Meta-Analysis and Systematic Review

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Comparison of short and long axis ultrasound-guided approaches to internal jugular vein puncture: a meta-analysis

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Abstract

Objective: To compare short-axis versus long-axis plane for ultrasound-guided internal jugular vein puncture.

Methods: PubMed, Embase, Cochrane Library and CNKI databases were searched for randomized controlled trials, published to 1 June 2019, that compared short- versus long-axis plane in ultrasound-guided internal jugular vein puncture. Statistical analyses were performed using RevMan software, version 5.3. Statistical results are presented as risk ratio (RR) (95% confidence interval [CI]) for dichotomous data and standard mean difference (SMD) (95% CI) for continuous data.

Results: Ten studies fulfilled the inclusion criteria. Analyses of pooled results showed no statistically significant differences in arterial puncture incidence between the two planes (RR 0.73 [95% CI 0.38, 1.39]). First-pass success rate (RR 1.08 [95% CI 0.95, 1.22]), total success rate (RR 1.00 [95% CI 0.99, 1.02]) and number of attempts required (SMD –0.09 [95% CI –0.37, 0.18]) were also similar between the two approaches. Trial sequential analysis indicated that the available evidence was insufficient to detect potential differences between the two techniques.

Conclusions: There is insufficient data for an evidence-based choice of either short- or long-axis plane in ultrasound-guided internal jugular vein puncture.

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Introduction

Internal jugular vein puncture is an important invasive surgical procedure that is widely used in the intensive care unit, operating room and emergency department for monitoring central venous pressure, fluid resuscitation and parenteral nutrition. Internal jugular vein puncture is conventionally guided with the aid of internal carotid artery palpation and anatomical knowledge, which can be challenging in patients with obesity and can lead to several complications, such as arterial puncture and haematoma.[1–3] Several published studies on the topic have noted that, compared with the 'landmark' technique, the incidence of arterial puncture and number of attempts required were significantly reduced, and first-pass success rate was improved, with the application of ultrasound to aid internal jugular vein puncture.[4–6] In addition, the Association of Anaesthetists of Great Britain and Ireland recommend the routine use of ultrasound for internal jugular vein puncture.[7]

The short-axis plane and the long-axis plane are two common ultrasonic positioning methods employed in ultrasound-guided internal jugular vein puncture, and it remains unclear which of the two techniques is superior in terms of lower complications and higher first-pass success rate. To date, several randomized controlled trials (RCTs) on this topic have been published in English or Chinese.[8–17] Two of these studies found that the first-pass success rate was higher in the long-axis group than in the short-axis group,[8,10] whereas one study reported no difference between the techniques.[14] In the present authors' experience, the long-axis approach is associated with fewer complications, thus, it has been assumed that use of the long-axis plane reduces the incidence of arterial puncture and increases the first-pass success rate.

The present meta-analysis was performed with the aim of estimating the safety and efficacy of the long- and short-axis plane methods for ultrasound-guided internal jugular vein puncture. In addition, trial sequential analysis was applied to reduce the risk of false-positive results from conventional meta-analysis methods.

Materials and methods

This systematic review with meta-analysis was based on methodology recommended by the Cochrane Collaboration[18] and is reported according to PRISMA guidelines.[19] The study protocol was registered with PROSPERO (registration No. CRD42018083863), and ethics approval was not deemed necessary.

Search strategy

A systematic electronic search of the PubMed, Embase, Cochrane Library and CNKI databases was performed to identify RCTs published from inception up to 1 June 2019, that compared the short-axis plane method with the long-axis plane method in ultrasound-guided internal jugular vein puncture. The following search terms were used, with no language restrictions: in PubMed, [(ultrasound) OR (ultrasonography (MeSH Terms)) OR (ultrasonics (MeSH Terms))] AND [(short axis) OR (out of plane) OR (long axis) OR (in plane)] AND [(internal jugular vein) OR (jugular veins (MeSH Terms))]; and in Embase, [ultrasound: ab AND (humans)/lim] AND {[short axis: ab OR out of plane: ab OR long axis: ab OR in plane: ab AND (humans)/lim] AND [internal jugular vein: ab AND (humans)/lim]}. In addition, the reference lists of relevant meta-analyses, review articles and the selected studies were reviewed for further eligible trials.

Inclusion and exclusion criteria

All RCTs that compared the short-axis plane with the long-axis plane in ultrasound-guided internal jugular vein puncture, in patients aged ≥18 years, were included. Studies were excluded for the following reasons: (1) non-RCTs; (2) retrospective studies; (3) reviews and/or case reports; or (4) studies that did not include the relevant reporting outcomes. Authors were contacted for further clarification whenever data were available in abstract format only.

Data extraction and outcome measures

Following removal of duplicate publications identified using EndNote, two authors (JZ and XHW) independently assessed study eligibility by screening titles and abstracts. Full text articles were then screened for eligibility prior to data extraction. Disagreement was resolved through discussion between the two authors or in consultation with a third author (SM). Two authors (JZ and SM) independently extracted the following data items from each trial using data extraction forms: first author, year of publication; country or region, sample size, target outcomes. The authors were contacted for further clarification if data were insufficiently reported in the original report. The involved bias domains were classified as unclear if there was no response. The primary outcome measure was the incidence of arterial puncture. Secondary outcomes comprised the first-pass success rate, total success rate and the number of attempts required.

Bias risk assessment

The risk of bias for the included studies was independently assessed by two authors (XHW and SM) according to the Cochrane Collaboration's risk of bias tool,[20] and any differences were resolved through discussion. The following domains were evaluated from each study: (1) random sequence generation; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessors; (5) incomplete outcome data; (6) selective outcome reporting; and (7) other bias. Each of the above domains was judged as low, unclear, or high risk of bias. Studies were classified as high risk of bias if one or more of these domains were scored as unclear or high risk of bias.

Statistical analyses

Categorical data are presented as *n* incidence and continuous data are presented as mean ± SD. Statistical results are presented as risk ratio (RR) with 95% confidence interval (CI) for dichotomous data and standard mean difference (SMD) with 95% CI for continuous data. All statistical analyses were performed using Review Manager software, version 5.3 (Cochrane Collaboration, Copenhagen, Denmark).

Heterogeneity in the meta-analysis was assessed using the I^2 statistic, and an I^2 value >50% was considered to indicate significant heterogeneity.[21] Between-trial heterogeneity regarding population characteristics, operators' experience and ultrasound equipment was assessed using the random effects model to calculate pooled effects. If heterogeneity was found among the included studies, sensitivity and subgroup analyses were conducted. Sensitivity analyses to test the stability of the results were performed by removing each study, one at a time. Subgroup analyses were conducted to determine the effect of sample size based on the data (≥99 or <99).

Trial sequential analysis

Trial sequential analysis was applied to reduce false-positive results caused by sparse data and repeated testing of cumulative data.[22,23] The required information size and the trial sequential monitoring boundaries for the incidence of arterial puncture were calculated. When the cumulative z-curve crosses the trial monitoring boundary, a sufficient level of evidence for the intervention may be deemed as achieved, and further trials are not needed. If the trial sequential monitoring boundary is not crossed, then there is insufficient evidence to support a conclusion. Thresholds for futility are also derived, and when the z-curve crosses into the futility area, future trials are unlikely to change the result. Two-sided tests, a type I error of 5%, a power of 80%, with a relative risk reduction of 20%, and a model variance-based heterogeneity correction were used to calculate the required information size. A threshold of 4% was set for the incidence of arterial puncture in the long-axis plane group.

Results

Trial selection

Results of the search procedure are shown in Figure 1. The initial search of databases identified 85 studies, of which, 52 remained following removal of duplicates. After excluding nonrelevant literature and nonoriginal studies by screening titles and abstracts, 22 articles were selected for full-text assessment. A further 12 studies were then excluded, leaving a final total of 10 eligible studies,[8–17] comprising 1141 patients, included in the meta-analysis.

Characteristics and quality of the included studies

Details of the included studies are shown in Table 1. The degree of operator experience in ultrasound-guided internal jugular vein puncture differed between all the included studies. The incidence of arterial puncture was measured in nine studies;[8,9,11–17] seven studies reported the first-pass success rate;[8,10,11,13–15,17] total success rate was reported in six studies,[9,10,12,14,15,17] and the number of attempts required was assessed in six studies.[8–11,13,15]

The Cochrane risk of bias analysis is detailed in Figure 2. Nine of the 10 studies adequately described the randomization procedure. Only one study explicitly stated whether allocation concealment was undertaken or whether participants and personnel were blinded. Three studies explicitly stated whether the outcome assessors were blinded. No study exceeded the attrition threshold set in the methods for patients lost to follow-up, and one trial reported the same outcomes as those that were specified. Therefore, all included studies had a high risk of bias.

Incidence of arterial puncture

Nine studies comprising 993 participants reported the incidence of arterial puncture in ultrasound-guided internal jugular vein puncture (short-axis group, $n = 496$; long-axis group, $n = 497$). No significant heterogeneity was identified between studies ($I^2 = 0\%$). Conventional meta-analysis revealed that the overall incidence of arterial puncture was similar between the two groups (RR 0.73 [95% CI 0.38, 1.39], $P = 0.34$; Figure 3). Trial sequential analyses showed that the cumulative Z-score failed to cross the conventional boundary

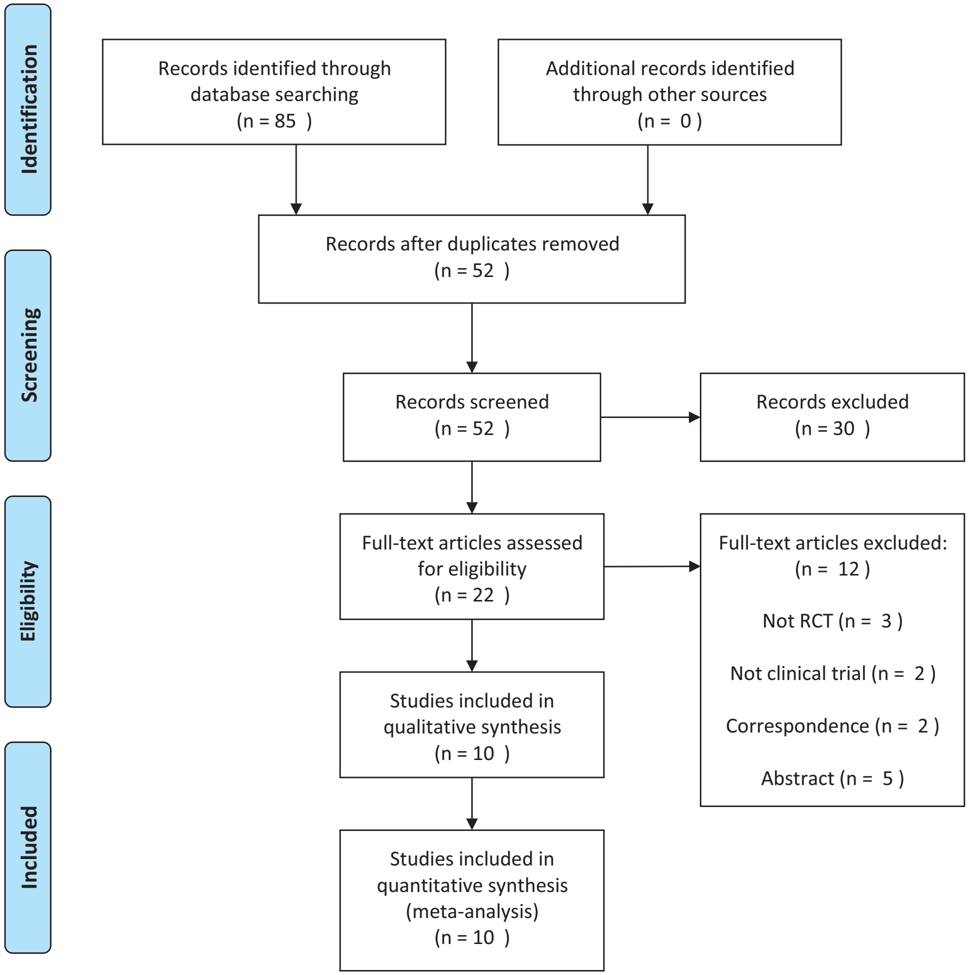

Figure 1. Flow diagram of study selection process.

value, and the required information size of 17 025 was not reached (Figure 4).

First-pass success rate

The first-pass success rate in ultrasound-guided internal jugular vein puncture was reported in seven studies, comprising 737 patients (short-axis group, $n = 367$; long-axis group, $n = 370$). Significant heterogeneity was found between the studies ($I^2 = 74\%$). No statistically significant overall difference was found in the first-pass success rate between the two groups (RR 1.08 [95% CI 0.95, 1.22], $P = 0.25$; Figure 5). Trial sequential analyses showed that the cumulative Z-score failed to cross the conventional boundary value, and the required information size of 6 500 was not reached (Figure 6).

Total success rate

Six studies reported the total puncture success rate, comprising 700 patients (short-axis group, $n = 349$; long-axis group, $n = 351$). No significant heterogeneity was found between studies ($I^2 = 0$).

Table 1. Study characteristics of 10 randomized clinical trials included in the meta-analysis.

			Outcome measure			
Study reference	Country	Number of patients (*n*)	Arterial puncture (*n*)	Success rate of first puncture (*n*)	Success rate of puncture (*n*)	Number of attempts required (mean ± SD)
Chittoodan S, 2011[8]	Ireland	S: 49 L: 50	S: 0 L: 2	S: 48 L: 39	NR	S: 1.02 ± 0.20 L: 1.24 ± 0.56
Tammam TF, 2013[9]	Egypt	S: 30 L: 30	S: 1 L: 0	NR	S: 30 L: 30	S: 1.13 ± 0.35 L: 1.17 ± 0.38
Batllori M, 2016[10]	Spain	S: 73 L: 75	NR	S: 51 L: 39	S: 71 L: 73	S: 1.51 ± 0.97 L: 1.92 ± 1.36
He QZ, 2015[11]	China	S: 51 L: 51	S: 1 L: 1	S: 46 L: 48	NR	S: 1.30 ± 0.60 L: 1.10 ± 0.70
Xi CS, 2015[12]	China	S: 112 L: 112	S: 1 L: 2	NR	S: 112 L: 112	NR
Pan LF, 2014[13]	China	S: 60 L: 60	S: 2 L: 2	S: 54 L: 56	NR	S: 1.30 ± 0.90 L: 1.10 ± 0.60
Shrestha GS, 2016[14]	Nepal	S: 41 L: 41	S: 1 L: 1	S: 21 L: 28	S: 41 L: 41	NR
Wang W, 2016[15]	China	S: 40 L: 40	S: 0 L: 1	S: 35 L: 34	S: 38 L: 37	S: 1.17 ± 0.05 L: 1.23 ± 0.57
Wu W, 2016[16]	China	S: 60 L: 60	S: 6 L: 5	NR	NR	NR
Kang ZJ, 2017[17]	China	S: 53 L: 53	S: 3 L: 8	S: 48 L: 37	S: 51 L: 30	NR

Data presented as *n* incidence or mean ± SD.
S, short axis; L, long axis; NR, not reported.

The meta-analysis results showed no overall statistically significant difference in the puncture success rate between the two groups (RR 1.00 [95% CI 0.99, 1.02], $P = 0.89$; Figure 7). Trial sequential analyses showed that the Z-score failed to cross the conventional boundary value, and the required information size of 7 653 was not reached (Figure 8).

Number of attempts required

Six studies, comprising 609 patients, reported the number of attempts required (short-axis group, $n = 303$; long-axis group, $n = 306$). There was significant heterogeneity between the studies ($I^2 = 65\%$), and a random-effect model was used to analyse the outcome. The number of attempts required was similar between the two groups. The overall standardized mean difference of –0.09 was not statistically significant between the groups (95% CI –0.37, 0.18, $P = 0.52$; Figure 9). Trial sequential analyses showed that the cumulative Z-score failed to cross the conventional boundary value, and required information size of 8 338 was not reached (Figure 10).

Sensitivity analyses and subgroup analyses

Between-study heterogeneity was statistically significant for the first-pass success rate and number of attempts required.

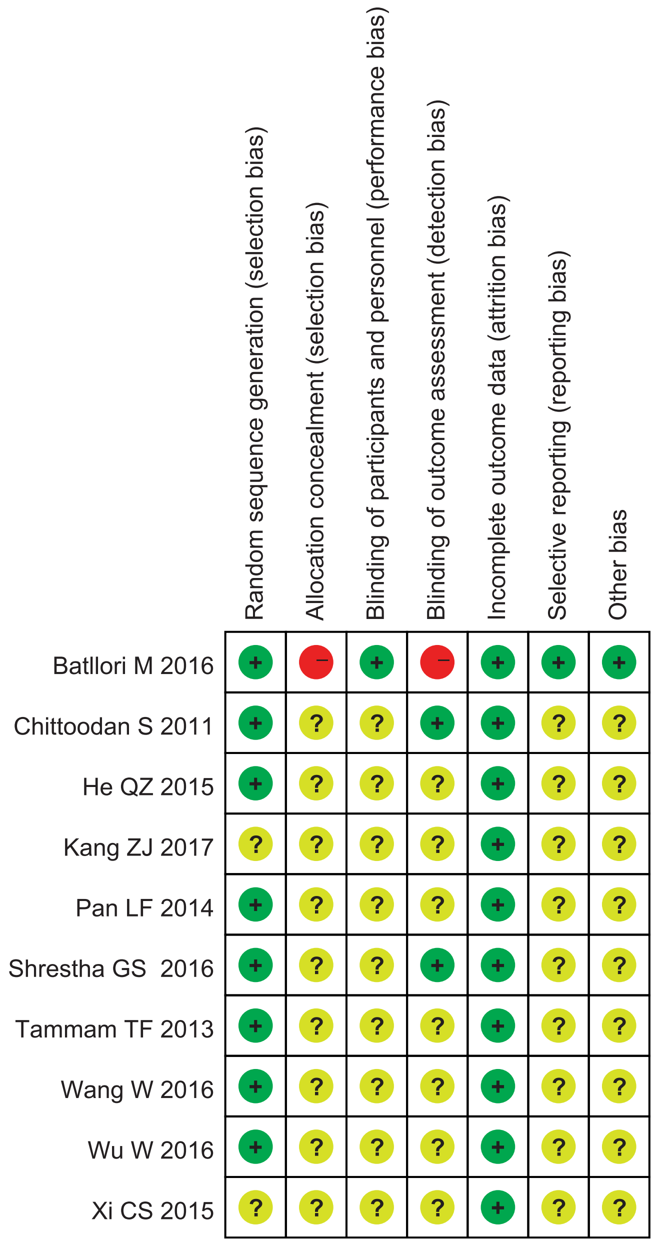

Figure 2. Risk of bias in 10 randomized contolled trials included in the current meta-analysis. + = low risk of bias, ? = unclear risk, − = high risk of bias.

Sensitivity analysis, which removed one single study at a time, did not resolve the heterogeneity and did not alter the pooled results. Subgroup analyses were performed according to the sample size, and the pooled results did not change in either the $\geq$99 sample size group or the <99 sample size group.

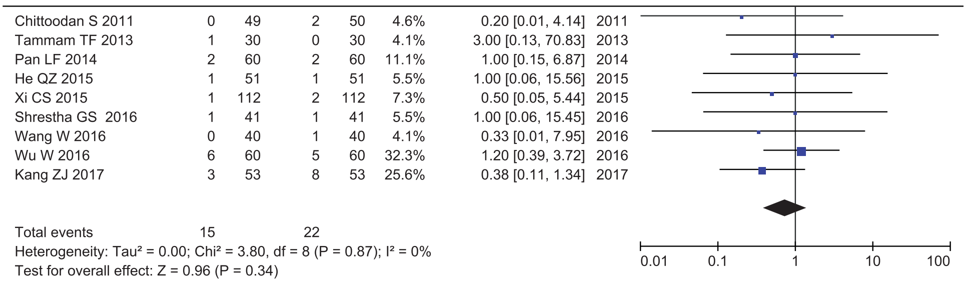

Figure 3. Forest plot showing incidence of arterial puncture associated with the short-axis versus long-axis methods for ultrasound-guided internal jugular vein puncture in nine randomised controlled trials.

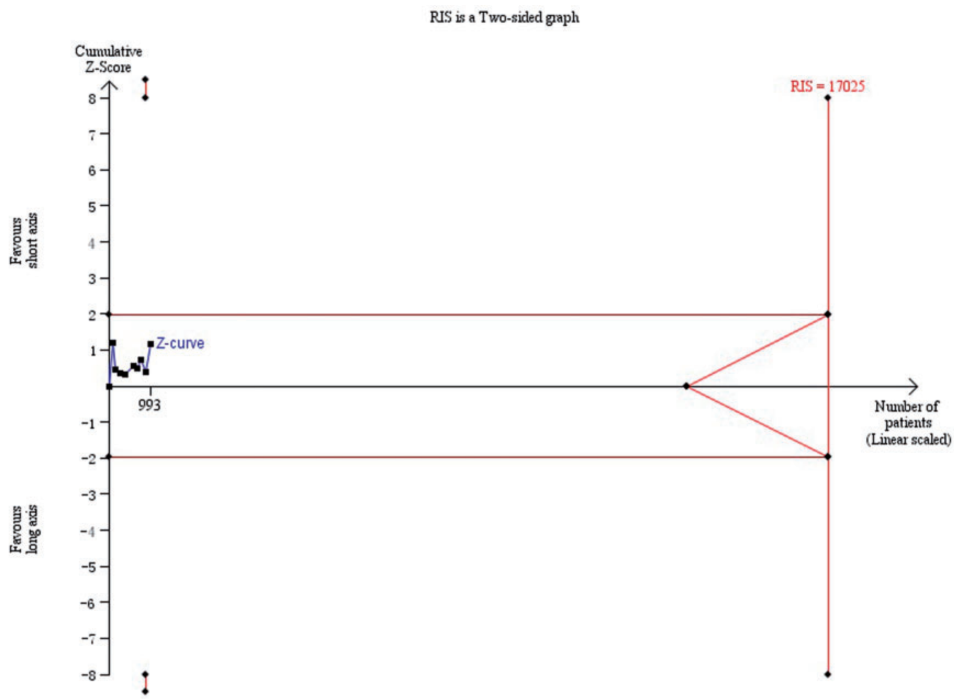

Figure 4. Trial sequential analysis of the incidence of arterial puncture associated with the short-axis versus long-axis methods for ultrasound-guided internal jugular vein puncture in nine randomised controlled trials. RIS, required information size.

Discussion

The present meta-analysis included 10 RCTs with 1141 patients to demonstrate the use of short-axis plane and long-axis plane methods in ultrasound-guided internal jugular vein puncture, in patients aged 18 years or older. The results showed that there were no statistically significant differences between the two approaches in the incidence of arterial puncture

Study or Subgroup	short axis Events	short axis Total	long axis Events	long axis Total	Weight	Risk Ratio M-H, Random, 95% CI	Year
Chittoodan S 2011	48	49	39	50	16.1%	1.26 [1.08, 1.46]	2011
Pan LF 2014	54	60	56	60	18.3%	0.96 [0.87, 1.07]	2014
He QZ 2015	46	51	48	51	18.1%	0.96 [0.86, 1.07]	2015
Batllori M 2016	51	73	39	75	10.9%	1.34 [1.03, 1.75]	2016
Shrestha GS 2016	21	41	28	41	7.6%	0.75 [0.52, 1.08]	2016
Wang W 2016	35	40	34	40	15.0%	1.03 [0.86, 1.23]	2016
Kang ZJ 2017	48	53	37	53	13.9%	1.30 [1.07, 1.58]	2017
Total (95% CI)		**367**		**370**	**100.0%**	**1.08 [0.95, 1.22]**	
Total events	303		281				

Heterogeneity: Tau² = 0.02; Chi² = 22.72, df = 6 (P = 0.0009); I² = 74%
Test for overall effect: Z = 1.15 (P = 0.25)

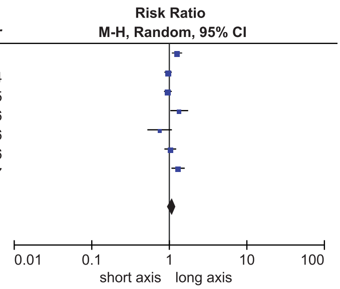

Figure 5. Forest plot the first-pass success rate in the short-axis versus long-axis groups in ultrasound-guided internal jugular vein puncture reported in seven randomised controlled trials.

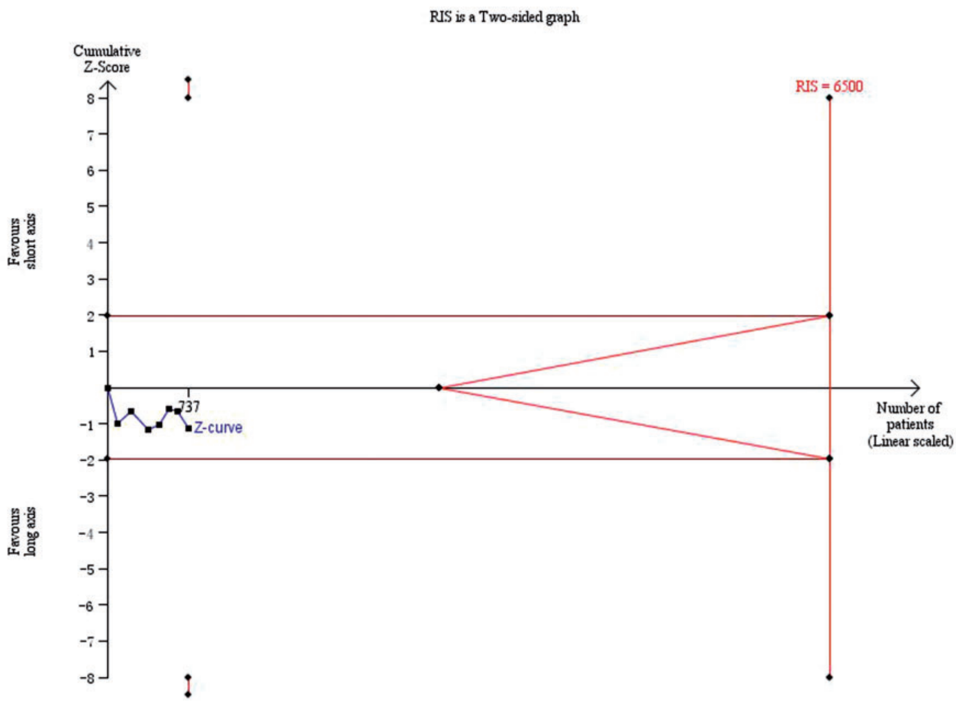

Figure 6. Trial sequential analysis of the first-pass success rate in the short-axis versus long-axis groups in ultrasound-guided internal jugular vein puncture reported in seven randomised controlled trials. RIS, required information size.

(RR 0.73 [95% CI 0.38, 1.39]; nine studies, 993 patients), first-pass success rate (RR 1.08 [95% CI 0.95, 1.22]; seven studies, 737 patients), total success rate (RR 1.00 [95% CI 0.99, 1.02; six studies, 700 patients) or number of attempts required (SMD –0.09 [95% CI –0.37, 0.18]; six studies, 609 patients).

Two meta-analyses on ultrasound-guided vascular access, have been previously published.[24,25] The study by Gao et al. (2016),[24] included five RCTs with

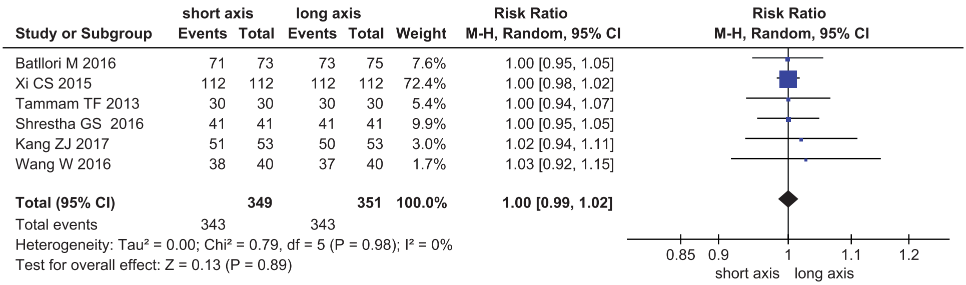

Figure 7. Forest plot showing total success rate of puncture associated with the short-axis versus long-axis methods for ultrasound-guided internal jugular vein puncture in six randomised controlled trials.

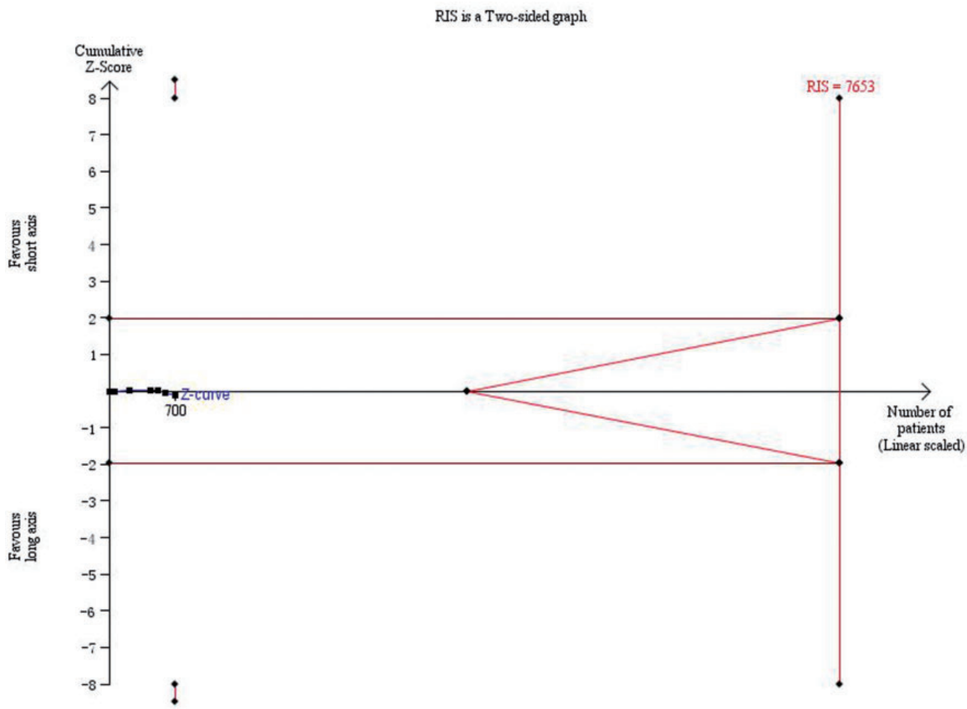

Figure 8. Trial sequential analysis of the total success rate of puncture associated with the short-axis versus long-axis methods for ultrasound-guided internal jugular vein puncture in six randomised controlled trials. RIS, required information size.

470 patients, and showed that there was insufficient evidence for choosing either the short-axis plane or long-axis plane in ultrasound-guided vascular access. The study by Liu et al. (2018),[25] comprising 11 studies with 1210 patients, also showed that there was insufficient evidence to state whether one approach was superior to the other. Although the main finding of the present meta-analysis was consistent with previous meta-analyses, there are notable differences between the present meta-analysis and the previous published studies. First, the present study focused

Study or Subgroup	short axis Mean	SD	Total	long axis Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Batllori M 2016	1.51	0.97	73	1.92	1.36	75	19.0%	-0.34 [-0.67, -0.02]
Chittoodan S 2011	1.02	0.2	49	1.24	0.56	50	16.7%	-0.52 [-0.92, -0.12]
He QZ 2015	1.3	0.6	51	1.1	0.7	51	17.0%	0.30 [-0.09, 0.69]
Pan LF 2014	1.3	0.9	60	1.1	0.6	60	17.9%	0.26 [-0.10, 0.62]
Tammam TF 2013	1.13	0.35	30	1.17	0.38	30	13.8%	-0.11 [-0.61, 0.40]
Wang W 2016	1.17	0.05	40	1.23	0.57	40	15.6%	-0.15 [-0.59, 0.29]
Total (95% CI)			**303**			**306**	**100.0%**	**-0.09 [-0.37, 0.18]**

Heterogeneity: Tau² = 0.08; Chi² = 14.35, df = 5 (P = 0.01); I² = 65%
Test for overall effect: Z = 0.65 (P = 0.52)

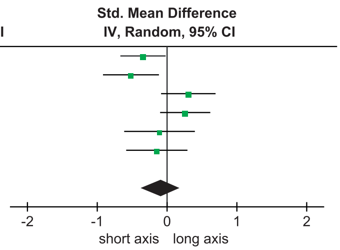

Figure 9. Forest plot showing the number of attempts required in the short-axis versus the long-axis groups for ultrasound-guided internal jugular vein puncture in six randomised controlled trials.

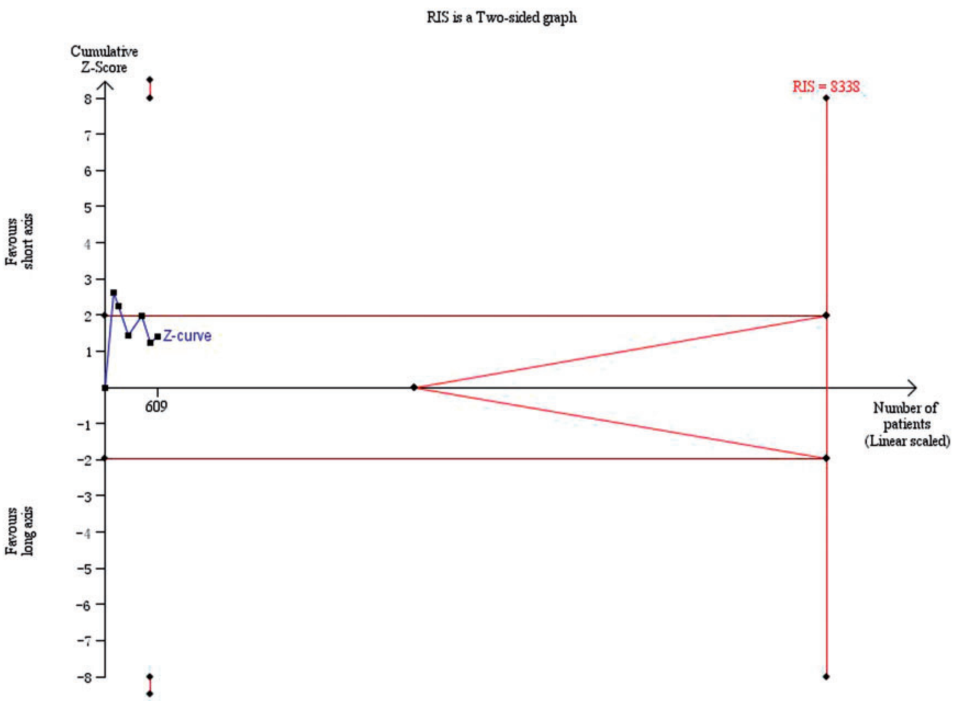

Figure 10. Trial sequential analysis of the number of attempts required associated with the short-axis versus long-axis methods for ultrasound-guided internal jugular vein puncture in six randomised controlled trials. RIS, required information size.

only on internal jugular vein puncture, in an attempt to facilitate the avoidance of complications in this particular procedure. Following needle puncture of the internal carotid artery, the arteries must be pressed, and this may extend the time taken to access the central vein and increase the risk of bleeding in patients with weakened coagulation.[26] Secondly, the study by Gao et al. included only two RCTs that specifically compared the two approaches for ultrasound-guided internal jugular vein puncture, both published in English, and Liu et al. included only four RCTS (also published in English) that compared the two approaches for ultrasound-guided internal jugular vein puncture. The other seven RCTs in the Liu study compared the use of ultrasound in radial artery puncture, subclavian vein puncture or peripheral intravenous puncture. By including a further six RCTs conducted in China, to reduce the selection bias and increase the sample size, the present outcomes represent a more accurate meta-analysis than the previously published studies. The present meta-analysis failed to find a significant difference in the risk of arterial puncture between the two approaches, which is consistent with the findings of previously published studies.[16,17]

In the current meta-analysis, the first-pass success rate, total success rate and number of attempts required were similar between the two approaches used for ultrasound-guided internal jugular vein puncture, which was performed by operators with different degrees of experience in this technique. Significant heterogeneity was found for the first-pass success rate and number of attempts required, and the pooled results did not change when sensitivity or subgroup analyses were performed. Possible differences in the degree of operator experience, the definition of outcomes between studies and whether the procedure was performed under general anaesthesia, are three potential factors that may have resulted in heterogeneity. The present authors note that they remain in communication with patients during the internal jugular-vein puncture procedure, as long as the patient is conscious and fully awake, and if the patient moves their head during the puncture procedure, it can lead to serious adverse events, such as arterial puncture. Further studies should focus on the application of the two approaches in awake patients.

A three-step procedure has been described for placing an internal jugular vein catheter, to promote safe needle advancement and penetration of the internal jugular vein anterior wall, as follows:[27] first, advancing the needle tip to the internal jugular vein with a short-axis image; secondly, rupturing the anterior wall using a long-axis image; and thirdly, confirming the guidewire position using a short-axis image. Furthermore, the use of combined short-axis and long-axis planes was found to significantly improve the success rate of internal jugular vein puncture in a manikin.[28] Future studies should investigate the combination of short- and long-axis planes, as this may be more effective in internal jugular vein puncture.

The results of the present meta-analysis may be limited by several factors. First, none of the included studies adopted the correct random allocation or concealment methods, which may have resulted in selection bias. Secondly, the complication rate is a very important component of central venous access procedures and the reason why ultrasound-guided procedures have become the standard of care. However, the present meta-analysis did not report complications, as few of the included RCTs reported complications. Thirdly, trial sequential analysis showed that the required information size ranged from 4 962 to 17 025. It is unrealistic to conduct a trial of several thousand patients in one setting, thus, large-sample, multicentre, high-quality RCTs are required to elucidate the outcomes associated with using ultrasound-guided procedures for internal jugular vein puncture.

In conclusion, there is a lack of sufficient data to show differences between the use of short- and long-axis plane in ultrasound-guided internal jugular vein puncture, in terms of the incidence of arterial puncture, first-pass success rate, total success rate of puncture and number of attempts. The present authors recommend that future studies focus on the combined short-axis plane and long-axis plane for the internal jugular vein puncture procedure.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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