THE IMPORTANCE OF TRAINING FOR ULTRASOUND GUIDANCE IN CENTRAL VEIN CATHETERIZATION

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Abstract

Objective: To review the complication and success rates associated with CVC placement in patients undergoing cardiovascular surgery depending on the technique utilized and the degree of ultrasound experience of the anesthesia provider.

Design: Randomized controlled trial.

Setting: Operating room and post anesthesia care unit.

Patients: 325 patients with CAD requiring cardiovascular surgery with an ASA of III or above.

Interventions: The subjects underwent CVC of the Internal Jugular vein with or without ultrasound guidance in preparation for cardiovascular surgery.

Measurements: Utilization of US, carotid artery puncture/cannulation and the presence of post procedure pneumothorax.

Results: When comparing the group that had CVC without US versus the group having CVC placement with US, there was significant difference in complication rates based on Z-testing (95% confidence level). Furthermore, with 90% confidence (based on Z-testing) there was a significant difference in complication rates between the experienced and non experienced US practitioners.

Conclusions: With adequate US training, the complications from CVC including carotid artery puncture and pneumothorax can be significantly reduced.

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Introduction

Ultrasound (US) technology has many uses in clinical medical practice and with improvement in portability and cost-effectiveness its use has further expanded. In many facilities, the use of sonography when placing central venous catheters has become increasingly popular. However, currently there remains no national standard for US use or a well accepted standard in training for central venous cannulation (CVC).

Catheterization of venous vessels allows access for hemodynamic monitoring, drug and/or fluid administration, parenteral nutrition and hemodialysis. Currently the internal jugular vein (IJV), subclavian vein and femoral vein are the vessels of choice when acquiring central access. Among anesthesiologists, the IJV is a common first choice. Historically, entry into the IJV has been facilitated by the visualization and palpation of certain anatomical landmarks. Additional techniques include the use of a smaller bore "finder needle" to first locate the IJV prior to cannulation with a larger bore needle, an *indirect* US method where the practitioner marks the path of the vein prior to cannulation, as well as a *direct* US technique where the vein is visualized using sonography while cannulating the vessel.

Risk of complication in CVC is reported to be between 2%-15%[1]. This complication rate varies significantly depending on several factors including the relative experience of the practitioner and the overall status of the patient[2,3]. Some of the more frequently encountered complications of CVC and respective incidences include: pneumothorax (0-6.6%), carotid artery puncture (6%), subclavian artery puncture (0.5-4%), and hemothorax (1%)[5-12]. In addition, it has been reported that the overall rate of unsuccessful CVC insertion for the IJV is approximately 12%[4]. Previous studies have shown that the use of an US technique may increase the success rate of central venous catheter placement and may reduce the incidence of traumatic complications[13]. This study reviewed the complication and success rates of CVC placement in patients undergoing cardiovascular surgery with and without US techniques by clinical anesthesiologists and resident trainees in a university hospital setting. A critical number of teaching clinical US experiences can greatly reduce morbidity and perhaps mortality.

Materials and Methods

Following LSU School of Medicine at New Orleans Institutional Review Board approval, evaluation of both outcomes and techniques was performed for CVC with and without US at University Hospital in New Orleans, Louisiana. Three hundred twenty five consecutive central line insertions by 18 different clinical anesthesiologists on elective cardiothoracic surgical patients prior to induction of general anesthesia were evaluated following informed consent during the period of 2006-2008. The results of each CVC placement, the technique employed and the level of experience were all noted in the data collection form. The data collection form additionally included: (1) name of the patient (2) date of birth of the patient, (3) practitioner, (4) date procedure was performed, (5) surgical procedure, (6) location of CVC, (7) whether or not a "finder needle" was utilized in the CVC, (8) if US was used and whether it was a *direct* or *indirect* technique by an experienced or inexperienced clinician, (9) whether or not there was carotid puncture, and/or any other morbidities or mortalities. The US machine, a Sonosite Turbo, and the head anesthesia technician were waiting in the operating room for the anesthesiologist and available at each CVC. There were three stages to the study: (1) the anesthesiologists performed the procedure without US guidance; (2) the anesthesiologists utilized sonography with varied techniques; (3) a formal US course with direct hands on training and subsequent critical clinical experiences were completed. It is important to note that at the inception of the study, no one was considered "experienced" in the use of US. One patient was removed from the study because of a history of bilateral IJV thrombosis. Complete data was available for 324 patients.

As mentioned, all clinical anesthesiologists involved in the present study prior to 2007 utilized techniques for CVC cannulation without US and without attending a course in US. After 2007, all anesthesiologists utilized US. Initially, anesthesiologists utilized sonography without participation in a one day review course on US guided placement. Two different scheduled US course at the institution were

held and each anesthesiologist attended at least one and were then taught by anesthesiologists extensively experienced with US based on a mandate from the LSU Department of Anesthesia quality improvement pilot program on safety in the operating room. For those CVC cannulations without sonography, the anatomic landmark technique was performed following administration of 1% lidocaine as a local anesthetic to the most superior portion of the triangle formed by the clavicular and sternal heads of the sternocleidomastoid muscle. The carotid pulse was then palpated and the internal jugular was presumed to be lateral to carotid palpation. It was then the practitioner's choice to use a 21-gauge "finder needle" connected to a 3-mL syringe to locate the internal jugular vein. If used, the "finder needle" was then advanced through the anesthetized skin at an approximately 60-degree angle toward the right nipple. Following aspiration of venous blood, the "finder needle" was used to guide an 18-gauge needle also connected to a 3-mL syringe. If the smaller bore "finder needle" was not used, the practitioner utilized the 18-gauge needle to first locate and cannulate the vein. Once the 18-gauge needle cannulated the vein, a guidewire was passed and the needle was removed. A dilator was then passed over the guidewire and removed followed by insertion of the triple-lumen catheter over the guidewire into the internal jugular vein.

When the practitioner practiced with sonography, a *direct* or *indirect* method was utilized for CVC placement under sterile conditions by a single operator. In the *indirect* technique, the clinician used anatomic landmarks to predict the plane of the IJV and confirmed the path of the vein with US by marking its site. The vein was then cannulated in the manner described above. If the practitioner chose the *direct* method of sonography, the vein and surrounding vessels/tissues were under real-time visualization throughout the vein puncture and cannulation with both longitudinal and transverse plane techniques. Following proper needle placement, the technique was no different than described above without sonography. Z-testing was then utilized to compare the complication rates between the use of US versus the absence of US during CVC as well as to compare the complication rates between experienced US providers versus inexperienced providers during CVC. Details of patients with unusual complications or co-morbidities were documented during data gathering. Review of the anesthesia record and anesthesia preoperative evaluation was performed and reported in the chart review.

Results

Complete data was available on the placement of 324 total CVCs (Fig. 1). One patient was excluded because of history of bilateral IJV thrombosis. There was no significant difference in age or gender of the subjects (data not shown). One hundred and one cannulations were done without US, and 223 were done with US. Of the 101 done without US, 92 were without complication, 8 had carotid puncture and 1 resulted in pneumothorax. Of the 223 done with US, 216 were without complication, 6 had carotid puncture and 1 resulted in pneumothorax (Fig. 2). Practitioners with and without experience had a different rate of complications. The experienced US practitioners performed 114 without complications and 1 had carotid puncture. The non-experienced US practitioners performed 102 without complications, 5 had carotid puncture and 1 resulted in pneumothorax (Fig. 3). When comparing the group that had CVC without US versus the group having CVC placement with US, there was significant difference in complication rates based on Z-testing (95% confidence level). Furthermore, with 90% confidence (based on Z-testing) there was a significant difference in complication rates between the experienced and non experienced US practitioners (Fig. 4).

Fig. 1
Different techniques for central venous catheter cannulation were utilized and outcomes were evaluated.

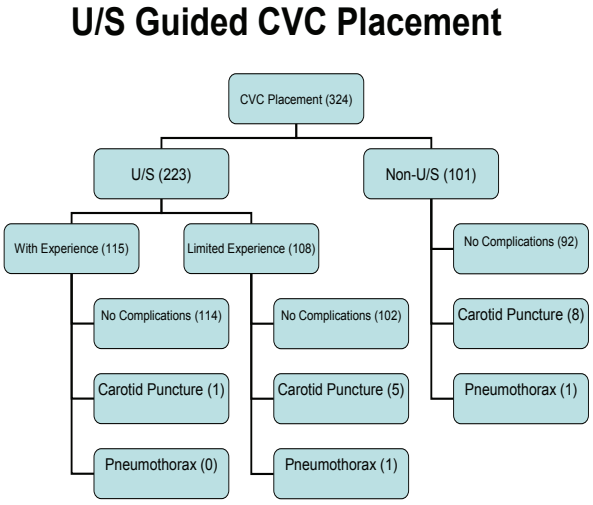


Fig. 2
Complication rates with US vs. blind technique (non-US). Practitioners utilizing ultrasound had reduced complications rates.

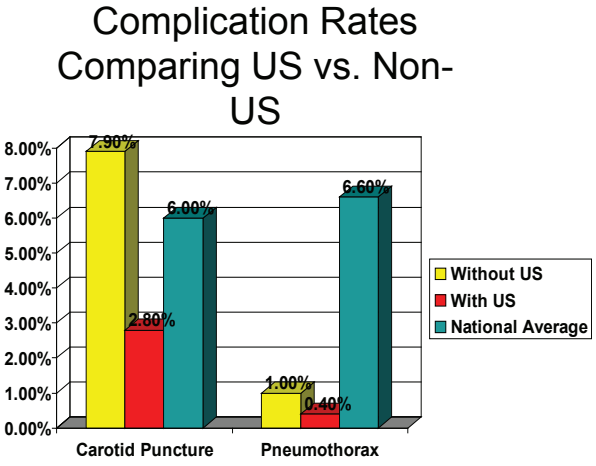


Fig. 3
Complication rates with experienced US practitioners versus non-experienced US practitioners. National average represents blind technique. Experienced US practitioners had significantly reduced complication rates.

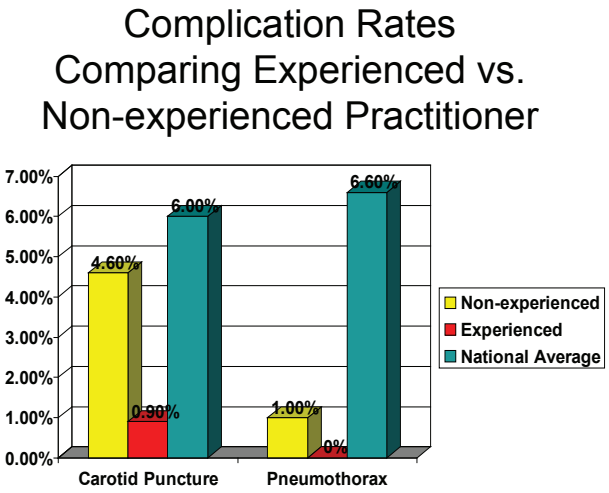
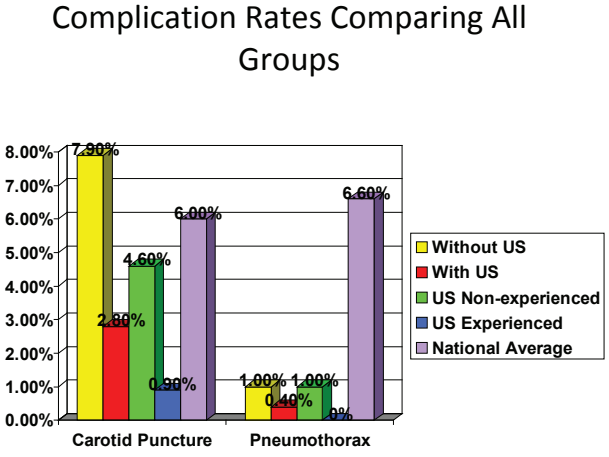


Fig. 4
Complication rates comparing all groups. US experienced practitioners had the lowest complications rates.



Discussion

Although the present investigation was limited to patients undergoing elective cardiothoracic surgery, the data clearly indicates that those anesthesia providers with educational training, in conjunction with critical US teaching experiences, greatly improved outcomes and reduced the incidence of complications. The results of the present study demonstrated a 1% carotid puncture rate, significantly lower than data previously published on blind insertion without US. Further, the present study also demonstrates that utilizing US without a critical number of placements either through simulation or teaching, though slightly better than blind insertion, still resulted in significantly higher complication rate when compared with experienced US practitioner results.

Patients having CVC placement without US had the highest complication rate and was concordant with most literature that ranges from 7-10%[1]. Patients who were marked prior to cannulation using US had a lower incidence of morbidity when compared with blind techniques. However, practitioners experienced in US and using the contiguous *direct* method experienced the least morbidity compared to all other techniques (approximately 1%). As the clinician's level of experience has been previously found to correlate with complication rates for central line placement[2, 20, 21], it is not be surprising to find the highest level of success with the greatest level of education and training. An optimal number of cases is uncertain and future studies are warranted to more precisely define a critical case experience.

Utilizing US imaging to facilitate IJV cannulation cannot, by itself, eliminate all possibility of needle injury to the common carotid artery (CCA) or guarantee successful IJV cannulation. However, the results of this study clearly demonstrate a correlation between critical experience with US and outcomes. The following technical and conceptual pitfalls of US-guided vascular cannulation must also be avoided: 1) mistaking the CCA for the IJV and so targeting the wrong blood vessel, 2) failing to properly aim the needle along a well chosen line of needle advancement, 3) falsely assuming that the anatomic relationship between the IJV and CCA at the level of venipuncture is identical to that at the axial level of (transverse) US imaging[21], 4) confusing the needle shaft for its tip on the US screen[22] and 5) paying insufficient attention to the US device screen (relative to the puncture site) during needle advancement. Present and future residents in both surgery and anesthesiology would be well advised to consider simulation training and a certain well-defined number of critical experiences to be an expectation for clinical competency in CVC.

The management of patients requiring cardiac surgery necessitates central venous access for several reasons including hemodynamic monitoring, drug administration and possible rapid fluid resuscitation. Since all patients undergoing cardiac surgery in our facility have CVCs, we designed our study to look at this subset of patients. We are confident that had we utilized any other subset of patients for this study that the results would have been concordant with those in this study.

US guidance for the cannulation of central venous access had been recommended as early as 1984 to reduce complication rates as well as increase success rates[14]. While US guidance has been shown to be cost-effective as well as critical in reducing complication rates, number of sticks and procedure time, it is still not utilized at least two thirds of the time, according to a nation-wide survey of cardiovascular anesthesiologists[13,14,17,18]. In addition, although it is not the standard of care, the use of US to guide CVC is strongly recommended by many organizations including the National Institute for Clinical Excellence in the United Kingdom[16-18].

Simulation models for CVC are now available for training purposes. In the future, LSU Anesthesia Department in New Orleans will be evaluating outcomes after a course, simulation and a critical number of clinical experiences with US. The results of the present study provides evidence that outcomes can be improved with appropriate levels of training However, although the use of US appears to reduce morbidity compared to blind techniques, the risk of significant morbidity persists despite the presence of US.

In conclusion, US-assisted CVC is an easily learned and readily available technique that can be used in the pre-operative setting and throughout hospital practice. This study demonstrates that quality of care can be improved by sonography and that complication rates can be decreased with appropriate US training. The authors of the present study suggest that an American Society of Anesthesiology Task Force develop a standard for training future generations of anesthesiologists.

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