CHEST

Ultrasound Guidance Facilitates Radial Artery Catheterization

A Meta-analysis With Trial Sequential Analysis of Randomized Controlled Trials

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BACKGROUND: Potential benefits and possible risks associated with ultrasound guidance compared with traditional palpation for radial artery catheterization are not fully understood.

METHODS: We searched PubMed, Embase, and the Cochrane Library through July 2015 to identify randomized controlled trials that evaluated ultrasound guidance compared with traditional palpation for radial artery catheterization. Primary outcome was first-attempt failure. Secondary outcomes included mean attempts to success, mean time to success, and hematoma complications. A random-effects model was used to estimate relative risks (RRs) with 95% CIs.

RESULTS: Twelve trials used dynamic two-dimensional (2-D) ultrasound guidance (N = 1,992) and two used Doppler ultrasound guidance (N = 666). Compared with traditional palpation, dynamic 2-D ultrasound guidance was associated with a reduced first-attempt failure (RR, 0.68; 95% CI, 0.52-0.87). Trial sequential analysis showed that the cumulative *z* curve crossed the trial sequential monitoring boundary for benefit establishing sufficient and conclusive evidence. Dynamic 2-D ultrasound guidance further reduced mean attempts to success, mean time to success, and hematoma complications. No evidence of publication bias was detected. Compared with traditional palpation, Doppler ultrasound guidance had no benefit on first-attempt failure (RR, 1.00; 95% CI, 0.87-1.15), which was confirmed by trial sequential analysis as the cumulative *z* curve entered the futility area.

CONCLUSIONS: The use of dynamic 2-D ultrasound guidance for radial artery catheterization decreases first-attempt failure, mean attempts to success, mean time to success, and the occurrence of hematoma complications. Dynamic 2-D ultrasound guidance is recommended as an adjunct to aid radial arterial catheterization. CHEST 2016; 149(1):166-179

KEY WORDS: catherizations; meta-analysis; ultrasound

ABBREVIATIONS: 2-D = two-dimensional; GRADE = Grading of Recommendations Assessment, Development, and Evaluation; MD = mean difference; MeSH = Medical Subject Headings; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-analyses; RCT = randomized controlled trial; RR = relative risk; TSA = trial sequential analysis

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Arterial catheterization is a common invasive procedure in many clinical settings including the operating room, ICU, and ED.[1,2] It allows continuous arterial pressure monitoring and repeated arterial blood sampling.[2,3] The radial artery is the most commonly used site and the preferred access for arterial catheterization because of its superficial accessibility and low incidence of complications.[4,5] Traditionally, radial artery catheterization has been guided by using anatomic knowledge and pulse palpation. However, the technique often can be technically challenging in infants, small children, and patients who are hypotensive or obese, even for experienced operators.[1,4] The first unsuccessful attempt and next multiple attempts increase patient discomfort and may lead to local hematoma, arterial spasm, or other complications.[1,3,4,6,7]

To overcome this issue, ultrasound has been introduced as an adjunct to aid radial artery catheterization, because it allows easy visualization of the targeted vessel.[8] However, potential benefits and possible risks associated with ultrasound guidance compared with traditional palpation for radial artery catheterization are not fully understood. Evidence from randomized controlled trials (RCTs) reported inconsistent results[9-17] and consecutive meta-analyses were underpowered to reach determinate conclusions.[18-20] Moreover, four recent trials with adequate power have been published and involve new evidence.[21-24] Thus, we undertook a meta-analysis of the latest and most convincing evidence to evaluate the efficacy and safety of ultrasound guidance compared with traditional palpation for radial artery catheterization, and we further applied trial sequential analysis (TSA) to determine whether the currently available evidence was sufficient and conclusive.

Materials and Methods

The current meta-analysis was performed according to the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*[25] and was reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines (e-Appendix).[26] There was no registered protocol.

Literature Search

We performed a systematic electronic search in PubMed, Embase, and the Cochrane Library from inception through May 2015. We conducted electronic searches using exploded Medical Subject Headings (MeSH) terms and corresponding key words. The search terms used were (MeSH exp "Ultrasonography," "Ultrasonics," and key words "ultrasonography*," "ultrasonic*," and "ultrasound*"), and (MeSH exp "Radial Artery" and key words "radial artery" and "radial arterial"). No language restriction was applied. To ensure literature saturation, we reran the searches on July 20, 2015. We also searched ClinicalTrials.gov registry (www.clinicaltrials.gov) and manually checked the bibliographies of previous reviews and included trials to identify other potentially eligible trials.

Selection Criteria

Two authors (W.-J. G. and X.-D. W.) independently carried out the initial search, deleted duplicate records, screened the titles and abstracts for relevance, and identified records as included, excluded or uncertain. In case of uncertainty, the full-text article was acquired to identify eligibility. Any discrepancy was resolved by discussion and consensus.

Published RCTs meeting the following criteria were included: (1) population: children or adults requiring radial artery catheterization regardless of clinical settings; (2) intervention: dynamic two-dimensional (2-D) or Doppler ultrasound guidance technique; (3) comparison: traditional palpation technique; and (4) $\geq$ 1 of the following outcomes: first-attempt failure, mean attempts to success, mean time to success, and hematoma complications.

Data Extraction

Data extraction was performed by W.-J. G. and confirmed independently by other authors (X.-D. W. and F. W.). Collected data included the following: first author, year of publication, country, number of patients, clinical setting, ultrasound type, ultrasound machine (type, device, and approach), operator experience, and outcomes data. Extracted data were entered into a standardized Excel (Microsoft Corporation) file. We also sought supplementary appendixes of included trials or contacted corresponding authors to verify extracted data and request the missing data. Discrepancies were resolved by discussion with coauthors. Predefined primary outcome was first-attempt failure. Secondary outcomes included mean attempts to success, mean time to success, and hematoma complications.

Risk of Bias Assessment

Two authors (W.-J. G. and F. W.) independently assessed risk of bias using the Cochrane risk-of-bias tool.[27] We reviewed each trial and scored as high, low, or unclear risk of bias to the following criteria: random sequence generation; allocation concealment; blinding of participants and personnel to the study protocol; blinding of outcome assessment; incomplete outcome data; selective reporting; and other bias. Blinding of patients and clinicians to the study protocol was extremely difficult and generally not feasible in these trials, and we judged that the primary outcome (that is, first-attempt failure) was less prone to be influenced by lack of blinding. Thus, trials with high risk of bias for $\geq$ 1 key domains except blinding were considered to be at high risk of bias whereas trials with low risk of bias for all key domains except blinding were considered to be at low risk of bias; otherwise they were considered to be at unclear risk of bias.

Grading Quality of Evidence

Two authors (W.-J. G. and Z.-L. M.) independently evaluated the quality of evidence for primary and secondary outcomes according to Grading of Recommendations Assessment, Development, and Evaluation (GRADE)[28] methodology for risk of bias, inconsistency, indirectness, imprecision, and publication bias, classified as very low, low, moderate, or high. Summary tables were constructed using the GRADE Profiler (version 3.6, GRADEpro).

Statistical Analysis

We calculated relative risks (RRs) with 95% CIs for dichotomous outcomes and mean differences (MDs) with 95% CIs for continuous