Chapter 18. Use of Real-Time Ultrasound Guidance During Central Line Insertion: Brief Update Review

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Introduction

Central venous catheters (CVCs) have multiple indications, including parenteral nutrition, treatment of intravascular depletion, access for vasoactive medications, hemodynamic monitoring, intravenous access during cardiopulmonary arrest, difficult peripheral intravenous (IV) access, and long-term IV access for medications, such as antibiotics. Although these catheters can be life saving, they are also associated with significant risk. This risk is heightened by a number of factors, including patient characteristics (e.g., morbid obesity, cachexia, or local scarring from surgery or radiation treatment), patient setting (e.g., patients receiving mechanical ventilation or during emergencies such as cardiac arrest), co-morbidities (e.g., bullous emphysema or coagulopathy), the variable training and experience of the clinicians who perform the procedure, and the method of insertion (e.g., percutaneous insertions are often performed “blind” and rely on anatomic landmarks). However, protocols have been developed that use portable ultrasound (US) devices to provide bedside imaging of the central veins during catheter placement. The advantages associated with US-guided CVC placement include detection of anatomic variations and exact vessel location (for example, the carotid artery is anterior to the internal jugular vein in 3% to 9% of patients), avoidance of central veins with pre-existing thrombosis that may prevent successful CVC placement, and guidance of both guidewire and catheter placement after initial needle insertion.

The original report included a review of the efficacy, safety, and cost-effectiveness of real-time US guidance on the safety of CVC insertions. This review found that, in general, US improves the success rates and reduces the risks of CVC placement, particularly for inexperienced clinicians and for patients in high-risk situations. The purpose of the present report is to provide an update on the impact of US CVC insertion. We used the articles cited as evidence in the 2001 report to create a list of search terms and then used these terms to conduct an update search.

What Is the Practice of Using Ultrasound Guidance for Central Venous Catheter Insertion?

As a patient safety practice, utilizing portable two-dimensional ultrasonography to guide the insertion of CVCs (internal jugular, subclavian or femoral) can take one of two forms— the “static” approach, whereby a mark is placed on the skin to indicate where to insert the needle, or the “real time” approach, where the needle insertion is visualized during the procedure. The alternative to using US guidance is the “landmark” approach, whereby anatomic landmarks are used to determine, to the extent possible, where the underlying vein is located. A recent 18-minute video (and accompanying text) demonstrates the use of US guidance for internal jugular vein catheterization (www.nejm.org/doi/full/10.1056/NEJMvcm0810156#figure=preview.jpg).
How Has the Use of Ultrasound To Guide Central Venous Catheter Insertion Been Implemented?

Our search identified two surveys of the use of US for CVC. In 2006, an Internet survey was sent to members of the Society of Cardiovascular Anesthesiology; 1,494 responses were received from 4,235 members (35%). Of these respondents, 37 percent stated they “never” used US for CVC insertion, and another 30 percent “almost never” used it. Only 15 percent “always” or “almost always” used US guidance.8 A survey from the United Kingdom (U.K.) asked 2000 senior members of the Association of Anesthetists of Great Britain and Ireland about their use of US guidance; 1,455 replied, for a response rate of 73%). Of the respondents, 93 percent regularly inserted internal jugular venous catheters as part of their practice, and 27 percent of respondents indicated that the use of US was their “first choice” as a technique (50% of respondents used “surface landmarks” and 30% used “palpation/balloting”; some respondents indicated more than one first choice).9

Educating clinicians on the use of US for central line placement has received relatively little attention. Studies have shown that clinical US guidance skills are improved by implementing simulator-based training (see Chapter 38). Although several medical schools offer training in portable ultrasonography, scant information exists on teaching US guided (USG) central line placement to medical students.10-12 Particular specialties mandate portable US training for residents, including procedural skills like USG central line placement, whereas others have just begun to explore the benefits of portable US in their graduate medical education programs. In emergency medicine residency training for instance, the first US curriculum was published in 1994.13 While no clear consensus exists regarding the need for training in USG central line placement in emergency medicine residencies, a novel training program consisting of a brief web-based instructional module and a practical session was effective in enhancing emergency resident competency in USG central line placement.14 Carilion Clinic trains physicians in the use of US using a curriculum consisting of 16 hours of didactic and hands on experience during the first month of residency; this training covers physics, “knobology” (e.g., what all the knobs on the machine are for), echocardiography, abdominal US, vascular US, and includes 2.5 hours of procedural skills, of which USG central line placement is prominent. Physicians who are experienced in the procedure use special models to conduct the “hands-on” portion of this curriculum for groups of four to five trainees. Currently, skills assessment is done by observation, although a competency and performance checklist is being developed. With respect to continuing medical education, medical schools, clinics, and medical education companies sponsor a range of activities. These activities cover hands-on USG central line placement as part of multiday courses that concentrate on U.S. education.

What Have We Learned About the Use of Ultrasound Guidance for Central Venous Catheter Insertion?

The most relevant meta-analysis identified was published by Hind and colleagues in 2003, and was commissioned by the U.K. National Institute for Clinical Excellence.15 These authors identified 18 eligible randomized trials that compared either two-dimensional US or Doppler US with either the landmark method or the cut-down method (whereby an incision is made to directly visualize the vein) and that measured any one of five relevant outcomes. Data for adults and children were pooled separately, and data from 2D and from Doppler studies were also pooled separately. For all five relevant outcomes (failed catheter placement, complication with
placement, failure on the first attempt, mean number of attempts to successful catheterization, and seconds to successful catheterization), two-dimensional US had statistically significantly better outcomes than the landmark method for internal jugular vein catheterization in adults. More limited data in children and for subclavian and for femoral vein insertion favored the use of two-dimensional US. Pooled results from studies of Doppler US also favored its use. No studies directly compared two-dimensional and Doppler US. The authors made an indirect comparison by assessing the size of the pooled effects for each compared with the landmark method. This analysis favored the use of two-dimensional US. This review scored nine of 11 relevant AMSTAR criteria. A companion cost-effectiveness analysis estimated the marginal cost (in 2002) for use of US in CVC to be about 10 pounds sterling (approximately $16) per procedure, assuming the machine was used for 15 procedures each week. The base case scenario estimated that for every 1000 patients, 90 complications would be avoided, with a net cost saving of about 2000 pounds sterling (approximately $3200).16

Since that time, randomized trials in adults have consistently supported the conclusions about effectiveness, including patients treated in the Emergency Department,17 ventilated patients,18 critical care patients,19,20 and patients in other miscellaneous clinical settings.21,22 A new outcome—central venous catheter-associated bloodstream infection—has been assessed and found to be statistically significantly lower in one trial of US-guided catheter insertion compared with landmark methods.19

A more recent meta-analysis included five studies that focused only on children, most of whom were cardiac surgery patients. Although pooled point estimates favored the use of US, the 95% confidence intervals were wide and none of the results were statistically significant.23 Two trials published since that meta-analysis, one of which compared real time to static US, both found that two-dimensional real-time US improved some outcomes.24,25

Recent trials of US have focused less on its use in adult internal jugular vein catheterization and more on its use in other locations and refinements of the technique, including the insertion of hemodialysis catheters,26 the radial artery,27-29 the femoral artery,30 and even peripheral venous catheters in difficult patients.31-36 In general, studies reported that US guidance improved outcomes compared with techniques without US guidance. Systematic reviews of the use of US guidance for hemodialysis catheter insertion37 and radial artery catheters38 each concluded that the use of real-time two-dimensional US improved outcomes.

Clearly, USG central line placement education varies in undergraduate, graduate, and continuing medical education. While educators at all levels are making inroads, greater consistency is needed in curricula, evaluation of outcomes, and guideline development.

Conclusions and Comment

In 2001, “Making Health Care Safer” concluded that the use of US guidance for the placement of CVCs is one of the patient safety practices with the strongest evidence. Since that time, new evidence continues to support and strengthen this conclusion. Simulator-based training can improve implementation of this patient safety practice. Emerging evidence suggests that two-dimensional real-time US guidance may also be beneficial for other kinds of catheter insertions. A summary table is located below (Table 1).
### Table 1, Chapter 18. Summary table

<table>
<thead>
<tr>
<th>Scope of the Problem Targeted by the PSP (Frequency/Severity)</th>
<th>Strength of Evidence for Effectiveness of the PSPs</th>
<th>Evidence or Potential for Harmful Unintended Consequences</th>
<th>Estimate of Cost</th>
<th>Implementation Issues: How Much do We Know?/How Hard Is It?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/Low-to-moderate</td>
<td>High</td>
<td>Negligible</td>
<td>Low-to-moderate</td>
<td>A lot/Moderate</td>
</tr>
</tbody>
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### References


