Expert Evaluation of a Chicken Tissue-based Model for Teaching Ultrasound-guided Central Venous Catheter Insertion

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Original Article

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Abstract

Background: Ultrasound-guided central venous catheterization (CVC) is a commonly performed procedure which carries significant risks for complications. Current models used for simulation-based teaching are expensive and may not replicate tissue feel and ultrasound qualities of human tissues. We aimed to evaluate a tissue model composed of chicken breast and balloons and compare it to a commercially available mannequin.

Methods: Forty attending physicians from four departments with extensive CVC experience were enrolled. Participants completed an ultrasound-guided central line placement utilizing both models during a hands-on workshop. Following CVC placement on each model, participants completed a survey to assess their experience with that particular model.

Results: 40 attending physicians (12 (30%) anesthesia, 11 (28%) emergency medicine, 11 (28%) internal medicine, and 6 (15%) surgery) participated in the study. The chicken model was rated significantly higher than the mannequin model with regard to ultrasound quality (p=0.02) and tissue feel (p=0.002). In a direct comparison, participants rated the chicken model more highly than the mannequin in all categories except similarity to the human anatomy. Overall the chicken model was preferred to the mannequin, (mean score 44.5; standard deviation 26.0). The mannequin was rated higher with regard to similarity to human anatomy (mean score 52.8; standard deviation 25.7). The comparison between key features (ultrasound characteristics, similarity to human anatomy and teaching trainees) of the models did not vary significantly by area of practice, with the exception of ease of use (p=0.045).

Conclusions: In this prospective study of experienced clinicians we found that a novel tissue model for ultrasound-guided CVC placement was rated more highly compared to a commercially available mannequin task trainer.

Key words: central venous catheter, education, simulation training, ultrasonography

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Introduction

Central venous catheter (CVC) insertion is a common procedure in the hospital setting, performed by physicians and trainees in many specialties. The procedure carries substantial risks, with major implications for patient outcomes and healthcare costs[1]. Mechanical complications include pneumothorax, arterial cannulation, thrombosis, and bleeding. In addition, CVC associated blood stream infections cause significant morbidity and mortality despite major improvements in sterile technique and infection control practices[1–3]. Real-time ultrasound guidance for catheter placement has become standard of care, as this approach decreases complications and time to cannulation[1,4–6].

Given the potential risks associated with CVC placement, simulation is an appealing modality to ensure competency prior to exposure to live patients. Research using simulation-based education for CVC placement has demonstrated increased operator comfort as well improved performance in both simulated and patient care environments[7–11]. Current methods rely heavily on commercially available mannequins, or task trainers, which mimic human anatomy. These mannequins offer trainees the opportunity for repeated deliberate practice with expert feedback without placing patients at risk. However, these mannequins have several notable limitations. The cost of these trainers is often prohibitively high, with each device costing more than $1,500[12,13]. In addition, these require maintenance and regular replacement to continue functioning properly. Finally, some practitioners feel that these mannequins have unrealistic haptics and ultrasound qualities compared to human tissues[14]. In this setting, novel and cost-effective models are required to provide high level simulation based-training to trainees and clinicians learning ultrasound-guided CVC placement.

The goal of this study was to evaluate a tissue model constructed of chicken breast and balloons as a teaching tool for ultrasound-guided CVC insertion. We hypothesized that experienced physicians would consider the chicken model to be a superior teaching tool, preferring the more realistic ultrasound images and tissue feel as compared to a commercially available mannequin.

Methods

Study Design

We conducted a prospective observational study of faculty members at an urban, tertiary care center in Boston, Massachusetts. A convenience sample of forty attending physicians from four departments (anesthesia, emergency medicine, internal medicine, and surgery) with extensive experience placing and supervising CVCs was enrolled. Participants were asked to attend a single hands-on session and fill out a series of surveys designed to assess and evaluate the use of different models as a tool for CVC insertion. The study design is summarized in Figure 1. After verbal consent was obtained, participants were randomized to insert a CVC on a chicken model first or a commercially available mannequin (Simulab) model first. Following randomization, the two groups completed a baseline survey to obtain demographic information and details of their experience placing and teaching CVCs. Participants then completed a simulated central line placement utilizing both models in the order dictated by randomization. Subjects were provided with a standard CVC insertion kit and an ultrasound machine with high frequency linear probe and instructed to place the CVC as they normally would, beginning with ultrasound identification of vessels and ending with insertion of the catheter. Subjects were not asked to perform sterile preparation or suture the line in place. Following CVC placement on each model, participants completed a survey to assess their experience with that particular model. The survey included questions about the similarity of the model to human tissue, ultrasound characteristics (image quality and acquisition), as well as a general evaluation of the quality of the model as a teaching tool. A final comparison survey was administered at the conclusion of the study. Surveys were confidentially administered using REDCap, a secure web-based application for data collection. The Institutional Review Board at Beth Israel Deaconess Medical Center declared this study exempt from review, with a waiver of written informed consent.

CVC Lab Sessions

The tissue model was created by wrapping a raw chicken breast around two cylindrical balloons filled with colored water (blue for venous, red for arterial) (Figure 2). The model was then wrapped in plastic wrap and placed on a covered bedside table. Ultrasound probe covers were used to prevent contamination of the machines, and cleaned with sterilizing wipes after each use. Subjects were provided with alcohol-based hand cleanser and advised to wash their hands after the session. A new chicken breast was used for each lab session. Subjects were provided with tablet computers to complete the study surveys immediately after each portion of the lab.

Statistical Analysis

All analyses were performed using SAS 9.3 (SAS Institute, Cary, NC). Categorical variables are presented as frequencies or proportions and were compared using the Chi-square test. Experienced physicians were first asked to rate the mannequin and chicken models individually with regard to ultrasound imaging, tissue quality and overall effectiveness as a teaching tool. Physicians were asked to rate on a scale of 0 to 100 how well each individual model rated in each of the respective categories. Responses were anchored by indicating that values of 0 were not at all, 50 indicating somewhat, and 100 indicating extremely realistic. These continuous variables are presented using mean (± standard deviation) or median (interquartile range) values depending on the distribution of the data, as evaluated by the Shapiro-Wilk test for normality. Differences in provider perception between model ratings were assessed using a paired t test.
Physicians were also asked to indicate in a direct comparison, on a scale from 0 to 100, their preference between the two types of models, with values of 0 indicating the chicken model performed better and 100 indicating the mannequin model performed better. Differences in model preference by provider area of practice were assessed using the Wilcoxon Rank-Sum test. All tests were two sided and p-values <0.05 were considered statistically significant given the feasibility nature of this study.

Results

Physicians were randomized to one of two groups – those who complete the chicken model first and those who complete the mannequin model first – so that provider perception would not be biased by the order in which they completed the assessment. While our sample size was small, no significant association was found between the order in which they completed the models and their overall comparison between which model was better (p=0.88).

Baseline Characteristics

Clinician demographic characteristics are presented in table 1. A total of 40 attending level physicians participated, with 12 (30%) indicating anesthesia, 11 (28%) emergency medicine, 11 (28%) internal medicine, and 6 (15%) surgery as their primary area of practice. The median age of participants was 41 years (IQR: 37-46). Physicians were predominantly trained on live patients (97.5%), however one provider indicated they had been trained using a mannequin. The median number of years spent supervising CVC placements was 9.0 (IQR: 5.5-14.0).

Model Evaluations

On average, when referring to how realistic the model was, physicians' ratings of the chicken model were higher than the mannequin model in all categories (Table 2). Physicians indicated the chicken model produced significantly more realistic ultrasound images (mean rating 67.4) as compared to the mannequin model (mean rating 55.8; p=0.02). Similarly, clinicians rated the chicken model as having a more realistic tissue feel, with an average rating of 57.5, as compared to its mannequin counterpart which received an average rating of 41.3 (p=0.002). The least realistic component of the mannequin model identified was the quality of the tissue, with a mean rating of 41.3 (± 22.3 standard deviation). Despite these differences, when asked how realistic the model was overall, no significant difference (p=0.25) was found between the mannequin and chicken model scores. For both models, clinicians suggested training on the model three times prior to practicing on live patients.

Direct Comparisons of CVC Models

When asked to compare the mannequin model to the chicken model directly, participants favored the chicken model in all categories except similarity to the human anatomy (Table 3). On average, clinicians reported a mean score of 52.8 (standard deviation 25.7), indicating that the mannequin model was rated better than the chicken with respect to anatomy. The chicken model was rated as substantially better than the mannequin when assessed for ultrasound characteristics, with a mean rating of 37.3. Physicians indicated that overall they preferred the chicken model to the mannequin, with mean scores of 44.5 (standard deviation 26.0). The comparison between key features (ultrasound characteristics, similarity to human anatomy and teaching trainees) of the models did not vary significantly by area of practice, with the exception of ease of use (p=0.045).

Discussion

In this prospective study of experienced clinicians we found that a novel tissue model for ultrasound guided central venous catheter placement was rated more highly compared to a commercially available mannequin task trainer. Specifically, subjects scored the tissue model as more realistic with regard to ultrasound image quality and tissue feel. Furthermore, in a direct comparison, subjects preferred the tissue model over the task trainer with regard to ultrasound characteristics, use as a teaching tool, ease of use, and overall.

We satisfied our hypothesis that this easily assembled tissue model is preferred as a model for venous catheter placement compared to a commercially available trainer. We believe this is due to the qualities of the model which allow clear ultrasound visualization and more complete performance of the procedure compared to commercially available models. It is notable that our study population included faculty from a variety of specialties with variable practice patterns for teaching and placement of CVCs.

Our findings are consistent with the limited literature suggesting that animal tissue models are cost effective realistic trainers for ultrasound guided procedures[15–18]. Rosen and Ault have described a model using an entire chicken with tunneled simulated vessels and demonstrated high levels of acceptability and improved learner performance with standardized training. As described, the cost of commercially available task trainers are often prohibitive for training programs, and the quality of the tissues and ultrasound images are variable[14]. While this was a not a cost analysis study, it is notable that our model costs less than $5, and the tissue can be reused for multiple learners in a lab session while only replacing the balloon. To our knowledge, this is the first study to validate a chicken tissue model for CVC teaching using expert clinicians from various specialties.

Participants did rate the tissue model lower than the commercially available mannequin with respect to similarity to human anatomy. This finding may have implications related to transfer of skills to patient care, and further studies should address this issue. In addition, while most of the findings related to comparison of the models by different subspecialists did not reach significance, there are notable trends. In particular, internal medicine physicians appear to rate the mannequin higher than the tissue model in several key domains compared to surgeons, anesthesiologists, and emergency medicine providers. Future research should examine variable training approaches among different fields.

This study has several limitations. The sample size is relatively small and all faculty members were from the same institution, which may limit the generalizability of these results. Our institution relies heavily on ultrasound use, which may influence the assessment of the two models. In addition, this feasibility study relies on expert assessment of the teaching tool, but does not examine whether this tool will improve learner acquisition of these procedural skills. Of note, there were several aspects of the chicken model that were identified during this feasibility study which have now been improved. Specifically, several providers indicated that a different type of balloon might provide room with which to insert the wire completely. This may have contributed to a providers' perception of the tissue model. We believe the impact of these specific issues was mitigated by asking targeted questions about specific aspects of each model. In addition, providers indicated an overall preference using the chicken model suggesting that minor improvements in the model were overlooked by clinicians and used as a basis on which to build future improvements.

In conclusion, experts found a tissue model composed of chicken breast and balloons to be significantly more realistic than a commercially available task trainer in several key domains. The commercially available mannequin was rated higher with regard to similarity to human anatomy. While simulation-based mastery learning has been shown to improve patient outcomes related to CVC placement, the impact of the model used has not been examined in detail. Further studies will examine the use of this model on trainee skill acquisition and competence as well as patient outcomes.

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Table 1:

Table 1. *Baseline Frequency Statistics*

Age (years)	41 (37-46)
Primary Area of Practice	
Anesthesiology	12 (30.00)
Emergency Medicine	11 (27.50)
Internal Medicine	11 (27.50)
Surgery	6 (15.00)
Attending's Training Background	
Live Patients	39 (97.5)
Mannequin	1 (2.5)
Years Supervising CVL Placements	9.0 (5.5-14.0)
Number of CVL Placements Supervised During a Month of Clinical Service	5 (4-10)
Number of CVL Placements Done Personally During a Month of Clinical Service	1 (1-2)

Numbers are presented as median (IQR) or number (%) depending on the variable type.

Table 2:

Table 2. *Model Evaluations*

	Mannequin Model	Chicken Model	P-Value
How Realistic the Model Is			
US image acquisition of vascular structures and needle	55.88 ± 23.82	64.16 ± 23.84	0.10
US image quality of vascular structures and needle	55.78 ± 22.76	67.40 ±20.77	0.02
Tissue quality ("the feel" of advancing needle)	41.33 ± 22.28	57.53 ± 21.98	0.002
Teaching trainees to prevent arterial cannulation from CVL placement	55.38 ± 20.95	61.47 ± 24.85	0.26
Teaching trainees the skills of CVL insertion	58.73 ± 18.99	62.82 ± 20.68	0.58
How Realistic the Model Is Overall	53.61 ± 23.72	60.84 ± 24.57	0.25
Times Suggested to Use the Model Before Practicing on Patients	3.0 (2.0-5.0)	3.0 (2.0-4.5)	0.55

CVL: Central venous line; US: Ultrasound.
Responses are anchored as such: 0 indicates not at all realistic, 50 indicates somewhat realistic, 100 indicates extremely realistic
Numbers are presented as mean ± standard deviation or median (IQR).

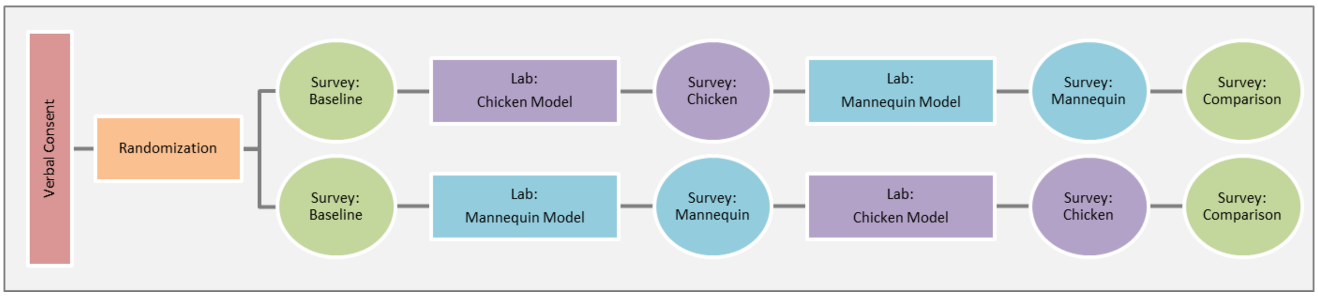
Table 3:

Table 3. *Direct Comparison of Models*

	Entire Cohort (N=40)	*Primary Area of Practice* Anesthesia (N=12)	Emergency Medicine (N=11)	Internal Medicine (N=11)	Surgery (N=6)	P-Value
Comparison Between Models						
Ultrasound characteristics	37.29 ± 24.82	32.00 ± 20.23	40.36 ± 26.37	49.09 ± 25.89	33.33 ± 14.67	0.51
Similarity to human anatomy	52.76 ± 25.65	46.92 ± 27.23	51.45 ± 23.34	57.09 ± 27.78	57.50 ± 18.03	0.77
Teaching trainees to prevent arterial cannulation	44.93 ± 24.53	52.75 ± 22.00	39.45 ± 23.27	48.45 ± 21.49	41.33 ± 14.64	0.81
Teaching trainees the skills of CVL insertion	47.75 ± 24.81	50.33 ± 24.98	42.27 ± 23.89	55.55 ± 20.52	41.33 ± 14.28	0.59
Ease of Use	44.15 ± 24.10	46.33 ± 23.70	40.73 ± 26.45	56.09 ± 15.60	30.00 ± 12.76	0.045
Overall Model Assessment	44.50 ± 25.98	48.58 ± 26.97	40.73 ± 27.33	55.00 ± 19.94	27.67 ± 14.33	0.15

Responses are anchored as such: 0 indicates the chicken is better, 50 indicates that the models are equivalent, 100 indicates the mannequin model is better. Numbers are presented as mean ± standard deviation.

Figure 1: Study Flow. Participants were asked to verbally consent prior to being randomized to one of two groups: those who worked with the chicken model first and those who worked with the mannequin model first. Subjects were then asked to complete a series of surveys and CVL labs as described.



<u>Figure 2:</u> Images of the tissue model. A) The chicken model is created by placing red and blue food coloring in cylindrical balloons. The two balloons are placed longitudinally between two chicken breasts. B) The model is wrapped with plastic wrap. C) Ultrasound probe in a transverse position while needle is aspirating simulated venous blood. D) Transverse view of simulated vessels using color doppler while squeezing one of the balloons to simulate arterial flow. E) Transverse view of vessels with needle tip entering the lumen. F) Confirmation of guidewire position using a longitudinal view of the vessel.