Systematic Review and Meta-Analysis

Medicine

OPEN

Ultrasound guided axillary vein catheterization versus subclavian vein cannulation with landmark technique

A PRISMA-compliant systematic review and meta-analysis

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Abstract

Background: Although ultrasound (US) guided axillary vein (AV) catheterization has been well described, evidence for its efficacy and safety compared with conventional infraclavicular landmark guided subclavian vein (SCV) cannulation have not been comprehensively appraised. Thus, we conducted a systematic review and meta-analysis to determine whether US guided AV catheterization reduces catheterization failures and adverse events compared to SCV puncture based on landmark technique.

Methods: We searched the PubMed, Embase, Cochrane Library, CINAHL, Web of Science, SCOPUS, China Biology Medicine, China National Knowledge Infrastructure, Wan Fang, and Wei Pu databases for randomized controlled trials (RCTs) studies published from inception to May 2021. Two investigators reviewed and extracted data on study design, number and type of inclusion criteria. Study quality was assessed using the Jadad scale. Outcomes included the puncture success rates and the incidence of adverse events.

Results: Data of 1852 patients from five RCTs were included in this meta-analysis. The analysis showed that US guided AV catheterization increased the first (risk ratio (RR), confidence interval (CI)) (RR = 1.17, 95% CI = 1.13~1.22, $P < .01$) and overall (RR = 1.09, 95% CI = 1.04~1.15, $P < .01$) puncture success rate, and reduce the occurrence of adverse events, including the risk of arterial puncture (RR = 0.18, 95% CI = 0.06~0.55, $P < .01$), pneumo-and hemothorax (RR = 0.12, 95% CI = 0.02~0.64, $P = .01$).

Conclusion: This meta-analysis indicates that US guided AV catheterization reduces catheterization failures and mechanical complications compared with conventional landmark guided SCV puncture.

Abbreviations: AV = axillary vein, CI = confidence interval, CVC = central venous catheter, RCTs = randomized controlled trials, RR = risk ratio, SCV = subclavian vein, US = ultrasound.

Keywords: axillary vein, catheterization, landmark technique, meta-analysis, subclavian vein, ultrasound guided

1. Introduction

Central venous catheter (CVC) is a commonly performed invasive procedure for giving drugs, access for extracorporeal blood circuits, hemodynamic monitoring and intervention.[1] The internal jugular vein, femoral vein, and subclavian vein (SCV) are commonly used sites.[2] Traditionally, the subclavian venous catheter has been considered superior to internal jugular vein and femoral vein approach in many ways, including reduced potential for carotid artery injury, reduced the risk of intravascular thrombosis and catheter-related blood stream infection, ease of nursing, and improved comfort level for patients.[3]

However, due to the proximity of SCV to the pleural space, the subclavian venous catheter is hindered by increased risk of mechanical complications, especially pneumo-and hemothorax, and can be life threatening.[4] The axillary vein (AV) starts at the axillary fold and becomes the SCV at the lateral border of the first rib. This vein lies entirely outside the thoracic cavity. Theoretically, AV catheterization combines the advantages of the SCV access while obviating its inherent risk of pneumo-and hemothorax. Moreover, the clavicle restricts the use of ultrasound (US) for the SCV cannulation, the AV is free of this limitation and allow clear viewing of the vein and adjacent anatomical structures.[5] For these reasons, the US guided AV

The authors have no funding to disclose.

The authors declare that they have no competing conflicts of interest related to this meta-analysis.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Supplemental Digital Content is available for this article.

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How to cite this article: Zhou J, Wu L, Zhang C, Wang J, Liu Y, Ping L. Ultrasound guided axillary vein catheterization versus subclavian vein cannulation with landmark technique: A PRISMA-compliant systematic review and meta-analysis. Medicine 2022;101:43(e31509).

Received: 3 September 2022 / Received in final form: 3 October 2022 / Accepted: 4 October 2022

http://dx.doi.org/10.1097/MD.0000000000031509

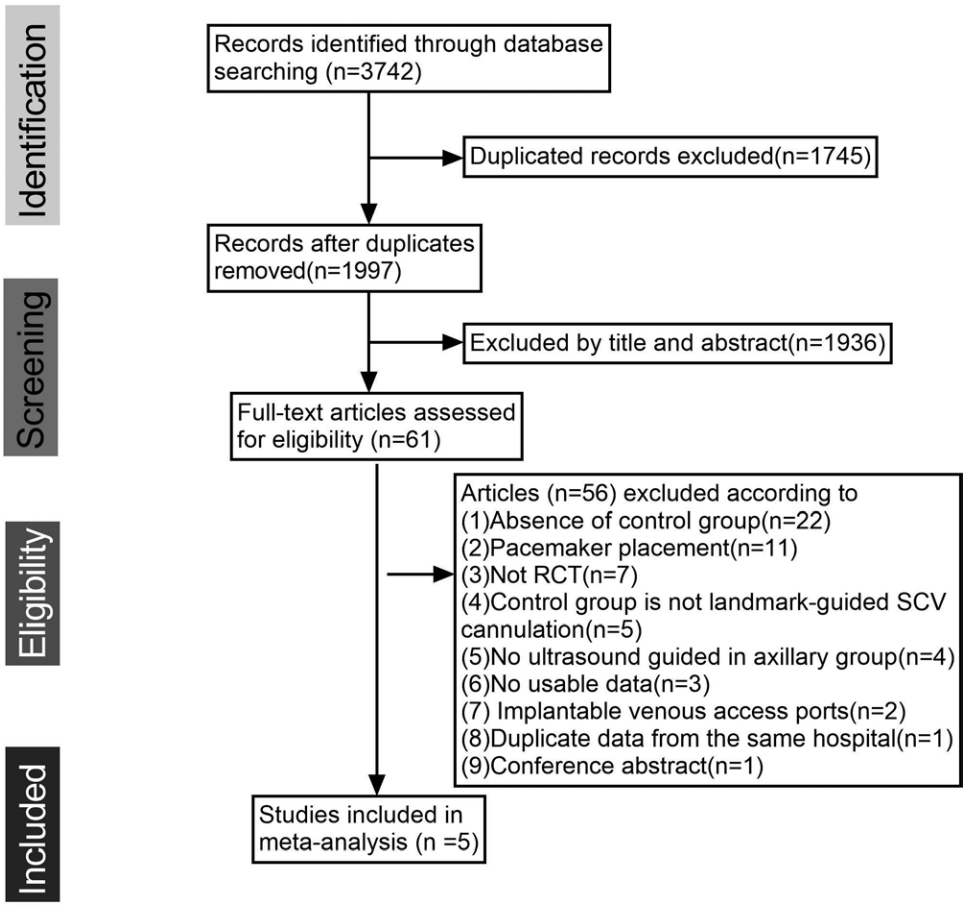

Figure 1. Flowchart of study selection process.

catheterization seems to be an alternative option as a site for CVC.

The landmark method of the infraclavicular AV cannulation was first described by Nickalls in 1987.[6] It never achieved popularity because of the landmarks were difficult to identify. In the era of US guided CVC, the infraclavicular approach to the AV was rediscovered. Nowadays, the technique of US guided AV catheterization has been well described,[7–9] but the evidences for its efficacy and safety compared with landmark guided SCV cannulation have not been comprehensively appraised. Thus, we conducted a systematic review and meta-analysis of RCTs to assess the effectiveness and safety of US guided AV catheterization.

2. Materials and methods

This meta-analysis is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[10] No protocol was used for this meta-analysis. The ethical approval was not necessary and waived.

2.1. Data sources and search strategy

We conducted a literature search using PubMed, Embase, Cochrane library, CINAHL, Web of Science, SCOPUS, China Biology Medicine, China National Knowledge Infrastructure, Wan Fang, and Wei Pu databases from the inception to May 1, 2021. A variety of synonyms for "AV," "CVC" were combined in the search process. The complete search strategy is presented in Additional file 1, Supplemental Digital Content, http://links.lww.com/MD/H817. Reference lists of selected studies were checked to ensure complete coverage. No language restrictions were made in this process.

2.2. Eligibility criteria

The inclusion criteria were as follows: population: either adult or pediatric patients undergoing US guided AV catheterization; intervention vs control: AV with US guidance vs SCV with landmark technique; outcome measures: our primary outcome was the first puncture success rate, the secondary outcomes were the overall puncture success rate, the incidence of complications (arterial puncture, pneumo-and hemothorax, etc); study design: randomized controlled trials (RCTs). The exclusion criteria were as follows: pacemaker placement or implantable venous access port via AV; the intervention group technique was not US guidance; complete data that were unavailable for the meta-analysis.

2.3. Data extraction and quality assessment

Two authors (L.P and J.Z) reviewed all retrieved articles and extracted data independently. The titles and abstracts were first screened to identify potentially eligible articles, and then, full texts were read to confirm their eligibility for inclusion. The extracted data included the following information: first author, publication year, country, patient population, sample size, age, US devices used, operator experience, outcomes, and quality of each study (Jadad scale). The outcomes included the efficacy and safety of the catheterization. Efficacy included the first and overall puncture success rate, access time was excluded from this analysis because its definition varied greatly among studies.

Table 1

The main characteristics of included studies.

Study	Country	Patient population	Sample size		Age (mean ± SD or median(IQR))		Ultrasound device	Operator experience	Outcomes	Jadad score			
			AV group	Control group	AV group	Control group				Randomization	Blind	Withdrawals and Dropouts	Total
Kang 2020	China	ICU patients	96	95	67.8 ± 7.2y	68.1 ± 7.4y	NR	NR	①② ③④	1	0	1	2
Zheng 2019	China	NR	50	50	54.2 ± 20.2y	52.2 ± 18.6y	SonoSite	NR	①②④ ⑤⑥	2	0	1	3
Kim 2017	Korea	Age < 18 years	66	66	29.0 (12.0–48.0)m	19.5 (5.0–48.0)m	Alpinion	One pediatric anesthetist experienced CVC	①③④	2	2	1	5
Xu 2013	China	NR	687	682	55.21 ± 13.43y	56.31 ± 13.37y	GE	NR	①②③ ④⑦	1	0	1	2
Cui 2013	China	ICU patients	30	30	NR	NR	Mindary	One anesthetist experienced CVC	②③ ④⑥	2	0	1	3

Abbreviations: AV = axillary vein, CVC = central venous catheter, IQR = interquartile range, ICU = intensive care unit, m = month, NR = not reported, SD = standard deviation, y = year.
① = first puncture success rate, ② = overall puncture success rate, ③ = arterial puncture, ④ = pneumo-and hemothorax, ⑤ = nerve injury, ⑥ = hematoma, ⑦ = catheter misplacement.

The safety was defined by the prevalence of the adverse events, which included arterial puncture, pneumo-and hemothorax, nerve injury and so on. The extracted data were cross-checked, and any disagreements were resolved by discussion or consultation with the third author (L.W).

The quality assessment was evaluated according to the Jadad scale.[11] In detail, randomization (0-2 points), blinding (0-2 points), and the dropouts and withdrawals (0-1 points) were defined in the scale. A score of less than or equal to 2 indicates low quality, whereas a score of greater than or equal to 3 indicates high quality. In additional, the risk of bias was assessed by the Cochrane risk of bias tool.[12]

2.4. Statistical analysis

Review Manager version 5.3 was used for the statistical analysis. The risk ratio (RR) and 95% confidence interval (CI) were calculated using the fixed or random effect model. The heterogeneity of outcomes across studies was estimated by I^2 statistic (a scale of 0-100%, I^2 = 25% was considered low, 50% was moderate, and 75% was high). When I^2 > 50% was identified for substantial heterogeneity, we used the random effect model, and we further performed sensitivity and/ or subgroup analysis to identify the potential sources of heterogeneity. If $I^2 \leq 50\%$, a fixed-effects model was adopted. The funnel plot will be used to evaluate publication bias. All significance tests were two-sided, and the results were considered statistically significant at $P < .05$.

3. Results

3.1. Search results and characteristics of included studies

A total of five qualifying RCTs involving 1852 participants.[13–17] The detailed study screening and selection was shown in Figure 1, and the main characteristics of included studies are summarized in Table 1.

3.2. Quality and risk-of-bias assessment

Details of quality and risk-of-bias assessment are, respectively, summarized in Table 1 and Figure 2. Two of five studies were classified as low-quality (Jadad score of ≤2); three studies were all classified as high quality studies (Jadad score of ≥3), with one study full score. The risk-of-bias analysis showed that all trials were followed at low risk in terms of randomization, incomplete outcome data and selective reporting. Four of five trials had unclear risk of bias across the allocation concealment and blinding domains. Only one study reported allocation concealment with sealed opaque envelope, and the patients and outcome assessors were blinded.

3.3. Pooled analysis of outcomes

3.3.1. First puncture success rate. Four studies reported the incidence of first puncture success rate. No heterogeneity was found between studies (I^2 = 0%), hence, a fixed effect model was used to analyze the outcome. The first puncture success rate in the two groups differ significantly (RR = 1.17, 95% CI = 1.13~1.22, $P < .01$; Fig. 3).

3.3.2. Overall puncture success rate. Four studies reported the incidence of overall puncture success rate. High heterogeneity was found between studies (I^2 = 85%), a random effect model was used to analyze the outcome. No significant difference was found (RR = 1.07, 95% CI = 0.98~1.17, $P = .14 > 0.05$). After the exclusion of Xu's study, among study heterogeneity was not detected (I^2 = 0%), so we chose to eliminate Xu's study because

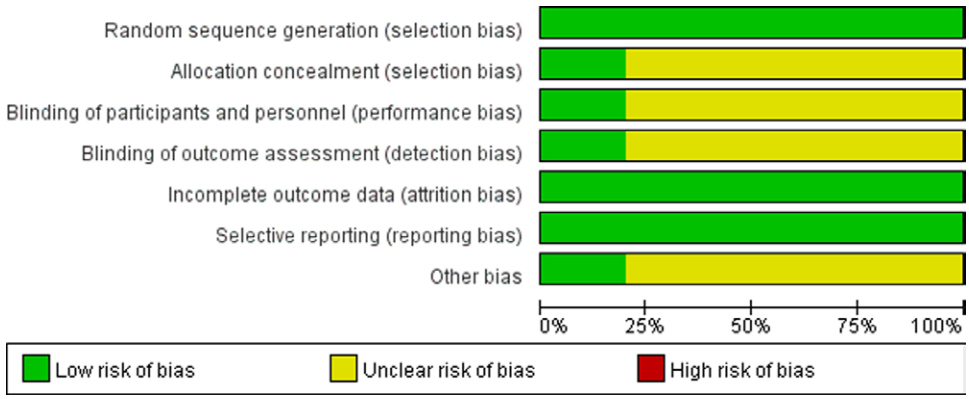

Figure 2. Risk of bias graph: the authors' judgments about each risk-of-bias item presented as percentages across all included studies.

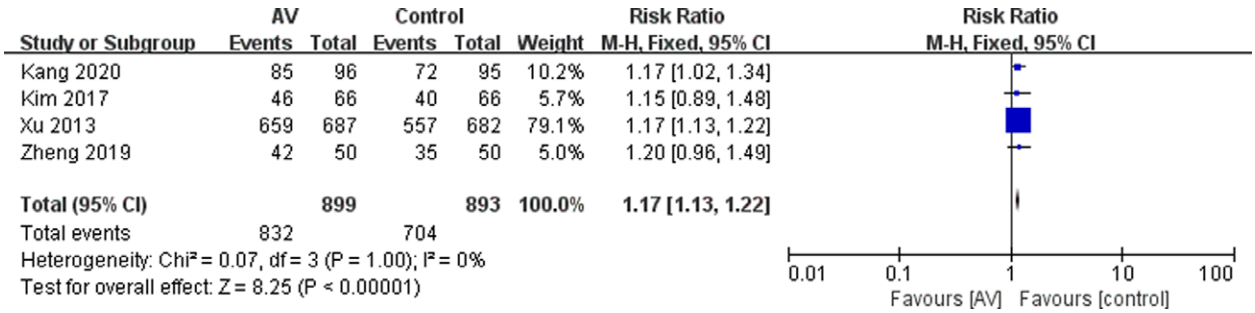

Figure 3. Forest plot for first puncture success rate: 4 studies were included, I^2 = 0%, fixed-effect model was adopted; the result showed an increased in the first puncture rate with the use of US guided AV catheterization.

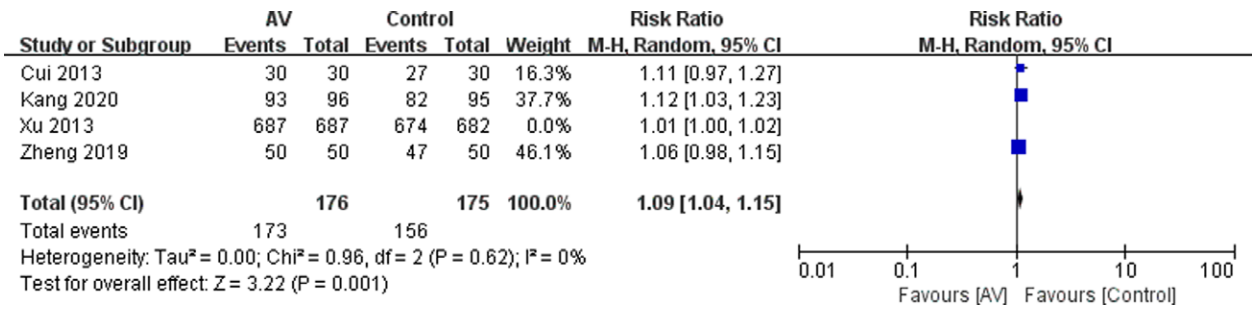

Figure 4. Forest plot for overall puncture success rate: 3 studies were included, I^2 = 0%, fixed-effect model was adopted; the result showed a increased in the overall puncture rate with the use of US guided AV catheterization.

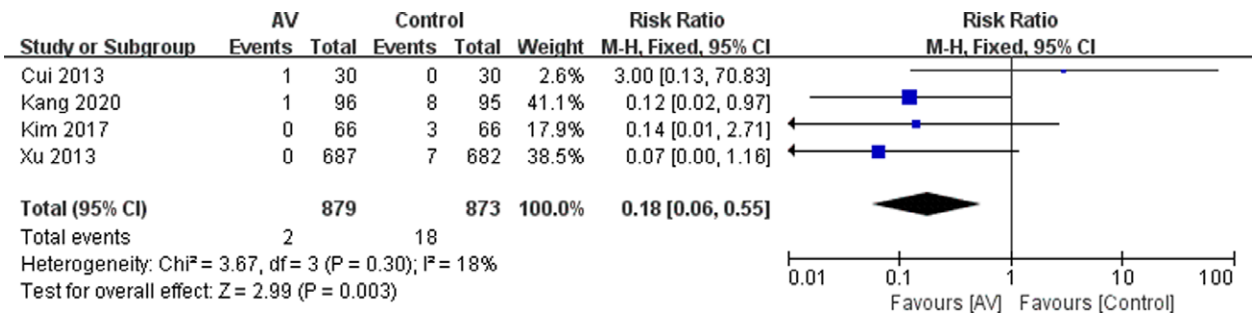

Figure 5. Forest plot for arterial puncture: 4 studies were included, I^2 = 18%, fixed-effect model was adopted; the result showed a reduction in the risk of artery puncture with the use of US guided AV catheterization.

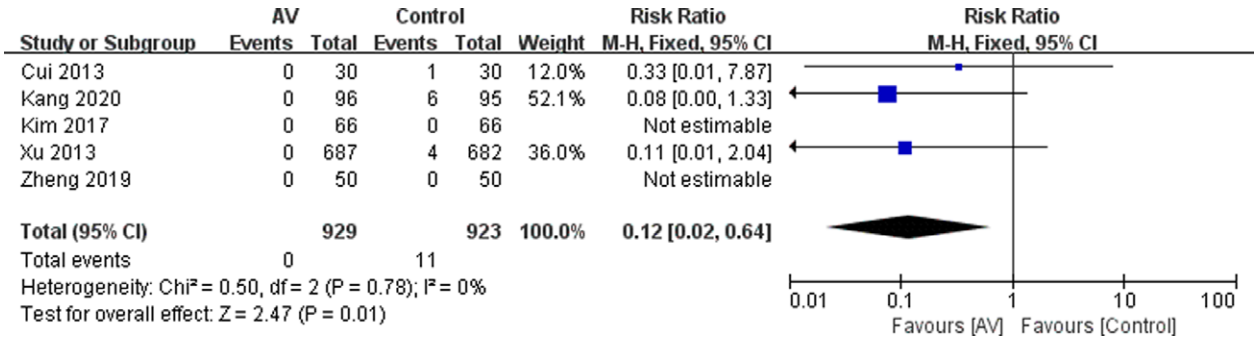

Figure 6. Forest plot for pneumo-and hemothorax: 5 studies were included, I^2 = 0%, fixed-effect model was adopted; the result showed reduction in the risk of pneumo-and hemothorax with the use of US guided AV catheterization.

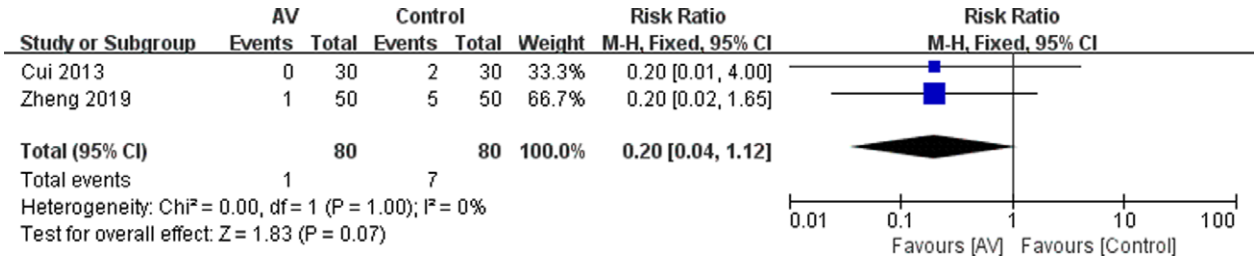

Figure 7. Forest plot for hematoma: 2 studies were included, I^2 = 0%, fixed-effect model was adopted; the result showed hematoma in the two group did not differ significantly.

the heterogeneity was entirely attributable to it. Accordingly, a fixed effect model was used to analyze the outcome. The final pooling result showed that a increase in the overall puncture success rate with the use of US guided AV catheterization (RR = 1.09, 95% CI = 1.04~1.15, $P < .01$; Fig. 4).

3.3.3. Arterial puncture. Four studies reported the incidence of arterial puncture. Low heterogeneity was found between studies (I^2 = 18%), hence, a fixed effect model was used to analyze the outcome. Our pooling result revealed that a reduction in the risk of arterial puncture with the use of US guided AV catheterization (RR = 0.18, 95% CI = 0.06~0.55, $P < .01$; Fig. 5).

3.3.4. Pneumo-and hemothorax. Five studies reported the incidence of pneumo-and hemothorax. No heterogeneity was found between studies (I^2 = 0%), hence, a fixed effect model was used to analyze the outcome. Meta-analysis reported that a reduction in the risk of pneumo-and hemothorax with the use of US guided AV catheterization (RR = 0.12, 95% CI = 0.02~0.64, $P = .01$; Fig. 6).

3.3.5. Hematoma. Two studies reported the incidence of hematoma. No heterogeneity was found between studies (I^2 = 0%), hence, a fixed effect model was used to analyze the outcome. The hematoma in the two group did not differ significantly (RR = 0.20, 95% CI = 0.04~1.12, $P = .07 > 0.05$; Fig. 7).

3.4. Publication bias

As a rule of thumb, funnel plot test should not be used when there are fewer than 10 studies in the meta-analysis,[18] so publication bias was not assessed.

4. Discussion

Our analysis is, to the best of our knowledge, the first meta-analysis to compare the efficiency and safety of the US guided AV and landmark guided SCV catheterization. After analyzing the comprehensive results of five RCTs, we demonstrated that US guided AV catheterization reduces catheterization failures and mechanical complication compared with landmark guided SCV puncture.

We observed significantly differences in first and overall puncture success rate between AV group and SCV group. This may be due to the AV group with the US guidance, but the SCV group with the landmark technique. US guidance is the standard of care for CVC in many centers, and its use is strongly recommended by clinical practice guidelines.[19,20] Numerous studies have demonstrated US guided CVC significantly decreased failed catheterization and reduced time for the procedure.[21,22] The image offered by two-dimensional ultrasonography allow the operator to predict variant anatomy and assess the patency of a target vein.

The incidences of arterial puncture and pneumo-and hemothorax in the AV group were lower than SCV group, indicating that US guided AV catheterization was safer and had low risk of mechanical complications. Some studies suggested that AV approach had many anatomical advantages giving a greater safety because the vein lies at a greater distance from the artery and rib cage.[23,24] Additionally, the US guided AV puncture take the steep approach of the needle and with the rib as a nature protective barrier, which can effectively avoid arterial puncture and pneumo-and hemothorax.[25] In contrast, The SCV transverses close to the dome of the lung, the approach may be complicated by pneumo-and hemothorax and subclavian artery puncture.[26]

This study also has some limitations. Firstly, the number included studies were small, as such our finding should be interpreted with caution. Secondly, we believe that the inability to blind of the operators performing the puncture, especially when the same person was performing all punctures, was a potential source of bias. Thirdly, the puncture's success and adverse events may be related to operator experience; but the subgroup analysis of operator experience had to eventually be omitted due to lack of information. Finally, all studies were conducted in Asia, more studies involving different races and countries still needed to estimate the global practice of US guided AV catheterization.

5. Conclusion

This meta-analysis indicates that US guided AV catheterization reduces catheterization failures and mechanical complications compared with conventional landmark guided SCV puncture.

Acknowledgments

We thank all of the participants recruited for this study.

Author contributions

Conceptualization: Lidong Wu, Luyi Ping.
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Investigation: Lidong Wu, Luyi Ping.
Methodology: Chunquan Zhang.
Supervision: Luyi Ping.
Writing – original draft: Jinchuan Zhou.
Writing – review & editing: Chunquan Zhang, Jiwei Wang, Yanna Liu.

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