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Comparison of ultrasound-guided and traditional localization in intraspinal anesthesia: a systematic review and network meta-analysis

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Abstract

Introduction:The optimal puncture technique for intraspinal anesthesia in different populations is unclear.We attempted to obtain data from randomized controlled trials to compare the impact of ultrasound-guided techniques and traditional localization techniques on the success rate of intraspinal anesthesia puncture.

Method:In a systematic review and network meta-analysis,we searched trials in PubMed, Embase , Cochrane Library and Web of science, from inception to 31 September 2022, for technique of intraspinal anesthesia.The primary outcome was the success rate of the first puncture.We used surface under the cumulative ranking curve(SUCRA) to establish the probability of an intervention ranking highest.A pairwise comparative analysis of various techniques was conducted using forest maps.

Results:Twenty-two randomized controlled trials containing 3 different interventions were included.The SUCRA values of the interventions for first-pass success rate were real-time guidance(82.8%), ultrasound-assisted (67.1%), traditional localization (0.1%).Compared with traditional localization, both ultrasound-assisted and real-time guidance could improve the success rate of the first puncture, but there was no statistical difference between them.In the subgroup analysis, first puncture success rate in pregnant women and obese patients.When compared with traditional positioning,real-time ultrasound guidance (mean difference, 2.33; 95% Crl,1.27 to 4.27), and ultrasound-assisted(mean difference, 1.52; 95% Crl,1.10 to 2.10).In terms of the success rate of the first puncture attempt in elderly patients with lumbar anatomic abnormalities,compared with traditional positioning,real-time ultrasound guidance (mean difference, 1.16; 95% Crl,0.95 to 1.43), and ultrasound-assisted(mean difference, 1.88; 95% Crl,1.55 to 2.28).

Conclusion:Compared with traditional positioning, ultrasound guidance technology can improve the success rate of the first puncture in intraspinal anesthesia, but there is no significant difference between ultrasound assistance and real-time guidance technology.In the subgroup analysis.In terms of the success rate of the first puncture, real-time ultrasound guidance technology is more suitable for pregnant women and obese patients, and ultrasound-assisted technology is more suitable for elderly patients with lumbar anatomic abnormalities.

Keywords:ultrasound guidance;landmark;spinal anesthesia;lower limb surgery

1.Introduction

As a common anesthesia method, the traditional operation method is to manually touch the body surface markers to determine the puncture position.Recently ultrasound is increasingly being used for intraspinal anesthesia[1].Currently, there are two kinds of ultrasound techniques used in intraspinal anesthesia. On the one hand, preoperative ultrasound scan can help to determine the puncture point and estimate the puncture depth; on the other hand, real-time ultrasound guidance technology (needle insertion under ultrasound visualization) can more accurately estimate the location and trajectory of needle insertion.Among the existing studies,

some studies have compared the application of ultrasound-assisted technology with traditional positioning methods, and some studies have compared the real-time ultrasound guidance technology with traditional positioning methods. There are few studies between the two ultrasound techniques. A study by Chen pointed out that ultrasound-assisted spinal anesthesia is superior to real-time guidance in hip surgery of elderly patients[2], while Parli pointed out that ultrasound-guided real-time spinal anesthesia has shorter operation time and higher success rate of the first puncture in lower limb surgery of obese patients[3].At present, it is still controversial which of the three spinal anesthesia methods is the best. Therefore, we reviewed the articles comparing the application of traditional localization, ultrasound-assisted and real-time guidance techniques in spinal anesthesia. Through network meta-analysis, the three methods of spinal anesthesia were systematically evaluated.

2. Materials and methods

We adhered to the recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[4]and registered the meta-analysis and systematic review in the PROSPERO database.We developed the protocol for this review and registered it in the PROSPERO network (registration number:CRD42022376041) on 28 November 2022. The present network meta-analysis(NMA) was conducted in accordance with the protocol recommended by the Cochrane Collaboration[5]and presented following the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines[6].

2.1 Search strategy

We searched PubMed,EMBASE,Web of science and Cochrane Library databases to search for all relevant articles up to 31 September 2022. The key words are "ultrasound real-time guidance", "ultrasound assistance", “landmark palpation”, “traditional positioning” , "epidural anesthesia", "spinal anesthesia" and "combined spinal-epidural anesthesia". The search is conducted by the combination of subject words and free words.

2.2 Inclusion and exclusion criteria

We only included randomized controlled trials(RCT) and compared two or three auxiliary methods for intraspinal anesthesia.The PICO-SD information was as follows： patients(P): under intraspinal anesthesia included epidural anesthesia, spinal anesthesia and combined spinal-epidural anesthesia;intervention(I):traditional positioning, ultrasound-assisted localization or real-time ultrasound guidance;comparison(C):one auxiliary method for intraspinal anesthesia;outcome measures(O):the primary outcome was first-pass success rate(defined as the needle achieving successful dural puncture through a single attempt without redirection);the secondary outcomes were first-attempt success rate(defined as the needle reaching the subarachnoid space within a single insertion attempt and allowing redirection),identify time(the time from when the operator touched the patients’ skin to the marking of the insertion point on the skin, and the time from when the probe was placed on the skin to the marking of the insertion point) and puncture time(interval between the contact of the skin with the needle, and the observation of cerebrospinal fluid from the spinal needle);and study design (SD): RCT.

The exclusion criteria were as follows: 1) review articles, case reports, case-series, letters to the editor, commentaries, proceedings, laboratory science studies, and any other non-relevant studies and 2) studies that did not report the outcomes of interest.

2.3. Study selection

Two authors individually scanned the titles and abstracts of the reports identified via the

search strategies described above. If a report was determined eligible from the title or abstract, the full paper was retrieved and evaluated. The same authors also discussed to arrive at a consensus as to whether a study should be included or excluded. Disagreement over inclusion or exclusion was settled in discussion with a third author.

2.4. Data extraction

All interrelated data from the included studies were independently extracted and entered into standardized forms by other two authors and then cross-checked. Any discrepancy was resolved through consultation.The standardized form included the following items: 1) title, 2) name of first author, 3) year of publication, 4) study design, 5) choice of anesthesia, 6) type of surgery, 7) risk of bias, 8) inclusion criteria, 9) exclusion criteria, 10) BMI, 11) age, 12) number of subjects, 13) first-pass success, 14) first attempt success, 15)identify time,16) and procedure time.

The data were initially extracted from the tables or text.When it comes to transforming continuous variables that do not conform to normal distribution into the form of mean and standard deviation, we make the transformation according to the corresponding method[7-9].

2.5. Risk of bias assessment

The quality of studies was independently assessed by two authors using the tool of 'risk of bias' according to Review Manager (version 5.3). The quality was evaluated using the following potential sources of bias: random sequence generation, allocation concealment, blinding of participants and personnel,blinding of outcome assessment,incomplete outcome data and selective reporting. The methodology for each study was graded as 'high', 'low', or 'unclear', which reflects the risk of bias[5].

2.6. Statistical analysis

A multiple treatment comparison NMA is a meta-analysis generalization method that includes both direct and indirect RCT comparisons of treatments. A random-effects NMA based on a frequentist framework was performed using STATA 15 software and Review Manager (version 5.3).

Before conducting the NMA, we evaluated the transitivity assumption by examining the comparability of the risk of bias (all versus removing high risks of bias for randomization, allocation concealment, and blinding of outcome assessor) as a potential treatment-effect modifier across comparisons[4].

A network plot linking all the included research was formed to indicate the types of auxiliary methods for intraspinal anesthesia, number of patients under different research and amount of pair-wise comparison. The nodes showed auxiliary methods for intraspinal anesthesia being compared, and the edges showed available direct comparisons among auxiliary methods for intraspinal anesthesia. The nodes and edges were weighed on the basis of the numbers of patients and studies.

A rankogram and cumulative ranking curve were drawn for each auxiliary method for intraspinal anesthesia. A rankogram plots the probabilities for treatments to assume any of the possible ranks. We used the surface under the cumulative ranking curve (SUCRA) values to present the hierarchy of auxiliary methods for intraspinal anesthesia for first-pass success rate and the first-attempt success rate . The SUCRA is a relative ranking measure that accounts for the uncertainty in treatment order, that is, accounts both for the location and the variance of all relative treatment effects[10]. A higher SUCRA value was regarded as a better result for individual

interventions.

2.7. Patient and Public Involvement

No patients were involved in the study.

3. Results

From the PubMed and EMBASE database search, 128 and 359 studies were initially evaluated.At the same time, we retrieved the Web of science and Cochrane Library database.After adjusting for duplicates, 148 studies remained. Of these, 92 studies were discharged because it appeared that these studies were out of our interest after reviewing the titles and abstracts. The full texts of the 56 remaining studies were reviewed in detail;34 studies were excluded for the reasons: not set control(n=20),not report outcome of interest(n=14)(Fig.1).

3.1. Study characteristics

The characteristics of the 22 studies are summarized in Table 1.All the experiments were two-arm or three-arm experiments. Among them, 13 studies compared ultrasound-assisted localization with traditional localization[11-23], 5 studies compared ultrasound-assisted localization with traditional localization[24-28], and 3 studies compared the application of ultrasound-assisted localization and real-time guidance in intraspinal anesthesia[2,19,3].A study compared the application of three methods in spinal cord anesthesia[20].Table 1 lists the first author and the year of publication in the literature, as well as basic information such as the mode of anesthesia, type of operation, sample size in each group, patient age, BMI, including maternal (including obese), orthopedic patients (including the elderly and patients with spinal anatomy abnormalities).In all of the included studies, the ultrasound probes used were portable low-frequency convex array probes and did not include special puncture probes.

Table 1.

The characteristics of studies included in this analysis.

The author	Time of Publication	Type of patient	Type of surgery	Method of anesthesia (E、S、CSE)	Age(&、#、*)	BMI(&、#、*)	Sample size(&、#、*)
Karthikeyan[11]	2018	adult	knee and hip surgery	S	65.3±9.7# 68.2±10.3&	30.1±6.4# 30.6±4.7&	59# 60&
Sangeeta Dhanger[12]	2018	maternal	cesarean section	S	23.06±3.01# 24.03±3.43&	27.2±3.8# 27.2±4.2&	50# 50&
Cristian Arzola[13]	2015	maternal	childbirth	E	32.3±5.8# 32.7±4.7&	29±5.1# 29.3±6&	60# 68&
Y. C. Lim[14]	2014	adult	lower limb surgery	S	61.1±13.3# 63.7±12.6&	25.4±5.6# 25.0±5.9	85# 85&
Chin[15]	2018	maternal	cesarean section	CSE	No	30.2[a](27.0-36.5)# 30.5[a](26.9	105# 110&

						-34.2)&	
Bingdong Tao[16]	2021	maternal	cesarean section	CSE	32.3±5.2# 30.6±3.8&	28.3±3.0# 28.3±2.2&	64# 64&
Mohd Anas Khan[17]	2022	orthopedic patient	lower limb surgery	CSE	54.5±12.8# 57.7±13.2&	29.3±4.6# 27.7±3.8&	50# 50&
Mengzhu Li[18]	2019	obese patients	cesarean section	CSE	29.5±3.9# 30.1±4.5&	No	40# 40&
Sun-Kyung Park[19]	2019	old age patient	lower limb surgery	S	71.1±7.2# 71.2±6.1&	25.8±3.1# 25.8±3.1&	40# 40&
Mohamed Mohamed Tawfik[20]	2017	maternal	cesarean section	CSE	27.7±4# 26.7±3.8&	29.2±3# 29.2±2.9&	53# 55&
Sun-Kyung Park[21]	2020	anatomic abnormality of lumbar spine	lower limb surgery	S	70.5±8.8# 66.5±13.2&	26.1±3.2# 25.9±2.9&	22# 22&
Bo Qu[22]	2020	old age patient	hip surgery	CSE	83.3±6.7# 82.3±7.1&	21.6±3.6# 20.6±3.0&	40# 40&
Xiu Ni[23]	2021	obese patients	cesarean section	CSE	31.8±4.8# 31.4±4.2&	33.5±2.1# 33.0±2.1&	40# 40&
Bertam[24]	2017	adult	lower limb surgery	S	No	No	30* 30&
Tanya Mital[25]	2021	children	chest and abdominal surgery	E	2.4±1.3* 3.0±1.7&	No	23* 22&
Jatuporn Pakpirom[26]	2020	adult	chest and abdominal surgery	E	60.0[a](51.0-67.0)* 58.5[a](53.75-70.25)&	23.4±4.0* 22.8±3.5&	48* 48&
Jindi Jiang[27]	2021	overweight mothers	childbirth	E	29.2±3.1* 28.4±3.4&	35.6±2.0* 35.2±2.4&	30* 30&
Hesham[28]	2017	anatomic abnormality of lumbar spine	knee and hip surgery	S	69±10* 70±10&	34±11* 33±8&	14* 18&
Luying Chen[2]	2021	old age patient	hip surgery	S	82.7±6.6* 84.5±6.2#	21.9±3.1* 21.3±3.4#	57* 57#
Yasser Mohamed[29]	2020	maternal	childbirth	E	25.4±5.1* 26.8±5.65#	37.9±4.3* 38.1±4.2#	50* 50#
Parli	2021	obese	lower limb	S	58.5[a](50.3,6	34.9[a](33.1,	40*

Raghavan Ravi[3]		patients	surgery		5.8)* 59.5[a](52.3,6 5.8)#	36.35)* 34.9[a](33.1, 36.40)#	40#
Deepak Bhardwaj [30]	2022	adult	lower limb surgery	S	39.66± 13.27& 42.88± 12.72# 43.6±15.24*	22.8±2.8& 22.4±3.4# 23.9±3.0*	50& 50# 50*
[a] range							
&:landmark group #: ultrasound assisted group *:real time group							
E:Epidural anesthesia S:Spinal anesthesia CSE:Combined spinal and epidural anesthesia							

3.2. Risk of bias assessment

The quality indicators of the included studies are described in Figure 2.All studies applied random sequence generation,and twelve studies included concealed allocation.Blinding of participants was not specified, except in five studies, which had a low risk.And one study had a high risk of bias in blinding of procedure performers which can be explained by the difficulty of blinding in procedure.Incomplete outcome data was also difficult to achieve; five studies had an unspecified risk.None of the studies had blinding of outcome and selective reporting.

3.3. Synthesis of results

For all the results of each specific data, we give the network map, the forest map of a single study, the forest map of pairwise comparison, and the cumulative ranking curve. A summary of the results is shown in figures 3 to 7.

3.4. First pass rate

The success rate of the first pass of the needle was recorded in 19 two-arm studies and one three-arm study,which were pooled for analysis[2,3,11-17,19-27,29,30].In all studies, traditional positioning is the most frequent reference(Fig.3A).In this study, the success rate of puncture in the ultrasound-assisted group and real-time guidance group seemed to be higher than that in the traditional localization group(Fig.4A). However, there was no significant difference between ultrasound-assisted group and real-time guidance group(Fig.5A).Draw a cumulative sorting chart to calculate the SUCRA probabilities of traditional positioning, auxiliary positioning and real-time guidance (Fig. 6A).According to SUCRA, real-time guidance had the highest success rate in the first puncture (82.8%), followed by ultrasound-assisted (67.1%), and finally traditional localization (0.1%).Funnels are roughly distributed on both sides of the midline, and publication bias is unlikely to occur(Fig.7A).

3.5. First attempt rate

A total of 16 trials provided data on the pass rate of first attempts[2,3,11,12,14,18-22,24-28,30]. The forest map results show that the use of ultrasound is related to the pass rate of the first attempt (Fig.4B). However, the combined network Meta analysis showed that there was no significant difference between ultrasound-assisted and real-time guidance(Fig.5B).The cumulative ranking chart shows that ultrasound-assisted has the highest pass rate in the first attempt (75.3%), followed by real-time guidance (74.6%) and traditional positioning (0.1%). However, there was no significant statistical difference between ultrasound-assisted and real-time guidance in the pairwise comparison of the combined results(Fig.6B).Funnel chart also shows that there is little

publication bias(Fig.7B).

3.6. Identify time

The results[2,3,11-12,17-19,21-23,26-27,30] of Meta analysis showed that the traditional location method had the shortest location time(Fig.6C), but there was no significant difference between ultrasound-assisted and real-time guided puncture location time(Fig.5C).The funnel is shown in figure 7C.

3.7. Procedure time of spinal anesthesia

A total of 9 studies, including 8 double-arm studies and 1 three-arm study[3,11,12,14,18,19,21,28,30], were collected to compare the whole process of spinal anesthesia from puncture needle contact to cerebrospinal fluid outflow. The combined analysis showed that the ultrasound-assisted operation time was the shortest(Fig.6D), and there was no significant difference between the real-time guidance group and the traditional positioning group(Fig.5D).Funnel also shows that publication bias is unlikely(Fig.7D).

3.8. Subgroup analysis

In the first subgroup, we included nine studies of pregnant women and obese people with an average age of less than 60 years and a BMI greater than 33.The network diagram comparing the first pass rate[3,12,13,15,16,20,23,27,29] and the first attempt[3,12,18,20,27] rate is shown in figure 3E and figure 3F.The cumulative sorting chart shows that real-time guidance seems to be the recommended method in terms of the first puncture pass rate and the first attempt pass rate (Fig. 6E and 6F). The funnel chart indicates that a publication bias is unlikely(Fig. 7E and 7F).

In the second subgroup analysis, we included patients with an average age of over 70 years, including lumbar anatomical abnormalities (previous lumbar surgery or scoliosis)[2,19,21,22,28].The results of meta analysis and merger show that the pass rate of the first attempt seems to be higher in the ultrasound-assisted group(Fig. 5G), and the cumulative ranking chart also shows that ultrasound-assisted is the most recommended(Fig. 6G). The funnel chart is symmetrical around the zero line, indicating that publication bias is unlikely(Fig. 7G).

Discussion

Recently, more and more people are interested in using ultrasound to guide or assist spinal anesthesia, epidural anesthesia or combined spinal-epidural anesthesia[31-33].The research supports that the application of this technology can improve the success rate and reduce the number of attempts[34-35].the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom published guidelines[36]suggesting that ultrasound could be used both as a pre-procedural assessment tool and for real-time needle insertions.

The two main indicators to measure the difficulty of intraspinal anesthesia are the number of times needed to adjust the needle for successful puncture and the time required for the whole operation.Multiple acupuncture is an independent predictor of complications, such as unintentional dural puncture, vascular puncture and sensory abnormalities[37].The ideal intraspinal anesthesia requires a single successful puncture[24].Minimizing the number of attempts helps to reduce the risk of complications and improve patient satisfaction[38].Previous studies have shown that pre-puncture ultrasound scan can improve the success rate of puncture and reduce the number of puncture[39].The feature of real-time guidance technology is that the trajectory of needle can be observed in real time during puncture to improve the success rate of puncture[24,40-42].This is consistent with our analysis.

However, the analysis results showed that there was no difference between ultrasound

assistance and real-time guidance in the success rate of the first puncture and the success rate of the first attempt. However, subgroup analysis found that real-time guidance technology had more advantages for puerpera and obese people.Ultrasound-assisted technique is more recommended in the elderly and patients with abnormal spinal anatomy.

We analyze the reasons for this difference.It is difficult for pregnant women and obese patients to achieve the ideal puncture position in the process of intraspinal anesthesia, and the difficulty of palpation may lead to the increase of puncture times, resulting in patient discomfort or puncture failure[43].During pregnancy, an increase in lumbar protrusion, enlargement and rotation of the pelvis results in a deeper and narrower epidural space and a narrowing of the "safe area" between the ligamentum flavum and the dura mater[44].However, this kind of people are generally younger, the ligaments of the waist are relatively soft, the boundary between muscle and fat is obvious, the anterior and posterior complex can be clearly seen under ultrasound, and the number of needle redirection can be significantly reduced by using real-time guidance technology[34,45].However, real-time puncture is difficult in elderly patients. Due to the hyperplasia of vertebral body and appendages and the narrowing of vertebral space in elderly patients, the ordinary ultrasonic probe is more likely to block the puncture needle entry path, thus affecting the observation of the real-time trajectory of the puncture needle.Another advantage of ultrasound-assisted localization is that it can shorten the anesthesia operation time. Studies have shown that real-time guidance technology is not superior to ultrasound-assisted localization, because real-time guidance requires longer operation time, especially for elderly patients, which will reduce the satisfaction score[2].

Of course, we can't ignore other factors that affect our results. The puncture path adopted by the researchers included in the literature is not completely consistent. According to previous studies[46], the para-median puncture path is better than the median position, because supraspinous and interspinous ligaments are avoided, and the calcification of ligaments will make the operator inject more hard and increase the number of attempts.Another aspect that cannot be ignored is the operator's experience.In the included literature, the operators were almost anesthesiologists who were skilled in the application of ultrasound technology for intraspinal anesthesia.The seniority of the anesthesiologist is also a factor in the success rate, an effect that may exaggerate the advantages of ultrasound-guided technology[47].In addition, real-time ultrasound guidance technology is very difficult, which requires the operator to hold the probe to ensure the stability of the image while observing the needle trajectory.It is also a challenge for anesthesiologists with years of experience in ultrasound-assisted localization.This technical difference also affects our results.On the other hand, the choice of ultrasound probe will also affect real-time guided puncture.Due to the appearance of the common low-frequency convex array probe, the contact surface of the probe cannot completely fit the skin, and the curved shell of the probe will block the Angle of the needle in the process of puncture.Recently, TranD operated with a new puncture probe[45]. The probe is equipped with an epidural needle holder on the side, and the needle Angle can be adjusted in the probe plane.According to the pre-positioned intervertebral space and the pre-set needle insertion Angle, the operator only needs to pay attention to the needle insertion depth to complete the puncture.This method keeps the needle in the same plane as the probe, making the needle's trajectory visible at all times.

This study also has a few limitations. Due to the difficulty of real-time guidance technology,

there are few researches on this aspect at present, and the sample size included is smaller than that of assisted positioning, which will also affect our analysis.Therefore, our result cannot be extrapolated to other relevant studies.

Conclusion:

Our study shows that ultrasound-guided technique has a significant advantage in improving the success rate of the first puncture during intraspinal anesthesia.In addition, subgroup analysis showed that in terms of the success rate of the first puncture, real-time ultrasound guidance technology is more suitable for pregnant women and obese patients, and ultrasound-assisted technology is more suitable for elderly patients with lumbar anatomic abnormalities.The evidence in the current study is insufficient, mainly due to the heterogeneity and inaccuracy of the comparison.Due to the difficulty of real-time guidance technology, there are few studies at present. Future studies should focus on real-time ultrasound guidance technology and expand the application of visualization technology in spinal anesthesia.

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Contributors:Yinzhou Zhang, Jieling Huang, Junying Wei, Wuhua Ma and Yuhui Li were involved in the design and conception of the research scheme.Yinzhou Zhang and Jieling Huang will screen the title, abstract and full text.If disagreement arises on inclusion or exclusion, it will be resolved through discussion with all authors (Junying Wei,Wuhua Ma and/or Yuhui Li).Yinzhou Zhang and Jieling Huang will extract data from the article independently, and third party reviewers (Junying Wei and/or Wuhua Ma) will check the integrity and correctness of the extracted data in the results evaluation.All authors drafted and revised this research protocol and approved it for publication.

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Figure explanation

Fig.1.Flow diagram

Fig.2.Consensus risk-of-bias assessment of the included studies.

Green = low risk; yellow = unclear; red =high risk.

Fig3:Network plot of the direct comparisons of the outcomes for all included studies.The width of the lines is proportional to the number of trials comparing every pair of treatments, and the size of every node is proportional to the number of randomized participants (sample size). 1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

Fig4:Forest plot for all included studies.1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance. A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time

of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

Fig5:Two-comparison forest diagram for all included studies.LAN:Traditional positioning,ULT:Ultrasound assistance, REA: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

Fig6:Cumulative ranking curve of all included studies.landmark:Traditional positioning,ultrasound:Ultrasound assistance, real: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

Fig7:funnel plots A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

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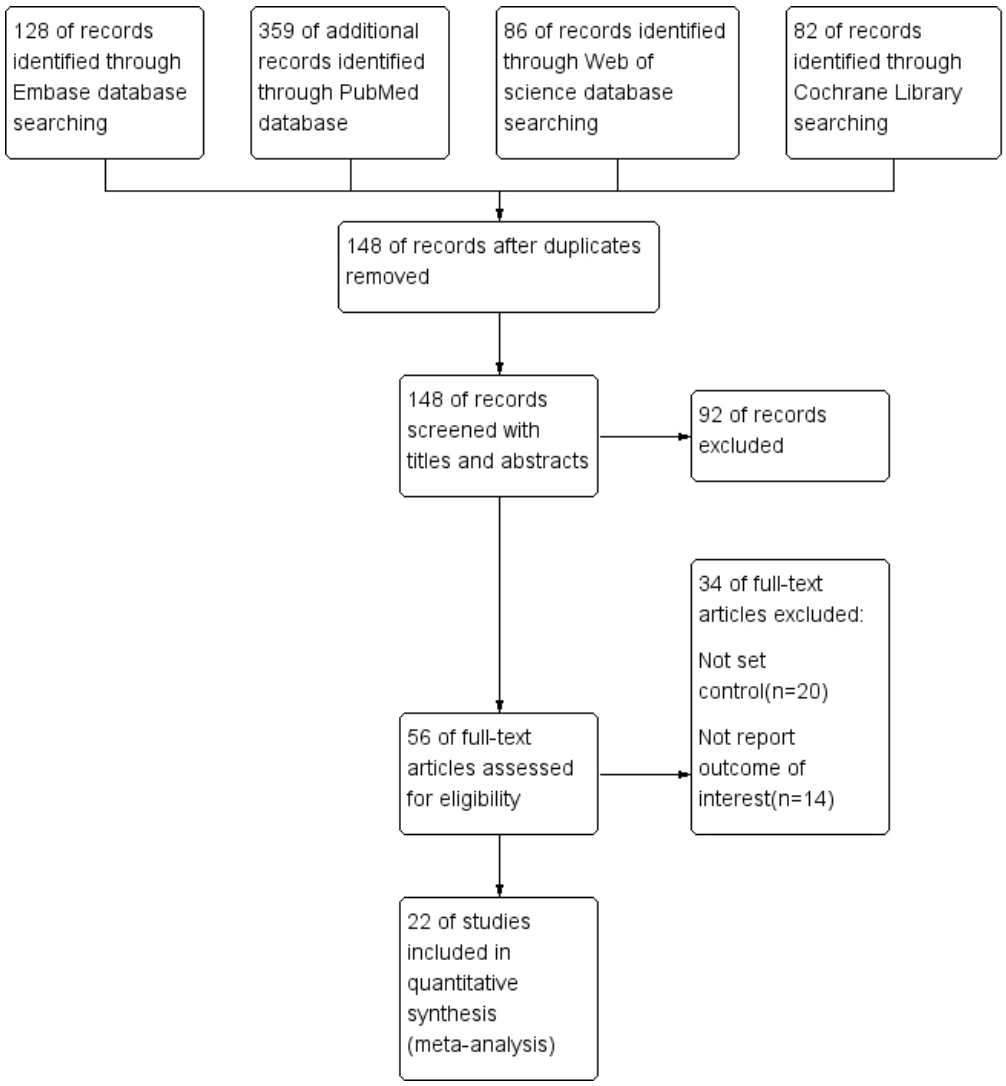

Fig.1.Flow diagram

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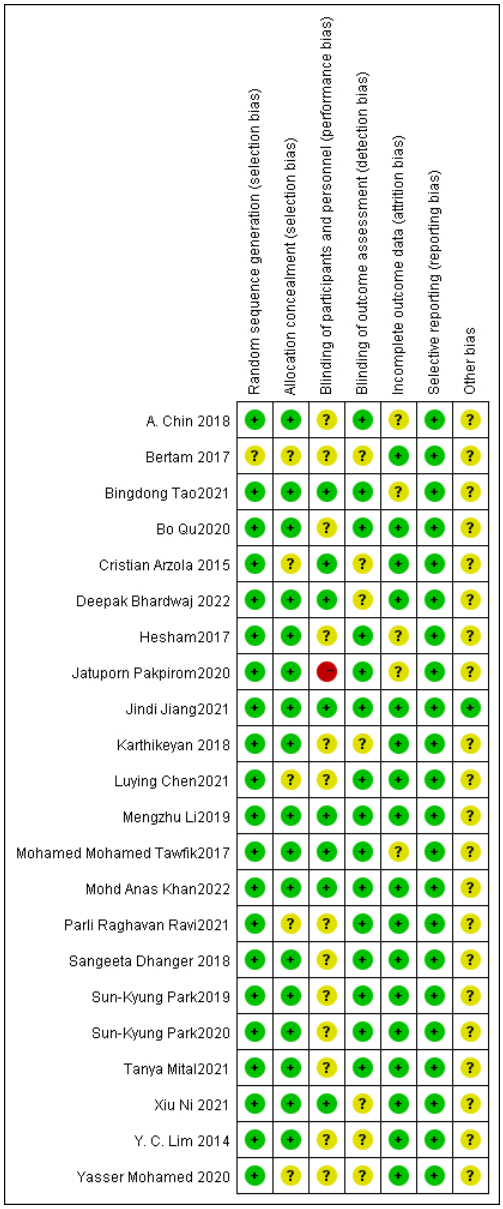

Fig.2.Consensus risk-of-bias assessment of the included studies.
Green = low risk; yellow = unclear; red =high risk.

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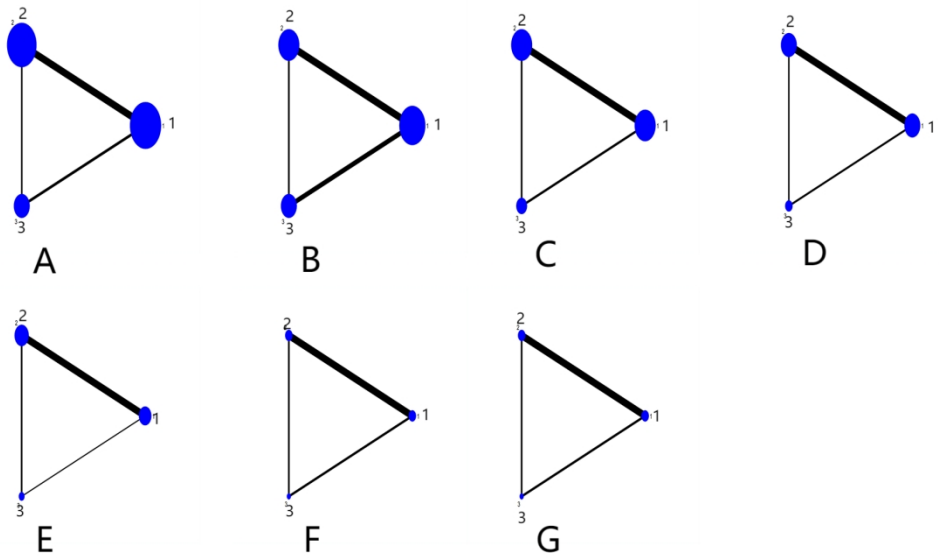

Fig3:Network plot of the direct comparisons of the outcomes for all included studies.The width of the lines is proportional to the number of trials comparing every pair of treatments, and the size of every node is proportional to the number of randomized participants (sample size). 1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

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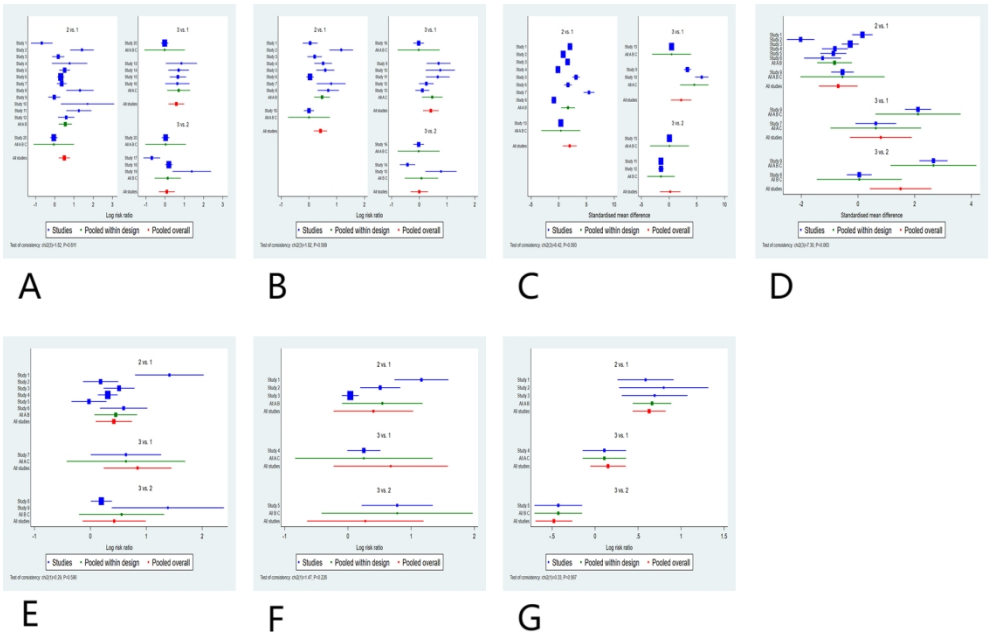

Fig4:Forest plot for all included studies.1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance. A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

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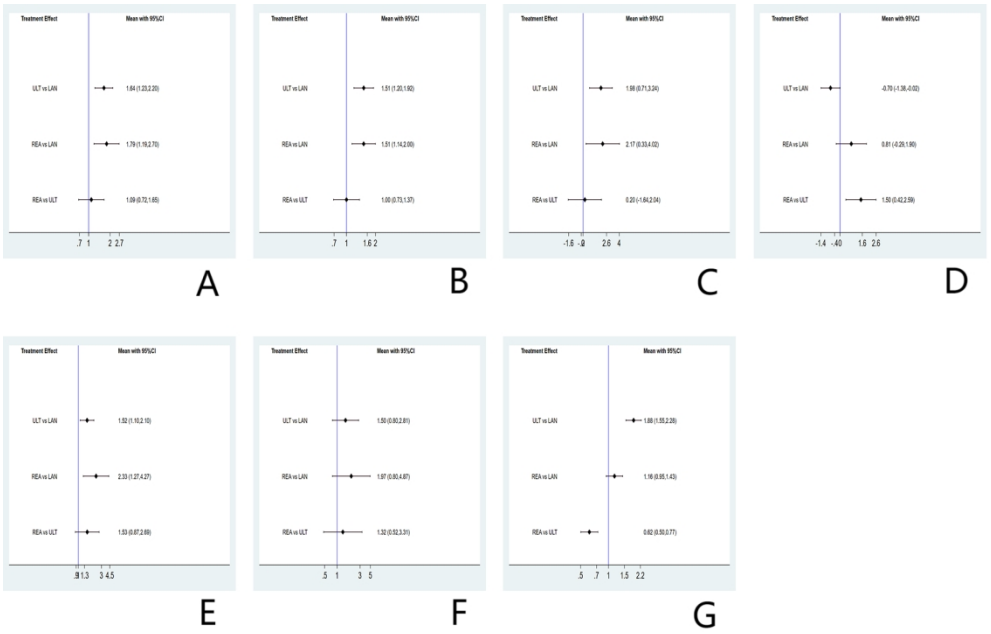

Fig5:Two-comparison forest diagram for all included studies.LAN:Traditional positioning,ULT:Ultrasound assistance, REA: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

666x423mm (72 x 72 DPI)

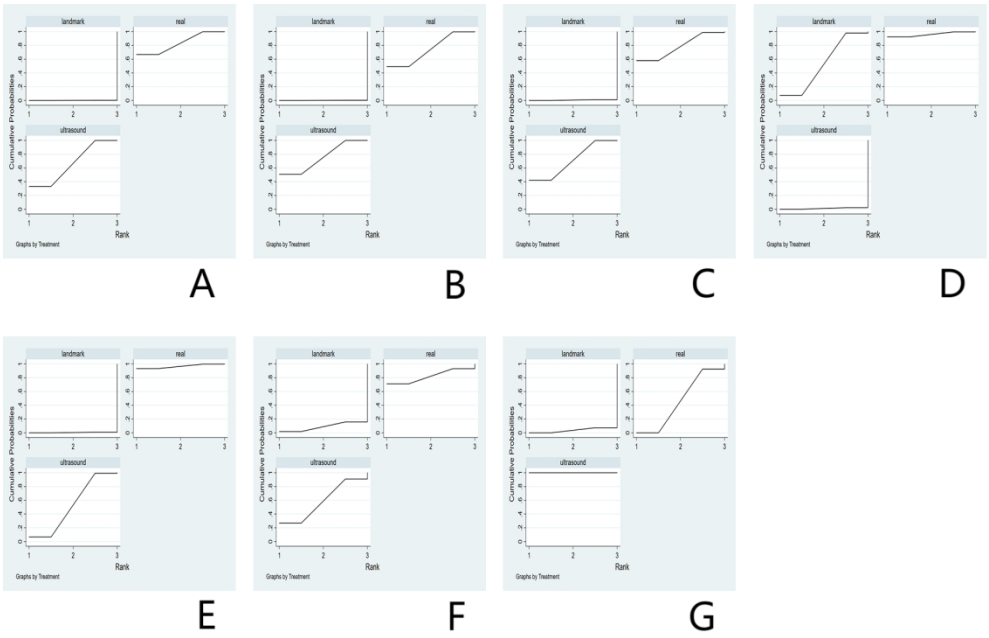

Fig6:Cumulative ranking curve of all included studies.landmark:Traditional positioning,ultrasound:Ultrasound assistance, real: Real-time guidance; A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

666x423mm (72 x 72 DPI)

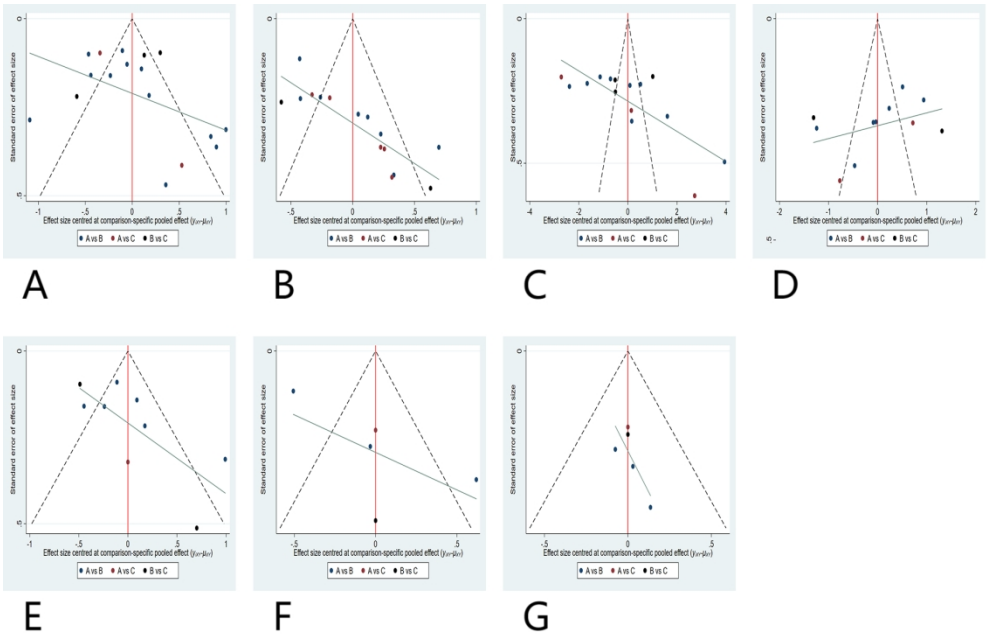

Fig7:funnel plots A) First pass rate, B) First attempt rate; C) Identify time; D) Procedure time of spinal anesthesia; E) Subgroup 1 first pass rate; F) Subgroup 1 first attempt rate; G) Subgroup 2 first attempt rate

666x423mm (72 x 72 DPI)

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page1
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page2
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page2
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page3
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page3
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page3
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page6
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page6

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page4
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	Page5
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page6
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page6
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page7
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page7
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page7
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page7
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page8
	23b	Discuss any limitations of the evidence included in the review.	Page8
	23c	Discuss any limitations of the review processes used.	
	23d	Discuss implications of the results for practice, policy, and future research.	Page8
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page9
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page9
Competing interests	26	Declare any competing interests of review authors.	Page9
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page9

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

BMJ Open

Comparison of ultrasound-guided and traditional localization in intraspinal anesthesia: a systematic review and network meta-analysis

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Comparison of ultrasound-guided and traditional localization in intraspinal anesthesia: a systematic review and network meta-analysis

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Abstract

Objectives: The optimal puncture technique for intraspinal anesthesia in different populations is unknown. We sought to obtain data from a randomized controlled trial comparing the effect of ultrasound-guided techniques and conventional positioning techniques on the success rate of puncture for intraspinal anesthesia.

Design: Systematic evaluation and network meta-analysis using study population, interventions, comparison of interventions, outcome indicators, and study type.

Data sources: PubMed, Embase, Cochrane Library, and Web of science were searched for through September 31, 2022.

Eligibility Criteria: We included randomized controlled trials comparing three types of intraspinal anesthesia: ultrasound-assisted, ultrasound real-time guided, and conventional positioning, to describe which is best for patients undergoing intraspinal anesthesia and the recommended intraspinal anesthesia for different populations.

Data extraction and synthesis: five independent reviewers used standardized methods to retrieve, screen, and edit the included studies. Risk bias was assessed using the Cochrane Collaboration and Evidence Project tools. Network meta-analysis was performed using STATA 15 statistical software.

Results: Twenty-two studies containing three different interventions were included. The SUCRA values for first-pass success rates for the three intraspinal anesthesia methods were real-time guidance (82.8%), ultrasound-assisted (67.1%), and conventional positioning (0.1%). Compared with traditional positioning, two ultrasound techniques improve the first-pass success rate , but there was no significant difference between them.Subgroup analysis showed that the use of ultrasound real-time guided spinal anesthesia in pregnant women and obese patients improved the first-pass success rate. The success rate of first attempt in elderly patients with lumbar anatomical abnormalities can be improved by ultrasound-assisted techniques.

Conclusion:Compared with conventional positioning, ultrasound-guided technique can improve the success rate of the first puncture of intraspinal anesthesia, but there was no significant difference between ultrasound-assisted and real-time guidance techniques. The results of subgroup analysis tell us that the most suitable intraspinal anesthesia methods are different for different populations.

PROSPERO number: CRD42022376041

Strengths and limitations of this study:

1.To the best of our knowledge, this is the first study to compare three types of intraspinal anesthesia with a systematic review and network meta-analysisthis.

2.This study will help clinical anesthesiologists to choose the appropriate intraspinal anesthesia

for different populations

3.Due to the technical difficulty of real-time ultrasound guidance and the lack of evidence from clinically relevant studies, this may be one of the main limitations of this meta-analysis.

1. Introduction

As a commonly used method of anesthesia, intraspinal anesthesia is traditionally performed by manually touching the body markers to determine the puncture location. In recent years ultrasound techniques have been increasingly used in intraspinal anesthesia [1]. There are two types of ultrasound techniques currently used in intraspinal anesthesia: ultrasound-assisted and ultrasound real-time guidance techniques. The preoperative ultrasound scan helps to identify the puncture point and estimate the depth of puncture, while the ultrasound real-time guidance technique (puncture under ultrasound visualization) allows a more accurate observation of the position and trajectory of the needle entry. Some of the existing studies have compared the use of ultrasound-assisted techniques with conventional localization methods, and some studies have compared ultrasound real-time guidance techniques with conventional localization methods. However, few studies have compared between these two ultrasound techniques. Chen's study noted a higher first puncture success rate and higher patient satisfaction with ultrasound-assisted intraspinal anesthesia than real-time guidance techniques in hip surgery in elderly patients [2], while Parli noted a shorter operative time and higher first puncture success rate with ultrasound real-time guidance for intraspinal anesthesia in lower extremity surgery in obese patients [3]. There is controversy as to which of these three methods of endotracheal anesthesia is most effective. Therefore, we reviewed articles comparing conventional positioning, ultrasound-assisted, and real-time guidance techniques used in intraspinal anesthesia. A systematic evaluation of the three methods of intraspinal anesthesia was performed through a network meta-analysis.

2. Materials and Methods

We followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [4] to register meta-analyses and systematic reviews to the PROSPERO database and to the PROSPERO network on November 28, 2022 (registration number: CRD42022376041). The current network meta-analysis (NMA) is based on the scheme recommended by the Cochrane Collaboration [5] and follows the preferred reporting items of the systematic review and meta-analysis guidelines [6].

2.1. Search strategy

We searched PubMed, EMbase, Web of Science, and Cochrane Library databases for all relevant articles up to September 31, 2022. Keywords: "ultrasound real-time guidance", "ultrasound-assisted", "landmark palpation", "conventional positioning" , "epidural anesthesia," "spinal anesthesia," and "combined lumbar and epidural anesthesia. The search was performed using a combination of subject terms and free words. The complete search strategy can be found in the supplement.

2.2. Inclusion and exclusion criteria

We included randomized controlled trials (RCTs) and compared two or three methods of intraspinal anesthesia. The information is as follows: study population: intraspinal anesthesia including epidural, spinal, and combined lumbar and epidural anesthesia; intervention: conventional positioning, ultrasound-assisted positioning, or ultrasound real-time guidance; comparison of interventions: one method of intraspinal anesthesia; outcome indicators: primary

outcome was first puncture success rate (defined as needle successfully performing epidural puncture in one attempt without reorientation); secondary outcomes were first attempt success rate (defined as needle reaching the subarachnoid space in one insertion attempt and allowing for needle reorientation), identification time (time from operator touching the patient's skin to marking the puncture point on the skin and time from placing the probe on the skin to marking the puncture point) and puncture time (interval from skin contact with the needle to observation of cerebrospinal fluid flow from within the puncture needle); study design: randomized controlled trial.

Exclusion criteria were as follows: review articles, case reports, case series, letters to the editor, reviews, conference proceedings, laboratory science studies, and any other irrelevant studies, as well as studies that did not report results of interest.

2.3. Study selection

Two authors, Yinzhou Zhang and Junying Wei, searched the database by the above search strategy, respectively. The type of randomized controlled trial or clinical trial was selected through the filter of the online database. The retrieved literature was saved and de-duplicated by the literature management software (NoteExpress). The screened literature was read through title and abstract one by one, and if the title and abstract matched the criteria, the full text was evaluated to see if the results of interest were reported. Yinzhou Zhang, Junying Wei, and Jieling Huang also discussed whether each study should be included or excluded to reach a consensus. The disagreement about inclusion or exclusion was resolved in a discussion with Yuhui Li and Wuhua Ma.

2.4. Date extraction

All relevant data from the included studies were extracted and entered into a standardized form by Yinzhou Zhang and Junying Wei independently and then cross-checked. The standardized table included the following items: title, first author's name, year of publication, study design, choice of anesthesia, type of procedure, risk of bias, body mass index, age, number of subjects, first-pass success rate, first-attempt success rate, time to identification, time to operation, intervention, and best intervention. Data extracted for age and body mass index were mean $\pm$ standard deviation and median (interquartile spacing). When it comes to the presentation of data for outcome indicators in the study as quartile spacing, we followed the appropriate method for conversion [7-9] and finally used the mean $\pm$ standard deviation for statistical analysis.

2.5. Study quality

Independent assessment was performed by Jie-Ling Huang and Wu-Hua Ma using the Risk of Bias tool in the Review Manager (version 5.3). Quality was assessed using the following possible sources of bias: random sequence generation, allocation concealment, participant and personnel blindness, outcome assessment blindness, incomplete outcome data, and selective reporting. The methods of each study were rated as "high", "low" or "unclear", reflecting the risk of bias [5].

2.6. Statistical analysis

Multiple treatment comparison NMA is a meta-analysis generalization method that includes direct and indirect randomized controlled trial comparisons of treatments. We used STATA 15 software to download the network package for statistical analysis, using RR values for dichotomous variables effect values and SMD as effect values for continuous variables. The

inconsistency model was used to test for consistency when the p-value was >0.05 and local inconsistency analysis was performed using the node splitting method. Ring inconsistency tests were performed for network plots that formed closed loops, and if the 95% CI did not contain 0 then sensitivity and subgroup analyses were required for large heterogeneity.

A network diagram linking all included studies is formed to indicate the type of intraspinal anesthesia, the number of patients in the different studies, and the number of pairwise comparisons. Nodes show the intraspinal anesthesia being compared, and edges show the direct comparisons available between methods of intraspinal anesthesia. Cumulative probability plots are plotted for each method of intraspinal anesthesia as well as two-by-two comparisons for each intervention. We used cumulative ranking area under the curve (SUCRA) values to present a hierarchy of first-pass success rates and first-attempt success rates for methods of intraspinal anesthesia. SUCRA is a relative ranking measure that statistically ranges from 0 to 100%, and it indicates the likelihood that the therapy will be rated as the best [10]. Higher SUCRA values are considered to be a better outcome for individual interventions.

2.7. Patient and Public Involvement

No patients participated in the study

3. Results

PubMed and EMBASE databases were searched, and 128 and 359 studies were initially evaluated. Also, we searched Web of science and Cochrane Library databases for 352 and 90 studies each, and a total of 929 publications were retrieved. Randomized controlled trials or clinical trials were screened using online database filters, and 692 studies were withdrawn. After removing duplicates using literature management software, 218 studies remained. The remaining studies were reviewed in detail for title, abstract, and full text; 184 of these studies were not available, and 20 studies were excluded because they did not have controls and 14 studies did not report outcomes of interest (Figure 1).

3.1. Research characteristics

The characteristics of the 22 studies are summarized in Table 1 and Table 2. All experiments were two- or three-armed. Of these, 13 studies compared ultrasound-assisted positioning with conventional positioning [11-23], five studies compared ultrasound real-time guidance with conventional positioning [24-28], and three studies compared the application of ultrasound-assisted positioning with real-time positioning to guide intraspinal anesthesia [2,19,3]. One study compared the use of three methods in spinal anesthesia [20]. Table 1 lists the first author and year of publication of the literature, as well as basic information, such as patient type, procedure, patient age, and body mass index, and Table 2 lists the anesthesia method, sample size of the study, intervention, primary outcome indicator (first pass success rate), and better outcome of the intervention. In all included studies, the probe used for ultrasound was a portable low-frequency convex array probe, excluding special puncture probes.

Table 1

The author	Time of Publication	Type of patient	Type of surgery	Age(&、#、*)	BMI(&、#、*)
Karthikeyan	2018	adult	knee and hip surgery	65.3±9.7# 68.2±10.3&	30.1±6.4# 30.6±4.7&

Sangeeta Dhanger	2018	maternal	cesarean section	23.06±3.01# 24.03±3.43&	27.2±3.8# 27.2±4.2&
Cristian Arzola	2015	maternal	childbirth	32.3±5.8# 32.7±4.7&	29±5.1# 29.3±6&
Y. C. Lim	2014	adult	lower limb surgery	61.1±13.3# 63.7±12.6&	25.4±5.6# 25.0±5.9
Chin	2018	maternal	cesarean section	NM	30.2[a](27.0-36.5)# 30.5[a](26.9-34.2)&
Bingdong Tao	2021	maternal	cesarean section	32.3±5.2# 30.6±3.8&	28.3±3.0# 28.3±2.2&
Mohd Anas Khan	2022	orthopedic patient	lower limb surgery	54.5±12.8# 57.7±13.2&	29.3±4.6# 27.7±3.8&
Mengzhu Li	2019	obese patients	cesarean section	29.5±3.9# 30.1±4.5&	NM
Sun-Kyung Park	2019	old age patient	lower limb surgery	71.1±7.2# 71.2±6.1&	25.8±3.1# 25.8±3.1&
Mohamed Mohamed Tawfik	2017	maternal	cesarean section	27.7±4# 26.7±3.8&	29.2±3# 29.2±2.9&
Sun-Kyung Park	2020	anatomic abnormality of lumbar spine	lower limb surgery	70.5±8.8# 66.5±13.2&	26.1±3.2# 25.9±2.9&
Bo Qu	2020	old age patient	hip surgery	83.3±6.7# 82.3±7.1&	21.6±3.6# 20.6±3.0&
Xiu Ni	2021	obese patients	cesarean section	31.8±4.8# 31.4±4.2&	33.5±2.1# 33.0±2.1&
Bertam	2017	adult	lower limb surgery	NM	NM
Tanya Mital	2021	children	chest and abdominal surgery	2.4±1.3* 3.0±1.7&	NM
Jatuporn Pakpirom	2020	adult	chest and abdominal surgery	60.0[a](51.0-67.0)* 58.5[a](53.75-70.25)&	23.4±4.0* 22.8±3.5&
Jindi Jiang	2021	overweight mothers	childbirth	29.2±3.1* 28.4±3.4&	35.6±2.0* 35.2±2.4&
Hesham	2017	anatomic abnormality of lumbar spine	knee and hip surgery	69±10* 70±10&	34±11* 33±8&
Luying Chen	2021	old age patient	hip surgery	82.7±6.6* 84.5±6.2#	21.9±3.1* 21.3±3.4#
Yasser Mohamed	2020	maternal	childbirth	25.4±5.1* 26.8±5.65#	37.9±4.3* 38.1±4.2#

Parli Raghavan Ravi	2021	obese patients	lower limb surgery	58.5[a](50.3,65.8)* 59.5[a](52.3,65.8)#	34.9[a](33.1,36.35)* 34.9[a](33.1,36.40)#
Deepak Bhardwaj	2022	adult	lower limb surgery	39.66±13.27& 42.88±12.72# 43.6±15.24*	22.8±2.8& 22.4±3.4# 23.9±3.0*

[a] :median(interquartile range) NM: no mention

&:landmark group #: ultrasound assisted group *:real time group

E:Epidural anesthesia S:Spinal anesthesia CSE:Combined spinal and epidural anesthesia

Table 2

The author	Time of Publication	Method of anesthesia (E、S、CSE)	Sample size(&、#、*)	intervention	first pass success rate(%)	Effect Estimate(better)
Karthikeyan	2018	S	59# 60&	Landmark vs ultrasound assisted	43# 22&	ND
Sangeeta Dhanger	2018	S	50# 50&	Landmark vs ultrasound assisted	18# 74&	ultrasound assisted
Cristian Arzola	2015	E	60# 68&	Landmark vs ultrasound assisted	50# 60&	ND
Y. C. Lim	2014	S	85# 85&	Landmark vs ultrasound assisted	7# 15&	ND
Chin	2018	CSE	105# 110&	Landmark vs ultrasound assisted	38.2# 63.8&	ultrasound assisted
Bingdong Tao	2021	CSE	64# 64&	Landmark vs ultrasound assisted	68.8# 93.8&	ultrasound assisted
Mohd Anas Khan	2022	CSE	50# 50&	Landmark vs ultrasound assisted	60# 86&	ultrasound assisted
Mengzhu Li	2019	CSE	40# 40&	Landmark vs ultrasound assisted	52.5# 87.5&	ultrasound assisted
Sun-Kyung Park	2019	S	40# 40&	Landmark vs ultrasound assisted	17.5# 65.0&	ultrasound assisted

Mohamed Mohamed Tawfik	2017	CSE	53# 55&	Landmark vs ultrasound assisted	60# 58.5&	ND
Sun-Kyung Park	2020	S	22# 22&	Landmark vs ultrasound assisted	9.1# 50&	ultrasound assisted
Bo Qu	2020	CSE	40# 40&	Landmark vs ultrasound assisted	20# 70&	ultrasound assisted
Xiu Ni	2021	CSE	40# 40&	Landmark vs ultrasound assisted	40# 72.5&	ultrasound assisted
Bertam	2017	S	30* 30&	Landmark vs real time	47* 30&	real time
Tanya Mital	2021	E	23* 22&	Landmark vs real time	82.6* 40.9&	real time
Jatuporn Pakpirom	2020	E	48* 48&	Landmark vs real time	68.6* 35.4&	real time
Jindi Jiang	2021	E	30* 30&	Landmark vs real time	56.7* 30&	real time
Hesham	2017	S	14* 18&	Landmark vs real time	72.2* 83.3&	ND
Luying Chen	2021	S	57* 57#	ultrasound assisted vs real time	31.6* 63.2#	ultrasound assisted
Yasser Mohamed	2020	E	50* 50#	ultrasound assisted vs real time	90* 74#	real time
Parli Raghavan Ravi	2021	S	40* 40#	ultrasound assisted vs real time	40* 10#	real time
Deepak Bhardwaj	2022	S	50& 50# 50*	Landmark vs ultrasound assisted vs real time	82& 78# 80*	ND

ND:no difference

&:landmark group #: ultrasound assisted group *:real time group

E:Epidural anesthesia S:Spinal anesthesia CSE:Combined spinal and epidural anesthesia

3.2. Risk of bias assessment

The quality indicators of the included studies are shown in Figure 2. All studies were generated using a randomized sequence, and 12 of them had a hidden allocation. Thirteen of the

studies did not specify blinding of subjects. One study had a high risk of bias in terms of blinding the operator, which can be explained by the difficulty of blinding in the operation. Most of the studies did not have incomplete outcome data, but five of them had unspecified risks. All studies did not report outcomes selectively.

3.3. Synthesis of results

For all results for each specific data, we give network plots, forest plots for individual studies, forest plots for two-by-two comparisons, and cumulative ranking curves.The results is shown in figures 1S to 7S.The results of inconsistency model detection, consistency analysis, local inconsistency analysis, ring inconsistency detection, and funnel plots can be found in the Supplementary file. The heterogeneity of the study is small from the model detection as well as the funnel plot.

3.4. First pass success rate

The success rate of first pass of the needle was recorded in 19 two-arm studies and one three-arm study, which were pooled for analysis [2,3,11-17,19-27,29,30]. In all studies, conventional positioning was the most frequently referenced (Figure 1SA). In the present study, the puncture success rate in the ultrasound-assisted and real-time guidance groups appeared to be higher than that in the conventional localization group (Figure 1SB). However, there was no significant difference between the ultrasound-assisted group and the real-time guidance group (Figure 1SC). The probability of SUCRA for conventional localization, assisted localization, and real-time guidance was calculated by plotting the cumulative ranking graph (Figure 1SD). According to the SUCRA data, the highest first puncture success rate was achieved with real-time guidance (82.8%), followed by ultrasound-assisted (67.1%), and finally conventional localization (0.1%).The funnel diagram is shown in figure 1SE.

3.5. First attempt rate

A total of 16 trials provided data on first-attempt pass rates [2,3,11,12,14,18-22,24-28,30]. The network node diagram is shown in Figure 2SA.The forest plot results showed that the use of ultrasound was associated with first attempt pass rates (Figure 2SB). However, there was no significant difference between ultrasound-assisted and real-time guidance (Figure 2SC). Cumulative ranking plots showed that ultrasound-assisted first attempt pass rate was the highest (75.3%), followed by real-time guidance (74.6%) and conventional positioning (0.1%) (Figure 2SD).The funnel diagram is shown in Figure 2SE.

3.6. Identification time

Network plots, forest plots for individual studies are shown in figure 3SA and figure 3SB.Meta-analysis results [2,3,11-12,17-19,21-23,26-27,30] showed that the conventional localization method had the shortest localization time (Figure 3SD), but there was no significant difference between ultrasound-assisted and real-time guided puncture localization time (Figure 3SC).The funnel diagram is shown in Figure 3SE.

3.7. Duration of spinal anesthesia

A total of nine studies, eight two-arm studies and one three-arm study [3,11,12,14,18,19,21,28,30], were collected to compare the entire spinal anesthesia procedure, from puncture needle contact with the skin to cerebrospinal fluid flow. Network plots, forest plots for individual studies are shown in figure 4SA and figure 4SB.The combined analysis showed that ultrasound-assisted surgery time was the shortest (Figure 4SD), and there was no significant difference between the real-time guidance group and the conventional localization group (Figure

4SC).The funnel diagram is shown in Figure 4SE.

3.8.Subgroup analysis

In the first subgroup, we included 9 studies of obese adults and pregnant women (obese or not). The results of first pass success rates [3,12,13,15, 16,20,23,27,29] and first attempt success rates [3,12,18,20,27] are analyzed. For the first pass success rate, network plots(Figure 5SA), forest plots for individual studies(Figure 5SB), forest plots for two-by-two comparisons(Figure 5SC), cumulative ranking curves(Figure 5SD) and funnel diagram(Figure 5SE) are shown.For the first puncture success rate, network plots(Figure 6SA), forest plots for individual studies(Figure 6SB), forest plots for two-by-two comparisons(Figure 6SC), cumulative ranking curves(Figure 6SD) and funnel diagram(Figure 6SE) are shown.

In a second subgroup analysis, we included patients with a mean age over 70 years, including lumbar anatomical abnormalities (previous lumbar spine surgery or scoliosis) [2,19,21,22,28].Network plots, forest plots for individual studies are shown in figure 7SA and figure 7SB. The meta-analysis and combined results showed that the first attempt pass rate appeared to be higher in the ultrasound-assisted group (Figure 7SC), and the cumulative ranking chart also showed that ultrasound assistance was the most recommended (Figure 7SD).The funnel diagram is shown in Figure 7SE.

Discussion

In recent years, there has been increasing interest in ultrasound guidance for lumbar, epidural, or combined lumbar and epidural anesthesia [31-33]. Studies support the use of this technique to improve puncture success and reduce complications [34-35]. The National Institute for Health and Clinical Excellence (NICE) in the UK has published guidelines [36] suggesting that ultrasound can be used both as a preoperative assessment tool and to perform punctures in real time.

The two main indicators of the difficulty of intraspinal anesthesia are the number of needle transfers required for successful puncture and the time required for the entire procedure. Multiple needle punctures are an independent predictor of complications, such as penetration of the dura, injury to blood vessels, and sensory abnormalities [37]. Ideal intraspinal anesthesia requires a single successful puncture [24]. Minimizing the number of attempts can help reduce the risk of complications and improve patient satisfaction [38]. Previous studies have shown that pre-puncture ultrasound scanning can improve puncture success and reduce the number of punctures [39]. The real-time guidance technique is characterized by real-time observation of the needle trajectory during puncture, which improves the puncture success rate [24,40-42]. This is consistent with our analysis.

However, the analysis showed no significant difference between ultrasound-assisted and real-time guidance in terms of first puncture success rate and first attempt success rate. However, subgroup analysis revealed that the real-time guidance technique was more advantageous for maternal and obese populations. Ultrasound-assisted techniques are more recommended for older patients and those with abnormal spinal anatomy.

We analyze the reasons for this discrepancy. Pregnant and obese patients have difficulty achieving the ideal puncture position during intraspinal anesthesia, and difficulties in palpation may lead to an increased number of punctures, resulting in patient discomfort or puncture failure [43]. During pregnancy, the anterior lumbar protrusion increases and the pelvis enlarges and rotates, resulting in a deeper and narrower epidural space and a narrower "safety zone"

between the ligamentum flavum and the dura [44]. These individuals are generally younger, have softer lumbar ligaments and a clear muscle-fat demarcation, and the anterior-posterior complex can be clearly visualized under ultrasound, which can significantly reduce the number of needle transfers and is suitable for real-time guidance techniques [34,45]. However, there are difficulties in real-time puncture for elderly patients. Due to vertebral and ligamentous hyperplasia and narrowing of the vertebral space in elderly patients, the normal ultrasound probe is more likely to block the puncture needle path, thus affecting the observation of the real-time trajectory of the puncture needle. The advantage of ultrasound-assisted localization is that it can shorten the anesthesia operation time. Studies have shown that real-time guidance techniques are not superior to ultrasound-assisted localization because real-time guidance requires a longer operative time, especially in elderly patients, which can decrease satisfaction scores [2].

Of course, we cannot ignore the other factors that influenced our results. The puncture paths used by the investigators were not entirely consistent. According to previous studies [46], the paramedian puncture path is superior to the median position because it avoids the supraspinous and interspinous ligaments, whereas ligamentous calcification can make puncture more difficult for the operator and increase the number of attempts. Not to be overlooked is the experience of the operator. The operators in the included literature were almost always anesthesiologists skilled in the application of ultrasound techniques for intraspinal anesthesia. The seniority of the anesthesiologist is also a factor in the success rate, and its effect may influence the puncture success rate and thus exaggerate the advantages of ultrasound-guided techniques [47]. In addition, the real-time ultrasound guidance technique is difficult and requires the operator to hold the probe and ensure image stability while observing the needle trajectory. This is also a challenge for anesthesiologists with years of experience in ultrasound-assisted localization. This technical difference also influenced our results. On the other hand, the choice of ultrasound probe can also affect real-time guided puncture. Due to the common low-frequency convex array probe, the contact surface of the probe does not completely fit the skin and the curved housing of the probe blocks the angle of the needle during the puncture. Recently, TranD was performed using a new puncture probe [45]. The probe is equipped with an epidural needle holder on the side, which allows adjustment of the needle angle in the plane of the probe. Based on the pre-positioned vertebral space and the pre-set needle entry angle, the operator only needs to pay attention to the depth of needle insertion to complete the puncture. This method keeps the needle in the same plane as the probe so that the needle trajectory is always visible.

This study also has some limitations. Due to the difficulty of real-time guidance techniques, there are fewer studies in this area and contain smaller sample sizes than assisted localization, which can also affect our analysis. Therefore, our results cannot be extrapolated to other related studies.

Conclusion

This study showed a significant advantage of ultrasound guidance technique in improving the first puncture success rate of intraspinal anesthesia. In addition, subgroup analysis showed that real-time ultrasound guidance had a significant advantage in terms of first puncture success rate. Ultrasound-assisted techniques are more appropriate for pregnant and obese patients, and ultrasound-assisted techniques are more appropriate for older patients with anatomical

abnormalities of the lumbar spine. Current research evidence is insufficient, mainly because study designs vary and real-time guidance techniques are difficult and currently less studied. Future studies should focus on real-time ultrasound-guided techniques and expand the application of visualization techniques in intraspinal anesthesia.

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Figure explanation
Fig.1.Flow diagram
Fig.2.Consensus risk-of-bias assessment of the included studies.
Green = low risk; yellow = unclear; red =high risk.
Fig.1S: Results of first pass success rate
A:Network plots(The width of the lines is proportional to the number of trials comparing every pair of treatments, and the size of every node is proportional to the number of randomized participants. 1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance)
B:Forest plot for all included studies(1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance)
C:Two-comparison forest diagram for all included studies(LAN:Traditional positioning,ULT:Ultrasound assistance, REA: Real-time guidance)
D:Cumulative ranking curve of all included studies(landmark:Traditional positioning,ultrasound:Ultrasound assistance, real: Real-time guidance)
E:funnel plots(A:Traditional positioning,B:Ultrasound assistance, C: Real-time guidance)
Fig.2S: Results of first attempt rate
Fig.3S: Results of identify time
Fig.4S: Results of procedure time of spinal anesthesia
Fig.5S: Results of subgroup 1 first pass rate

Fig.6S: Results of subgroup 1 first attempt rate

Fig.7S: Results of subgroup 2 first attempt rate

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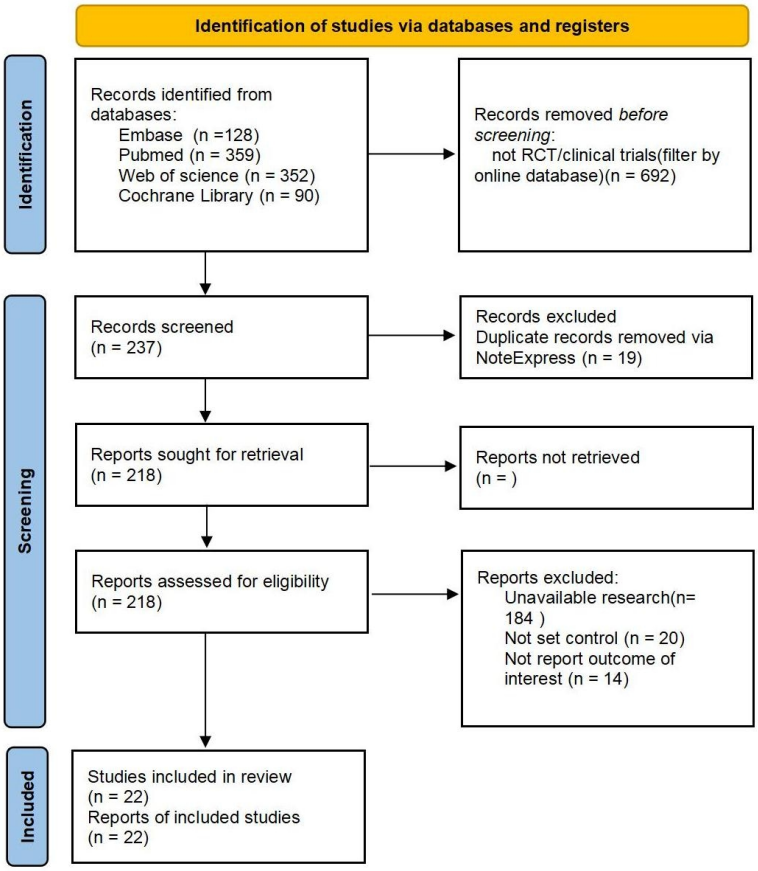


Fig.1.Flow diagram

239x229mm (144 x 144 DPI)

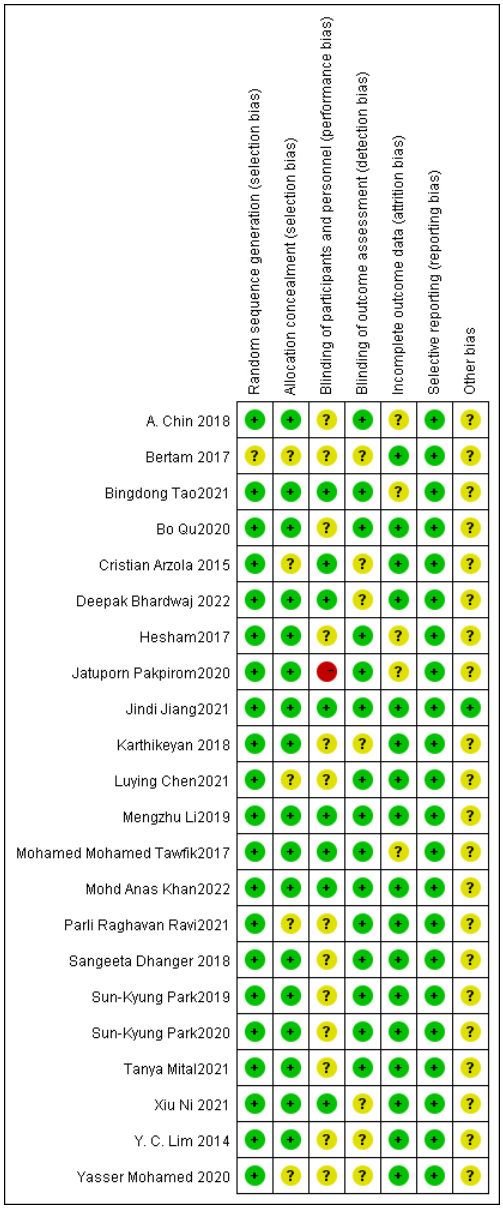


Fig.2.Consensus risk-of-bias assessment of the included studies.

146x353mm (72 x 72 DPI)

Search strategy

Embase（Performed on 31 September 2022）

#1	'real time ultrasound guided' OR 'ultrasound assisted' OR 'landmark palpation' OR 'traditional positioning'
#2	'spinal anesthesia'/exp OR 'spinal anesthesia' OR 'epidural anesthesia'/exp OR 'epidural anesthesia' OR 'combined spinal and epidural anesthesia'
#3	#1 AND #2 AND [controlled clinical trial]/lim

PubMed（Performed on 31 September 2022）

#1	real time ultrasound guided OR ultrasound assisted OR landmark palpation OR traditional positioning
#2	spinal anesthesia OR epidural anesthesia OR combined spinal and epidural anesthesia
#3	#1 AND #2 (Filters applied: Randomized Controlled Trial)

Web of science（Performed on 31 September 2022）

#1	TS=(real time ultrasound guided OR ultrasound assisted OR landmark palpation OR traditional positioning)
#2	TS=(spinal anesthesia OR epidural anesthesia OR combined spinal and epidural anesthesia)
#3	#1 AND #2 and Clinical Trial

Cochrane Library（Performed on 31 September 2022）

#1	("real time ultrasound guided" OR "ultrasound assisted" OR "landmark palpation" OR "traditional positioning")
#2	("spinal anesthesia" OR "epidural anesthesia" OR "combined spinal and epidural anesthesia")
#3	#1 AND #2 in Trials(search limit)

Inconsistency analysis, local inconsistency test, consistency analysis, ring inconsistency detection of each outcome index

First pass

Inconsistency analysis

Chi2（3）=1.82 Prob ＞ chi2 = 0.6113

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.488	0.162	0.596	0.45	-0.108	0.481	0.822	0.511
AC	0.526	0.262	0.719	0.375	-0.194	0.455	0.671	0.518
BC	0.099	0.287	0.074	0.340	0.026	0.466	0.954	0.517

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.498	0.148	3.36	0.001	0.207,0.788
A-C	0.584	0.208	2.81	0.005	0.176,0.992

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.083	0.667	0.125	0.901	(0.00,1.39)	0.228

First attempt

Inconsistency analysis

Chi2（3）=1.92　Prob ＞ chi2 = 0.5887

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.412	0.134	0.449	0.345	-0.037	0.371	0.920	0.365
AC	0.369	0.166	0.592	0.320	-0.223	0.359	0.534	0.364
BC	0.037	0.237	-0.034	0.234	0.071	0.333	0.830	0.367

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.415	0.120	3.44	0.001	0.179,0.651
A-C	0.413	0.144	2.87	0.004	0.131,0.695

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.126	0.319	0.395	0.693	(0.00,0.75)	0.106

Identify time

Inconsistency analysis

Chi2（3）=6.42　Prob ＞ chi2 = 0.0928

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	1.528	0.568	5.956	1.717	-4.427	1.809	0.014	1.678
AC	3.139	1.145	0.512	1.497	2.627	1.885	0.163	1.941
BC	-0.949	1.076	2.273	1.455	-3.222	1.810	0.075	1.851

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	1.977	0.644	3.07	0.002	0.715,3.204
A-C	2.174	0.943	2.30	0.021	0.176,4.023

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	2.378	1.745	1.363	0.173	(0.00,5.80)	2.322

Time of procedure spinal

Inconsistency analysis

Chi2（3）=7.30 Prob ＞ chi2 = 0.0629

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	-0.790	0.356	0.657	1.360	-1.447	1.405	0.303	0.913
AC	1.401	0.628	-0.323	0.864	1.724	1.065	0.106	0.834
BC	1.342	0.710	1.844	1.027	-0.501	1.247	0.688	0.975

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	-0.697	0.348	-2.01	0.045	-1.378,-0.016
A-C	0.806	0.557	1.45	0.148	-0.286,1.899

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.890	1.119	0.796	0.426	(0.00,3.08)	0.932

subgroup analysis

Obesity/Maternity

First pass

Inconsistency analysis

Chi2（3）=0.29 Prob ＞ chi2 = 0.5896

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.454	0.195	0.076	0.665	0.378	0.698	0.588	0.435
AC	0.636	0.541	1.012	0.441	-0.376	0.698	0.590	0.435
BC	0.559	0.389	0.182	0.575	0.377	0.698	0.589	0.435

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.419	0.165	2.54	0.011	0.096,0.743
A-C	0.845	0.310	2.73	0.006	0.238,1.452

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.257	0.732	0.351	0.726	(0.00,1.69)	0.094

First attempt

Inconsistency analysis

Chi2（3）=1.47 Prob ＞ chi2 = 0.2260

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.545	0.325	-0.529	0.825	1.074	0.887	0.226	0.539
AC	0.251	0.555	1.325	0.692	-1.074	0.887	0.226	0.539
BC	0.780	0.610	-0.294	0.643	1.074	0.887	0.226	0.539

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.403	0.322	1.25	0.210	-0.227,1.033
A-C	0.678	0.462	1.47	0.142	-0.227,1.583

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	1.072	0.890	1.204	0.228	(0.00,2.82)	0.272

Elderly/Abnormal Spinal Anatomy

First attempt

Inconsistency analysis

Chi2（3）=0.33 Prob ＞ chi2 = 0.5674

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.663	0.114	0.536	0.191	0.128	0.223	0.567	0.000
AC	0.108	0.129	0.236	0.182	-0.127	0.223	0.567	0.000
BC	-0.427	0.141	-0.555	0.172	0.127	0.223	0.567	0.000

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.630	0.098	6.41	0.000	0.437,0.822
A-C	0.151	0.105	1.43	0.151	-0.055,0.357

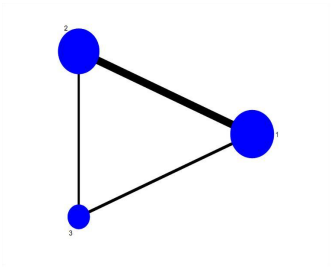
ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2

A-B-C	0.127	0.223	0.572	0.567	(0.00,0.56)	0.000

A：Traditional positioning B:Ultrasound assistance C: Real-time guidance

Figure 1S



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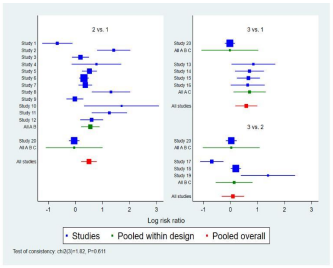

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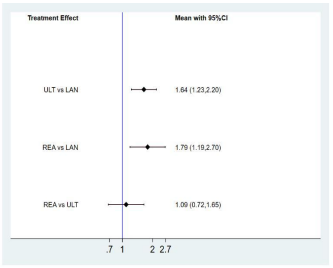

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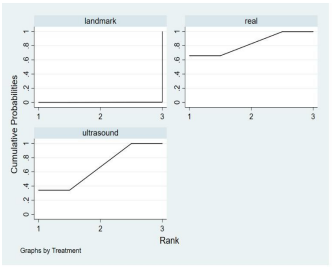

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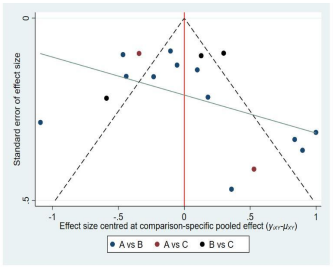

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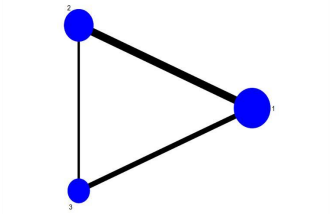
Figure 2S



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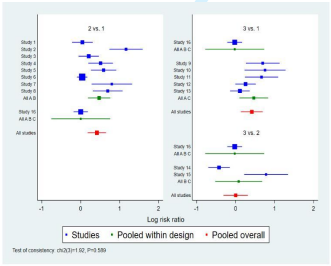

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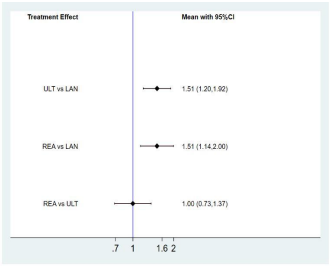

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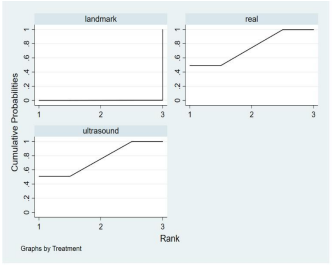

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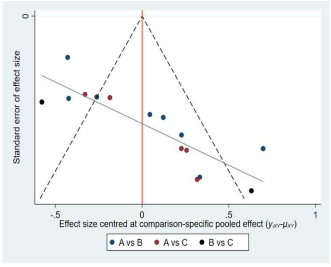

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Figure 3S

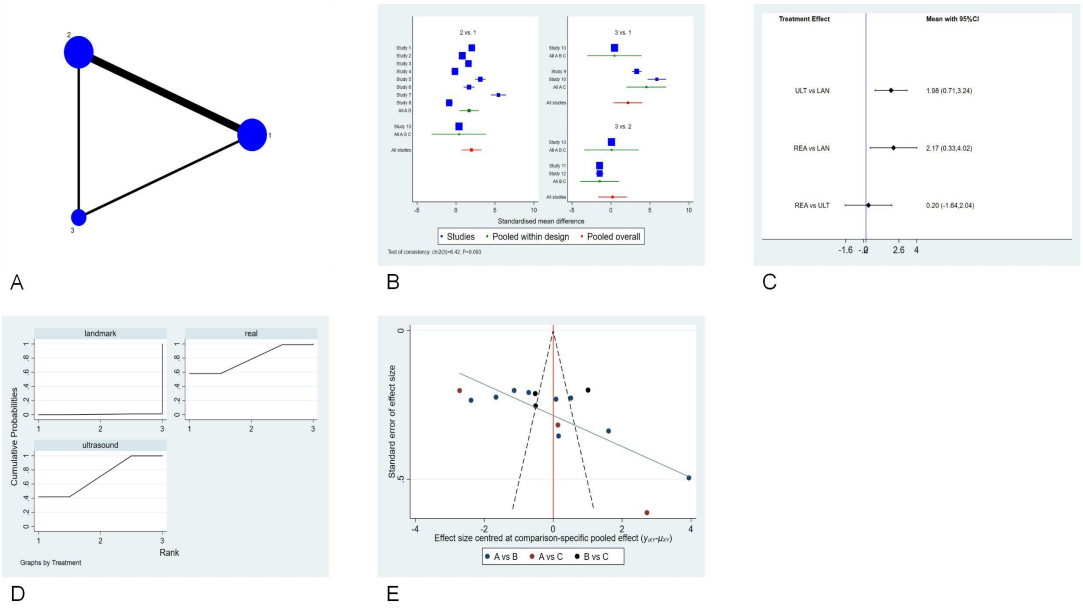


Figure 4S

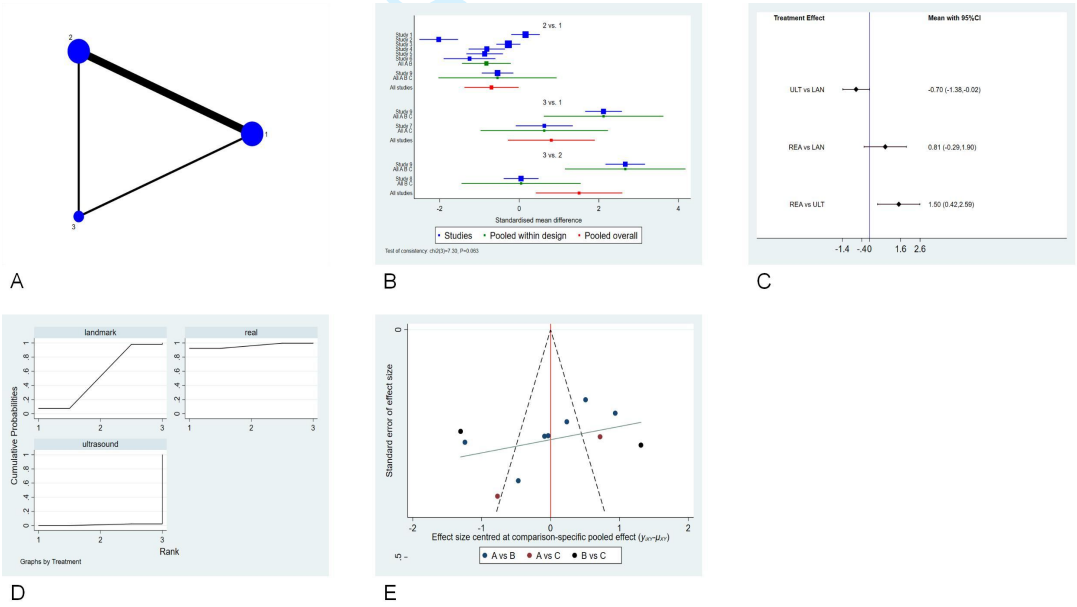


Figure 5S

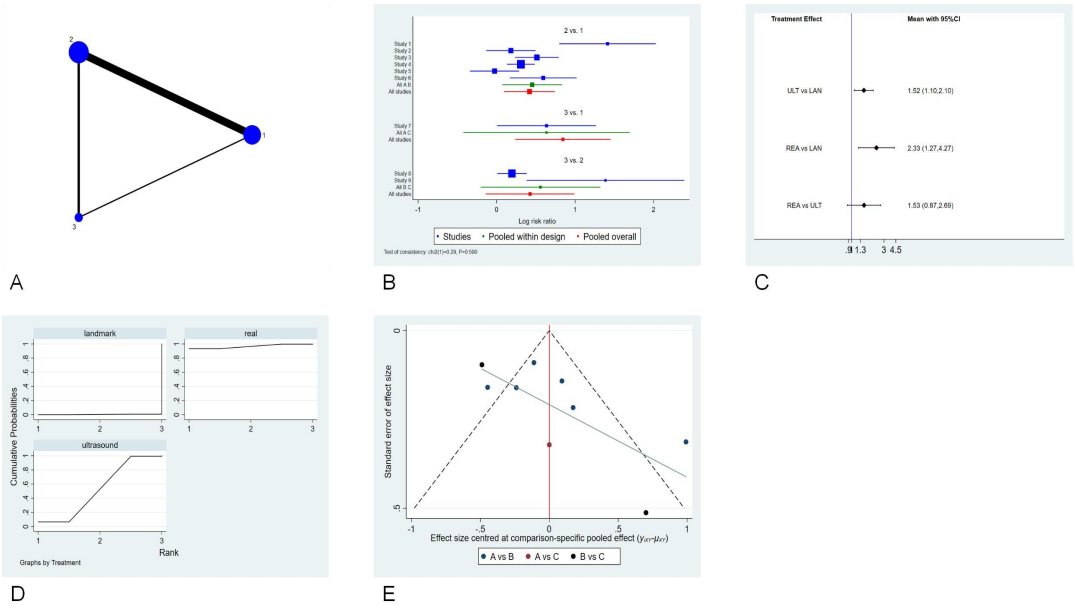


Figure 6S

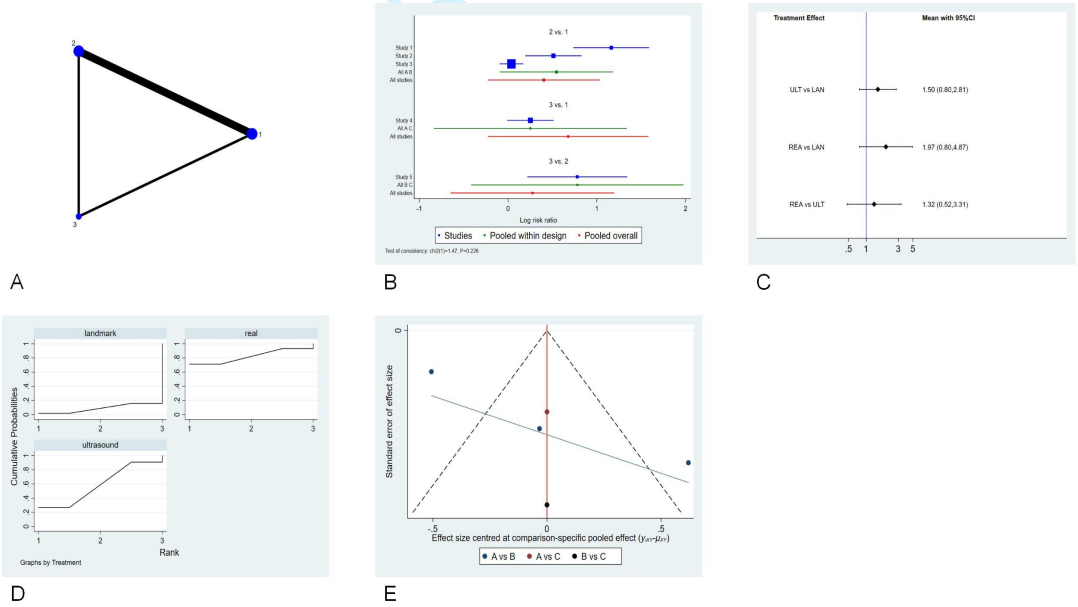
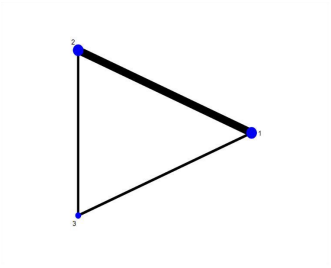


Figure 7S



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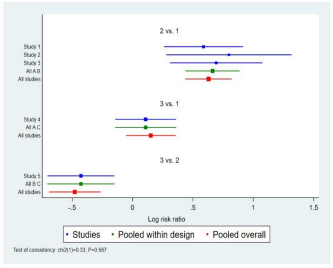

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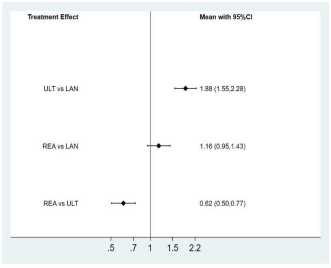

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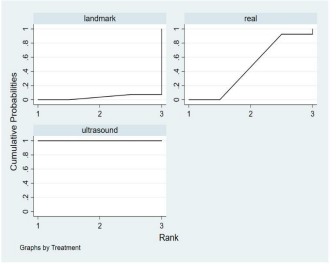

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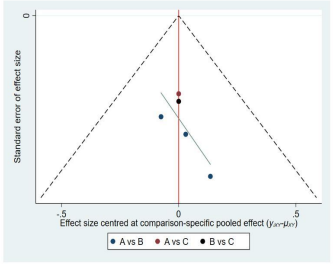

E

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page1
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page2
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page2
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page3
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page3
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page3
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Fig 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	Table1、2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Fig 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	supplemental material
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	supplemental material
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	supplemental material
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	supplemental material
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	supplemental material
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	supplemental material
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page9
	23b	Discuss any limitations of the evidence included in the review.	Page10
	23c	Discuss any limitations of the review processes used.	Page10
	23d	Discuss implications of the results for practice, policy, and future research.	Page10
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page11
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page11
Competing interests	26	Declare any competing interests of review authors.	Page11
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	supplemental material

PRISMA 2020 Checklist

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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Comparison of ultrasound-guided and traditional localization in intraspinal anesthesia: a systematic review and network meta-analysis

Yin-Zhou Zhang 1†,Ming-Ling Peng 1†,Jun-ying Wei 1,Jie-ling Huang 1 ,Wu-Hua Ma 1 ,Yu-Hui Li1*
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Abstract

Objectives: The optimal puncture technique for neuraxial anesthesia in different populations is unclear. We sought to obtain data from randomized controlled trials comparing the impact of ultrasound-guided technology and traditional positioning technology on the success rate of neuraxial anesthesia.

Design: Systematic review and network meta-analysis using study populations, interventions, intervention comparisons, outcome measures and study types.

Data sources: PubMed, Embase, Cochrane Library and Web of science were searched until September 31, 2022.

Eligibility Criteria: We included randomized controlled trials comparing three types of neuraxial anesthesia: ultrasound-assisted, ultrasound real-time guidance, and conventional positioning to describe which neuraxial anesthesia modality is best for patients and to recommend the appropriate one for different populations.

Data extraction and synthesis: Five independent reviewers retrieved, screened, and edited included studies using standardized methods. Assess risk of bias using the Cochrane Collaboration and Evidence Project tools. Network meta-analysis was performed using STATA 15 statistical software.

Results: Twenty-two studies containing three different interventions were included. The SUCRA values of first-pass success rates for the three neuraxial anesthesia methods were real-time guidance (82.8%), ultrasound-assisted (67.1%), and traditional positioning (0.1%). Both ultrasound techniques improved first-pass success rates compared with traditional localization, but there was no significant difference between the two. Subgroup analysis showed that the use of real-time ultrasound guidance for neuraxial anesthesia in pregnant and obese patients improved first-pass success rates. Ultrasound-assisted technology can improve first-attempt success rates in older patients with abnormal lumbar spine anatomy.

Conclusion: Compared with conventional positioning, ultrasound guidance technology can improve the first-pass success rate of neuraxial anesthesia, but there is no significant difference between ultrasound-assisted and real-time guidance technology. The results of subgroup analysis tell us that the most suitable neuraxial anesthesia method is different for different groups of people.

PROSPERO number: CRD42022376041

Strengths and limitations of this study:

1. To the best of our knowledge, this is the first study to compare the puncture success rates of three neuraxial anesthesia methods using a frequentist approach.
2. This protocol was created strictly based on the published PRISMA guidelines, and its research

results have certain reference value for clinical anesthesiologists.

3. Due to the technical difficulty of real-time ultrasound guidance and the lack of evidence from clinically relevant studies, this may be one of the main limitations of this meta-analysis.

1. Introduction

As a commonly used method of anesthesia, neuraxial anesthesia has traditionally been performed by manually palpating body markers to determine the puncture site. In recent years, ultrasound technology has been increasingly used in neuraxial anesthesia [1]. There are currently two types of ultrasound technologies used for neuraxial anesthesia: ultrasound-assisted technology and ultrasound real-time guidance technology. Preoperative ultrasound scanning helps identify puncture points and estimate puncture depth, while ultrasound real-time guidance technology (puncture under ultrasound visualization) allows for more accurate observation of the needle's location and trajectory. Some existing studies have compared ultrasound-assisted technology with traditional localization methods, and some have compared ultrasound real-time guidance technology with traditional localization methods. However, few studies have compared these two ultrasound techniques. Chen's study pointed out that ultrasound-assisted neuraxial anesthesia has a higher first-pass success rate and higher patient satisfaction than real-time guidance technology in hip surgery in elderly patients [2], while Parli pointed out that in the proposed operation in obese patients undergoing lower limb surgery, the use of real-time ultrasound guidance for neuraxial anesthesia shortens the operation time and has a higher first-pass success rate [3]. There is controversy as to which of these three methods of neuraxial anesthesia is the most effective. Therefore, we reviewed articles comparing traditional positioning, ultrasound-assisted, and real-time guidance techniques used in neuraxial anesthesia. A systematic review of three methods of neuraxial anesthesia was conducted through network meta-analysis.

2. Materials and Methods

We followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [4] and registered the meta-analysis and systematic review in the PROSPERO database and PROSPERO network on November 28, 2022 (registration number: CRD42022376041). The current network meta-analysis (NMA) is based on the protocol recommended by the Cochrane Collaboration [5] and follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [6].

2.1. Search strategy

We searched the PubMed, EMbase, Web of Science, and Cochrane Library databases for all relevant articles up to September 31, 2022. Keywords: “ultrasound real-time guidance”, “ultrasound-assisted”, “landmark palpation”, “traditional positioning”, “epidural anesthesia”, “spinal anesthesia” and “combined spinal and epidural anesthesia”. Searches were conducted using a combination of subject headings and free words. The complete search strategy can be found in the supplement.

2.2. Inclusion and exclusion criteria

We included randomized controlled trials (RCTs) comparing two or three methods of neuraxial anesthesia. The information is as follows: Study population: neuraxial anesthesia, including epidural anesthesia, spinal anesthesia, and combined spinal and epidural anesthesia; intervention: traditional positioning, ultrasound-assisted positioning, and ultrasound real-time guidance; intervention comparison: a neuraxial anesthesia method ; Outcome measures: The

primary outcome was first-pass success rate (defined as the needle successfully achieving epidural puncture in one attempt without reorientation); the secondary outcome was first-attempt success rate (defined as the needle reaching the epidural space in one insertion attempt and allows for needle reorientation), recognition time (the time from operator contact with the patient's skin to marking the puncture site on the skin and the time from placing the probe on the skin to marking the puncture site), and puncture time (from skin contact with needle to cerebrospinal fluid time interval between outflows); study design: randomized controlled trial.

Exclusion criteria were as follows: review articles, case reports, case series, letters to the editor, reviews, conference proceedings, laboratory science studies and any other irrelevant studies, as well as studies that did not report the results of interest.

2.3. Study selection

Two authors, Yinzhou Zhang and Junying Wei, respectively searched the database according to the above search strategy. The type of randomized controlled trial or clinical trial was selected through filters in online databases. The retrieved documents were saved and deduplicated through document management software (NoteExpress). The titles and abstracts of the selected literature were read one by one, and if the title and abstract met the criteria, the full text was evaluated to see if the results of interest were reported.Yinzhou Zhang,Junying Wei, and Jieling Huang also discussed whether each study should be included or excluded to reach consensus. Disagreements regarding inclusion or exclusion were resolved in discussions with Yuhui Li and Wuhua Ma.

2.4. Date extraction

All relevant data from the included studies were independently extracted and entered into standardized forms by Yinzhou Zhang and Junying Wei, and then cross-checked. The standardized form included the following items: title, author name, publication date, patient type, surgery type, body mass index, age, anesthesia method, sample size, first pass success rate, first attempt success rate, identification time, procedure time, intervention method, and the best way to intervene. Age and body mass index data were extracted as mean ± standard deviation and median (interquartile range). When data from included studies were presented in the form of interquartile ranges, we followed appropriate methods for transformation [7 – 9] and finally used mean ± standard deviation for statistical analysis.

2.5. Study quality

Jieling Huang and Wuhua Ma conducted independent assessments using the risk of bias tool in Review Manager (version 5.3). Quality was assessed using the following possible sources of bias: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessments, incomplete outcome data, and selective reporting. The methods of each study were rated as “high”, “low” or “unclear”, reflecting the risk of bias [5].

2.6. Statistical analysis

Multiple treatment comparison is a meta-analytic summary method that includes direct and indirect comparisons of treatments. We used STATA 15 software to download the network package for statistical analysis. The effect value of dichotomous variables used RR values, and the effect value of continuous variables used SMD. When the p value was >0.05, the inconsistency model was used to test consistency, and the node splitting method was used for

local inconsistency analysis. Perform a ring inconsistency test on the network diagram that forms a closed loop. If the 95% CI does not include 0, the heterogeneity is large, and sensitivity and subgroup analysis are required.

A network diagram was formed connecting all included studies to indicate the type of neuraxial anesthesia, the number of patients in the different studies, and the number of pairwise comparisons. Nodes show different neuraxial anesthesia methods, and lines show direct comparisons between neuraxial anesthesia methods. Cumulative probability plots for each neuraxial anesthesia method and pairwise comparisons for each intervention were plotted. We used cumulative ranking area under the curve (SUCRA) values to present the effect of neuraxial anesthesia methods on first-pass success rate and first-attempt success rate. SUCRA is a relative ranking metric with a statistical range from 0 to 100% that indicates the likelihood that the therapy will be rated the best [10]. Higher SUCRA values are considered better outcomes for individual interventions.

2.7. Patient and Public Involvement

No patients participated in the study

3. Results

PubMed and EMBASE databases were searched, and 128 and 359 studies were initially assessed. In addition, we searched the Web of science and Cochrane Library databases and retrieved 352 and 90 studies respectively, yielding a total of 929 publications. Online database filters were used to screen for randomized controlled trials or clinical trials and 692 studies were excluded. After removing duplicates using literature management software, 218 studies remained. Titles, abstracts, and full texts of the remaining studies were reviewed in detail; 184 studies were not available, 20 studies were excluded due to lack of controls, and 14 studies did not report the outcome of interest (Fig. 1).

3.1. Research characteristics

Tables 1 and 2 summarize the characteristics of the 22 studies. All experiments were two- or three-arm. Among them, 13 studies compared ultrasound-assisted localization with conventional localization [11-23], 5 studies compared ultrasound-assisted localization with conventional localization [24-28], and 3 studies compared ultrasound-assisted localization with real-time guidance in the spinal anesthesia [2,19,3]. One study compared the use of three methods in spinal anesthesia [20]. Table 1 lists the first author and publication year of the literature, as well as basic information such as patient type, surgical method, patient age and body mass index. Table 2 lists the anesthesia method, study sample size, intervention measures, and main outcome indicators (first time passing success rates) and better intervention outcomes. In all included studies, the probes used for ultrasound were portable low-frequency convex array probes, excluding special puncture probes.

Table 1

The author	Time of Publication	Type of patient	Type of surgery	Age(&、#、*)	BMI(&、#、*)
Karthikeyan	2018	adult	knee and hip surgery	65.3±9.7# 68.2±10.3&	30.1±6.4# 30.6±4.7&
Sangeeta	2018	maternal	cesarean section	23.06±3.01#	27.2±3.8#

Dhanger				24.03±3.43&	27.2±4.2&
Cristian Arzola	2015	maternal	childbirth	32.3±5.8# 32.7±4.7&	29±5.1# 29.3±6&
Y. C. Lim	2014	adult	lower limb surgery	61.1±13.3# 63.7±12.6&	25.4±5.6# 25.0±5.9
Chin	2018	maternal	cesarean section	NM	30.2[a](27.0-36.5)# 30.5[a](26.9-34.2)&
Bingdong Tao	2021	maternal	cesarean section	32.3±5.2# 30.6±3.8&	28.3±3.0# 28.3±2.2&
Mohd Anas Khan	2022	orthopedic patient	lower limb surgery	54.5±12.8# 57.7±13.2&	29.3±4.6# 27.7±3.8&
Mengzhu Li	2019	obese patients	cesarean section	29.5±3.9# 30.1±4.5&	NM
Sun-Kyung Park	2019	old age patient	lower limb surgery	71.1±7.2# 71.2±6.1&	25.8±3.1# 25.8±3.1&
Mohamed Mohamed Tawfik	2017	maternal	cesarean section	27.7±4# 26.7±3.8&	29.2±3# 29.2±2.9&
Sun-Kyung Park	2020	anatomic abnormality of lumbar spine	lower limb surgery	70.5±8.8# 66.5±13.2&	26.1±3.2# 25.9±2.9&
Bo Qu	2020	old age patient	hip surgery	83.3±6.7# 82.3±7.1&	21.6±3.6# 20.6±3.0&
Xiu Ni	2021	obese patients	cesarean section	31.8±4.8# 31.4±4.2&	33.5±2.1# 33.0±2.1&
Bertam	2017	adult	lower limb surgery	NM	NM
Tanya Mital	2021	children	chest and abdominal surgery	2.4±1.3* 3.0±1.7&	NM
Jatuporn Pakpirom	2020	adult	chest and abdominal surgery	60.0[a](51.0-67.0)* 58.5[a](53.75-70.25)&	23.4±4.0* 22.8±3.5&
Jindi Jiang	2021	overweight mothers	childbirth	29.2±3.1* 28.4±3.4&	35.6±2.0* 35.2±2.4&
Hesham	2017	anatomic abnormality of lumbar spine	knee and hip surgery	69±10* 70±10&	34±11* 33±8&
Luying Chen	2021	old age patient	hip surgery	82.7±6.6* 84.5±6.2#	21.9±3.1* 21.3±3.4#
Yasser Mohamed	2020	maternal	childbirth	25.4±5.1* 26.8±5.65#	37.9±4.3* 38.1±4.2#
Parli	2021	obese patients	lower limb surgery	58.5[a](50.3,65.8)	34.9[a](33.1,3

Raghavan Ravi				* 59.5[a](52.3,65.8) #	6.35)* 34.9[a](33.1, 36.40)#
Deepak Bhardwaj	2022	adult	lower limb surgery	39.66±13.27& 42.88±12.72# 43.6±15.24*	22.8±2.8& 22.4±3.4# 23.9±3.0*
[a]:median(interquartile range) NM: no mention					
&:landmark group #: ultrasound assisted group *:real time group					
E:Epidural anesthesia S:Spinal anesthesia CSE:Combined spinal and epidural anesthesia					

Table 2

The author	Time of Publication	Method of anesthesia (E、S、CSE)	Sample size(&、#、*)	intervention	first pass success rate(%)	Effect Estimate(better)
Karthikeyan	2018	S	59# 60&	Landmark vs ultrasound assisted	43# 22&	ND
Sangeeta Dhanger	2018	S	50# 50&	Landmark vs ultrasound assisted	18# 74&	ultrasound assisted
Cristian Arzola	2015	E	60# 68&	Landmark vs ultrasound assisted	50# 60&	ND
Y. C. Lim	2014	S	85# 85&	Landmark vs ultrasound assisted	7# 15&	ND
Chin	2018	CSE	105# 110&	Landmark vs ultrasound assisted	38.2# 63.8&	ultrasound assisted
Bingdong Tao	2021	CSE	64# 64&	Landmark vs ultrasound assisted	68.8# 93.8&	ultrasound assisted
Mohd Anas Khan	2022	CSE	50# 50&	Landmark vs ultrasound assisted	60# 86&	ultrasound assisted
Mengzhu Li	2019	CSE	40# 40&	Landmark vs ultrasound assisted	52.5# 87.5&	ultrasound assisted
Sun-Kyung Park	2019	S	40# 40&	Landmark vs ultrasound assisted	17.5# 65.0&	ultrasound assisted
Mohamed	2017	CSE	53#	Landmark vs	60#	ND

Mohamed Tawfik			55&	ultrasound assisted	58.5&	
Sun-Kyung Park	2020	S	22# 22&	Landmark vs ultrasound assisted	9.1# 50&	ultrasound assisted
Bo Qu	2020	CSE	40# 40&	Landmark vs ultrasound assisted	20# 70&	ultrasound assisted
Xiu Ni	2021	CSE	40# 40&	Landmark vs ultrasound assisted	40# 72.5&	ultrasound assisted
Bertam	2017	S	30* 30&	Landmark vs real time	47* 30&	real time
Tanya Mital	2021	E	23* 22&	Landmark vs real time	82.6* 40.9&	real time
Jatuporn Pakpirom	2020	E	48* 48&	Landmark vs real time	68.6* 35.4&	real time
Jindi Jiang	2021	E	30* 30&	Landmark vs real time	56.7* 30&	real time
Hesham	2017	S	14* 18&	Landmark vs real time	72.2* 83.3&	ND
Luying Chen	2021	S	57* 57#	ultrasound assisted vs real time	31.6* 63.2#	ultrasound assisted
Yasser Mohamed	2020	E	50* 50#	ultrasound assisted vs real time	90* 74#	real time
Parli Raghavan Ravi	2021	S	40* 40#	ultrasound assisted vs real time	40* 10#	real time
Deepak Bhardwaj	2022	S	50& 50# 50*	Landmark vs ultrasound assisted vs real time	82& 78# 80*	ND
ND:no difference						
&:landmark group #: ultrasound assisted group *:real time group						
E:Epidural anesthesia S:Spinal anesthesia CSE:Combined spinal and epidural anesthesia						

3.2. Risk of bias assessment

The quality indicators of the included studies are shown in Figure 2 . All studies used random sequence generation, 12 of which had allocation concealment. Thirteen of the studies did not specify how participants were blinded. One study had a high risk of bias in blinding the

operator, which could be explained by the difficulty in achieving blinding of the procedure. Most studies had incomplete outcome data, but five of the studies had unspecified risks. None of the studies reported results selectively.

3.3. Synthesis of results

For all results for each outcome measure, we present network plots, forest plots for individual studies, forest plots for pairwise comparisons, and cumulative ranking curves. The results are shown in Figures 1S to 7S. Results of inconsistency model detection, consistency analysis, local inconsistency analysis, ring inconsistency detection and funnel plots can be found in the supplementary file. From model testing and funnel plots, the heterogeneity of the study was minimal.

3.4. First pass success rate

Nineteen two-arm studies and one three-arm study documented first-pass success rates and were pooled for analysis [2,3,11-17,19-27,29,30]. Across all studies, traditional positioning was the most frequently cited (Figure 1SA). In this study, the puncture success rate of the ultrasound-assisted group and real-time guidance group seemed to be higher than that of the traditional positioning group (Fig. 1SB). However, there was no significant difference between the ultrasound-assisted group and the real-time guidance group (Fig. 1SC). The probabilities of conventional positioning, assisted positioning, and real-time guidance were analyzed by plotting a cumulative ranking graph (Fig. 1SD). According to SUCRA data, the first puncture success rate is highest for real-time guidance (82.8%), followed by ultrasound assistance (67.1%), and finally conventional positioning (0.1%). The funnel plot is shown in Figure 1SE.

3.5. First attempt rate

A total of 16 trials provided data on first-attempt success rates [2,3,11,12,14,18-22,24-28,30]. The network node diagram is shown in Figure 2SA. Forest plot results showed that the use of ultrasound was associated with first-attempt success rate (Figure 2SB). However, there was no significant difference between ultrasound-assisted and real-time guidance (Figure 2SC). The cumulative ranking chart shows that ultrasound-assisted first attempt success rate is the highest (75.3%), followed by real-time guidance (74.6%) and traditional positioning (0.1%) (Figure 2SD). The funnel plot is shown in Figure 2SE.

3.6. Identification time

The network diagrams and forest diagrams of each study are shown in Figure 3SA and Figure 3SB. The results [2,3,11-12,17-19,21-23,26-27,30] show that the traditional positioning method has the shortest positioning time (Figure 3SD), but the ultrasound-assisted and real-time guided puncture positioning time is not significant. differences (Fig. 3SC). The funnel plot is shown in Figure 3SE.

3.7. Duration of spinal anesthesia

A total of nine studies, eight two-arm studies and one three-arm study [3,11,12,14,18,19,21,28,30], were collected to compare the entire operation process from the puncture needle contacting the skin to the outflow of cerebrospinal fluid. The network diagrams and forest diagrams of each study are shown in Figure 4SA and Figure 4SB. Comprehensive analysis showed that the ultrasound-assisted operation time was the shortest (Figure 4SD), and there was no significant difference between the traditional positioning group and the real-time guidance group (Figure 4SC). The funnel plot is shown in Figure 4SE.

3.8.Subgroup analysis

In the first subgroup, we included 9 studies in obese adults and pregnant women (obese or not). Analyze the results of first pass success rate [3,12,13,15,16,20,23,27,29] and first attempt success rate [3,12,18,20,27]. For first-pass success rate, a network plot (Figure 5SA), a forest plot for a single study (Figure 5SB), a forest plot for pairwise comparisons (Figure 5SC), a cumulative ranking curve (Figure 5SD), and a funnel plot (Figure 5SE) are shown . The network diagram of the first puncture success rate (Fig. 6SA), the forest diagram of a single study (Fig. 6SB), the forest diagram of pairwise comparison (Fig. 6SC), the cumulative ranking curve (Fig. 6SD) and the funnel plot (Fig. 6SE) are as shown in the figure.

In a second subgroup analysis, we included patients with a mean age over 70 years and those with abnormal lumbar anatomy (previous lumbar surgery or scoliosis) [2,19,21,22,28]. The network diagram and forest diagram are shown in Figure 7SA and Figure 7SB. The results of the meta-analysis showed that the first-attempt success rate seemed to be higher in the ultrasound-assisted group (Figure 7SC), and the cumulative ranking chart also showed that ultrasound-assisted was the most recommended (Figure 7SD). The funnel plot is shown in Figure 7SE.

4.Discussion

In recent years, there has been increasing interest in ultrasound guidance for spinal, epidural, or combined spinal-epidural anesthesia [31-33]. Research supports the use of this technique to increase puncture success rates and reduce complications [34-35]. The UK National Institute for Health and Clinical Excellence (NICE) has published guidance [36] recommending that ultrasound can be used both as a preoperative assessment tool and as a live puncture.

Two major indicators of difficulty in neuraxial anesthesia are the number of needle turns required for successful puncture and the time required for the entire procedure. Multiple needle sticks are an independent predictor of complications such as dural penetration, vascular injury, and paresthesias [37]. Ideal neuraxial anesthesia requires a successful puncture [24]. Minimizing the number of attempts can help reduce the risk of complications and improve patient satisfaction [38]. Previous studies have shown that ultrasound scanning before puncture can improve the success rate of puncture and reduce the number of punctures [39]. The characteristic of real-time guidance technology is to observe the needle trajectory in real time during the puncture process, which improves the puncture success rate [24,40-42]. This is consistent with our analysis.

But the analysis showed no significant difference in first-pass and first-attempt success rates between ultrasound-assisted and real-time guidance. However, subgroup analysis showed that real-time guidance technology was more beneficial for pregnant women and obese people. Ultrasound-assisted technology is more recommended for older patients and patients with abnormal spinal anatomy.

Let us analyze the reasons for this difference. It is difficult for pregnant and obese patients to achieve the ideal puncture position during neuraxial anesthesia, and difficulty in palpation may lead to an increase in the number of punctures, resulting in patient discomfort or puncture failure [43]. During pregnancy, lumbar protrusion increases and the pelvis expands and rotates, resulting in a deeper and narrower epidural space and a narrower “safe zone” between the ligamentum flavum and the dura mater [44]. These individuals are generally younger, have soft lumbar ligaments, clear muscle-fat boundaries, and the anterior and posterior complexes are clearly visible under ultrasound, which can significantly reduce the number of needle

adjustments and are suitable for real-time guidance technology. [34,45]. However, real-time puncture is difficult for elderly patients. In elderly patients, due to vertebral body and ligament hyperplasia and intervertebral space narrowing, ordinary ultrasound probes are more likely to block the puncture needle path, thus affecting the observation of the puncture needle trajectory. The advantage of ultrasound-assisted positioning is that it can shorten the anesthesia operation time. Studies have shown that real-time guidance technology is not superior to ultrasound-assisted localization because real-time guidance requires longer operation time, especially in elderly patients, which reduces satisfaction scores [2].

Of course, we cannot ignore other factors that influence our results. The puncture paths used by the researchers were not entirely consistent. According to previous studies [46], the paramedian puncture route is better than the median position because it avoids the supraspinal and interspinous ligaments, and ligament calcification will make puncture more difficult for the operator and increase the number of attempts. The experience of the operator cannot be ignored either. Operators included in the literature were almost all anesthesiologists skilled in the use of ultrasound techniques for neuraxial anesthesia. The anesthetist's qualifications are also a factor that affects the success rate of puncture, and its effect may affect the success rate of puncture, exaggerating the advantages of ultrasound-guided technology [47]. In addition, real-time ultrasound guidance technology is difficult, requiring the operator to hold the probe and ensure image stability while observing the needle trajectory. This is also a challenge for anesthesiologists with many years of experience in ultrasound-assisted localization. This technical difference also affects our results. On the other hand, the choice of ultrasound probe will also affect real-time guidance of puncture. Due to the common low-frequency convex array probe, the contact surface of the probe does not completely fit the skin, and the curved shell of the probe blocks the angle of the needle during puncture. Recently, TranD [45] used a new puncture probe. An epidural needle holder is provided on the side of the probe to adjust the needle angle in the plane of the probe. According to the pre-positioned intervertebral space and the pre-set needle insertion angle, the operator only needs to pay attention to the needle insertion depth to complete the puncture. This method keeps the needle in the same plane as the probe so that the needle trajectory is always visible.

This study also has some limitations. Due to the difficulty of real-time guidance technology, there are fewer studies in this field and the sample size is smaller than assisted positioning, which will also affect our analysis. Therefore, our results cannot be extrapolated to other related studies.

5.Conclusion

This study demonstrates that ultrasound guidance technology has significant advantages in improving the first-pass success rate of neuraxial anesthesia. Furthermore, subgroup analysis showed that real-time ultrasound guidance had a significant advantage in first-pass success rate. Ultrasound real-time guidance technology is more suitable for pregnant and obese patients, and ultrasound-assisted technology is more suitable for elderly patients with abnormal lumbar spine anatomy. Current research evidence is insufficient, mainly because study designs vary, real-time guidance techniques are difficult, and there are currently few studies. Future research should focus on ultrasound real-time guidance technology and expand the application of visualization technology in neuraxial anesthesia.

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PROSPERO registration number:CRD42022376041

Figure explanation

Fig.1.Flow diagram

Fig.2.Consensus risk-of-bias assessment of the included studies.

Green = low risk; yellow = unclear; red =high risk.

Fig.1S: Results of first pass success rate

A:Network plots(The width of the lines is proportional to the number of trials comparing every pair of treatments, and the size of every node is proportional to the number of randomized participants. 1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance)

B:Forest plot for all included studies(1: Traditional positioning,2:Ultrasound assistance, 3: Real-time guidance)

C:Two-comparison forest diagram for all included studies(LAN:Traditional positioning,ULT:Ultrasound assistance, REA: Real-time guidance)

D:Cumulative ranking curve of all included studies(landmark:Traditional positioning,ultrasound:Ultrasound assistance, real: Real-time guidance)

E:funnel plots(A:Traditional positioning,B:Ultrasound assistance, C: Real-time guidance)

Fig.2S: Results of first attempt rate

Fig.3S: Results of identify time

Fig.4S: Results of procedure time of spinal anesthesia

Fig.5S: Results of subgroup 1 first pass rate

Fig.6S: Results of subgroup 1 first attempt rate

Fig.7S: Results of subgroup 2 first attempt rate

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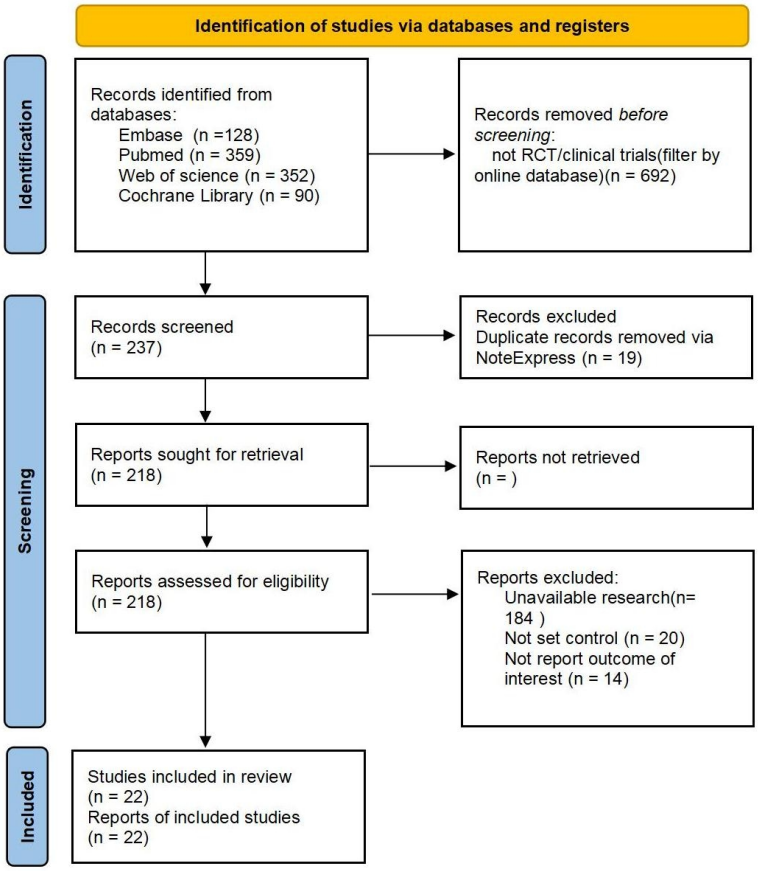


Fig.1.Flow diagram

239x229mm (144 x 144 DPI)

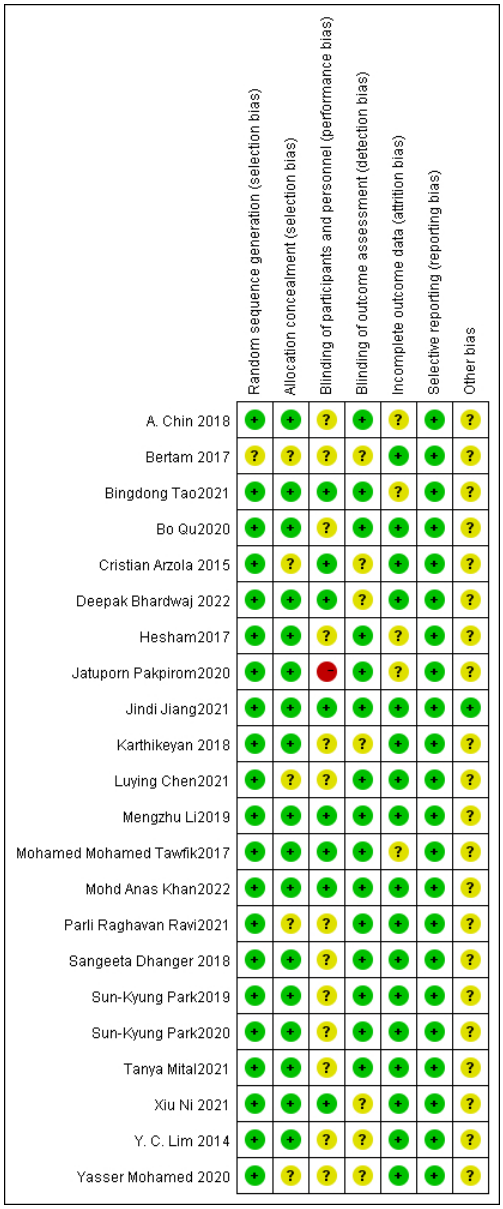


Fig.2.Consensus risk-of-bias assessment of the included studies.

146x353mm (72 x 72 DPI)

Search strategy

Embase（Performed on 31 September 2022）

#1	'real time ultrasound guided' OR 'ultrasound assisted' OR 'landmark palpation' OR 'traditional positioning'
#2	'spinal anesthesia'/exp OR 'spinal anesthesia' OR 'epidural anesthesia'/exp OR 'epidural anesthesia' OR 'combined spinal and epidural anesthesia'
#3	#1 AND #2 AND [controlled clinical trial]/lim

PubMed（Performed on 31 September 2022）

#1	real time ultrasound guided OR ultrasound assisted OR landmark palpation OR traditional positioning
#2	spinal anesthesia OR epidural anesthesia OR combined spinal and epidural anesthesia
#3	#1 AND #2 (Filters applied: Randomized Controlled Trial)

Web of science（Performed on 31 September 2022）

#1	TS=(real time ultrasound guided OR ultrasound assisted OR landmark palpation OR traditional positioning)
#2	TS=(spinal anesthesia OR epidural anesthesia OR combined spinal and epidural anesthesia)
#3	#1 AND #2 and Clinical Trial

Cochrane Library（Performed on 31 September 2022）

#1	("real time ultrasound guided" OR "ultrasound assisted" OR "landmark palpation" OR "traditional positioning")
#2	("spinal anesthesia" OR "epidural anesthesia" OR "combined spinal and epidural anesthesia")
#3	#1 AND #2 in Trials(search limit)

Inconsistency analysis, local inconsistency test, consistency analysis, ring inconsistency detection of each outcome index

First pass

Inconsistency analysis

Chi2（3）=1.82 Prob ＞ chi2 = 0.6113

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.488	0.162	0.596	0.45	-0.108	0.481	0.822	0.511
AC	0.526	0.262	0.719	0.375	-0.194	0.455	0.671	0.518
BC	0.099	0.287	0.074	0.340	0.026	0.466	0.954	0.517

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.498	0.148	3.36	0.001	0.207,0.788
A-C	0.584	0.208	2.81	0.005	0.176,0.992

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.083	0.667	0.125	0.901	(0.00,1.39)	0.228

First attempt

Inconsistency analysis

Chi2（3）=1.92　Prob ＞ chi2 = 0.5887

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.412	0.134	0.449	0.345	-0.037	0.371	0.920	0.365
AC	0.369	0.166	0.592	0.320	-0.223	0.359	0.534	0.364
BC	0.037	0.237	-0.034	0.234	0.071	0.333	0.830	0.367

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.415	0.120	3.44	0.001	0.179,0.651
A-C	0.413	0.144	2.87	0.004	0.131,0.695

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.126	0.319	0.395	0.693	(0.00,0.75)	0.106

Identify time

Inconsistency analysis

Chi2（3）=6.42　Prob ＞ chi2 = 0.0928

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	1.528	0.568	5.956	1.717	-4.427	1.809	0.014	1.678
AC	3.139	1.145	0.512	1.497	2.627	1.885	0.163	1.941
BC	-0.949	1.076	2.273	1.455	-3.222	1.810	0.075	1.851

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	1.977	0.644	3.07	0.002	0.715,3.204
A-C	2.174	0.943	2.30	0.021	0.176,4.023

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	2.378	1.745	1.363	0.173	(0.00,5.80)	2.322

Time of procedure spinal

Inconsistency analysis

Chi2（3）=7.30 Prob ＞ chi2 = 0.0629

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	-0.790	0.356	0.657	1.360	-1.447	1.405	0.303	0.913
AC	1.401	0.628	-0.323	0.864	1.724	1.065	0.106	0.834
BC	1.342	0.710	1.844	1.027	-0.501	1.247	0.688	0.975

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	-0.697	0.348	-2.01	0.045	-1.378,-0.016
A-C	0.806	0.557	1.45	0.148	-0.286,1.899

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.890	1.119	0.796	0.426	(0.00,3.08)	0.932

subgroup analysis

Obesity/Maternity

First pass

Inconsistency analysis

Chi2（3）=0.29 Prob ＞ chi2 = 0.5896

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.454	0.195	0.076	0.665	0.378	0.698	0.588	0.435
AC	0.636	0.541	1.012	0.441	-0.376	0.698	0.590	0.435
BC	0.559	0.389	0.182	0.575	0.377	0.698	0.589	0.435

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.419	0.165	2.54	0.011	0.096,0.743
A-C	0.845	0.310	2.73	0.006	0.238,1.452

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	0.257	0.732	0.351	0.726	(0.00,1.69)	0.094

First attempt

Inconsistency analysis

Chi2（3）=1.47 Prob ＞ chi2 = 0.2260

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.545	0.325	-0.529	0.825	1.074	0.887	0.226	0.539
AC	0.251	0.555	1.325	0.692	-1.074	0.887	0.226	0.539
BC	0.780	0.610	-0.294	0.643	1.074	0.887	0.226	0.539

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.403	0.322	1.25	0.210	-0.227,1.033
A-C	0.678	0.462	1.47	0.142	-0.227,1.583

ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2
A-B-C	1.072	0.890	1.204	0.228	(0.00,2.82)	0.272

Elderly/Abnormal Spinal Anatomy

First attempt

Inconsistency analysis

Chi2（3）=0.33 Prob ＞ chi2 = 0.5674

local inconsistency test（node-splitting method）

Side	Direct Coef.	Std. Err.	Indierect Coef.	Std. Err.	Difference Coef.	Std. Err.	P＞|z|	tau
AB	0.663	0.114	0.536	0.191	0.128	0.223	0.567	0.000
AC	0.108	0.129	0.236	0.182	-0.127	0.223	0.567	0.000
BC	-0.427	0.141	-0.555	0.172	0.127	0.223	0.567	0.000

consistency analysis

	Coef.	Std. Err.	z	P＞|z|	[95% Conf. Interval]
A-B	0.630	0.098	6.41	0.000	0.437,0.822
A-C	0.151	0.105	1.43	0.151	-0.055,0.357

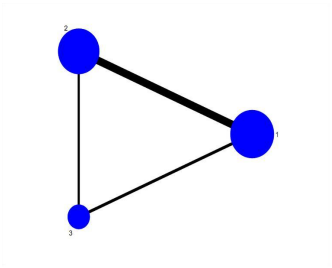
ring inconsistency detection

Loop	IF	seIF	z_value	P_value	CI_95	Loop_Heterog_tau2

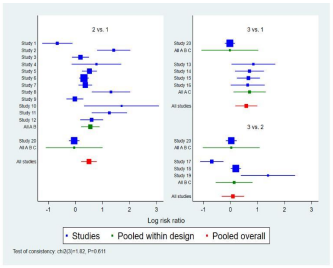
A-B-C	0.127	0.223	0.572	0.567	(0.00,0.56)	0.000

A：Traditional positioning B:Ultrasound assistance C: Real-time guidance

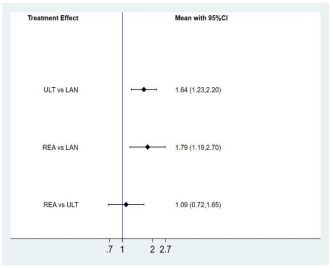
Figure 1S



A



B



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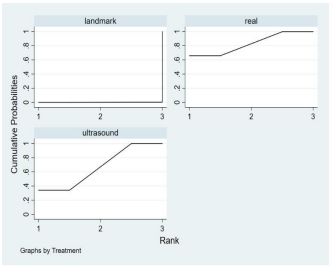

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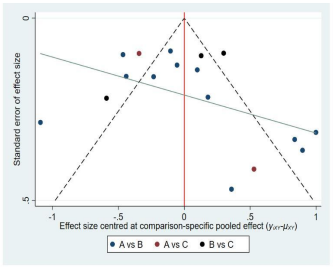

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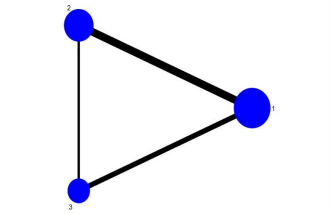
Figure 2S



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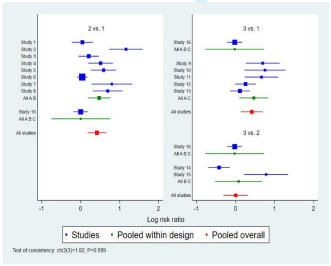

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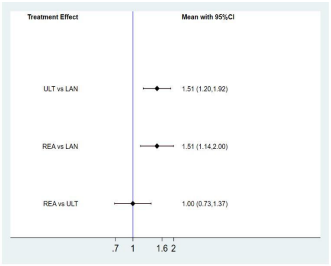

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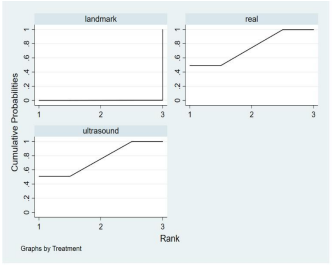

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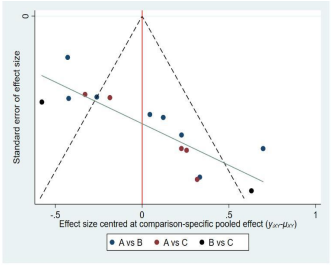

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Figure 3S

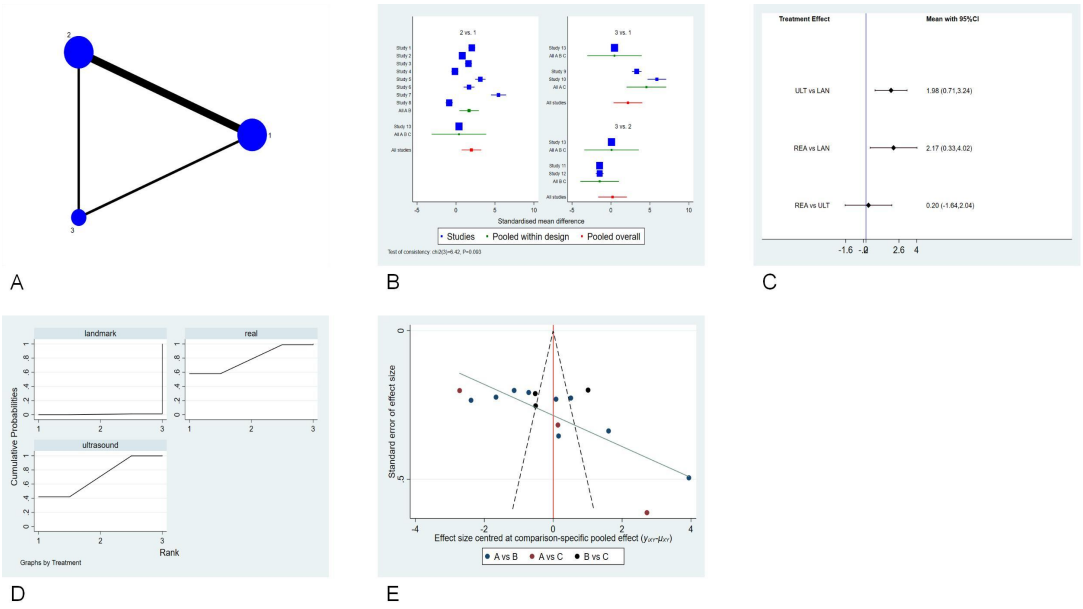


Figure 4S

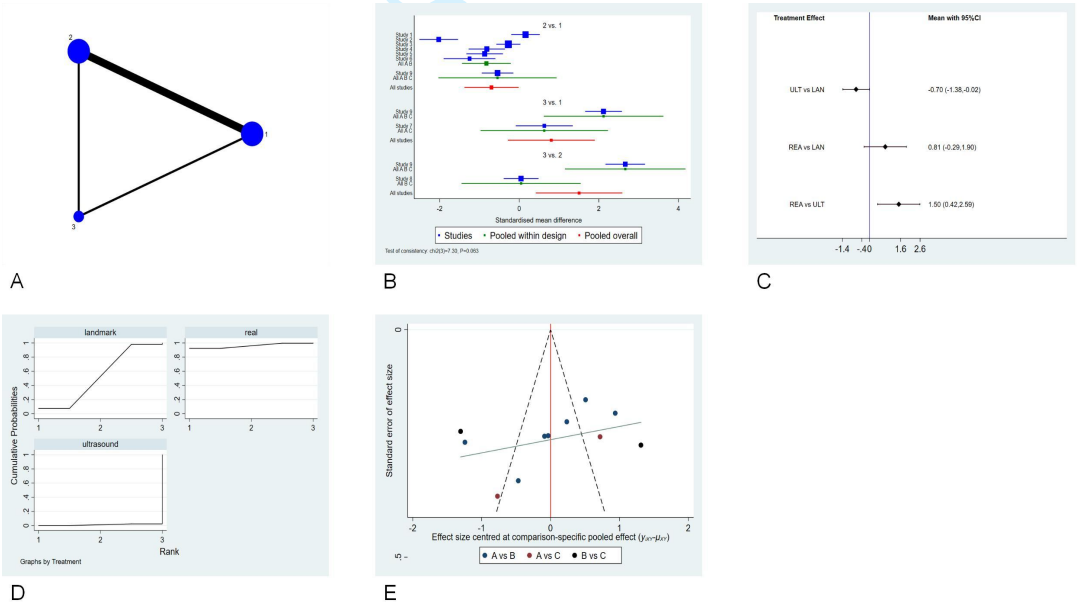


Figure 5S

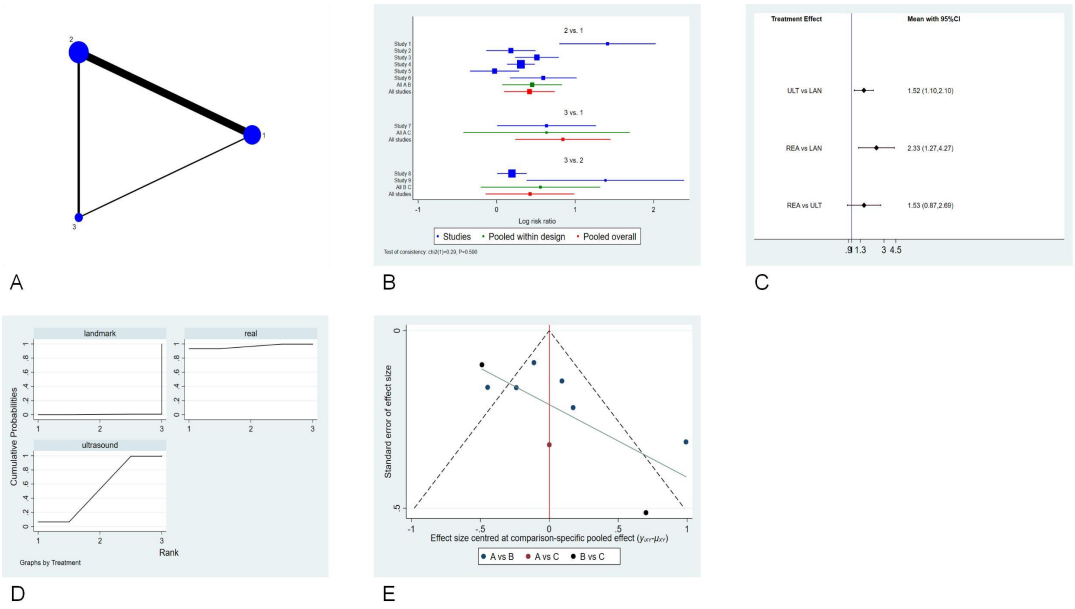


Figure 6S

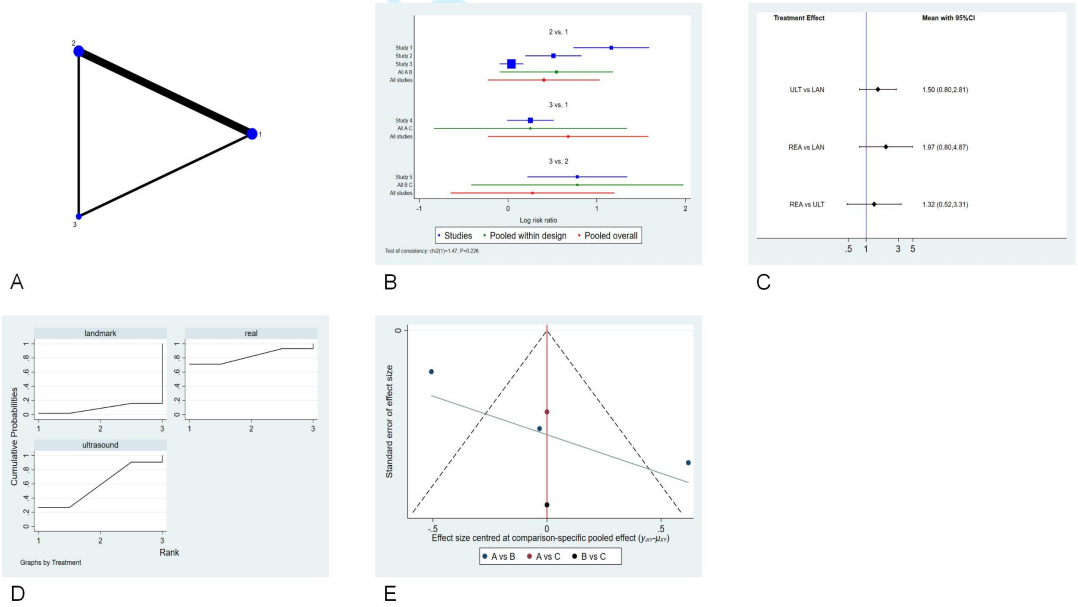
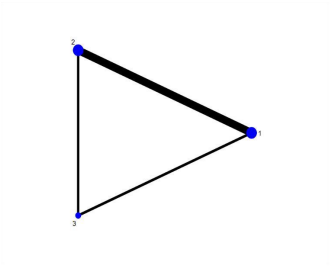


Figure 7S



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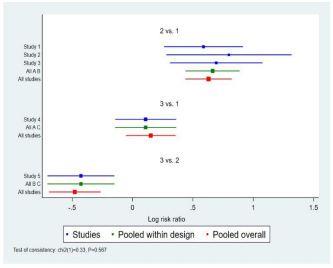

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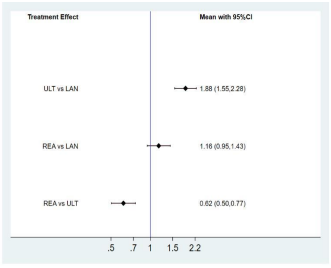

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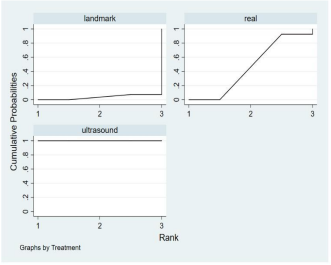

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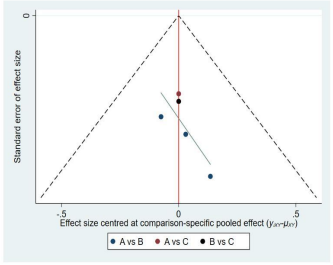

E

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page1
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page2
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page2
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page3
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page3
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page3
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page3
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Fig 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	Table1、2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Fig 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	supplemental material
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	supplemental material
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	supplemental material
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	supplemental material
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	supplemental material
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	supplemental material
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page9
	23b	Discuss any limitations of the evidence included in the review.	Page10
	23c	Discuss any limitations of the review processes used.	Page10
	23d	Discuss implications of the results for practice, policy, and future research.	Page10
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page11
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page11
Competing interests	26	Declare any competing interests of review authors.	Page11
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	supplemental material

PRISMA 2020 Checklist

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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