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Ultrasound-guided central venous catheterization around the neck: Systematic review and network meta-analysis

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ABSTRACT

Background: Ultrasound-guided central venous catheterization (CVC) has become the standard of care. However, providers use a variety of approaches, encompassing the internal jugular vein (IJV), supraclavicular subclavian vein (SupraSCV), infraclavicular subclavian vein (InfraSCV), proximal axillary vein (ProxiAV), distal axillary vein (DistalAV), and femoral vein.
Objective: This review aimed to compare the first-pass success rate and arterial puncture rate for different approaches to ultrasound-guided CVC above the diaphragm.
Methods: In May 2023, Embase, MEDLINE, CENTRAL, ClinicalTrials.gov, and World Health Organization International Clinical Trials Platform were searched for randomized controlled trials (RCTs) comparing the 5 CVC approaches. The Confidence in Network Meta-Analysis tool was used to assess confidence. Thirteen RCTs (4418 participants and 13 comparisons) were included in this review.
Results: The SupraSCV approach likely increased the proportion of first-attempt successes compared to the other 4 approaches. The SupraSCV first-attempt success demonstrated risk ratios (RRs) > 1.21 with a lower 95% confidence interval (CI) exceeding 1. Compared to the IJV, the SupraSCV approach likely increased the first-attempt success proportion (RR 1.22; 95% confidence interval [CI] 1.06–1.40, moderate confidence), whereas the DistalAV approach reduced it (RR 0.72; 95% CI 0.59–0.87, high confidence). Artery puncture had little to no difference across all approaches (low to high confidence).
Conclusion: Considering first-attempt success and mechanical complications, the SupraSCV may emerge as the preferred approach, while DistalAV might be the least preferable approach. Nevertheless, head-to-head studies comparing the approaches with the greatest first attempt success should be undertaken.

1. Introduction

Central venous catheterization (CVC) is used for continuous drug administration, central venous pressure measurement, and parenteral nutrition in critical and surgical situations. The time, success proportion, and immediate complications such as artery puncture, pneumothorax, and hematoma differ according to the CVC cannulation method [1]. Long-term complications such as catheter-related infections (CRI) and thrombosis, vary depending on the cannulation method [1]. However, their occurrence rates are lower compared to immediate complications (2% vs 8–15%) [2]. Consequently, simultaneous investigations with immediate complications are less common [3]. Although a peripherally inserted central catheter (PICC) offers the advantage of fewer mechanical complications, the procedure requires a prolonged insertion time of approximately 30 min [4]. Additionally, malposition potential

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necessitates additional measures such as fluoroscopy, intravascular Doppler, or intravascular electrocardiography [4]. Consequently, PICCs are not routinely placed in emergency settings [4].

Ultrasound (US) guidance for CVC encompasses a range of veins, including the internal jugular vein (IJV), subclavian vein (SCV), and femoral vein (FV) [5]. More recently, catheterization of the axillary vein (AV), a tributary of the SCV, has been increasingly performed in clinical practice [6]. SCV puncture techniques have become increasingly diverse, including the supraclavicular SCV (SupraSCV) and infraclavicular SCV (InfraSCV) approaches [7], as well as the proximal AV (ProxiAV) and distal AV (DistalAV) approaches for the AV, which are contiguous with the SCV [6]. From the perspective of nosocomial infection, thrombosis, and early mobilization, the IJV or SCV is preferred over the FV for central venous access [5]. Several guidelines recommend shifting from FV catheterization to alternative central venous access routes [5,8]. US guidance for CVC clearly reduces complications [9,10]. Moreover, puncturing the AV without US guidance can be challenging. Consequently, the standard of care has shifted from traditional landmark-based techniques to US guidance [11]. Many guidelines advocate the use of US-guided CVC [5,8,12]. Therefore, the scope of this review was limited to comparing the IJV, SCV, and their tributary, the AV, under US guidance for puncture sites.

Currently, a definitive conclusion has not been reached concerning the comparative efficacy of US-guided CVC via the IJV versus the SCV [13]. A recent narrative review mentioned the potential of SupraSCV to replace the conventional approach; however, there is a lack of systematic reviews exploring this aspect [14]. The purpose of this systematic review and network meta-analysis (NMA) was to evaluate the comparative efficacy and safety among IJV and SCV catheterizations via both supraclavicular and infraclavicular approaches, and AV catheterization via both proximal and distal approaches.

2. Methods

2.1. Protocol and registration

We followed the Preferred Reporting Items for Systematic Review and Meta-Analysis 2020 (PRISMA-2020) and PRISMA for Network Meta-Analyses (PRISMA-NMA) to report this systematic review and NMA [14,15]. Our protocol was registered in the Open Science Forum (https://osf.io/e8fvh/). Supplementary materials 1 contains the PRISMA checklist.

2.2. Inclusion criteria of the articles for the review

2.2.1. Study types

We included all papers, consisting of published and unpublished articles, conference abstracts, and letters. Language or country restrictions were not applied. Study exclusions were not based on observation period or publication year.

2.2.2. Participant types

We included all adult participants (aged ≥18 years) who required CVC. Only CVC procedures performed under US guidance in alignment with European and North American guideline recommendations and Japanese guidance were included [5,8,12]. We included CVCs placed in any hospital setting and for all conditions.

Studies that included both landmark and US guidance or both adults and children simultaneously were excluded due to differences in randomization allocation methods. In cases of ambiguity, exclusion was determined through author inquiries. Individuals <18 years old, patients with allergies to local anesthetics, those requiring catheter placement for dialysis, and those requiring PICCs were excluded. CVC insertion methods other than US guidance, such as landmark-based or fluoroscopy-guided approaches were excluded.

2.2.3. Intervention type

We included randomized controlled trials (RCTs) that assessed the comparative efficacy of US-guided CV puncture such as IJV and SCV catheterizations via the supraclavicular and infraclavicular approaches, and AV catheterization via the proximal and distal approaches. IJV originates just after the sigmoid sinus, merging with the SCV to form the brachiocephalic or innominate vein. IJV catheterization refers to accessing this site. SCV extends from the AV at the lateral border of the first rib, joining the IJV to create the brachiocephalic vein. We defined SupraSCV and InfraSCV approaches for catheterization from above and below the clavicle, respectively. AV originates from the brachial vein and continues to the SCV along the outer edge of the first rib. The AV has three segments: proximal (from the SCV to the medial border of the pectoralis minor muscle), posterior (running through the deep aspect of the muscle), and distal (extending from the lateral border of the pectoralis minor muscle to the peripheral aspect) [16]. We defined the ProxiAV approach as puncturing the proximal segment of the AV, and the DIstalAV approach as puncturing the distal segment of the AV (Supplementary materials 2).

2.2.4. Outcome types

The primary outcomes were first-attempt success and artery puncture. First-attempt success was determined by the successful insertion of the needle, guidewire, dilator, or catheter without the need for withdrawal, redirection, or reinsertion. An artery puncture was defined as the puncture of an artery, insertion of a guidewire into an artery, or insertion of a catheter into an artery as detected using a blood sample, ultrasound, or chest radiogram.

The secondary outcomes were failure, pneumothorax, hemothorax, and hematoma. Failure was defined as >3 attempts [7], a change in operator, or a change in the puncture site during catheterization. Pneumothorax was defined as being diagnosed during or after catheter placement using ultrasonography or chest X-ray. Hemothorax was defined as the presence of blood accumulation in the pleural space, which is the space between the chest wall and lungs, detected using diagnostic imaging methods such as ultrasonography or chest X-ray. The definition of the original authors was also acceptable for all outcomes.

2.3. Search strategy

We searched MEDLINE (PubMed), the Cochrane Central Register of Controlled Trials (Cochrane Library), and EMBASE (Dialog) from their inception through May 11, 2023, and the following databases for ongoing or unpublished trials: the World Health Organization International Clinical Trials Platform Search Portal (WHO ICTRP) and ClinicalTrials.gov from their inception through May 8, 2023 (Supplementary materials 3). The authors of the original studies were asked for unpublished or additional data. We also checked the reference lists of studies, including international guidelines [8,12,17], and the reference lists of eligible studies and articles citing eligible studies.

2.4. Study selection

Two of the 5 reviewers (5 authors) independently screened the titles and abstracts, followed by an assessment for eligibility based on the full texts. We contacted the original authors if relevant data were missing. In cases of disagreement, a resolution was achieved through discussion with 1 of the 3 reviewers who was not involved in screening the studies.

2.5. Data extraction and data items

Two reviewers (2 authors) independently extracted data from the included studies using a standardized data collection form. This form included information on study design (first author, year of publication, country, inclusion/exclusion criteria), study population (number of

patients, age, body mass index, setting, position), experience of interventionists, interventions (IJV, SupraSCV, InfraSCV, ProxiAV, or DistalAV), and outcomes (first-attempt success, artery puncture, failure, pneumothorax, hemothorax, and hematoma). Access time (the time to placement) was excluded due to significant variations in its definition among studies, which would lead to considerable heterogeneity. Disagreements were resolved through discussion with a third reviewer serving as an arbitrator (2 authors served as an arbitrator).

2.6. Assessing transitivity assumption

The assessment of the transitivity assumption involved visually examining how potential effect modifiers were distributed among different treatment comparisons. By comparing the distributions of the effect modifiers, body mass index, abnormal hemostasis, positive pressure ventilation, and patient positioning, we evaluated transitivity across different comparisons [18,19].

2.7. Network geometry

We presented a network geometry in which nodes were depicted as interconnected lines, enabling direct comparisons. Each node corresponded to a specific cannulation site. The numerical values presented above the lines indicated the number of RCTs included in the direct comparisons. The node sizes were proportional to the number of participants included in the respective nodes.

2.8. Bias assessment risk

We evaluated intention-to-treat effects for each outcome. Two reviewers (2 authors) independently evaluated the risk of bias using Risk of Bias 2 [20]. Disagreements were resolved through discussion with a third reviewer serving as an arbitrator (2 authors served as an arbitrator).

2.9. Data synthesis and statistical analyses

Group-level data were used in the study. The study effect sizes were synthesized using a random-effects model in the frequentist framework. We pooled the risk ratios (RRs) and 95% confidence intervals (CIs) for first-attempt success, artery puncture, failure, pneumothorax, hemothorax, and hematoma, which were binary variables. We used the results from the intention-to-treat analysis [18].

MetaInsight, version 4.2.0, for frequentist NMA [21] and Review Manager software (RevMan V.5.4.1, Cochrane Collaboration) were used for pairwise meta-analyses, if necessary. All effect sizes estimated by the NMA and conventional pairwise random-effects models were summarized in league tables, delineating the combined effect size of direct and indirect estimates in our findings.

2.10. Confidence and inconsistency assessment

The confidence assessment for each outcome was performed by 2 reviewers (EI and HO) using the Confidence in Network Meta-Analysis (CINeMA) tool [22,23]. Disagreements were resolved through discussion with a third reviewer serving as an arbitrator (2 authors served as an arbitrator). The CINeMA framework encompasses various domains such as within-study bias, across-studies bias, indirectness, imprecision, heterogeneity, and incoherence. We defined a minimal clinically important effect size an RR of 0.75 for first-attempt success [24], of 0.25 for artery puncture [25]. We conducted Meta-regression in the CINeMA and generated both regression plots and trace plots. The determination of whether it is a small size effect was based on the slope of the linear treatment effect. The Gelman-Rubin diagnostic value was considered indicative of convergence to a stationary state when it was <1.1 [26]. The results that include zero and cannot undergo meta-regression in CINeMA were assessed for risk of bias using the Rob ME tool [27]. Regarding within-study bias and indirectness, the CINeMA computes the contribution of each study to the network estimate and integrates these contributions with study-specific assessments to assign a rating (very low, low, moderate, or high) to the relative effect for each comparison in the network.

2.11. Reporting bias assessment

We conducted comprehensive searches in the clinical trial registry system (ClinicalTrials.gov and WHO ICTRP) and extensively searched the literature for unpublished trials. To evaluate outcome reporting bias, we compared the outcomes defined in the trial protocols with those reported in the publications. In addition, a visual evaluation of the funnel plots determined publication bias.

2.12. Subgroup and sensitivity analyses

Subgroup analyses of the primary outcomes in the presence of mechanical ventilation among patients were conducted. During mechanical ventilation, the cross-sectional area of the vein is augmented compared to that observed during spontaneous respiration [28,29].

We conducted sensitivity analyses of the primary outcomes based on our specific definition of primary outcomes as previously defined in “Outcome types” in this Methods section.

3. Results

3.1. Search results

After removing duplicates, 3711 reports were identified. Of these, 41 were considered for inclusion after reviewing their titles and abstracts. After a full-text review, 14 reports were excluded, and 27 reports from 13 studies involving 4418 patients were included [6,13,24,30–39] (Fig. 1). A list of the 14 excluded reports and the reasons for their exclusion are documented in Supplementary materials 4. Of those excluded, 7 studies were still in the protocol stage without results.

Table 1 presents the characteristics of the included studies, including participants, interventions, comparisons, outcomes, and transitivity assessments. Overall, there was no concern regarding transitivity across comparison evidence. Six studies were conducted in the ICU, 5 in the operating theater, and 2 in a mixed setting of the operating theater and the ICU. Of the 13 RCTs, 5 assessed SupraSCV vs. InfraSCV [33–35,38,39], 3 assessed ProxiAV vs. IJV [31,32,36], 3 assessed ProxiAV vs. DistalAV [6,30,37], 1 assessed SupraSCV vs. IJV [24] and 1 assessed InfraSCV vs. IJV [13].

The network of eligible comparisons for the meta-analysis is shown in Fig. 2. The risk of bias in the studies is presented in Table 2 and Supplementary materials 4.

3.2. Primary outcomes

3.2.1. First-attempt success

We included 13 RCTs involving 4418 patients (Fig. 2a) [6,13,24,30–39]. Regarding the risk of bias within studies, the overall risk of bias was assessed as low for 4, some concern for 6, and high for 3 trials (Supplementary materials 5 A). Compared to the IJV, the SupraSCV likely increased the first-attempt success proportion (RR 1.22; 95% CI 1.06–1.40; moderate confidence evidence), whereas DistalAV reduced the first-attempt success proportion (RR 0.72; 95% CI 0.59–0.87; high confidence evidence) (Fig. 3a). In indirect comparisons, the SupraSCV approach exhibited a higher first-attempt success proportion than all other approaches, whereas the DistalAV approach displayed a lower first-attempt success proportion than all other methods with moderate-to-high confidence (Table 3). Incoherence between direct and indirect RRs was not observed in any of the

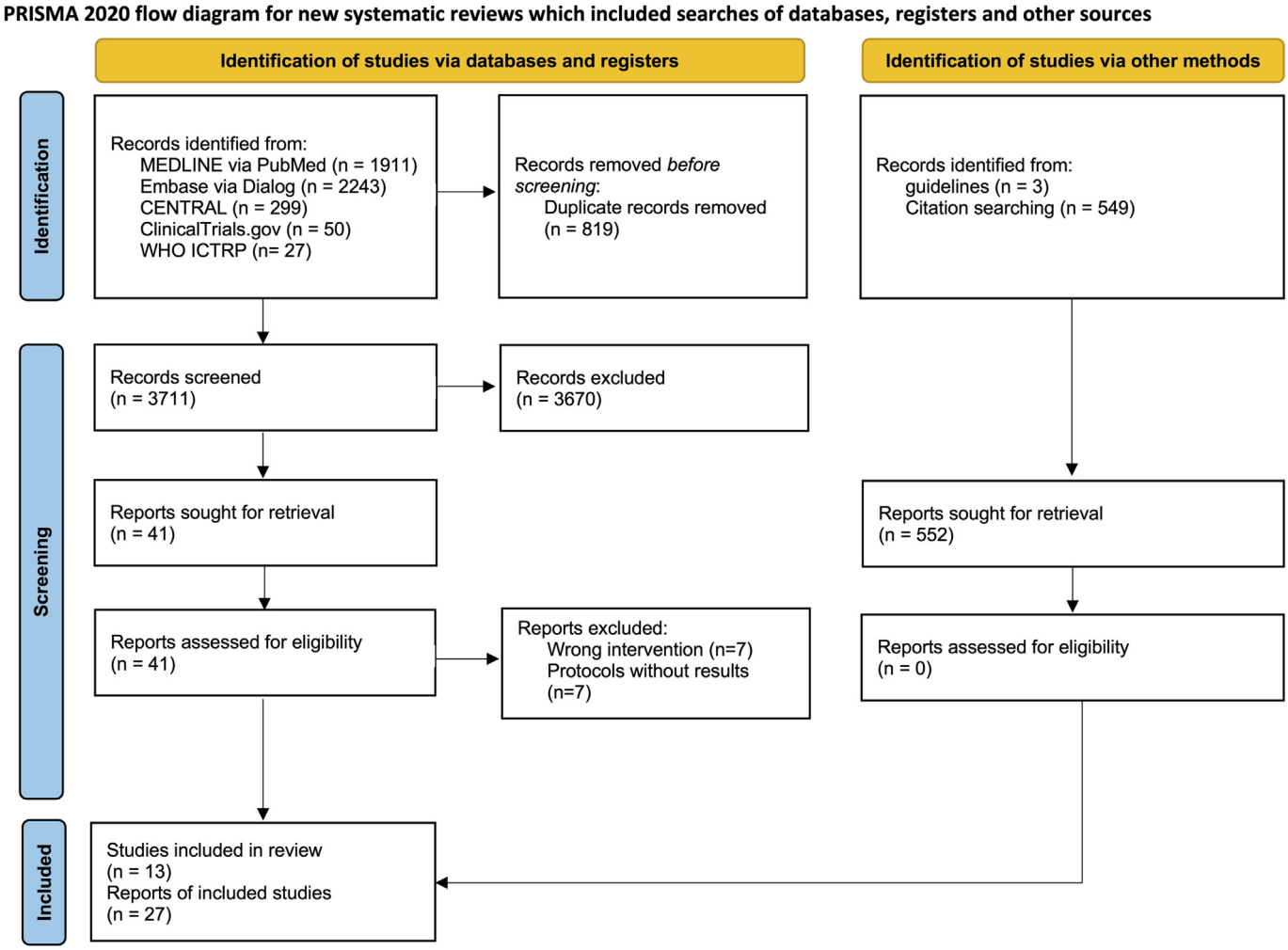

Fig. 1. Flow diagram of study selection.

Table 1
Summary of included studies.

Characteristic of included studies											
Reference	Country	Funding	No. of patients	Setting	MV or spontaneous respiration	Position	Intervention	Comparator	BMI	Experience of interventionalist-	Abnormal hemostasis
Becem et al., 2021 [33]	Tunisia	No funding	110	ICU	Mix	Supine	SupraSCV	InfraSCV	25.2	Expert	Excluded
Becem et al., 2022 [24]	Tunisia	No funding	250	ICU	Mix	Trendelenburg	SupraSCV	IJV	26.4	Expert	Excluded
Buzançais et al., 2016 [25]	France	Academic grants	122	ICU&OT	Mix	Trendelenburg	DistalAV	ProxiAV	25.8	Expert	Excluded
Czarnik et al., 2023 [26]	Poland	Undisclosed	610	ICU	Under MV	Supine	ProxiAV	IJV	27.9	Expert	Excluded
Fournil et al., 2023 [27]	France	Undisclosed	201	ICU&OT	Mix	Trendelenburg	ProxiAV	IJV	26.8	Expert	Excluded
Kim et al., 2022 [28]	Korea	No funding	401	OT	Under MV	Supine	SupraSCV	InfraSCV	26.8	Expert	Excluded
Mageshwaran et al., 2021 [34]	India	No funding	90	OT	Under MV	Trendelenburg	SupraSCV	InfraSCV	22.2	Expert	Excluded
Prasad et al., 2020 [29]	India	No funding	110	ICU	Mix	Trendelenburg	SupraSCV	InfraSCV	Not Reported	Expert	Excluded
Saini et al., 2022 [30]	India	No funding	96	OT	Under MV	Supine	SupraSCV	InfraSCV	23.4	Expert	Excluded
Shin et al., 2019 [11]	Korea	No funding	1350	OT	Under MV	Unknown	InfraSCV	IJV	23.0	Expert	Excluded
Shinde et al., 2019 [31]	India	No funding	97	OT	Spontaneous	Trendelenburg	ProxiAV	IJV	25.2	Expert	Not Reported
Su et al., 2020 [32]	China	Academic grants	198	ICU	Mix	Supine	DistalAV	ProxiAV	23.7	Expert	Excluded
Wang et al., 2020 [4]	China	No funding	99	ICU	Unknown	Supine	DistalAV	ProxiAV	18.4	Expert	Excluded

BMI, body mass index; DistalAV, distal axillary vein; ICU, intensive care unit; IJV, internal jugular vein; InfraSCV, infraclavicular subclavian vein; MV, mechanical ventilation; OT, operation theater; ProxiAV, proximal axillary vein; SupraSCV, supraclavicular subclavian vein.

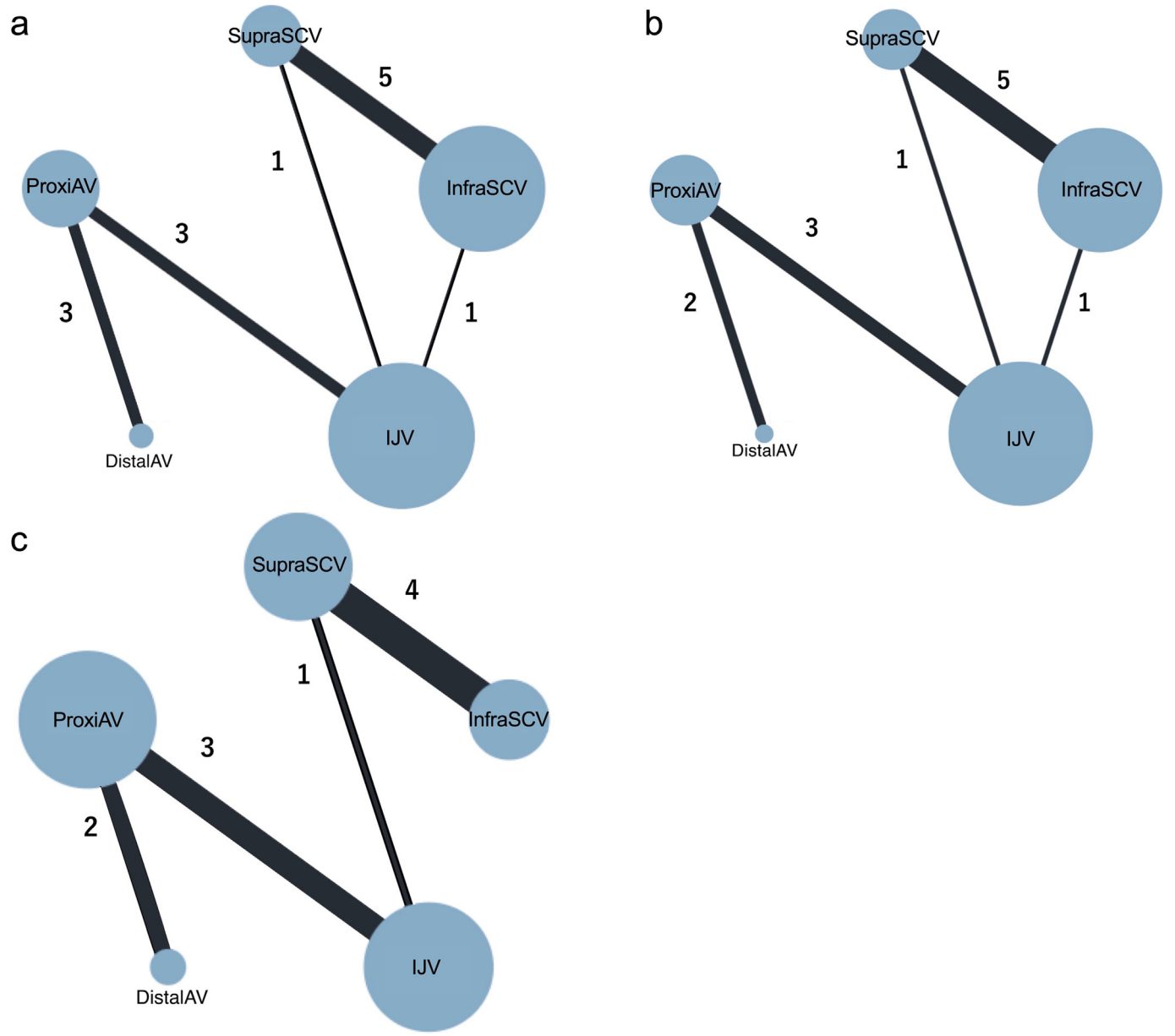

Fig. 2. Network plot of all interventions.
The size of the circles corresponds to the overall patient count for each treatment across all trials. The width of the lines is determined by the total number of studies directly comparing the two treatments.
a) First attempt success, artery puncture, failure, and pneumothorax. b) Hemothorax. c) Hematoma.
DistalAV, distal axillary veins; IJV, internal jugular vein; InfraSCV, infraclavicular subclavian veins; ProxiAV, proximal axillary vein; SupraSCV, supraclavicular subclavian vein.

Table 2
Summary of confidence in the results of a network meta-analysis for first attempt success.

Comparison	Number of studies	Within-study bias	Reporting bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Confidence rating
DistalAV vs ProxiAV	3	Some concerns	Some concerns	No concerns	No concerns	No concerns	No concerns	Moderate
IJV vs InfraSCV	1	Major concerns	Some concerns	No concerns	No concerns	No concerns	No concerns	Moderate
IJV vs ProxiAV	3	Major concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate
IJV vs SupraSCV	1	Some concerns	Low risk	No concerns	No concerns	Some concerns	No concerns	Moderate
InfraSCV vs SupraSCV	5	No concerns	Low risk	No concerns	No concerns	Some concerns	No concerns	High
DistalAV vs IJV	0	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	High
DistalAV vs InfraSCV	0	Major concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate
DistalAV vs SupraSCV	0	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	High
InfraSCV vs ProxiAV	0	Major concerns	Low risk	No concerns	No concerns	Some concerns	No concerns	Moderate
ProxiAV vs SupraSCV	0	Major concerns	Some concerns	No concerns	No concerns	No concerns	No concerns	Moderate

DistalAV, distal axillary veins; IJV, internal jugular vein; InfraSCV, infraclavicular subclavian veins; ProxiAV, Proximal axillary vein; SupraSCV, supraclavicular subclavian vein.

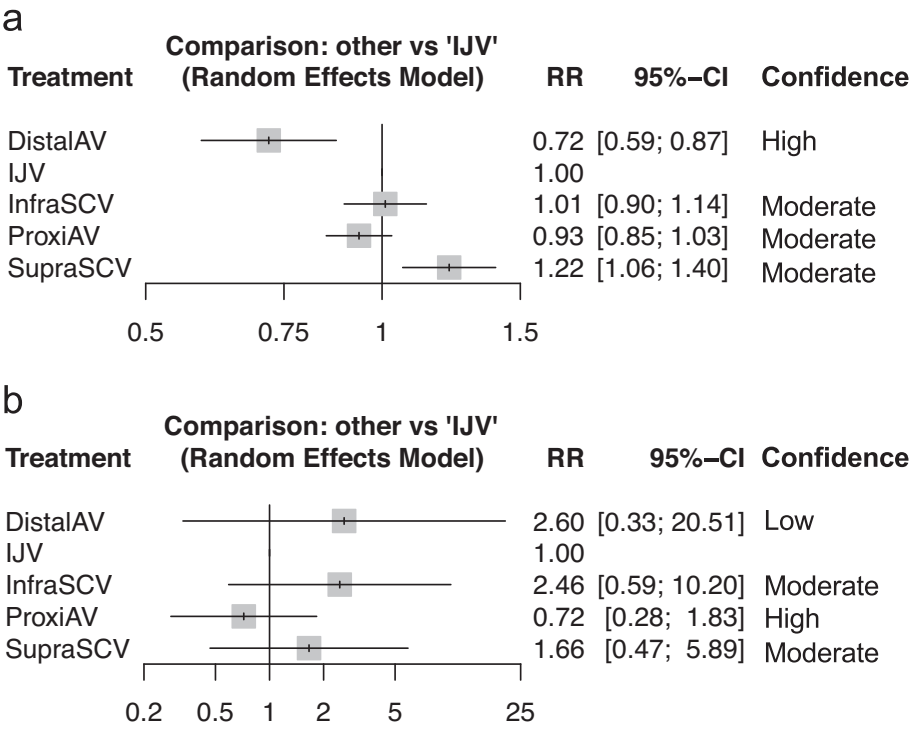

Fig. 3. Forest plot of the network meta-analysis with confidence rating.
a) First attempt success. b) Artery puncture.
CI, confidence interval; DistalAV, distal axillary veins; IJV, internal jugular vein; InfraSCV, infraclavicular subclavian veins; ProxiAV, proximal axillary vein; RR, risk ratio; SupraSCV, supraclavicular subclavian vein.

comparisons for IJV, SupraSCV, and InfraSCV that formed loops. There was moderate to high confidence for the estimates, supporting the choice of 5 cannulation sites for CVC (Table 2). Funnel plots for the pairwise analysis of first-attempt successes are shown in Supplementary materials 5 A. Egger's test was not performed because fewer than 10 studies were available for comparison. The slope of the linear treatment effect in the regression plot was not steep, and the Gelman-Rubin diagnostic value in the trace plot was <1.1 (Supplementary materials 5 A). For IJV vs. InfraSCV, IJV vs. ProxiAV, Distal AV vs. InfraSCV, InfraSCV vs. ProxiAV, and ProxiAV vs. SupraSCV comparisons, we downgraded the confidence rating by 1 level due to within-study bias. DistalAV vs. ProxiAV was downgraded by 1 level in the confidence rating due to within-study and reporting biases. The IJV vs. SupraSCV was downgraded by 1 level in the confidence rating due to within-study bias and heterogeneity. The confidence ratings of InfraSCV vs. SupraSCV, DistalAV vs. IJV, and DistalAV vs. SupraSCV were not downgraded (Table 2).

3.2.2. Artery puncture

We included 13 trials with 4418 patients (Fig. 2a) [6,13,24,30-39]. Regarding the risk of bias within studies, the overall risk of bias was assessed as low for 1, some concern for 8, and high for 4 trials (Supplementary materials 5B). Compared to the IJV, the other cannulation methods might have resulted in little to no difference in artery puncture (Fig. 3b). Both direct and indirect comparisons demonstrated there were almost no significant differences in any of the comparisons (Supplementary materials 5B). Incoherence between direct and indirect RRs was not observed in any of the comparisons for the IJV, SupraSCV, and InfraSCV that formed loops. Due to the presence of zeros in the outcomes, preventing meta-regression with CINeMA, we utilized the ROB ME tool to assess reporting bias. Reporting bias was determined to be low for all interventions (Supplementary material 5B). There was low to high confidence for the estimates, supporting the choice of 5 cannulation sites for CVC (Supplementary materials 5B). DistalAV vs. IJV was downgraded by 2 levels in the confidence rating due to within-study

Table 3
League table of the first attempt success.

	SupraSCV	InfraSCV	IJV	ProxiAV	DistalAV
SupraSCV		1.18 (1.05, 1.32)	1.32 (1.07, 1.62)	NA	NA
InfraSCV	1.21 (1.09, 1.34)		0.97 (0.85, 1.12)	NA	NA
IJV	1.22 (1.06, 1.40)	1.01 (0.90, 1.14)		1.07 (0.97, 1.18)	NA
ProxiAV	1.30 (1.10, 1.54)	1.08 (0.93, 1.26)	1.07 (0.97, 1.18)		1.30 (1.10, 1.55)
DistalAV	1.70 (1.34, 2.16)	1.41 (1.12, 1.77)	1.39 (1.14, 1.70)	1.30 (1.10, 1.55)	

Above the diagonal are the results of the pairwise analysis. Below shows the results of network estimates. Abbreviations: DistalAV, distal axillary veins; IJV, internal jugular vein; InfraSCV, infraclavicular subclavian veins; NA, not applicable; ProxiAV, proximal axillary vein; SupraSCV, supraclavicular subclavian vein.

bias, imprecision, and heterogeneity. DistalAV vs. ProxiAV, IJV vs. InfraSCV, IJV vs. SupraSCV, and ProxiAV vs. SupraSCV were downgraded by 1 level in the confidence rating due to within-study bias and imprecision. InfraSCV vs. SupraSCV was downgraded by 1 level in the confidence rating due to within-study bias and heterogeneity. DistalAV vs. InfraSCV and DistalAV vs. SupraSCV were downgraded by 1 level in the confidence rating due to imprecision. InfraSCV vs. ProxiAV was downgraded by 1 level in the confidence rating due to within-study bias. IJV vs. ProxiAV did not receive a downgrade in the confidence rating.

3.3. Secondary outcomes

3.3.1. Failure

We included 13 trials with 4418 patients (Fig. 2a) [6,13,24,30-39]. Regarding the risk of bias within the studies, the overall risk of bias was assessed as low for 7, some concern for 3, and high for 3 trials (Supplementary materials 5C). Compared to IJV, the other cannulation methods might result in little to no difference in the failure proportion (Supplementary materials 5C). There was moderate-to-high confidence in the estimates, supporting the choice of 5 cannulation sites for CVC (Supplementary materials 5C).

3.3.2. Pneumothorax

We included 13 trials with 4418 patients (Fig. 2a) [6,13,24,30-39]. Regarding the risk of bias within studies, the overall risk of bias was assessed as low for 5, some concern for 6, and high for 2 trials (Supplementary materials 5D). Compared to IJV, other cannulation methods might result in little to no difference in pneumothorax (Supplementary materials 5D). There was moderate confidence in the estimates supporting the choice of the 5 cannulation sites for CVC (Supplementary materials 5D).

3.3.3. Hemothorax

We included 12 trials with 3635 patients (Fig. 2b) [13,24,30-39]. Regarding the risk of bias within studies, the overall risk of bias was assessed as low for 3, some concern for 7, and high for 2 trials (Supplementary materials 5E). We did not perform a meta-analysis because the number of events for all the studies was 0. There was low to high confidence in the estimates, supporting the choice of 5 cannulation sites for CVC (Supplementary materials 5E).

3.3.4. Hematoma

We included 10 trials with 2195 patients (Fig. 2c) [24,30-38]. Regarding the risk of bias within studies, the overall risk of bias was assessed as low for 2, some concern for 5, and high for 3 trials (Supplementary materials 5F). Compared to IJV, SupraSCV may result in a reduction in hematoma (RR 0.36; 95% CI 0.13–0.96; low confidence evidence), and the other cannulation methods might result in little-to-no difference in hematoma (Supplementary materials 5F). There was low to high confidence in the estimates, supporting the choice of 5 cannulation sites for CVC (Supplementary materials 5F).

3.3.5. Subgroup analysis

In the subgroup analysis for the primary outcome, 5 studies only included patients on mechanical ventilation underwent NMA; 1 study including spontaneous respiration underwent a pairwise analysis. In the analysis of patients under mechanical ventilation, we compared the ProxiAV, InfraSCV, and SupraSCV approaches regarding the IJV. However, little to no difference was observed in terms of first-attempt success and artery puncture among the 3 approaches (Supplementary materials 6). In the analysis of patients with spontaneous respiration, little to no difference was found between the ProxiAV and IJV approaches.

3.3.6. Difference between protocol and review

We could not perform prespecified subgroup analyses because each study did not indicate body mass indexes (<30 or ≥30) and all punctures were performed exclusively by experts. An individual who performed a minimum of 8 prior ultrasound-guided CVC insertions was defined as an expert. Due to data deficiency, we could not conduct pre-planned sensitivity analyses.

4. Discussion

In this NMA, we demonstrated that SupraSCV likely increased the first-attempt success proportion compared to the other 4 cannulation approaches, IJV, InfraSCV, ProxiAV, and DistalAV. Conversely, DistalAV reduced the first-attempt success proportion compared to the others. Regarding complications, there was a reduction in hematoma in the SupraSCV compared to the IJV, whereas little to no differences were observed for other complications or approaches. Inserting the CVC from SupraSCV is believed to have advantages due to the following anatomical features: a short skin-to-vein distance, a wide target vein area, a less angular path to the vein, and minimal proximity to the lungs [35]. Although this NMA partially relied on estimates from indirect comparisons, the results suggest that SupraSCV was a likely optimal approach for CVC in the neck and clavicle regions.

By including new comparisons (DistalAV vs. SupraSCV and ProxiAV vs. SupraSCV), our NMA robustly established SupraSCV as the optimal site. The results for the first-attempt success proportion, indicated that SupraSCV outperformed InfraSCV (RR 1.21, 95% CI 1.09 to 1.34) and IJV (RR 1.22, 95% CI 1.06 to 1.40), which are consistent with the findings of previous RCTs [24,34,35,38,39]. Although SupraSCV vs. DistalAV and SupraSCV vs. ProxiAV have not been previously compared, this combined comparison highlights the superiority of SupraSCV. In addition, this NMA demonstrated that DistalAV had a lower first-attempt success proportion than all other approaches. US-guided DistalAV implantation is a novel approach, and there have been no direct comparisons with other approaches except ProxiAV [30]. The diminished success proportion for DistalAV is hypothesized to stem from its narrower vascular diameter and heightened respiratory variability, rendering more susceptibility to collapse [6,13,31,32,36].

This NMA indicated that the SupraSCV may have resulted in a reduction in hematoma compared to the IJV. A previous study indicated a potential association between a greater number of attempts during catheter insertion and an increased occurrence of complications in the landmark SCV approach [40]. This NMA, which only included US-guided catheterizations, also exhibited a similar trend, further enhancing previous observations. Furthermore, in a multicenter RCT that combined the use of both landmark and ultrasound techniques, IJV had a higher incidence of hematoma than SCV, consistent with our study findings [1]. However, considering the superficial location of the IJV compared to the SCV, there is a potential for hematomas to be more readily detectable, both visually and through ultrasound. In this NMA, little to no differences were observed for complications other than hematomas. This may be attributed to a low complication rate. Our pooled data across all the study groups exhibited a relatively low proportion of complications (pneumothorax, 0.46%; hemothorax, 0%; artery puncture, 1.28%), resulting in the lack of statistically significant differences between complications. Previous systematic reviews showed US guidance contributed an overall reduction in complications compared to the landmark method [9,10]. Thus, to compare the infrequent yet significant complications in each US guidance approach and identify differences, more extensive investigations and registry data would likely be necessary.

A minimum experience level of 8 US-guided CVC punctures was required to apply the results of our NMA. The expert definition of US-guided CVC techniques for sites other than IJV has not established [41]. In this review, we considered individuals with 8 or more experience performing CVC as experts. This criterion was based on the previous finding that there was no significant difference in outcomes between those with at least 8 attempts and those with 50 attempts for US-guided IJV puncture [41]. Further research is required to determine

the number of attempts required to achieve proficiency at non-IJV sites. However, if physicians achieve similar proficiency with other approaches in a comparable number of attempts, the higher success proportion for SupraSCV and lower success proportion for DistalAV among those with 8 or more puncture experiences can be generalized. Alternatively, for experts with well over 50 puncture experiences, factors such as familiarity come into play, and the determination of the optimal approach relies on the expertise of the individual.

There are several limitations of this NMA. First, the comparisons did not consider the alignment of the needle axis with the US plane or the US section axis relative to the vessel. In recent years, there has been diversification in approaches, and comparisons based on differences in US sections at the same site have been conducted [2]. However, for SupraSCV, the presence of the clavicle makes an out-of-plane approach difficult, necessitating the use of an in-plane approach with long-axis imaging [2]. Therefore, the results of this study are expected to remain consistent. Second, we used indirect comparisons to evaluate ProxiAV vs. SupraSCV, ProxiAV vs. InfraSCV, Distal AV vs. SupraSCV, DistalAV vs. InfraSCV, and DistalAV vs. IJV, because no studies have directly compared these approaches. However, in the assessment of first-attempt success, both direct and indirect comparisons showed no notable difference in effect sizes and confidence intervals between NMA treatment effects and NMR treatment effect at the smallest observed variance in meta-regression. In the trace plot of the meta-regression, the Gelman-Rubin diagnostic value was <1.1 for all approaches compared to IJV. Additionally, while there were many indirect comparisons, the confidence of evidence for first-attempt success was only moderate to high and not low (Supplementary materials 5 A). Therefore, it is suggested that similar results may be obtained even with an increase in direct studies. The emergence of new RCTs providing these direct comparisons and the release of results from ongoing studies comparing InfraSCV vs. IJV (NCT05140668, NCT04265703, and CTRI/2019/01/017212) may contribute to a clearer understanding of this evidence in the future. Third, there are limited data and few direct comparisons in this study. The addition of more direct comparisons may reveal clear differences between approaches, such as the comparison between IJV and ProxiAV, where significant differences were not apparent in the current analysis. Fourth, in addition to the transitivity assumption examined in this study, there are factors such as patient stability and the level of sedation that can influence the ease of puncture. However, these factors are not standardized, and studies included both ICU and OT settings. As head-to-head studies increase, the most suitable approach for each setting may become more apparent. Fifth, evaluations of long-term complications such as CRI and thrombosis were not conducted in this NMA. RCTs investigating immediate complications, like those included in this review, rarely examine long-term complications. Among the papers included in this review, only three investigated CRI [13,32,34], and only one explored thrombosis [32]. Long-term complications are crucial outcomes during CVC placement, and it is desirable to investigate these outcomes in future studies within the same research.

In conclusion, considering first-attempt success and mechanical complications, the SupraSCV may emerge as the preferred approach, while DistalAV might be the least preferable approach. Nevertheless, head-to-head studies comparing the approaches with the greatest first-attempt success should be undertaken. Furthermore, additional investigations focusing on needle alignment with the US plane and the relative US alignment with the vessel are required.

Data transparency

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

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Author contributions

EI is the guarantor and drafted the manuscript. All authors contributed to the development of the selection criteria, risk of bias assessment strategy, and data extraction criteria. EI, HO, YK and JW developed the search strategy. YK and JW provided statistical expertise. EI, YK, JW, HO and MY provided expertise on central venous catheterization. The final manuscript was collectively reviewed, critiqued, and endorsed by all authors.

CRediT authorship contribution statement

Eriya Imai: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Yuki Kataoka:** Writing – review & editing, Software, Project administration, Methodology, Formal analysis. **Jun Watanabe:** Writing – review & editing, Supervision, Project administration, Methodology. **Hiromu Okano:** Writing – review & editing, Software, Investigation, Formal analysis, Conceptualization. **Motoki Namekawa:** Writing – review & editing, Investigation. **Gen Owada:** Writing – review & editing, Investigation. **Yuko Matsui:** Writing – review & editing, Investigation. **Motoi Yokozuka:** Writing – review & editing, Supervision.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2024.01.043.

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