A novel homemade simulator for training and assessing competency of totally implantable venous access port implantation via venous cutdown

Chia-Lin Chen[a], Vicky Jen-Huei Yeh[b], Yi-Ting Yeh[a,c,*]

[a]Department of Surgery, Taipei Veterans General Hospital, Taipei, Taiwan, ROC; [b]Department of Surgery, Mayo Clinic, Rochester, MN, USA; [c]School of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan, ROC

Abstract: Total implantable venous access port (TIVAP) by cephalic vein cutdown (CVCD) is one of the first procedures surgery residents can be performed independently under supervision. There is currently a lack of affordable simulators for teaching and assessing TIVAP competency to improve patient safety. A panel of 10 experts divided the TIVAP by CVCD procedure into 9 steps. A homemade, low-cost ($3 USD) simulator was then designed for practicing standardized procedural steps in the context of a simulation-based mastery learning course. Residents were given a simulator for at-home practice and completed a survey evaluating the simulator and their learning experience. Twenty-eight first-year surgery residents participated in the course and completed the survey. They were highly satisfied with the simulator (mean score = 8.7 of 10) and generally agreed with its anatomical appearance and functional fidelity. They also appreciated the educational value of using this simulator to learn and practice basic techniques and procedural steps. Our novel, homemade simulator of CVCD TIVAP implantation is a cost-effective way of achieving procedural competence of a basic operation for inexperienced surgery residents. We envision the same principle can be applied to other procedures to enhance resident education.

Keywords: Low-cost simulation; Surgical simulation; Venous cutdown

1. INTRODUCTION

Total implantable venous access port (TIVAP) implantation is an essential procedure in modern medicine, providing safe and reliable long-term venous access for chemotherapy, fluid, and parenteral nutrition therapy since its introduction in the 1980s.[1] It is also one of the first procedures junior surgical residents can perform independently under supervision.[2,3] Therefore, training early in the residency and providing opportunities for deliberate practice are critical to improve patient safety, resident autonomy, and efficiency of care. This is particularly important with the implementation of resident duty hour restrictions. As a result, simulation-based training has gained attention in surgical training and shown promise in promoting surgical skill acquisition and transferring of skills to the operation room.[4–6]

Percutaneous puncture and venous cutdown are two widely used techniques for TIVAP placement.[7] While commercialized simulators are available, they are not only costly (>$2000 USD) but designed for practicing the percutaneous puncture approach,[8] thus limiting the technique and the feasibility of providing repeated practice opportunities for residents. To address this gap, we developed a homemade low-cost simulator for a simulation-based mastery learning (SBML) course for implanting TIVAP via cephalic vein cutdown (CVCD) approach for first-year surgery residents. This article reports how we created this simulator and resident feedback on the simulator.

*Address correspondence. Dr. Yi-Ting Yeh, Department of Surgery, Taipei Veterans General Hospital, 201, Section 2, Shi-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: chloroplast@gmail.com (Y.-T. Yeh).

Author contributions: Dr. Chia-Lin Chen and Dr. Vicky Jen-Huei Yeh contributed equally to this work.
Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.
Journal of Chinese Medical Association. (2022) 85: 259-262.
Received July 2, 2021; accepted October 13, 2021.
doi: 10.1097/JCMA.0000000000000654.

2. METHODS

A simulator for implanting TIVAP via CVCD was developed and implemented in an SBML course. The detail of the course is described elsewhere (unpublished results). Residents completed a survey after successful completion of the course (i.e., passing the post-test) on their learning experience and specific views about the simulator. The protocol was approved by the Taipei Veterans General Hospital Institutional Review Board.

2.1. Design and development of the simulator

A panel of 10 board-certified general surgeons at our institution collectively distilled nine distinct steps of a typical TIVAP implantation by CVCD: (1) identify surface anatomy, (2) administer local anesthesia, (3) skin incision, (4) tissue dissection, (5) maintain vascular control, (6) perform venous cutdown, (7) assemble the reservoir and catheter apparatus, (8) implantation of reservoir, and (9) wound closure. A simulator was then designed to enable residents to practice the proper surgical techniques in the correct sequence.

The simulator (Fig. 1) has three main components: the baseboard with anatomical landmarks, soft tissues, and skin layers.

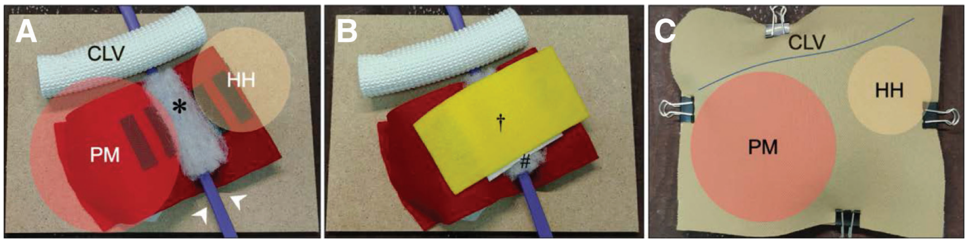

Fig. 1 A homemade simulator of cephalic vein cutdown (CVCD) for totally implantable venous access port (TIVAP) implantation. A, Baseboard and anatomical landmarks: the baseboard was made of plywood which has two eminences (two mounts of stuffing [faded circles]) representing the pectoralis major (PM) and the humeral head (HH) covered in red colored felt. The parallel black Velcro strips are used to hold the superficial felt layers in place. An insulation foam tube was added superior to the PM and HH representing the clavicle (CLV). The cephalic vein was simulated with an unfilled long balloon (arrowheads) running in between the PM and HH and under the CLV. The perivascular tissue was represented by wrapping a layer of cotton batting (asterisk) around the balloon. B, Soft tissues: the simulated vein was covered by a layer of white felt (hashtag) representing the Scarpa's fascia, and then a layer of yellow felt (dagger) representing the Camper's fascia. C, Skin: The whole assembly was then covered with tan-colored headliner fabric to represent the skin.

The baseboard was made of plywood with two eminences representing the pectoralis major muscle and humeral head/deltoid muscle and an oblique curved tube representing the clavicle. The cephalic vein was simulated by an unfilled long balloon traversing between the two eminences (Fig. 1A). To simulate the fatty connective tissues around the vascular bundle, a thin layer of cotton batting was wrapped around the balloon. The cephalic vein was then covered by layers of non-woven felt as the Scarpa's fascia and subcutaneous layer (Fig. 1B). Finally, we secured a layer of headliner fabric on top of the simulator to simulate the skin (Fig. 1C). Fig. 2 shows the surgical view that can be achieved by the simulator.

The total cost of one simulator is approximately $3 USD. The baseboard and anatomical landmarks of the simulator are reusable. The simulated cephalic vein (balloon) and the skin layers (fabrics) are easily replaceable after each practice. Residents were provided with a simulator with replacement parts and a TIVAP set (reusable) for at-home practice. A new simulator takes about 10 minutes to create and the time to repair a used simulator is about 5 minutes. Due to the modular design of the simulator, the steps to replicate and repair the simulator are simple and straightforward, no specific technical and/or medical training is needed.

Besides, a 25-item checklist (see Supplementary Material http://links.lww.com/JCMA/A124) was developed by the same panel of 10 surgeons. Twenty-one of the 25 items evaluate the technical aspect of the procedure, and 4 items evaluate the decision-making skills involved in the procedure. Each item was given a passing (A: done correctly) or failing (B: done incorrectly or not done) grade. Technical competency was considered when a resident could correctly perform all 21 technical items in the correct sequence.

2.2. Instructional materials

The residents were given written and video instructions of the procedure via an online platform before and during the course. This included one short video reviewing the instruments contained in the TIVAP tray, one full-length procedure video on a real patient, one full-length procedure video on the simulator, and nine short videos of each step of the procedure on the simulator.

2.3. Feedback survey of the simulator

Upon course completion, each participant was asked to fill out a feedback survey on their experience practicing with the simulator (Table 1). Questions include their overall rating of the simulator on a 10-point Liker scale (1 = very unsatisfied to 10 = very satisfied), and their level of agreement on the physical fidelity, functional fidelity, and educational value of the simulator using a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree).

3. RESULTS

Twenty-eight first-year surgery residents participated in the course. Of the 28, 14% had never observed an actual CVCD procedure, 46% had observed the procedure, 11% had hands-on experience with part of the procedure under supervision, and

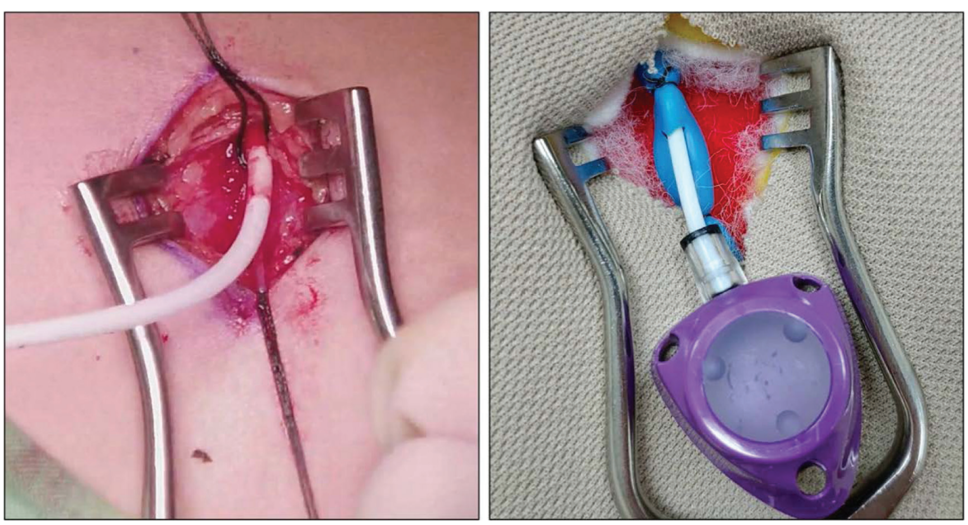

Fig. 2 A comparison of the surgical view of cephalic vein cutdown during the simulation (right) versus in the operating room (left).

Table 1

Resident mean rating (n = 28) of different components of the simulator

Questions	Mean Rating
Overall Rating (10-point Likert Scale[a])	
The overall rating of the simulator	8.7
Simulator Anatomical Appearance and Feel (4-point Likert Scale[b])	
The size of the simulator is appropriate	3.9
The clavicle can clearly be seen on the surface	3.4
The clavicle can clearly be palpated	3.9
The humeral head can clearly be seen on the surface	3.2
The humeral head can clearly be palpated	3.6
The pectoralis major can clearly be seen on the surface	3.6
The pectoralis major can clearly be palpated	3.8
The deltopectoral groove can clearly be seen on the surface	3.3
The deltopectoral groove can clearly be palpated	3.9
The external jugular vein can clearly be seen on the surface	2.7
The external jugular vein can clearly be palpated	3.1
Simulator Functional Fidelity (4-point Likert Scale[b])	
The overall fidelity of the simulator	3.3
The fidelity of the simulated skin	3.0
The fidelity of the simulated Camper's fascia	2.9
The fidelity of the simulated Scarpa's fascia	3.1
The fidelity of the simulated vascular bundle inside the deltopectoral groove	3.0
The fidelity of the cephalic vein	2.8
The fidelity of performing skin and subcutaneous tissue incision	2.8
The fidelity of performing vascular dissection and control	3.0
The fidelity of performing venotomy and catheterization	3.1
The fidelity of performing fixation of the reservoir	3.1
The fidelity of performing tissue approximation and skin closure	2.7
Simulator Value in Teaching and At-Home Practice (4-point Likert Scale[b])	
The simulator is valuable in practicing identification of surface anatomy landmarks	3.4
The simulator is valuable for practicing vascular dissection	3.3
The simulator is valuable for practicing vascular control	3.4
The simulator is valuable for practicing venotomy and catheterization	3.3
The simulator is valuable for practicing assembling the catheter to the reservoir	3.3
The simulator is valuable as a teaching tool	3.8
The simulator is valuable as an evaluation tool for competency	3.5
The simulator is valuable as a tool for practice	3.8

[a]10-point Likert Scale (1 = very unsatisfied, 10 = very satisfied).
[b]4-point Likert Scale (1 = strongly disagree, 4 = strongly agree).

29% had performed the whole procedure under supervision. All completed the feedback survey.

Overall, residents were highly satisfied with the simulator (mean = 8.7 of 10). They generally agreed (rated ≥3 on a 4-point Likert scale) with the simulator's anatomical appearance and feel and functional fidelity. Only 5 of 22 items were rated <3 on a 4-point Likert scale. They were: (1) the external jugular vein can clearly be seen on the surface (mean = 2.7), (2) the fidelity of the simulated Camper's fascia (mean = 2.9), (3) the fidelity of the cephalic vein (mean = 2.8), (4) the fidelity of performing skin and subcutaneous tissue incision (mean = 2.8), and (5) the fidelity of performing tissue approximation and skin closure (mean = 2.7).

In terms of the simulator's value in teaching and at-home practice, residents gave positive ratings (≥3 on a 4-point Likert scale) to the simulator's utility as a mean to practice identifying anatomic landmarks (mean = 3.4), vascular dissection (mean = 3.3), vascular control (mean = 3.4), venotomy (mean = 3.3), and assembling the catheter to the reservoir (mean = 3.3). They also affirmed that the simulator is a valuable tool for teaching (mean = 3.8), assessment (mean = 3.5), and practice (mean = 3.8). Detailed ratings of the simulator are presented in Table.

Lastly, comments from the residents also shed light on the education outcome of the simulator. One resident shared "… thinking back on my previous experience operating on patients, I hope that in the future other procedures could adopt similar training methods just like what we have for the venous access port implantation, so that we can be sufficiently prepared and reduce potential harm to the patients."

4. DISCUSSION

We present a novel, homemade simulator for educating first-year surgery residents on the basic surgical techniques and procedural steps in performing CVCD for TIVAP implantation. The simulator was highly rated by the residents for its appearance, function, and education value.

From our experience teaching with the simulator and resident feedback, several areas for future modifications and research were identified. First, the fidelity of the simulator can be improved by using different materials such as using thin silicone tubing to simulate vessels and silicone sheets to simulate skin. However, our simulator was created to meet the objective of learning and practicing procedural steps of TIVAP at an affordable cost; therefore, achieving high physical fidelity (e.g., appearance and feel) was secondary to achieving the simulator's functional fidelity. Based on residents' feedback, our objective was met. Second, while the literature suggests that surgical simulation is more beneficial for novice trainees,[9,10] our simulator could be modified to simulate common anatomical variations, such as adding branching to the simulated blood vessel to simulate external jugular vein cutdown after the failure of CVCD, which could help more experienced residents staying engaged. Third, to further improve the durability of the simulator and anatomical fidelity, one could consider incorporating 3D printing technology. We have successfully printed the baseboard, muscle eminences, and clavicle as one piece with polylactic acid plastic (Fig. 3). While the cost per simulator increases (from $3 to $10 USD), it is more durable and could potentially afford more practice repetition for the learners. Furthermore, we are currently conducting a prospective study evaluating the clinical performance of the residents after training.

In conclusion, our homemade simulator of CVCD for TIVAP implantation is a cost-effective way of teaching first-year surgical residents. We believe the same principle can also be applied to other basic, highly structuralized, and standardized surgical procedures, such as pediatric hernia repairs, in the future to enhance resident education.

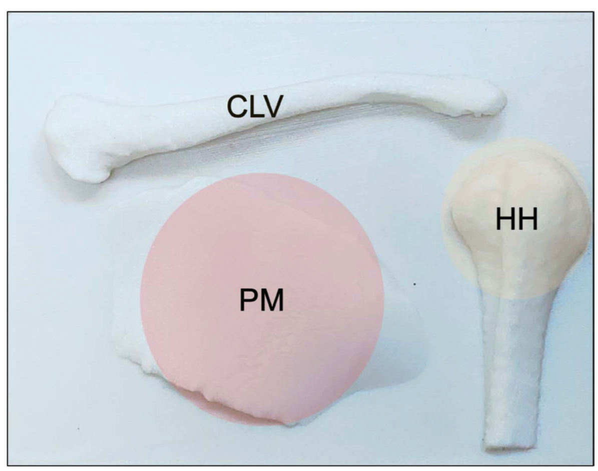

Fig. 3 3D-printed baseboard with anatomical-accurate pectoralis major (PM), humeral head (HH), and clavicle (CLV) as landmarks.

ACKNOWLEDGMENTS

The creation of the reported simulator was inspired by Dr. David R. Farley, Dr. Mariela Rivera, and their team's effort in developing affordable and accessible surgical simulation models for resident education at Mayo Clinic Rochester.

We would like to thank Professor Hsu Ma and the Division of Experimental Surgery, Department of Surgery, Taipei Veterans General Hospital, for their administrative support of this project. We would also like to thank Dr. Jonathan D. D'Angelo and Dr. Nizamuddin Shaikh for providing feedback on this article.

This study was supported by the Clinical Innovation Center, Taipei Veterans General Hospital [grant number CIC-009].

APPENDIX

Supplementary data related to this article can be found at http://links.lww.com/JCMA/A124.

A short video demonstration of the simulator can be found here: https://youtu.be/-Xitw0MXnDs.

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