) vs. 3 (1–5) [$p < 0.001$][e]		1 (1–1) vs. 2 (1–3) [$p < 0.001$][e]					480 (360–600) vs. 300 (240–360) [$p < 0.001$][e]		Backache 7 (14.6%) vs. 21 (42.9%) [$p = 0.003$][b]; headache 7 (14.6%) vs. 5 (10.2%) [$p = 0.56$][b]
Li,[13] 2019	40 vs. 40	35.7 (±3.43) vs. 35.9 (±4.43)[a]	PPU scan by single anesthesiologist (>150 US-guided neuraxial blocks), spinal performed by three anesthesiologists (≥3 years experience)		2.1 (±2.1) vs. 14.9 (±16.8) [$p < 0.001$][a]	35 (87.5%) vs. 21 (52.5%) [$p = 0.001$][b]	1.2 (±0.4) vs. 3.6 (±3.3) [$p < 0.001$][a]		New space 0 (0%) vs. 16 (40%) [$p < 0.001$][b]	202.5 (175.3–221.8) vs. 272 (82-310.5) [$p = 0.58$][e]	41.5 (38–58) vs 120 (56–359.8) [$p < 0.001$][e]	247 (225.3–272.8) vs. 378 (195–699.3) [$p < 0.001$][e]		

(Continues)

TABLE 2 (Continued)

Author, Year	Sample size	Mean BMI	Proceduralists	First-pass success	Number of passes	First insertion attempt success	Number of insertion attempts	Redirections	Number of puncture levels	Identifying time (s)	Needling time (s)	Overall procedural time (s)	Failed block	Adverse events
Tubinis,[20] 2019	75 vs. 75	43.3 (±7.1) vs. 44.4 (±6.9)[a]	All procedures performed by junior and senior anesthesiology residents (1–3 years experience, trained in PPU)		2.1 (±1.4) vs. 2.8 (±2.0) [$p = 0.02$][a]					44.5 (±24.7) vs. 30.9 (±16.3) [$p < 0.01$][a]	372 (±228) vs. 540 (±408) [$p < 0.01$][a]	414 (±234) vs. 570 (±408) [$p < 0.01$][a]	3 (4%) vs. 7 (9.3%) [$p = 0.19$][b]	
Ghisi,[21] 2020, **Accuro**	47 vs. 52	33.4 (±2.8) vs. 33.6 (±3.6)[a]	PPU (**Accuro**) and LM by three anesthesiologists[f]				1 (1–2) vs. 1 (1–3) [$p = 0.02$][e]	3 (0–9) vs. 6 (1–16) [$p = 0.01$][e]				558 (±232) vs. 348 (±255) [$p < 0.001$][a]	0 (0%) vs. 2 (3.8%) [$p = 0.52$][b]	3 (6.4%) vs. 4 (7.7%) [$p = 0.80$][b,g]
Ni,[22] 2021, **Accuro**	40 vs. 40	33.0 (±2.09) vs. 33.48 (±2.14)[a]	Identification (PPU and LM) performed single operator with>5 years experience and very familiar with **Accuro**, CSEA performed by several anesthesiologists (>5 years experience)	29 (72.5%) vs. 16 (40%) [$p = 0.003$][b]				16 (40%) vs. 29 (72.5%) [$p = 0.003$][b]	New space 1 (2.5%) vs. 3 (7.5%) [$p = 0.61$][b]	30 (26–36) vs. 39 (32–48) [$p = 0.001$][e]	65 (55–79) vs. 65 (50–111) [$p = 0.16$][e]	95 (82.3–124.5) vs. 111.5 (87.5–148.5) [$p = 0.57$][e]		Paresthesia 3 (7.5%) vs. 18 (45%) [$p < 0.001$][b]; intravascular catheter 3 (7.5%) vs. 6 (15%) [$p = 0.50$][b]
Weiniger,[23] 2022, **Accuro**	18 vs. 22	39.8 (±5.5) vs. 37.3 (±5.2)[a]	PPU identification by three anesthesiologists (familiar with **Accuro**), spinal performed by residents and anesthesiologists		4 (2–13) vs. 6 (4–10) [$p = 0.22$][e]	8 (44.4%) vs. 6 (27.3%) [$p = 0.33$][b]		2 (1–7) vs. 4 (2–6) [$p = 0.29$][e]	1 (1–2) vs. 1 (1–2) [$p = 0.72$][e]		287 (±386) vs. 255 (±245) [$p = 0.76$][a]			

Note: Results are reported as outcomes using preprocedural ultrasound versus using palpation of landmarks (*p* value if reported). Three studies evaluating the use of Accuro™ are identified.

First-pass success was defined as successful neuraxial anesthesia or analgesia on the first needle pass. Number of needle passes was defined as the sum of every needle insertion attempt and every needle redirection; an insertion was defined as each time the needle was inserted through the patient's skin; redirection was defined as any withdrawal and re-advancement of the needle within an intervertebral space without removal of the needle from skin.

[a]Mean (±SD).

[b]Count (%).

[c]Dural puncture.

[d]Median (IQR not reported).

[e]Median (IQR).

[f]After 90 participants recruited, increased number of trained proceduralists participated.

[g]Bloody tap, headache, and/or paresthesia.

TABLE 3 GRADE recommendations for certainty of evidence for primary and secondary outcomes.

Outcome	Number of studies	Sample size (PPU vs. LM)	Risk of bias	Inconsistency	Indirectness	Imprecision	Effect (number of studies)	Final grade
First-pass success	4	200 vs. 200	Serious[a]	Serious[b]	Not serious	N/A[c]	Increase (1), no effect (3)	⊕⊕◯◯ Low
Number of passes	5	286 vs. 291	Serious[a]	Not serious	Not serious	N/A[c]	Decrease (4), no effect (1)	⊕⊕⊕◯ Moderate
First insertion attempt success	4	188 vs. 192	Serious[a]	Not serious	Not serious	N/A[c]	Increase (3), no effect (1)	⊕⊕⊕◯ Moderate
Number of insertion attempts	5	265 vs. 271	Serious[a]	Not serious	Not serious	N/A[c]	Decrease (4)[d]	⊕⊕⊕◯ Moderate
Number of redirections	4	130 vs. 139	Serious[a]	Serious[b]	Not serious	N/A[c]	Decrease (2), no effect (1)[d]	⊕⊕◯◯ Low
Number of puncture levels	5	153 vs. 157	Serious[a]	Serious[b]	Not serious	N/A[c]	Beneficial effect (2), no effect (2)[d]	⊕⊕◯◯ Low
Identifying time	4	185 vs. 185	Serious[a]	Very serious[e]	Not serious	N/A[c]	Faster (1), no effect (1), slower (2)	⊕◯◯◯ Very low
Needling time	5	198 vs. 202	Serious[a]	Very serious[e]	Not serious	N/A[c]	Faster (2), no effect (2)[d]	⊕◯◯◯ Very low
Overall procedural time	6	280 vs. 286	Serious[a]	Very serious[e]	Not serious	N/A[c]	Faster (2), no effect (1), slower (3)	⊕◯◯◯ Very low
Failure rate	4	252 vs. 257	Serious[a]	Not serious	Not serious	N/A[c]	No effect (3)[d]	⊕⊕⊕◯ Moderate
Adverse events	5	270 vs. 276	Serious[a]	Serious[b]	Serious	N/A[c]	Backache: decrease (1). Paresthesia: decrease (1). Other outcomes no effect.	⊕◯◯◯ Very low

[a]Risk of bias due to inadequate blinding to proceduralist or patient.
[b]Significant inconsistencies in results between studies.
[c]No estimates generated.
[d]One study has a statistical analysis including nonobese patients.
[e]Conflicting results between different studies.

top-up.[20] Ghisi et al., using the Accuro device, found no significant difference between PPU and LM for adverse events (using a combined endpoint comprising bloody tap, headache, and/or paresthesia), the patient experience of procedural discomfort, or pain at 24 h.[21] One study found PPU had no effect on "puncture site hemorrhage rates."[17] Procedural discomfort was also found to be similar in the two groups when Accuro was used.[23] PPU was found to reduce rates of dural puncture,[16] incidence of paresthesia during CSE when Accuro was used,[22] and backache.[19]

3.4 | GRADE certainty of evidence

There was low certainty of evidence for the primary outcome of first-pass success (Table 3). There was moderate certainty of evidence for number of passes, first insertion attempt success, number of insertion attempts, and failure rate. There was low to very low certainty of evidence for all other outcomes.

4 | DISCUSSION

In this systematic review, we identified that in patients with obesity, PPU did not show a consistently significant benefit over LM with respect to first-pass success rates. Other indicators of procedure success (number of passes, first insertion attempt success, and number of insertion attempts) were found to be improved with PPU, supported by evidence of moderate certainty. There was no evidence that PPU affects identifying time, needling time, or overall procedural time, with supporting evidence of very low certainty. There was no evidence to suggest that PPU affected the overall failure rate of the procedure, although there was substantial variation in how that failure was defined. There was inconclusive evidence that PPU affected adverse events, however individual studies suggested a PPU benefit relating to dural puncture[16] and paresthesia[22] when CSE technique was used.

Although the primary outcome of first-pass success was not improved, the improvement in other outcomes of success is

important, particularly if multiple attempts contribute to patient discomfort or an increase in complications. There were mixed results regarding time-related outcomes with many potential reasons for this, including heterogeneous definitions for identifying time and procedural time, and the familiarity of the proceduralist with PPU. Interestingly, the study by Ni et al.[22] had high rates of paresthesia in both PPU and LM (7.5% and 45%, respectively), whereas Jain et al.[16] suggested a significant reduction in dural puncture, but reported a very high rate of 5.7% in LM. Reasons for these high complication rates were not commented on in the respective articles.

In a systematic review and meta-analysis including 3439 patients, Sidiropoulou et al.[9] identified that in nonobese patients, PPU increased first insertion attempt success while reducing the failure rate and number of needle redirections, with very low to low certainty of evidence. A systematic review and meta-analysis by Young et al.[10] that included 2462 obstetric patients found that PPU increased the first-pass success rate. Including participants irrespective of BMI, they also identified a reduction in complications without an increase in overall procedural time. Our review of patients with obesity identified that PPU was associated with an improvement in some markers of procedural success without increasing the required procedural time. There were differences in outcomes observed between conventional ultrasound and the Accuro device. While the available evidence suggests a benefit from the use of Accuro for some outcomes, heterogeneity in outcomes reported by a small number of studies makes it difficult to draw conclusions as to the superiority of Accuro over conventional ultrasound.

Patients with obesity have anatomical and physiological changes that predispose them to lumbar lordosis and narrowing of the intervertebral space, which may lead to technical difficulty with neuraxial insertion.[13] Ultrasound offers potential benefits in this context, with the ability to identify the "widest" intervertebral space and a specific angle of insertion. Unfortunately, the ability to accurately visualize the lumbosacral junction can be severely compromised in patients with severe obesity, limiting correct identification of the intervertebral levels. In this review, the mean BMI of included participants ranged from 32.5[16] to 44.4 kg/m^2.[20] Only one study had a mean participant BMI >40 kg/m^2.[20] Therefore, the results from this review may not be applicable to patients with BMI >40 kg/m^2 due to the impact of increased adipose tissue on sonographic imaging. Patients with BMI >55 kg/m^2 are arguably those who would derive the most clinical benefit from successful neuraxial blocks compared to risks of general anesthesia and these patients were not represented in the included studies.

This systematic review has some limitations. The findings relate to lumbosacral neuraxial techniques and are not generalizable to thoracic techniques. The low number of included studies and substantial heterogeneity in measured outcomes and definitions precluded meta-analysis. This reduces the precision and strength of our findings. Differences in the definition of "needle redirection"[16,21] affected both the primary outcome and secondary outcomes such as the number of redirections and number of passes. Studies evaluating Accuro made up one third of the included studies; however, results obtained from using Accuro may not be generalizable to PPU using standard ultrasound equipment. Due to the heterogeneity of outcomes studied, we are unable to draw conclusions as to the superiority of the artificial intelligence-supported handheld devices (Accuro) compared with conventional ultrasound. Successful application of standard PPU and Accuro require training and experience and there was substantial variation in the experience of sonographers and proceduralists in all the included studies. Finally, the lack of blinding of proceduralists and participants increased the risk of bias in most studies. When a separate operator was used to mark the skin, this may also impact procedural success rate, as skin markings alone are unable to convey the angle of needle insertion nor depth of epidural/intrathecal space to the operator, both of which are obtainable using PPU.[13,22]

High-quality RCTs applying standardized definitions of needle manipulation are required to definitively answer this research question. In addition, careful selection of objective, clinically relevant and patient-centered outcomes must be reported. The inclusion of patients with BMI over 50 kg/m^2 higher levels of obesity is essential, due to the attenuation of PPU image quality when there is increasing soft tissue depth. In the meantime, when available, the use of PPU in patients with obesity is likely to provide at least some benefits to proceduralists and patients.

5 | CONCLUSION

This review has summarized the evidence available assessing the potential benefits of PPU to aid neuraxial analgesia and anesthesia in patients with obesity. Further studies including patients with higher BMI are required, applying rigorous and standard definitions of needle manipulation and reporting clinically relevant outcomes. The available evidence suggests some benefits, with no increase in harm or overall procedure time when PPU is used. The benefits are likely to outweigh risks when PPU is used for neuraxial anesthesia or analgesia in patients with obesity.

AUTHOR CONTRIBUTIONS

Aaron K. Khoo: Data curation; investigation; methodology; visualization; writing—original draft; writing—review and editing. **Annie Huynh**: Data curation; investigation; writing—review and editing. **Anita Pelecanos**: Investigation; writing—review and editing. **Victoria A. Eley**: Conceptualization; supervision; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

Victoria A. Eley has previously received funding from Hicura Medical PTY LTD, a company developing artificial intelligence-supported ultrasound devices. Hicura Medical had no role in this work.

DATA AVAILABILITY STATEMENT

There are no original research data related to this manuscript as it is a systematic review.

TRANSPARENCY STATEMENT

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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