

Homemade phantoms improve ultrasound-guided vein cannulation confidence and procedural performance on patients

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ABSTRACT

BACKGROUND: Ultrasound-guided vein cannulation is an essential skill in emergency medicine. Prohibitive costs of commercial ultrasound phantoms limit the ability to adequately train residents. We assess the clinical utility of homemade phantoms for medical education.

METHODS: Eighteen emergency medicine residents each performed 10 ultrasound-guided IV attempts on patients, half of the attempts before and half after a training course using two homemade ultrasound phantoms with 14 total Penrose drains. We conducted a prospective feasibility study using pre- and post-training surveys comparing confidence and success rates of IV cannulation attempts on patients.

RESULTS: Residents demonstrated an improvement in successful ultrasound-guided peripheral vein cannulations from an average of 47.8% during the first five attempts to 71.1% in the last five attempts. No benefit was noted from the first to the fifth attempts, nor from the six to the tenth attempts, suggesting minimal benefit from experience early on. Residents reported increased confidence in performing ultrasound-guided venous cannulation on patients, identifying the correct probe, adjusting gain and depth, visualizing veins in short and long axis, differentiating arteries from veins, and vein cannulation on a phantom model.

CONCLUSION: Homemade ultrasound phantoms are cost effective, increase confidence, and improve emergency medicine residents' ability to perform ultrasound-guided vein cannulation.

Keywords: Emergency; phantom; training; ultrasound; vein.

INTRODUCTION

The use of ultrasound for both peripheral and central venous cannulation has become an essential skill in emergency medicine training curricula. Many randomized trials^[1-14] and meta-analyses^[15,16] have documented improved first insertion attempts, overall success rates, and lower rates of complications including pneumothorax and arterial puncture for internal jugular vein cannulation when using dynamic ultrasound

guidance. In 2001, the Agency for Healthcare Research and Quality cited the use of ultrasound guidance for the placement of central venous catheters as one of the top 11 evidence-based practices to improve patient care and safety.^[17] The National Institute for Clinical Excellence made a similar recommendation in 2002.^[18] These recommendations have been echoed by many professional medical organizations including the American College of Emergency Physicians, the Canadian Association of Emergency Physicians, American

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Society of Anesthesiologists, and the American College of Surgeons.^[9–24]

Simulation has become an important mechanism for training resident physicians to establish procedural competence and confidence. Prohibitive costs of commercial brand name ultrasound phantoms which range from \$449 to over \$5000 for venous access phantoms limit the ability of many residency programs and hospital systems to adequately train residents with simulation.

While many have described the creation and use of different phantoms using gelatin and psyllium,^[25] tofu,^[26] gel wax,^[27] and ballistics gel,^[25] we were not able to identify any study to date demonstrating improved procedural performance on patients in the clinical setting from such low-cost models. The objective of this study was to assess if training with homemade ultrasound phantoms led to any subjective (increased confidence) or objective (higher success rates with vein cannulation) benefit for emergency medicine residents when tested in a clinical setting.

MATERIALS AND METHODS

Study Design and Setting

This was a before-after survey study of emergency medicine residents at a large university-affiliated hospital, with an active emergency medicine residency, that sees over 100,000 patients per year. Residents who spanned postgraduate years 1–2 had no prior formal ultrasound training. Two homemade phantoms with 14 total Penrose drains simulating peripheral veins were created (see appendix Figs. 1 and 2 for information on phantom creation) as described by Kendall and Faragher.^[25]

These ultrasound phantoms were used by 18 emergency medicine residents. Confidence before and after a training course with a homemade ultrasound phantom were measured using a 5-point Likert scale (1 = not at all confident and 5 = extremely confident). Questions assessed comfort level with choosing the correct probe for vein identification, adjusting gain and depth on the ultrasound machine, visualizing vein in short and long axis, differentiating artery from vein, and performing vein cannulation on an ultrasound phantom and a real patient, and if they would like to have another training session using a homemade ultrasound phantom. An

open-ended question allowed for free-text comments. Surveys were completed by residents just before the training course then immediately after completion of the course.

For the measurement of clinical performance, residents working in the emergency department self-recorded success and failure rates immediately after each attempted placement of 10 ultrasound-guided IVs on different patients they were caring for. Half of these attempts were before and the other half were after the training session.

The training course was taught by an emergency physician based in the U.S. (who is not fellowship trained) with translation and further teaching by a Turkish emergency medicine senior resident. There was no advanced reading or preparatory work for participants. The lecture was approximately 15 min long, provided an overview of the use of ultrasound, including demonstration of proper technique and image review of good and poor techniques. Real-time feedback was provided by two faculty members while residents practiced

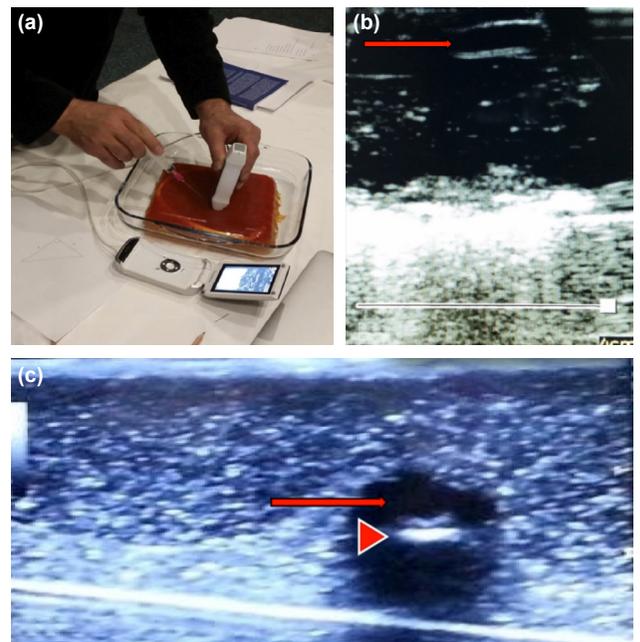


Figure 2. View of the homemade ultrasound phantom. (a) Practicing of an emergency resident. (b) Long-axis ultrasound view of the vein (red arrow). (c) Short-axis ultrasound view of the vein (red arrow) and needle point (red arrowhead).



Figure 1. Preparation of a homemade ultrasound phantom. (a) Materials (tray, gelatin, psyllium, and Penrose drains) needed for the preparation of the ultrasound phantom. (b) Penrose drains are containing tap water (simulating peripheral veins) and gelatin-psyllium mixture to prolong its shelf life. (c) Penrose drains were covered on the top and bottom layers of the by gelatin-psyllium mixture.

on the ultrasound phantoms for the remainder of the 1 h course with self-directed attempts. Successful IV placement was defined by aspirating fluid from the 1/4" Penrose drains mimicking veins then confirmation of proper catheter insertion based on a long-axis ultrasound view.

Approval was obtained from the ethics department of the home institution and patient consent was obtained before placement of each peripheral IV which was only placed in the normal care of patients who required hydration or administration of IV medications.

Statistical Analysis

The normality of distribution of continuous variables was tested by Shapiro–Wilk test. Wilcoxon rank-sum test was used for comparison of two dependent variables. Descriptive statistic parameters were presented as frequency, percentage (%), and mean±standard deviation (mean±SD). Statistical analysis was performed with SPSS for Windows version 22.0 and p<0.05 was accepted as statistically significant.

RESULTS

Procedural Competence

Self-reporting among all 18 residents demonstrated an improvement in successful ultrasound-guided peripheral vein cannulations. The first five attempts occurred before any ultrasound training and residents demonstrated an average success rate of 47.8%. After undergoing the simulation training using the homemade phantoms, successful venous cannulation increased to an average of 71.1% over the next five attempts (p=0.006) (Fig. 3). No benefit was noted from the first to the fifth attempts or from the six to the tenth attempts, suggesting minimal benefit from experience early on.

Resident Attitudes

Using 5-point Likert scale surveys, residents reported increased confidence in: Performing ultrasound-guided venous cannulation on patients (pre: 3.05, post: 3.83, p=0.023), identifying the correct probe (pre: 4.5, post: 4.94, p=0.034), adjusting gain and depth (pre: 3.3, post: 4.8, p=0.001), visualizing veins in short axis (pre: 3.7, post: 4.9, p=0.007) and long axis (pre: 3.1, post: 4.5; p=0.009), differentiating arteries versus veins (pre: 4.4, post: 4.9, p=0.020), and vein cannulation on a phantom model (pre: 3.7, post: 4.4, p=0.15) (Fig. 4). Residents generally wanted to practice more than the hour provided. Free-text comments were positive, with almost all residents leaving comments requesting more time to practice.

DISCUSSION

The standard of care for the placement of central lines has transitioned to include the use of dynamic ultrasound guidance. Many patients with difficult venous access required ultrasound-guided IV placement. This procedure requires

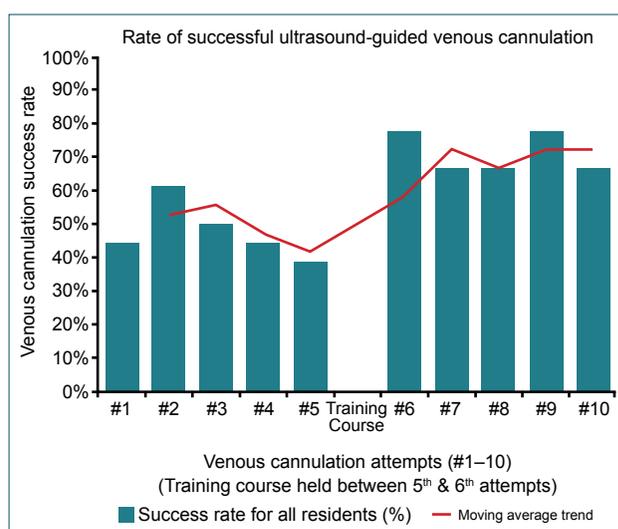


Figure 3. Rate of successful ultrasound-guided venous cannulation.

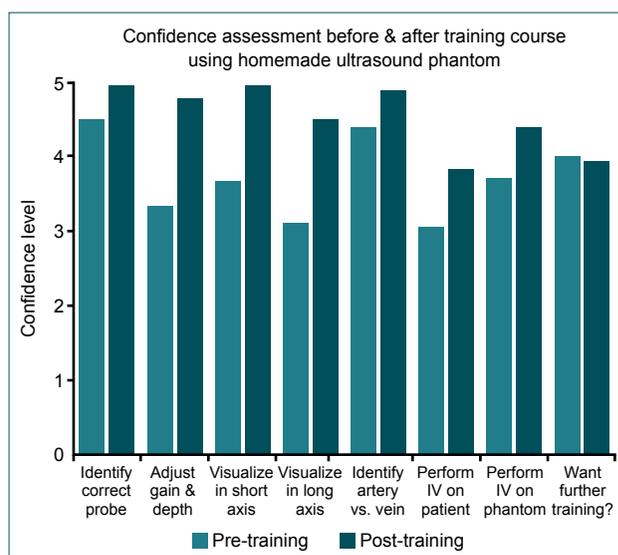


Figure 4. Confidence assessment before and after training course using homemade.

medical residents to be properly trained; however, training mannequins are often cost prohibitive for even well-funded departments, let alone resource-limited environments. Different models of low-cost, often homemade, ultrasound phantoms have been described.

Training with this rudimentary ultrasound phantom led to improved confidence and understanding of various steps in placing a peripheral IV under dynamic ultrasound guidance, as well as an improvement in the success rate in the placement of those IVs on the emergency department patients they care for.

While many studies have described how to create low-cost, homemade, ultrasound phantoms,^[28,29] we could not find any studies assessing if the skills acquired from these low-cost phantoms actually translate into improved procedural competence on patients in the clinical setting.

Our model is very basic and inexpensive, costing only \$1.11 per resident. While many potential enhancements to our model exist, such as the use of a hydrocolloid skin dressing to cover the gelatin-psyllium mixture to prolong its shelf life^[30] to the use of candle wax and ballistics gel, we believe the ability to demonstrate benefit from such a rudimentary model bodes well for the clinical utility from similar models and perhaps other more expensive models that have not been studied to assess improvement in clinical outcomes when used in medical education.

Conclusion

Homemade ultrasound phantoms are cost-effective alternatives to commercial products which are cost prohibitive for many hospitals. Training with these homemade phantoms led to an increase in confidence and procedural competence as well as improved ultrasound-guided peripheral vein cannulation on patients among emergency medicine residents. Ideal training sessions likely should last longer than 1 h.

Limitations

Language barrier may have limited feedback as residents answered the questionnaire by their own volition in English which was not the native language of any of the residents (although translators assisted those with questions). Successful IV cannulation attempts were all self-reported with the gold standard being IVs easily flushed and we did not evaluate for continued function after a set period of time or after pressure injection of contrast. The residents generally tried once and sometimes twice to obtain IV access although we did not a priori limit their number of attempts or pre-specify if an initial unsuccessful attempt would automatically be counted as a failed attempt. This was a single-center study with 18 residents which may limit external validity. A large multicentered study to validate our findings is the next logical step. It is difficult to discern if the benefit from the 1 h training course was from the didactic module or the hands-on portion that involved the homemade phantom. It is unclear if knowledge and skills retention at 6 months persisted.

Ethics Committee Approval: This study was approved by the Gaziantep University Clinical Research Ethics Committee (Date: 10.08.2015, Decision No: 224).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: M.S., A.H.H., L.D., S.Z., W.H.; Design: M.S., A.H.H., W.H.; Supervision: M.S., S.Z., W.H.; Resource: M.S., W.H.; Materials: M.S., W.H.; Data: M.S., S.Z.; Analysis: M.S., S.Z., W.H.; Literature search: M.S., A.H.H., L.D.; Writing: M.S., W.H.; Critical revision: M.S., S.Z., W.H.

Conflict of Interest: None declared.

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ORIJİNAL ÇALIŞMA - ÖZ

Hastalarda basit ev yapımı fantomların ultrason eşliğinde venöz erişimin güvenilirliğini ve girişimsel performansını artırması

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AMAÇ: Ultrason eşliğinde venöz erişim, acil tıpta önemli bir beceridir. Ticari ultrason fantomlarının fahiş fiyatları, asistanları yeterince eğitime yeteneğini sınırlamaktadır. Tıp eğitiminde basit ev yapımı fantomların klinik yararını araştırdık.

GEREÇ VE YÖNTEM: Acil asistanlarının yarısı, toplam 14 penrose drenli, iki basit ev yapımı ultrason fantomu kullanılarak yapılan bir eğitim kursu öncesi ve diğer yarısı kurs sonrasında vasküler girişim yapmıştır, 18 acil tıp asistanının her biri hastalar üzerinde ultrason eşliğinde 10 IV girişimde bulunmuştur. Hastalar üzerinde IV girişimlerinin güven ve başarı oranlarını karşılaştıran eğitim öncesi ve sonrası anketleri kullanarak ileriye yönelik bir fizibilite çalışması yaptık.

BULGULAR: Asistanlar, ultrason eşliğinde başarılı periferik venöz kanülasyonlarında ilk beş denemede ortalama %47.8'den son 5 denemede %71.1'e kadar bir iyileşme gösterdiler. İlk ile beşinci denemelerden veya altı ila onuncu girişimlerden hiçbir yarar saptanmadı, bu da erken dönem deneyimden minimum fayda sağladığını göstermektedir. Asistanlar, hastalara ultrason eşliğinde venöz kanülasyon uygulanması, doğru probu belirleme, kuvvet ve derinliği ayarlama, damarları kısa ve uzun eksenle görselleştirme, arterleri damarlardan ayırt etme ve fantom model üzerinde venöz kanülasyon gerçekleştirilmesi konusunda artan güven bildirdiler.

TARTIŞMA: Basit ev yapımı ultrason fantomları uygun maliyetlidir, güveni artırır ve acil tıp asistanlarının ultrason eşliğinde venöz kanülasyonu yapma becerisini geliştirir.

Anahtar sözcükler: Acil; eğitim; fantom; ultrason; ven.

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