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A comparison of a homemade central line simulator to commercial models

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ABSTRACT

Background: Simulation is quickly becoming vital to resident education, but commercially available central line models are costly and little information exists to evaluate their realism. This study compared an inexpensive homemade simulator to three commercially available simulators and rated model characteristics.

Materials and methods: Seventeen physicians, all having placed >50 lines in their lifetime, completed blinded central line insertions on three commercial and one homemade model (made of silicone, tubing, and a pressurized pump system). Participants rated each model on the realism of its ultrasound image, cannulation feel, manometry, and overall. They then ranked the models based on the same variables. Rankings were assessed with Friedman's and post hoc Conover's tests, using alphas 0.05 and 0.008 (Bonferroni corrected), respectively.

Results: The models significantly differed ($P < 0.0004$) in rankings across all dimensions. The homemade model was ranked best on ultrasound image, manometry measurement, cannulation feel, and overall quality by 71%, 67%, 53%, and 77% of raters, respectively. It was found to be statistically superior to the second rated model in all ($P < 0.003$) except cannulation feel ($P = 0.134$). Ultrasound image and manometry measurement received the lowest ratings across all models, indicating less realistic simulation. The cost of the homemade model was $400 compared to $1000-$8000 for commercial models.

Conclusions: Our data suggest that an inexpensive, homemade central line model is as good or better than commercially available models. Areas for potential improvement within models include the ultrasound image and ability to appropriately measure manometry of accessed vessels.

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Introduction

Simulation is quickly becoming a vital tool for resident education. Simulation-based education has been used in multiple areas of medical education to develop resident's technical skills and teach them safe practices.[1] Central line simulation is one of the most frequently simulated procedural techniques in resident education.

Insertion and use of Central Venous Access Devices (CVAD) constitute a routine component of daily medical practice across specialties, especially in the intensive care unit and the operative suite. Improper placement of CVAD has been associated with significant morbidity that can be prevented with appropriate training.[2] Unfortunately, CVAD complications are not rare events, with reported rates ranging from as low as 4% to as high as 45%.[3-5] Common adverse events related to placement of CVAD include infection, arrhythmia, arterial puncture and cannulation, pneumothorax, and hematoma. Major AEs include air embolism, superior vena cava perforation, aortic perforation, and cardiac tamponade.[5] Of all the risk factors for central line complications, the strongest predictor is the number of unsuccessful insertion attempts, a figure that correlates directly with procedural experience of the operator.[6,7] Inexperience requiring multiple insertion attempts has also been shown to increase the rate of central line–associated bloodstream infection (CLABSI), a complication that is associated with significant health care costs.[8,9]

The impact of these complications is significant, and efforts to minimize and prevent their occurrence should be standard practice at teaching hospitals. Simulation allows for proper CVAD insertion training without putting patients at risk of harm. Multiple studies have demonstrated that simulation-based education for CVAD insertion decreases CLABSI rates.[10] In addition to reducing CLABSI rates, simulation is associated with improved patient outcomes, including fewer insertion attempts and reduced pneumothorax rates.[11] Another study demonstrated that the use of manometry to measure intravascular pressure before vessel dilation essentially eliminates arterial injury due to arterial cannulation, a complication that occurs in 0.1%-0.5% of CVAD insertions.[12]

Unfortunately, commercially available CVAD simulation models are costly (prices ranging from $1000-$8000[13-15]) and are often limited in their functionality and the variable anatomy frequently encountered in clinical practice.[16] In addition, little information exists to evaluate how well each model mimics human anatomy and physiology (i.e., venous *versus* arterial pressures of model vessels), information that is necessary to perform key portions and safety checkpoints of procedures in clinical practice. As simulation continues to gain importance in resident training, simulation centers at many institutions have started creating homemade models to allow for cost reduction while providing comparable quality to commercially available simulators.[16-19] In addition, homemade models can be easily modified to provide the learner with challenging anatomy reflective of real-life practice. This study compared an inexpensive homemade internal jugular central line insertion simulator, developed to meet the needs of an institution-wide central line insertion training initiative,[20] to three high-end commercially available simulators; various model characteristics were also rated.

Materials and methods

Institutional review board approval was obtained prior to initiation of the study. Upper level residents, fellows, and attending physicians from the Departments of Surgery, Anesthesia, and Internal Medicine at the University of North Carolina were recruited via email and word of mouth to participate in this study on a voluntary basis.

Four internal jugular central line simulator models (three commercial models [CMA, CMB, and CMC] and a homemade model [HM] constructed at our onsite simulation center, see Fig. 1) were set up as per manufacturer recommendations and confirmed to be functioning appropriately at the beginning of the study. Models were draped in a fashion such that only the area of the model to be used for ultrasound and access were visible, blinding the participants from recognizable branding or identifiable markings on models. Central line kits were provided at each of the four central line stations; these were reset after each insertion, and broken or altered components were replaced to ensure similar experiences for all participants. Coinvestigators were available to answer questions or troubleshoot model dysfunction for all participants.

Participants, deemed expert based on experience of having placed >50 lines in their lifetime, were asked to perform ultrasound-guided central line insertions on each of the four central line training models in random order and subsequently rate each model's realism. A 10-point Likert scale was used, rating the following characteristics: ultrasound image, vessel appearance, tissue feel, ability to measure manometry, resistance when placing line, and overall impression (see Appendix A). After completion of all four insertions, participants then ranked the models against each other from best to worst based on the following characteristics: ultrasound image, manometry measurement, cannulation feel, and overall impression (see Appendix B). Surveys were collected in an opaque envelope to protect participant privacy.

Statistical analyses

Our primary analysis is a comparison of the rankings of the models. To assess the rankings, we used Friedman's test followed by Bonferroni corrected (alpha = 0.008) post hoc Conover's tests[21] of the models in sequence of mean rank. A prestudy power calculation determined we would need 17 participants to achieve 80% power while holding the family-wise type I error rate to 5%. We also gathered ordinal ratings on corresponding variables for exploratory purposes. We examined the pattern of correlations among the variables and fit a mixed effects ordinal logistic regression model predicting the overall rating from the component ratings to identify which aspects seemed to be most relevant to the models' quality. The analyses were conducted using R 3.3.0 and the ordinal and PMCMR packages.[22-24] Q3