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Original Article

Ultrasound-guided technique for both radial and femoral artery catheterization: a meta-analysis

Zheng Guan[1], Yi Lv[2], Lin Liu[1]

[1]*Department of Anesthesiology, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China;* [2]*Department of Hepatobiliary Surgery, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China*

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Abstract: Background: Artery catheterization was a common procedure in clinic. Palpation was the traditional method for artery catheterization. Whether the use of ultrasound-guided technique can increase the success rate and reduce the complication of artery catheterization were not identified. We therefore perfomed this meta-analysis. Methods: We searched Pubmed, EMBASE and Cochrane library, a total of 10 RCTs met our inclusive criteria. The patients included radial or femoral artery catheterization through ultrasound guidance or palpation. We compared the first attempt success rate and the incidence of hematoma. Results: Ultrasound-guided technique provided higher the first attempt success rate during both radial and femoral artery catheterization than traditional palpation technique [RR 1.35, 95% CI 1.09-1.67; P=0.005]. Ultrasound-guided technique also reduced the incidence of hematoma, especial during femoral artery catheterization [RR 0.39, 95% CI 0.24-0.65; *P*=0.0002]. Conclusion: Compared to traditional palpation technique, ultrasound-guided technique increased the first attempt success rate and reduced the incidence of hematoma during artery catheterization.

Keywords: Ultrasound-guided technique, artery catheterization, meta-analysis

Introduction

Artery catheterization is a common procedure in patients during perioperative period and angiography for continuous blood-pressure monitoring, frequent blood-gas analysis, or intravascular examination and treatment. The procedure may be more difficult in some patients leading to multiple insertion attempts or failed insertion, these may result in arterial spasm, local hematoma and patient's discomfort.

The use of ultrasound-guided technique for central vena catheterization and peripheral nerve blocks has been proved to increasing the success rate, reducing complications [1-4], but central vena and peripheral nerve are different from artery which can be confirmed by palpation easily due to the pulsation of artery. Cristie [5] firstly reported the function of doppler flow in femoral artery puncture in 1990, then another study reported the usefulness of ultrasound-guided technique in difficult femoral artery puncture [6]. Until now, there have some reviews and meta-analysis indicate that ultrasound-guided radial artery catheterization may offer many benefits including decreasing time of catheterization, decreasing the times of attempt [7-9], but these meta-analyses have not examined the femoral artery catheterization and the complication of artery catheterization using ultrasound-guided technique or not, we undertook a meta-analysis to examine these issues. Our primary outcome measure was the first attempt success rate of artery catheterization using ultrasound-guided (vs non-ultrasound) technique, the secondary outcome was the incidence of local-regional hematoma not requiring additional treatment of artery catheterization using ultrasound-guided (vs non-ultrasound) technique.

Methods

Search strategy

Two reviewers searched electronic databases (PubMed, EMBASE, and the Cochrane library) independently. The key words for our investigation were ultrasound, artery puncture, artery

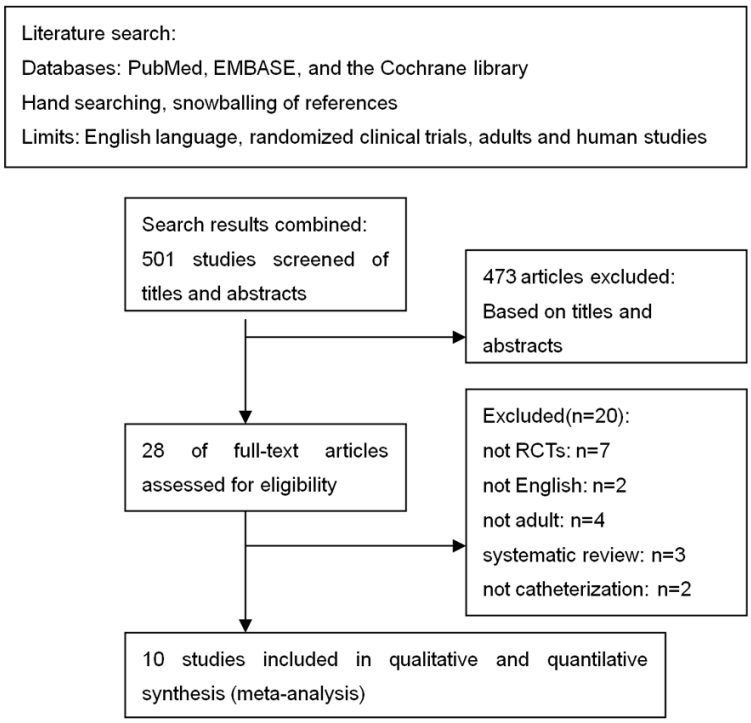

Figure 1. Flow chart showing the number of abstracts and articles identified and evaluated during the review process.

cannulation, artery cathetering and artery catheterization. The research strategy ran from 1985 to 31 October 2015. During databases searching, we restricted articles type to "randomized clinical trials (RCTs)", subjects to "adults and human studies only", and language to "English".

The titles and abstracts identified from the search strategy were then screened for potential articles by two investigators. After this primary exclusion, full articles were obtained and examined for suitability, the reference lists for identified studies were snowballed for additional articles.

Study inclusion criteria

Randomized controlled clinical trials (RCTs) evaluating the effect of using ultrasound for artery catheterization. All studies had to be prospective, properly randomized, and had to report the number or rate of the first attempt success and/or the incidence of local-regional hematoma as the outcome. Artery catheterization success was defined as successful placement of a vascular sheath, local-regional hematoma was defined as an obviously visible accumulation of subcutaneous blood after arterial catheterization. We collected data according to the definition in the original literatures.

Methodological quality of included studies and risk of bias assessment

Eligible studies were graded using the systems described by Jadad and colleagues. This scale is used to describe the study quality by scoring five elements of randomization, implementation, and blinding with a score range of 1 to 5.

The adequacy of concealment of allocation, blinding of participants and healthcare providers, blinding of outcome assessors, extent of loss of follow-up, and risk of selective reporting bias were determined by two reviewers respectively using the Review Manager, version 5.0 software (The Cocharane Collaboration, Oxford, UK). Risk was described for every item as "low risk" if the information provided in the study was clear and complete, "high risk" if there was no information about some of the items, and "unclear risk" when the information provided is incomplete.

Outcome measures

The primary outcome for assessment was the first attempt success rate of artery catheterization, the secondary outcome was the local-regional hematoma not requiring additional treatment.

A sensitivity analysis was performed on both the primary and secondary outcomes.

Statistical analysis

The meta-analysis was performed using the Review Manager, version 5.0 software (The Cocharane Collaboration, Oxford, UK), with a random-effect model when there is significant heterogeneity between studies, and with a fix-effect model when the between-study heterogeneity is no significance. The results are pre-

Table 1. Randomized clinical trials of ultrasound-guided artery catheterization

Study	Study population	Subjects (n)	Artery	Control group	Index
Levin PD 2003 [10]	M/F adults	34 US/35 C	RA	Palpation	FS
Tada T 2003 [11]	M/F adults	72 US/94 C	RA	Palpation	FS
Dudeck O 2004 [12]	M/F adults	56 US/56 C	FA	Palpation	FS, LH
Shiver S 2006 [13]	M/F adults	30 US/30 C	RA	Palpation	FS, LH
Seto AH 2010 [14]	M/F adults	503 US/501 C	FA	Palpation, fluoroscopy	FS, LH
Gedikoglu M 2013 [15]	M/F adults	108 US/100 C	FA	Palpation, fluoroscopy	FS, LH
Zaremski L 2013 [16]	M/F adults	92 US/91 C	RA	Palpation	FS
Hansen MA 2014 [17]	M/F adults	40 US/40 C	RA	Palpation	FS
Peters C 2015 [18]	M/F adults	63 US/62 C	RA	Palpation	FS, LH
Slattery MM 2015 [19]	M/F adults	53 US/47 C	FA	Palpation, fluoroscopy	LH

US: Ultrasound-guided group; C: Control group; RA: Radial artery; FA: Femoral artery; FS: First attempt success rate; LH: Local-regional hemotoma.

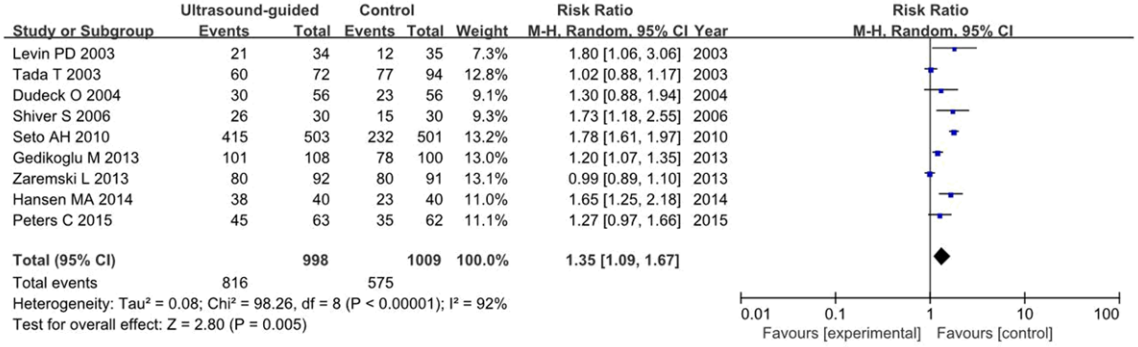

Figure 2. Forest plot showing the ultrasound-guided artery catheterization on first attempt success rate vs control group. M-H, Mantel-Hoenszel.

sented as a risk ratio (RR) for dichotomous data with 95% confidence intervals (CIs). Significance was set at a *P*-value <0.05. Inconsistency was tested using the I^2 statistic and it was considered significant when it was >50%.

Results

Included trials

Our search resulted in abstract, of which a total of 501 titles were suitable for further review after database searching. 28 articles were selected after thorough examination of titles and abstracts. Further examination led to exclusion of 18 studies from the analysis. Because they were not RCTs (n=7), not English (n=2), not adult (n=4), not doing artery catheterization (n=2) and systematic review (n=3) (**Figure 1**). 10 articles were finally included in the analysis. There were 2107 subjects included in the 10 randomized trials.

Description of studies

Table 1 provides a detailed description of the studies included in the analysis. Of which, 5 articles reported both the first attempt success rate of artery catheterization and the incidence of local-regional hematoma, 4 articles only reported the first attempt success rate of artery catheterization, and 1 article only reported the incidence of local-regional hematoma. The radial artery catheterization was performed in 6 articles, the other 4 articles were for femoral artery catheterization. 7 articles used the palpation technique in control groups, 3 articles used palpation plus fluoroscopy-assisted technique in control groups.

The first attempt success of artery catheterization

The first attempt success of artery catheterization was available for 9 trials on 2007 patients.

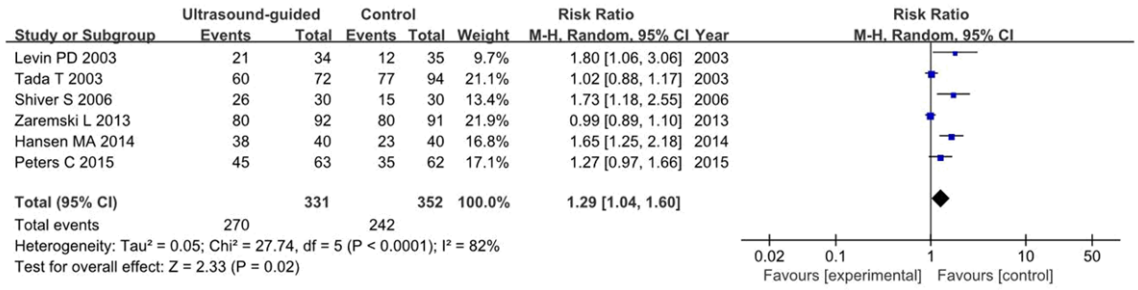

Figure 3. Forest plot showing the ultrasound-guided radial artery catheterization on first attempt success rate vs control group. M-H, Mantel-Hoenszel.

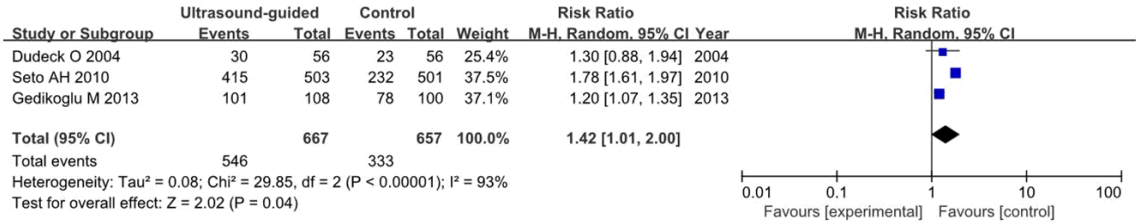

Figure 4. Forest plot showing the ultrasound-guided femoral artery catheterization on first attempt success rate vs control group. M-H, Mantel-Hoenszel.

Figure 5. Forest plot showing the ultrasound-guided artery catheterization on the incidence of local hematomas vs control group. M-H, Mantel-Hoenszel.

The overall success rate when combining the studies was significant higher in the ultrasound-guided group than in the control group [RR 1.35, 95% confidence interval (CI) 1.09-1.67; *P*=0.005] (**Figure 2**). But significant heterogeneity was detected within this comparison [I^2=92%, *P*<0.00001]. In order to get a more accurate conclusion, we divided the articles into two subgroups, however, the result was still significant in both radial artery catheterization subgroup [RR 1.29, 95% CI 1.04-1.60; *P*=0.02] (**Figure 3**) and femoral artery catheterization subgroup [RR 1.42, 95% CI 1.01-2; *P*=0.04] (**Figure 4**). At the same time, significant heterogeneity among studies was still existed [I^2=82%, *P*<0.0001; I^2=93%, *P*<0.00001 respectively].

The incidence of local-regional hematoma

The incidence of local-regional hematoma was available for 6 trials on 1609 patients. There was a total of 68 local-regional hematomas, while 19 in the ultrasound-guided group and 49 in the control group. In the pooled analysis, there was a significant reduction of local-regional hematoma incidence in the ultrasound-guided group [RR 0.39, 95% CI 0.24-0.65; *P*=0.0002] (**Figure 5**). Subgroup analysis, we ruled out two studies which performed the radial artery catheterization. However, the result was still significant [RR 0.51, 95% CI 0.25-1.05; *P*=0.07] (**Figure 6**). No obvious heterogeneity was detected among studies [I^2= 42%, *P*=0.12; I^2=44%, *P*=0.15 respectively].

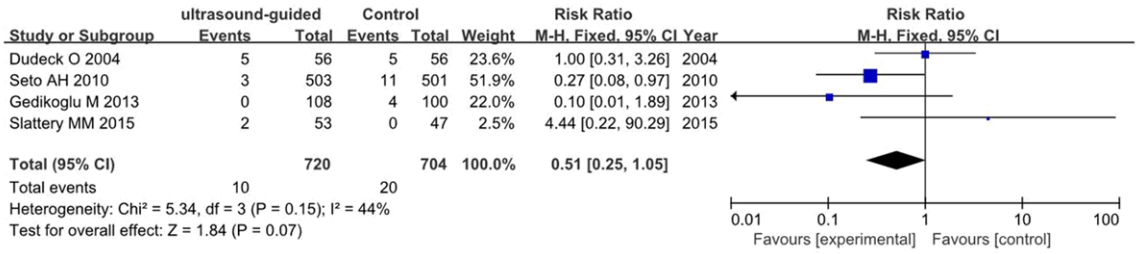

Figure 6. Forest plot showing the ultrasound-guided femoral artery catheterization on the incidence of local hematoma vs control group. M-H, Mantel-Hoenszel.

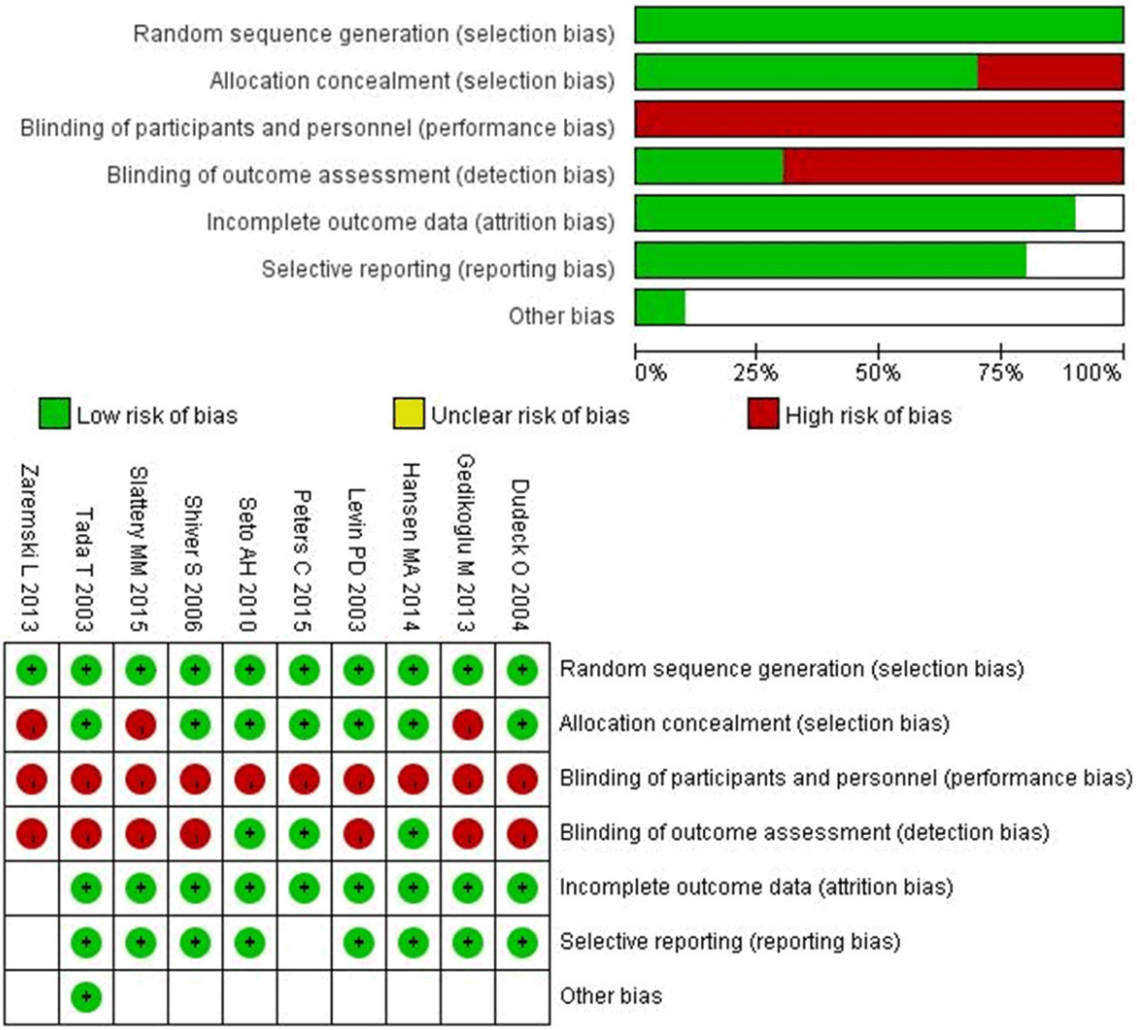

Figure 7. Risk-of-bias assessment.

Trial quality

The Jadad score was 1 for 1 studies [16], 2 for 5 studies [10, 11, 15, 17, 19], 3 for 4 studies [12-14, 18]. Neither of the studies was performed in a doubled-blinded way and all of them were done in a single centre. There were 3 studies performed in a single-blinded way [14, 17, 18]. **Figure 7** presents the risk-of- bias of the individual RCTs.

Discussion

The demography of participants was described in the included studies, including: age, gender, height and weight. The artery catheterization was performed by radiologists [12, 15], anesthesiologists [11, 17], cardiology fellows and attending physicians [14, 16] respectively. This meta-analysis represents the most up-to-date evaluation of ultrasound-guided artery catheterization in adult patients. Our analysis found a significant increase in the first attempt success rate for artery catheterization using ultrasound-guided technique versus non-ultrasound technique, especially in femoral artery catheterization, but significant heterogeneity was detected within this comparison, so the result should be therefore interpreted with caution. Furthermore, there was a significant reduction of local-regional hematoma incidence in the ultrasound-guided group, and no significant heterogeneity was detected with this comparison.

US-guided technique has been proved to increasing the success rate in peripheral nerve block and control vein puncture, and reducing the complication in several randomized controlled trials and meta-analysis [1-4]. According to our point of view, the ultrasound-guided technique was helpful in artery catheterization making the process more effective and safer. Except for the procedural benefits, the ultrasound can also be used for evaluation of the healthy vessel, anatomical variants [20], assess for surrounding anatomy and artery diameter [21], enabling the physician to choose an alternative approach. Previous systematic review of 3 RCTs also found the use of ultrasound-guided technique for radial artery catheterization was associated with a increased first attempt success rate [7-9], which was similar to our results.

Though the time of artery catheterization was recorded in 8 studies, but the defination was various in different studies, in two studies, it was defined as from first skin perforation to full catheter insertion [11, 17], in one study, it was defined as from local anesthetic injection to sheath placement [19], while in another study, it was defined as from pulse determination to successful catheterization [18], so we don't do analysis of this issue.

In three studies, the subgroup analysis was performed, including subgroup with weak arterial pulse [12, 16] and subgroup with obesity participants [14, 16], the ultrasound-guided technique was also proved to be effective in artery catheterization in these subgroups.

There are limitations of our meta-analysis. First, there are a few studies which have less than 50 subjects in each group. Second, these studies were performed at centers where providers were likely to be highly skilled in ultrasound-guided technique, so their conclusion may not be generalizable to all medical center. Third, there was significant heterogeneity among the included studies. The heterogeneity may due to the ultrasound-guided technique (short axis or long axis approach), the patients they selected (gender [22], weight, blood pressure level), the difference of operators (anesthesiologist, physician, radialogist). Finally, it is very difficult to have a properly double-blind study when the two groups need to have artery catheterization through different technique.

In summary, compared with traditional artery catheterization, the ultrasound-guided technique can increase the first attempt success rate and reduce the incidence of local-regional hematoma in both radial and femoral artery catheterization. More clinical trials are needed to confirm these conclusions.

Disclosure of conflict of interest

None.

Address correspondence to: Zheng Guan, Department of Anesthesiology, The First Affiliated Hospital of Xi'an Jiaotong University, No. 277, Yanta West Road, Xi'an, China. Tel: +86-13572592715; E-mail: guanzheng1980@126.com

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