Simulation Technology & Operations Resource Magazine (STORM)

STORM highlights exemplar work contributing to the advancement of healthcare simulation operations. All submissions are peer reviewed before publication in the STORM special edition of the SSH Simulation Spotlight. With articles covering training, policy & procedure, emerging technologies, and professional development, STORM has everything needed to stay current and well-rounded in the pursuit of simulation operations excellence.

CONTENTS

EDITORIAL BOARD

Training Systems for Female Trauma and Prolonged Casualty Care: Time for New Approaches

Authors
William Y. Pike, PhD[1], Mark V. Mazzeo, MS[1]

[1]US Army Combat Capabilities Development Command Soldier Center Simulation and Training Technology Center, Orlando, Florida

Conflict of Interest Statement
The authors declare no conflict of interest.

Corresponding Author
William Y. Pike, PhD, US Army Combat Capabilities Development Command Soldier Center Simulation and Training Technology Center, Orlando, Florida
(Email: William.y.pike.civ@army.mil)

Brief Description

In the commercial world, technological innovations often occur over a period of time, and can be traced back to a series of timely events that make a disruption, or leap ahead in the technology possible. For the U.S. military, it is often a change in doctrine that causes military research organizations to push for technology solutions to meet the needs of the new doctrine and adapt to emerging threats. A notable example is the development of self-contained, wireless patient simulators that operate without requiring a cumbersome rack of equipment. Army research and development personnel saw the need for patient simulators to be more mobile to support changing doctrine. Once Army research and development produced the first wireless patient simulator, all manikin manufacturers followed suit. The paper explores two capability gaps in medical training systems, Prolonged Casualty Care (PCC) and female trauma, and presents a case that it is time to reconsider medical modeling and simulation technologies to properly support training of these two areas.

Background

In the late 1990's, the military led industry to reconsider the design of human patient simulators. Manikins at the time were extremely robust, but they were tethered to large racks of equipment, which limited their movement to just a few feet. The principles of Tactical Combat Casualty Care, or TCCC, require patients be moved to a safe location, out of the line of fire, as soon as possible (Butler, Hagmann, & Butler, 1996). Tethered manikins were forcing instructors to teach one thing, and trainees to practice another. The Army challenged industry to develop patient simulators that were not tethered to immobile racks of equipment, a challenge that resulted in the first Standalone Patient Simulator. Within a few years of this research and development project, all patient simulator companies were marketed as self-contained, wireless patient simulators. The Standalone Patient Simulator, and other commercial models that followed, were tailored specifically to military trauma, allowing trainees to treat the leading causes of battlefield death. More importantly, they allowed trainees to carry the manikin from the point of injury to a casualty collection point, load it in an ambulance, take it to a field surgical hospital, perform battlefield handoff, and continue treatment. Civilian emergency response mass casualty exercises can likewise simulate an active shooter casualty that can be treated at the scene, taken in an ambulance to a hospital, and treated in an emergency department.

The primary driver of the development of this technology was the emergence of TCCC principles. Developed by Special Forces in the late 1990s (Butler, Hagmann, & Butler, 1996), TCCC was soon adopted by conventional forces (Savage et al., 2011). TCCC is composed of three stages: Care Under Fire, Tactical Field Care, and Combat Casualty Evacuation Care (CASEVAC) (Butler, Hagmann, & Butler, 1996). While Care Under Fire can occur at the point of injury, a tenet of Tactical Field Care is that the medic and the casualty are no longer under enemy fire. Suppressing enemy fire is one method to ensure the medic and casualty are safe; moving the casualty to a "safe" location is another. During CASEVAC, care is still rendered.

Figure 1: Standalone Patient Simulator

A capability gap thus existed for training: manikins that could replicate battlefield trauma could only be moved a few feet from the equipment that controlled fluid exchanges and the manikin's physiology (e.g., simulated breathing and bleeding). As stated earlier, this capability gap drove the Army science and technology (S&T) community to develop the Standalone Patient Simulator.

Training to Treat Female Trauma

In 2015, then-Secretary of Defense, Ash Carter, removed gender restrictions on females serving in combat roles (U.S. Department of Defense, 2015). Even before Secretary Carter removed the restrictions, a 2014 study showed 12% of the U.S. veterans of operations in Iraq and Afghanistan were female (Rivera & Johnson, 2014). This created a capability gap in medical modeling and simulation. Unlike the capability gap that drove the Standalone Patient Simulator, the military was not teaching one thing while technology limited training to another. There simply was no capability to train trauma on a female patient simulator.

To further illustrate the need for realistic female trauma patient simulators, Cross et al. (2011) indicated mortality appeared higher for women than men in both Iraq and Afghanistan. While later research (e.g., Schauer et al. (2019)) disputed higher mortality rates for females, peacetime research indicates females should survive at a higher rate than men (e.g., Deitch et al. (2007)).

Following Secretary Carter's removal of gender-based restrictions, the military's medical modeling and simulation community began a multi-year S&T effort to develop realistic female trauma patient simulators and explore whether the lack of such simulators was a capability gap that could lead to more trauma-related deaths of females on the battlefield. The initial approach was a "Gender Retrofit Kit" (GRK) that made the patient simulator fielded at the Medical Simulation Training Centers more female in anatomical appearance, while not altering physiology. The GRK was tested in a variety of user tests (e.g., Mazzeo et al. (2018), Craig et al. (2022), Craig et al. (2022)) and was used in mentoring cadets over three years of capstone projects at the United States Military Academy to assess its utility and effectiveness. Two issues were evident in many of the tests: medics and non-medics alike hesitate to remove undergarments, a necessary step in treating an upper chest wound, and performance was consistently suboptimal when placing a chest seal over wounds that required partial placement over breast tissue. The GRK has since undergone operational testing and has been licensed by the major manikin manufacturer it fits.

In addition to the GRK, the Army led development of a full-fidelity patient simulator, designed to realistically simulate a female in both anatomy and physiology – not simply converting an existing male manikin. Measurements were based on a comprehensive 2012 anthropometric survey of Army personnel undertaken by the U.S. Army's Soldier Center (Gordon et al., 2012). This manikin is designed for all critical TCCC tasks and procedures, in addition to some Prolonged Casualty Care procedures. The manikin has a full physiology engine, and condition deteriorates in the absence of treatment. In addition to the ability to place wounds in the upper chest, the manikin has an optional inguinal (groin) wound which can be set to bleed and requires removal of underpants to see and pack. This manikin likewise underwent a series of usability tests and is on schedule for operational testing in early 2024.

Figure 2: Left-to-right: Gender Retrofit Kit (background), full-fidelity female patient simulator

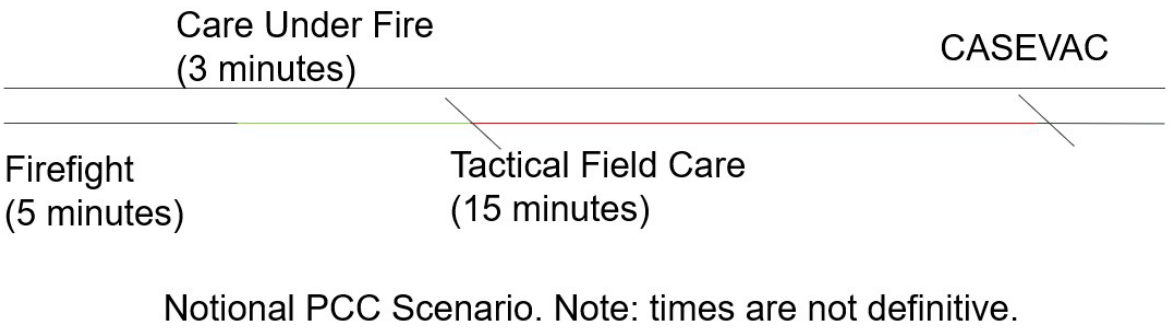
Prolonged Casualty Care

The nature of future conflicts is expected to change. The US may no longer be able to evacuate casualties quickly – the "golden hour" of medical treatment. Instead, a near-peer conflict in which casualties may need to remain with their operational units for longer periods of time is increasingly likely. Therefore, the concept of Prolonged Casualty Care, or PCC, is becoming more important (Aker, 2022). Medics may need to not only treat casualties at the point of injury but continue to treat them for an extended amount of time until friendly forces are able to reach them to evacuate casualties. Like TCCC, PCC has its roots in the Special Operations community. Called Prolonged Field Care, or PFC, the treatment guidelines were

based on the necessity of a unit not risking providing opposing forces with information on its location.

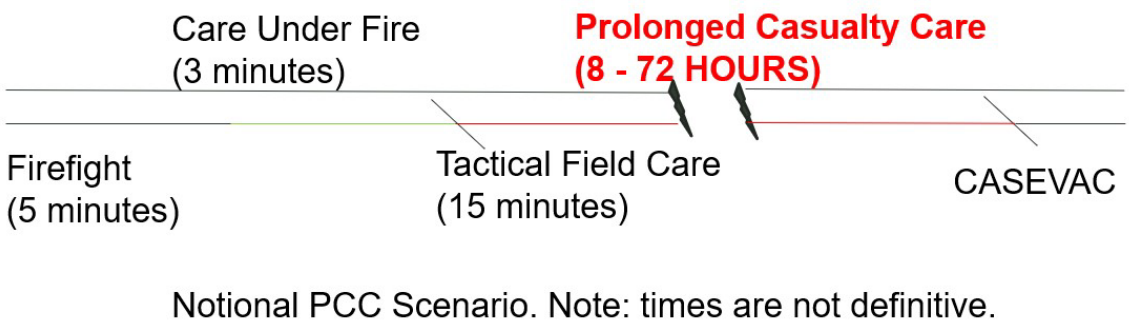
Providing technology to train for PCC is quite complex. First, the element of time makes training difficult. Training a TCCC scenario, which may involve a short, simulated firefight or explosion, a few minutes of Care Under Fire, a few more minutes of Tactical Field Care, then preparing the casualty for evacuation, takes typically 30 minutes to an hour – certainly not a taxing requirement for a training day. PCC takes considerably more time. While doctrine does not set limits on what constitutes "prolonged," a unit may need to maintain their casualty or casualties for days, perhaps while additional unit members are injured. Such a multi-day training exercise is difficult to fit into a unit's training regimen.

Figure 3: Notional Tactical Combat Casualty Care timeline



Second, an injured casualty's physiology will improve, or worsen, over time based on initial and on-going treatment. Most human patient systems (as well as virtual and extended reality training systems) rely on a human physiology engine to provide physiological feedback. Physiology engines model human physiology and run separately from the patient simulator (be it live or virtual). This allows developers of patient simulators to focus on what they do best and allow a validated physiology model to run in the background (Barnes, et al., 2020). Physiology engines, however, were originally designed to run in real time. To overcome the tyranny of time, physiology engines must receive an initial injury and treatment, and then allow time to pass at different speeds. Physiology engines should then be able to return to real-time to allow medics to read vitals and perform follow-on treatments, then speed up again.

Figure 4: Notional Prolonged Casualty Care timeline



Third, injuries will likewise improve or deteriorate over time. Simply applying a new piece of moulage provides a low-tech, inexpensive method to solve this problem. Virtual simulations can easily display a change in an injury. Thin film displays may also provide a method for human-worn or manikin-worn injuries.

Finally, PCC does not always equate to a field environment. Patients may be forced to stay longer in a Role 2 facility for longer than normal. Similar to nurses in an ICU, medics must be trained in how to properly care for a patient for extended periods of time. Current patient simulators, built to simulate and train point of injury and trauma, are not optimized to train injuries such as rashes, blisters, pressure ulcers (bedsores), and similar injuries caused by lying in a bed too long.

A simple solution to teaching PCC concepts is to present students with a patient simulator, moulaged and programmed to show an injury and physiological response. Students can then treat the simulator. Instructors can brief students on additional PCC concepts while another instructor re-programs the simulator and changes moulage. While effective for a “show-and-tell” demonstration, this approach will not work well for a mass casualty exercise. Furthermore, the breaks in training may limit simulating the stress of the operational environment (Cole et al., in press).

In a 2022 article, LTC Matthew Marsh and CPT Ryan Hampton analyzed the vital role Army medical training will have in future, large-scale combat operations, or LSCO (Marsh & Hampton, 2022). Marsh and Hampton reference a 2021 report from the Center for Army Lessons Learned explaining how larger numbers of casualties will overwhelm conventional medical evacuation capabilities. To combat this limitation, training must focus on building and rehearsing plans for casualty management, evacuation, and logistics to gain efficiency of movement and increase casualty survival rates. In their interview with U.S. Army Surgeon General, LTG Raymond Dingle confirms that “LSCO may result in a significant increase in casualties from what [the] DoD experienced... in Iraq and Afghanistan,” adding that operations must change “due to the sheer number of patients presented.” In a LSCO situation with numerous casualties, evacuation “may not be an option (Marsh & Hampton, 2022).” For these reasons, medical training and the patient simulations it requires must evolve to incorporate realistic rehearsal for triaging, treating, and/or moving dozens, even hundreds of patients at the division or company level. This will require a rethinking of current patient simulators, as scenarios can be expected to last well beyond the “Platinum 10 Minutes” (Bendall & Parsell, 2005) or even the “Golden Hour” timeframes.

The Path Forward

Female Trauma Manikins

The progression from tethered manikins to the first Standalone Patient Simulator was not easy. Industry pushed back on the necessity for an untethered manikin. Likewise, the initial user test of the first female patient simulator caused a senior medic instructor to wonder why the Army was paying for the development of a female manikin, since he considered the difference in male and female anatomy to be insignificant (a paraphrase of his actual quote). Medics having been trained for so long in point of injury care, and the concept of the “Platinum Ten Minutes” having become almost synonymous with the role of a medic, the concept of simply adapting current technologies rather than inventing new technologies will seem more attractive to industry.

The Standalone Patient Simulator was ultimately designed from the inside out. Reinventing the manikin meant first understanding what untethering would mean to the internals of the manikins. Developing a highly realistic female trauma patient simulator means so much more than making a manikin built to male standards look like a female by adding breasts and a wig and changing the appearance of the genitalia. The anatomical appearance is easy, but that

is only the very beginning. Tissues behave and feel differently. Physiological differences are critical. Blood from a blood sweep in the groin of on a male could mean a potentially fatal wound, whereas on a female it might only mean menstruation.

Prolonged Casualty Care Training

The tyranny of time is the biggest issue to resolve in PCC training. How to compress a 48–72-hour PCC scenario into a 1–2-hour training period while capturing all the physiology changes, and changes to injury patterns, necessarily means changing how we think about training medics, as does considering issues involved with a casualty staying in the same bed in the same treatment facility for an extended period of time.

The Challenge

The Standalone Patient Simulator arose from the implementation of TCCC. Just as a human would not stay where injured but would be moved to a safe location, then to a casualty collection point, and ultimately to an evacuation vehicle, a human patient simulator should be capable of being moved. The need for a female trauma patient simulator does not come from any real change in doctrine, but from the fact the military did not push for a simulator that faithfully represented, in all aspects, 17% of its enlisted personnel. A system, or more likely systems, to train PCC is based on changing guidelines, and must consider the variety of ways it will be used and concepts it will train, all while overcoming the tyranny of time.

References

Aker, J.A. (2022). How military medicine is preparing for the next conflict. Retrieved from https://www.health.mil/News/Articles/2022/06/08/How-Military-Medicine-Is-Preparing-for-the-Next-Conflict?type=Policies&page=2#pagingAnchor on June 27, 2023.

Barnes III, J. J., Kiberenge, K., Sweet, R., Keller, J., & Konia, M. R. (2020). Comparing hemorrhage in human physiology simulation tools: How they compare with expected human physiology and each other. *Simulation in Healthcare*, 15(5), 310-317.

Bendall, J. C., & Parsell, B. (2005). Pre-hospital trauma life support (PHTSL) advanced provider course. *Journal of Emergency Primary Health Care*, 3 (1-2).

Butler Jr, F. K., Hagmann, J., & Butler, E. G. (1996). Tactical combat casualty care in special operations. *Military Medicine*, 161(suppl_1), 3-16.

Cole, R., Wagner, R., Egan, S. J., & Van Shufflin, M. (in press) Military Medical Student Experiences during a prolonged casualty care simulation. *Journal of Military and Veterans' Health.*

Craig, C. M., Drahos, B., Schwieters, K. R., Morris, N. L., Lye, M., Kowalewski, T. M., Norfleet, J.E., & Mazzeo, M. V. (2022, April). Evaluating gender differences in treatment of simulated gunshot wounds using a female retrofit. *Frontiers in Biomedical Devices* (Vol. 84815, p. V001T06A004).

Craig, C. M., Schwieters, K. R., Drahos, B. A., & Morris, N. L. (2022). A pilot study on the role of experience and patient gender on MARCH Treatment Sequence. *Military Medicine*, 2022 Dec 14:usac383.

Cross, J. D., Johnson, A. E., Wenke, J. C., Bosse, M. J., & Ficke, J. R. (2011). Mortality in female war veterans of Operations Enduring Freedom and Iraqi Freedom. *Clinical Orthopaedics and Related Research*, 469, 1956-1961.

Deitch, E. A., Livingston, D. H., Lavery, R. F., Monaghan, S. F., Bongu, A., & Machiedo, G. W. (2007). Hormonally active women tolerate shock-trauma better than do men: A prospective study of over 4000 trauma patients. *Annals of Surgery*, 246(3), 447.

Gordon, C.C., Blackwell, C.L., Bradtmiller, B., Parham, J.L., Barrientos, P., Paquette, S.P., Corner, B.D., Carson, J.M., Venezia, J.C., Rockwell, B.M. and Mucher, M. (2014). 2012

anthropometric survey of US Army personnel: Methods and summary statistics. Army Natick Soldier Research Development and Engineering Center, Natick, MA.
Marsh, Matthew K. & Hampton, Ryan L. (2022). Army medicine's critical role in large-scale combat operations – enable the force. *Military Review*, July-August 2022, 106-113.
Mazzeo, M. V., Sotomayor, T. M., Coulter, J. N., & Alban, A. M. (2018, November). Development & assessment of a human patient simulator gender retrofit kit. *Proceedings from the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC)*, Orlando, FL.
Rivera, J. C., & Johnson, A. E. (2014). Female veterans of Operations Enduring and Iraqi Freedom: Status and future directions. *Military Medicine*, 179(2), 133-136.
Savage, L. E., Forestier, M. C., Withers, L. N., Tien, C. H., & Pannell, C. D. (2011). Tactical combat casualty care in the Canadian Forces: Lessons learned from the Afghan war. *Canadian Journal of Surgery*, 54(6 Suppl), S118.
Schauer, S. G., Naylor, J. F., Long, A. N., Mora, A. G., Le, T. D., Maddry, J. K., & April, M. D. (2019). Analysis of injuries and prehospital interventions sustained by females in the Iraq and Afghanistan combat zones. *Prehospital emergency care*, 23(5), 700-707.
US Department of Defense (2015). Carter opens all military occupations, positions to women. Retrieved from https://www.defense.gov/News/News-Stories/Article/Article/632536/carter-opens-all-military-occupations-positions-to-women/ on June 27, 2023.

A Simplified Medical Record Template Compared to Traditional EMR in Simulation-Based Medical Education

Authors

Martin Leisin, MS, CHSOS[1]; Lorena Navarro, MSHS, CHSE, RN BSN[1]; Pascual E. Reyes, BMS[1]; Jordan B. Coulston, MD[1]; James A. Lindgren, MD, CHSE, FAAP, FACP[1]

[1]University of Arizona, Center for Simulation and Innovation, Phoenix, Arizona

Conflict of Interest Statement
The authors declare no conflict of interest.

Corresponding Author
Martin Leisin, MS, CHSOS, University of Arizona, Center for Simulation and Innovation, Phoenix, AZ
(Email: mleisin@arizona.edu)

Brief Description

Electronic Medical Records (EMR) have become critical in healthcare. Their streamlined workflows, improved documentation, and communication among interprofessional teams have brought more efficient and safer patient care. Integrating EMR into medical education creates some challenges. EMR adoption barriers include accession and maintenance costs (Kim et al., 2019). Other barriers may include time constraints, cost of software licensure and complexity of setup/support needed for use. In addition, learners who visit diverse training sites may encounter multiple EMR solutions with different communication boundaries (Kim et al., 2019). This makes selecting one solution for a training environment difficult. We address these challenges by proposing a simplified medical record template solution that is tailored for medical education. The solution uses a whiteboard approach with a custom template and video capture software. This system enables learners to practice documentation, order entry, and decision-making efficiently. It also supplies a written record to improve communication and debriefing between educators and learners. The solution does lack some features available within computer based EMR systems, such as integrated laboratory and imaging. Nevertheless, the fact that it requires almost no training to use and provides a quick, dynamic and trackable experience more than makes up for its limitations. We further submit that this simplified medical record option prepares learners with skills that can translate into future EMR systems they will encounter during their healthcare training and practice.

Introduction

In today's clinical world, the EMR functions as a shared store of medical information. It allows the compilation of pertinent patient data to serve as a critical thinking tool (Shala et al., 2021). However, even with all its benefits, the EMR has its share of limitations and challenges. Unfortunately, learners throughout healthcare systems, have limited access to EMR systems in hospitals to be able to gain competency in this skill before entering the workforce. Their ability to use these clinical systems remains low and requires timely training and system exposure to gain competency (Herrmann-Werner et al., 2019). The cost, time and resources needed for training, customization, as well as the "risk" of having access to live ordering and documentation, are all barriers encountered by these healthcare learners. According to Herrmann-Werner et al., the EMR benefits in medical education are significantly lowered due to

a lack of live EMR documentation, leading to loss of information within the healthcare team (2019).

EMR systems ease communication and coordination of patient care amongst the diverse but integrated healthcare teams of today's clinical environment. Ultimately, having medical learners learn how to organize their ideas and clearly communicate these to other members of the healthcare team allows for more coordinated and better continuity of care. According to Manca, there is improved communication between family physicians, other healthcare providers and patients in areas utilizing an effective EMR system (2015).

EMR System Integration into Simulation

Challenges in integrating EMR into the simulation environment include the cost of the hardware and software required for use. Data volume, compatibility, as well as the amount of time required for data input and customization of the platform are further problems. Hospitals have health information professionals (HIP) employed full-time to help their system succeed. This is an expense not available to most simulation centers as well as the lack of funding for technology purchasing (Chung & Cho, 2017). Further, the amount of training needed to teach a student and instructor to use the system competes for time for educational activities that are already stretched by duty hour limits and competing educational demands. In discussing our proposed solution, we focus on cost, training time constraints, and complexity in customization.

Cost

The cost of EMR software can run into the hundreds of thousands of dollars or more, depending on features, functionalities, number of users and vendor pricing structure (Fleming et al., 2011). Hardware, database configuration, network setup, and user training add to this already costly system. Instructional EMR systems are expensive and can range from $3,000 start up price but add up to $30,000 in annual maintenance fees per license (Lucas, 2010). Educational needs assessments and learning objectives should guide the type of system required. The exact configuration tailored to meet these needs then determines the final cost to implement. This involves a complicated number of parameters and can be difficult to estimate.

Time Constraints for Use in Training

Users within the simulation environment, including students, faculty, and full-time staff, need to understand and navigate the integrated EMR features effectively. Training and familiarization sessions are necessary to ensure that users can utilize the EMR integration to its fullest potential, while keeping their psychological safety and learning as top priority. There is a fixed cost in time and finances to complete this training and this competes with the time and finances required for the other aspects of running effective simulation events. Training for learners would need to occur before the simulation took place and individual assigned logins would need to be distributed. Learning objectives would need to be aligned with the EMR activity and full-time staff and faculty would need to be well versed in the instructional EMR system to improve the overall evaluation of the learner for this skill. It is essential that the healthcare learners' education be supported by academia and all practice settings to assure their competency and success in the workforce (Lucas, 2010).

Complexity of Customization

Customizing a simulated patient chart that properly aligns with a specific simulation scenario requires advanced knowledge of the EMR system and time to create. Some systems require real-time entry to have the simulated time match the clinical scenario. This is where realism and time constraints can become an issue, especially if the learner, faculty, or full-time staffer has a time constraint. Simulation environments rely on quick access to accurate

information for effective analysis and decision-making in a designated time frame. Therefore, it is essential to address quality issues and ensure that the integrated EMR data is reliable and complete. Adequate support needs to be given to the instructional EMR system for appropriate skill transfer and application to occur. This gap is difficult to bridge as technology rapidly advances in the healthcare field (Lucas, 2010).

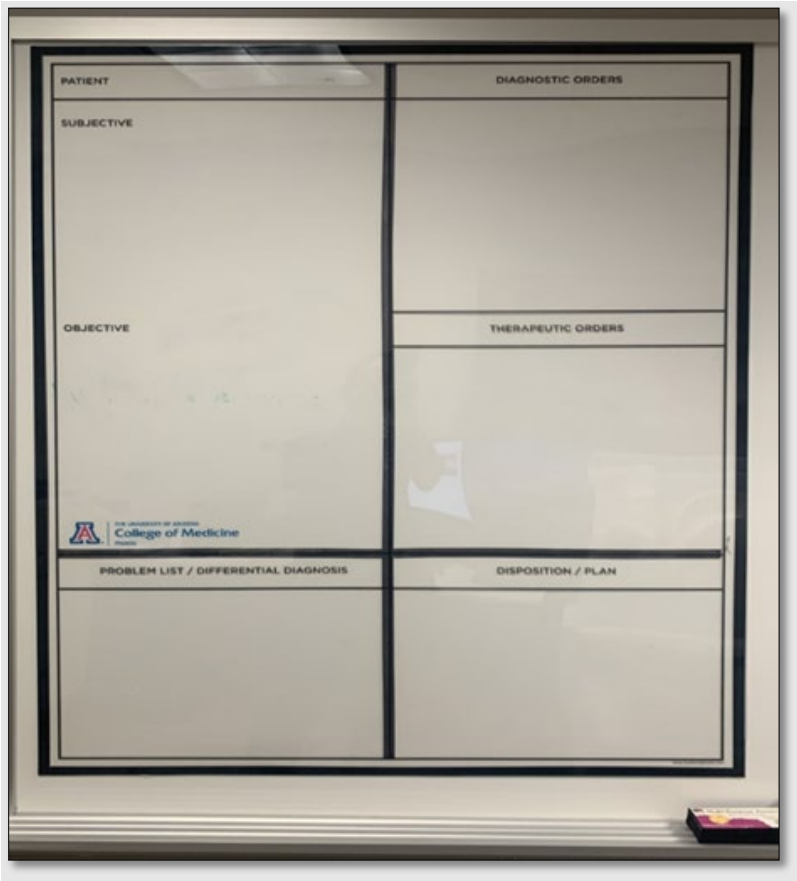
Though EMR integration into healthcare academia is challenging, Mollart, et al. suggests an adjustment in teaching loads to better accommodate learning for new technologies (2020). We considered implementing improvements in communication and thought processes to take priority in a medical learner's skill before taking on the technology portion. This allowed us to come up with a simulated instructional EMR system with removed challenges, lowered costs, and improved ease of customization. This simulated EMR system is customized for medical learners but can definitely be molded to fit other healthcare disciplines.

Methods

To determine the content needed to create a simulated medical record solution for our center, our curricular co-directors reviewed learning objectives established by the College of Medicine's curriculum committee. Key elements were distilled to create a simple documentation format. The components of a standard history and physical, along with the ability to generate a differential diagnosis were considered important. In addition, order entry for both diagnostic and therapeutic interventions were prioritized. Finally, the ability to document a plan for treatment and disposition were needed. The SOAP Note (Subjective, Objective, Assessment and Plan) method (Podder et. al., 2022) was reviewed as providing many of these components, however, it lacked order entry. We determined that creating a custom template incorporating these elements would work best for our purposes. The sections in the template correspond to the Subjective (historical data), Objective (vital signs, physical exam and applicable diagnostic data), Differential Diagnosis, Diagnostic Orders, Therapeutic Orders, Assessment and Plan elements. With the limited amount of time available to run our simulation scenarios, we wanted a quick and straightforward way to implement the template. Since the simulation rooms already had white boards available, we determined that a magnetic overlay printed with sections would be easy to incorporate (see Figure 1).

(Continued on next page)

Figure 1: Simulation Medical Record Template with University Branding



We generated a graphic representation of our template according to the specified criteria (Subjective, Objective, Problem List/Differential Diagnosis, Diagnostic Orders, Therapeutic Orders, Disposition/Plan). These criteria are adaptable to fit the requirements of other health professional disciplines. Subsequently, we engaged a vendor, Visual Workplace Inc. in Byron Center, MI, to produce our template on transparent plastic with magnetic backing. The template was then attached to a whiteboard in each one of our simulation training rooms. Since our simulation instructors are normally located within a control room during simulation sessions, we needed a way for them to easily view the content written by the learners. We also wanted a way to save the information to allow for review in debriefing.

The Kaptivo® whiteboard capture system was identified as being cost effective and easy to incorporate into our existing equipment (Lifesize Austin, TX). The Kaptivo® system consists of a telescoping camera mount, that when coupled with a proprietary network integrated encoder, will record and digitize any writing onto the surface of the template/whiteboard (See Figure 2.1 and 2.2). The content is captured and presented on a computer monitor, accessible through a shared hyperlink, this can enable simultaneous viewing on multiple devices (See Figures 3.1, 3.2 and 3.3). Using appropriate network permissions, the content can also be viewed remotely over an internet connection. Using a sharing link, a learner participating in a simulation session remotely can view the digital whiteboard for real-time collaboration. The Kaptivo® software solution allows users to print out a copy of the board contents as well as to save the content as a pdf. Optical Character Recognition (OCR) software within Kaptivo® can also convert handwritten notes into printed text if desired. Text can also be translated into other languages.

Figure 2.1: Kaptivo® Camera Mount with Network Input

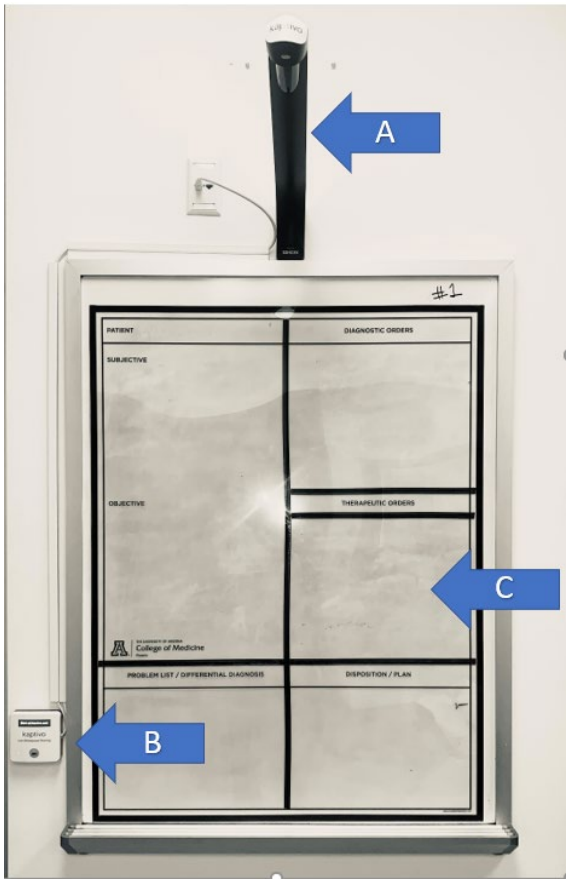


Figure 2.2: The start/end session button (B) turns on the telescopic camera (A) that captures the information on the whiteboard overlay template (C).

Figure 3.1: As the learner writes on the template (A) inside the simulation room, the notes are digitized and can be viewed live on a computer browser (B) by the faculty in the control room.

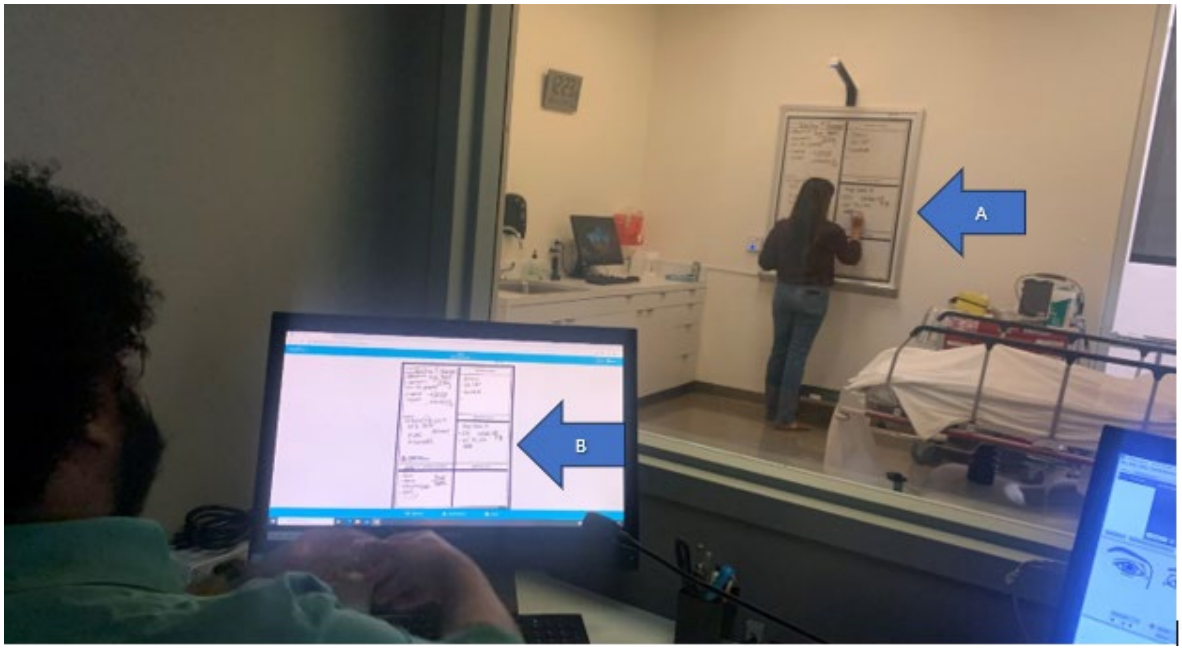


Figure 3.2: Learner written notes

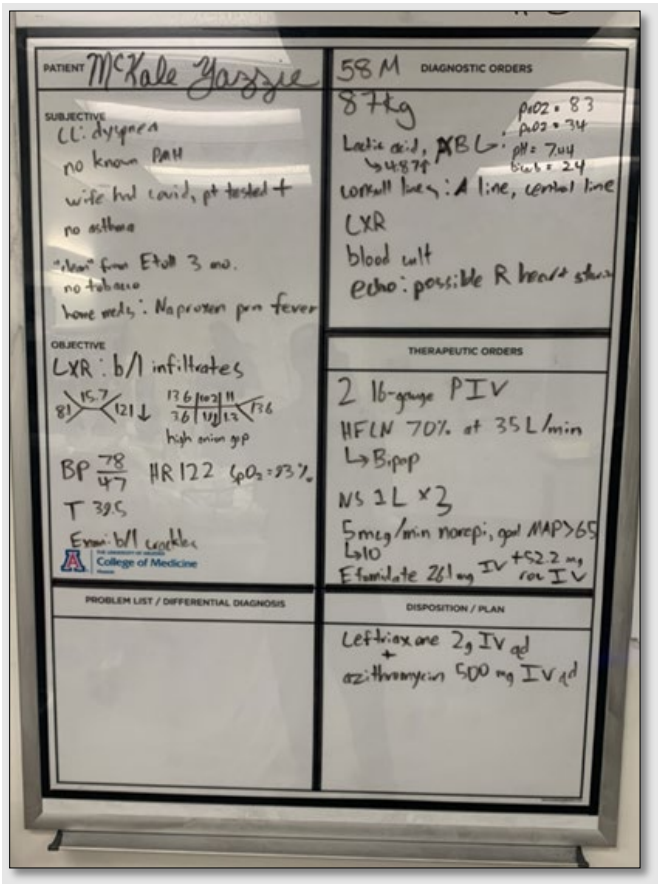
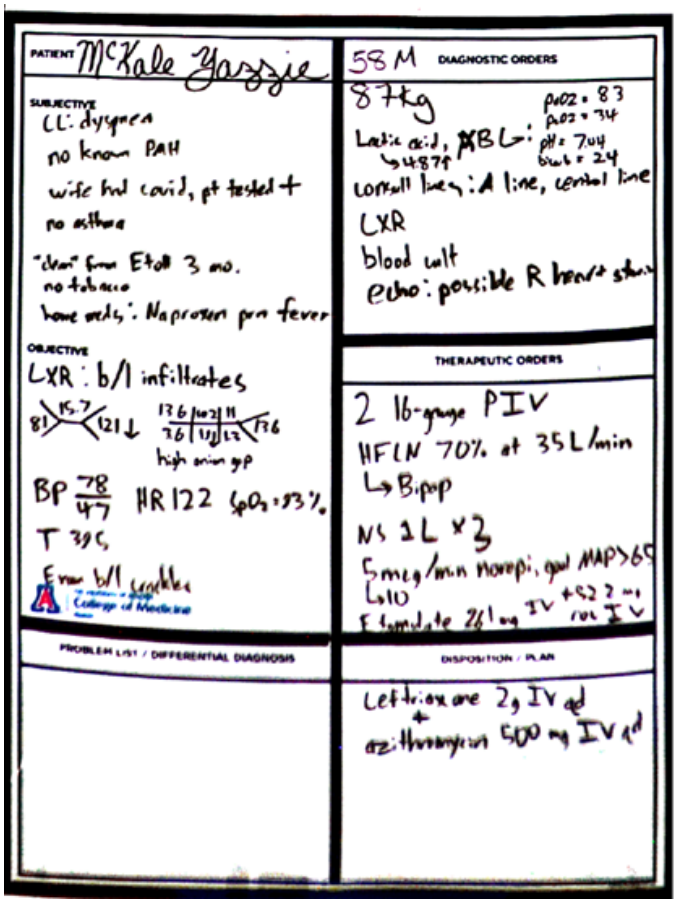


Figure 3.3: Kaptivo® digitized format



Total production cost per room for our simple medical record solution (consisting of a magnetic steel whiteboard, custom printed magnetic overlay template and Kaptivo® camera) are as follows:

Table 1: Estimated Production Cost

Item Description	One Time Cost	Ongoing Cost
Kaptivo® Whiteboard Camera	$395	
Annual enterprise subscription for web browser access, remote access, fleet management and handwriting recognition (OCR) software (Optional)		$280
Magnetic overlay	$140	
Magnetic 4x3'white board	$170	
Total Estimate	$705	$280
Total Cost	$985	

For setup, the camera was added to the university network allowing access from any browser. Other local configurations are available if network restrictions are in place. Our I.T. department and simulation technicians were able to easily complete the installation once the hardware and software was acquired.

An additional enhancement we are currently pursuing is to add an extra encoder to our video capture system. This will allow the whiteboard notes to be incorporated along with other video windows into our simulation recordings. This will ensure that all patient interactions, vital sign monitor/changes and whiteboard medical records will be captured and rendered onto one multi-view screen. This in turn will make review, debriefing and assessment as user friendly as possible.

Results

The implementation of our medical record solution has helped guide our learners through a standard patient interaction. It provides a template for the acquisition of pertinent history and physical exam findings. We are finding that students are capturing better histories and physical exam findings. Furthermore, the use of the system provides a place for real-time order entry of diagnostic and/or therapeutic interventions. This has allowed our interprofessional providers (e.g. nurse presence or other allied health) in our simulations to require orders to be written, before carrying out the directives. This mirrors a real clinical environment and reinforces good practice. The template has also guided the generation of a differential diagnosis. This has helped uncover the thought process of the learners as they progress through the simulation scenario. Finally, by requiring an assessment and plan, the simulated EMR guides the learners to decide on a proper disposition and any necessary consultations needed to treat the patient.

Cost

As shown above, the cost for implementing our simple medical record system is very low compared to a bonified electronic medical record. This makes it attainable for most simulation centers.

Time Constraints for Use in Training

The Kaptivo® whiteboard does not require the amount of time for set-up or implementation training that a standard EMR needs. This simulated EMR system was introduced, and expectations were reviewed with our learners during a student pre-brief before the simulation took place. Medical learners were allowed to see the template and ask questions regarding their expectation in use and thought process assessment. Our full-time staff and faculty were introduced to the simulated EMR system in faculty preparation sessions and staff training. The estimated time for this was 15 minutes for staff and educators and about 5-10 minutes for learners during their first exposure.

Complexity of Customization

Our simple Kaptivo® whiteboard medical record is a set template. As such, it does not allow customization once the template elements are chosen. Individual simulation programs can alter the template structure as needed to better fit their needs prior to production of the overlay. We utilize computers with simple files that our interprofessional staff members open to provide the stimuli required for cases (labs, ECG, imaging, etc.). This allows customization to a degree, although it is not integrated into our medical record solution.

Our experience since implementing this system has found that our teams of learners communicate better by having a single point of documentation/order reference. The team leaders delegate a team member to scribe the documentation and order entry. By having this information easily viewable, our educators are better able to follow the clinical scenario unfold

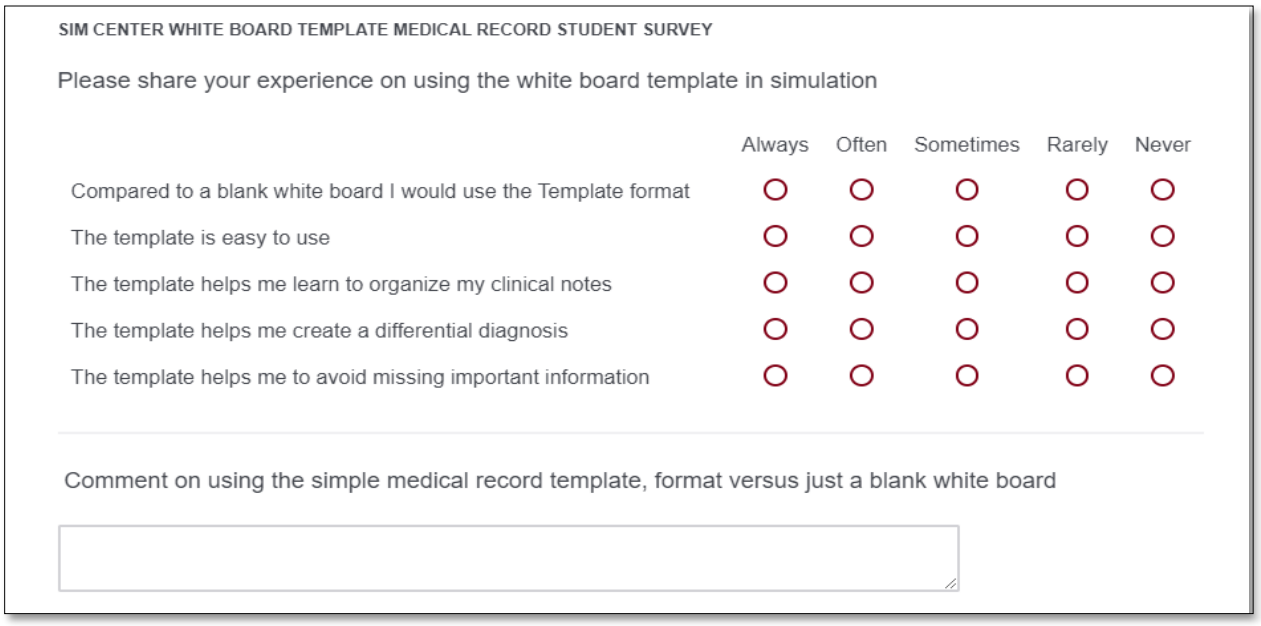
and the thought process of the learners for later debriefing. With the ability to take a snapshot of the information documented during simulation, the educator can target critical teaching points. Learners can use the provided feedback to better improve their documenting methods in preparation for when introduced to hospital EHR systems during clinical rotations or graduate medical education (GME).

Overall, the solution has supplied a pivotal advancement in our simulation activities. Prior to use, critical elements such as checking allergies before administering medications have, at times, been missed. Now learners and interprofessional providers can refer to the "chart" to see if there are contraindications and to make sure that desired orders are documented and communicated with the entire team in the room.

Assessment Instruments

To evaluate the subjective effectiveness of the white board template in our simulation we created a questionnaire for our students and faculty using a 5-point Likert scale (See Figure 4.1 and Figure 4.2). Questionnaires were distributed using a QR code and submitted anonymously to our simulation students and faculty.

Figure 4.1: White board template survey.



SIM CENTER WHITE BOARD TEMPLATE MEDICAL RECORD STUDENT SURVEY

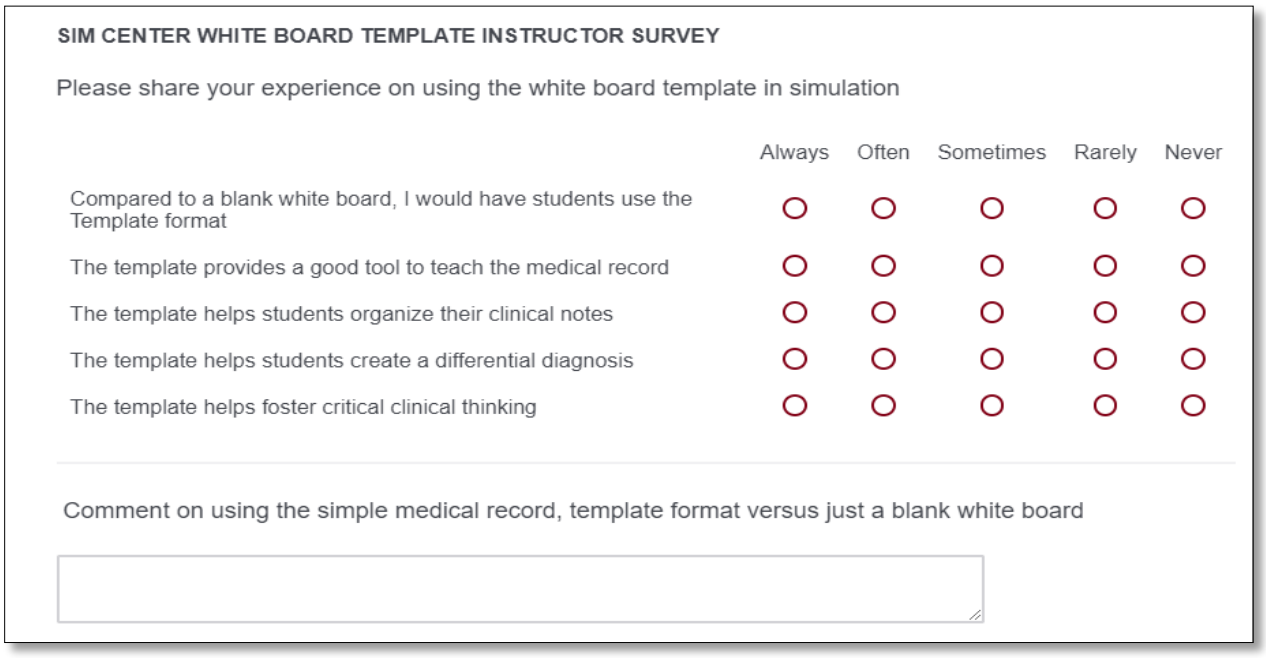
Please share your experience on using the white board template in simulation

	Always	Often	Sometimes	Rarely	Never
Compared to a blank white board I would use the Template format	○	○	○	○	○
The template is easy to use	○	○	○	○	○
The template helps me learn to organize my clinical notes	○	○	○	○	○
The template helps me create a differential diagnosis	○	○	○	○	○
The template helps me to avoid missing important information	○	○	○	○	○

Comment on using the simple medical record template, format versus just a blank white board

(Continued on next page)

Figure 4.2: White board template survey.



SIM CENTER WHITE BOARD TEMPLATE INSTRUCTOR SURVEY

Please share your experience on using the white board template in simulation

	Always	Often	Sometimes	Rarely	Never
Compared to a blank white board, I would have students use the Template format	○	○	○	○	○
The template provides a good tool to teach the medical record	○	○	○	○	○
The template helps students organize their clinical notes	○	○	○	○	○
The template helps students create a differential diagnosis	○	○	○	○	○
The template helps foster critical clinical thinking	○	○	○	○	○

Comment on using the simple medical record, template format versus just a blank white board

We conducted surveys of our learners (N=19) and educators (N=9) and the results show that a majority of students found the simple Kaptivo® whiteboard medical record was: easy to use (84%), helped them organize their clinical notes (74%) and helped avoid missing important information (58%). Most students would choose to always and often use the solution versus an untemplated white board (84%). Most of our faculty surveyed indicated that they: would have students use the simple medical record (89%) of the time, versus the previous practice of a blank white board. Most of the faculty respondents (89%) agreed that the template provides a good tool to teach the medical record and helps students organize their clinical notes (See Figure 5.1 and 5.2).

Figure 5.1: Graph displays instructors feedback after using the whiteboard template (N=9)

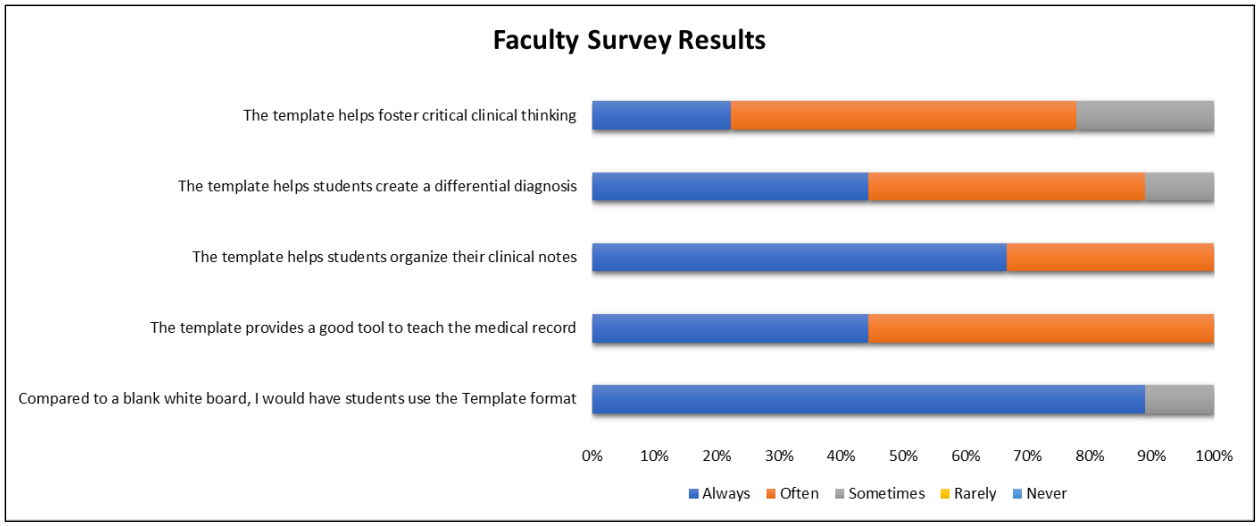
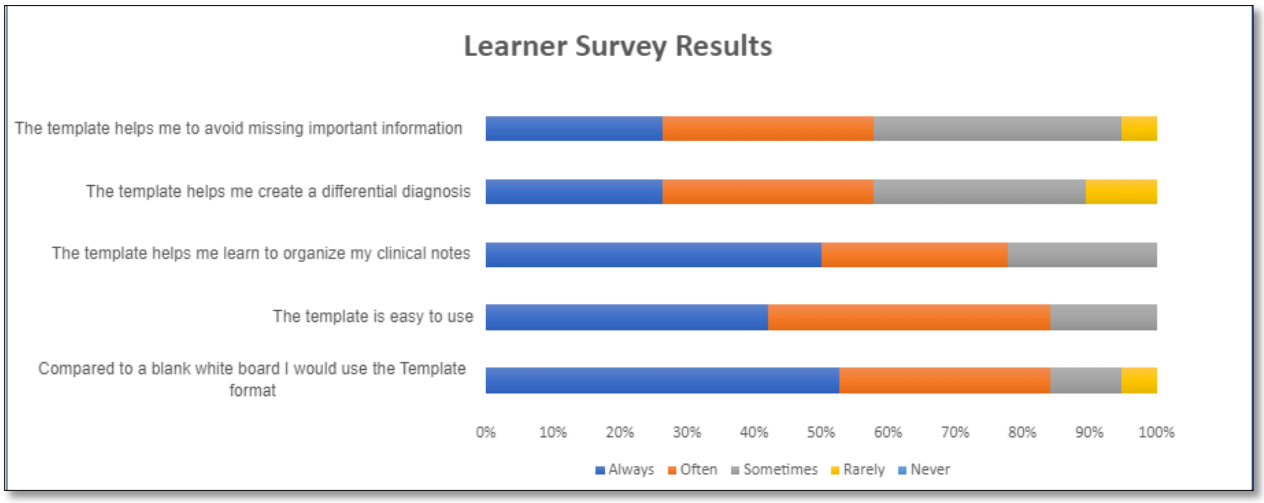


Figure 5.2: Graph displays leaner's feedback after using the whiteboard template (N=19)



Discussion

The incorporation of our simple Kaptivo® whiteboard medical record has led to a dynamic and immersive learning experience for both our learners, educators, and simulation staff. By providing learners with a platform to practice entering orders and to document patient information, learners have the potential to gain experience and critical thinking skills that can be seamlessly translated to other traditional electronic EMR systems in the future. This practice not only aids in sharpening learner communication, but it also helps them gain a deeper understanding of healthcare-related decision making in a team-oriented environment.

With all the positive aspects of implementing our simulated EMR solution, we have also seen certain limitations. The solution does not replicate the complexity of a traditional EMR system. It lacks alerts and parameters that would normally help to keep the patient safe, such as flagging inappropriate dosing of medications. Nevertheless, with its limitations, our system has proven to be an effective approach to a simulated patient record which can be captured electronically and incorporated into a video capture system.

References

Chung, J., & Cho, I. (2017). The need for academic electronic health record systems in Nurse Education. Nurse Education Today, 54, 83–88. https://doi.org/10.1016/j.nedt.2017.04.018

Fleming, N. S., Culler, S. D., McCorkle, R., Becker, E. R., & Ballard, D. J. (2011). The financial and nonfinancial costs of implementing electronic health records in Primary Care Practices. Health Affairs, 30(3), 481–489. https://doi.org/10.1377/hlthaff.2010.0768

Herrmann-Werner, A., Holderried, M., Loda, T., Malek, N., Zipfel, S., & Holderried, F. (2019). Navigating through electronic health records: Survey study on medical students' perspectives in general and with regard to a specific training. JMIR Medical Informatics, 7(4). https://doi.org/10.2196/12648

Kim, E., Rubinstein, S. M., Nead, K. T., Wojcieszynski, A. P., Gabriel, P. E., & Warner, J. L. (2019). The evolving use of electronic health records (EHR) for research. Seminars in Radiation Oncology, 29(4), 354–361. https://doi.org/10.1016/j.semradonc.2019.05.010

Lifesize. (2019, June 20). Lifesize Whiteboard Capture with Kaptivo. YouTube. https://www.youtube.com/watch?v=IHFTpfja3Cw%E2%80%AF

Lucas, L. (2010). Partnering to enhance the nursing curriculum: Electronic medical record accessibility. Clinical Simulation in Nursing, 6(3). https://doi.org/10.1016/j.ecns.2009.07.006

Manca, D. (2015). Do electronic medical records improve quality of care? Yes. PubMed, 61(10), 846–1. https://pubmed.ncbi.nlm.nih.gov/26472786

Mollart, L., Newell, R., Geale, S. K., Noble, D., Norton, C., & O'Brien, A. P. (2020). Introduction of patient electronic medical records (EMR) into Undergraduate Nursing Education: An integrated literature review. Nurse Education Today, 94, 104517. https://doi.org/10.1016/j.nedt.2020.104517

Shala, D. R., Jones, A., Alexander, N., Young, S., & Fairbrother, G. (2021). Responding to the challenge of a pandemic. CIN: Computers, Informatics, Nursing, 39(4), 171–175. https://doi.org/10.1097/cin.0000000000000735

Podder V, Lew V, Ghassemzadeh S. SOAP Notes. [Updated 2022 Aug 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK482263/

Evaluation of a Low-Cost, Innovative Radial Artery Catheterization Trainer

Authors

Jason E. Konzelmann, BS, M.Ed., NR-P, CHSOS, CHSE[1], Jonathan Titus, AS[2]

[1]University of Central Florida College of Medicine, Orlando, Florida
[2]DeSales University, Center Valley, Pennsylvania

Conflict of Interest Statement
The authors report no financial interest in the material presented here.

Corresponding Author
Jason Konzelmann, University of Central Florida – College of Medicine, Clinical Skills and Simulation Center, Orlando, Florida
(Email: jason.konzelmann@ucf.edu)

Abstract

Radial artery catheterization training is needed for acute care. It is used the world over in ICUs and other critical care units. They are placed in the radial, brachial, or femoral arteries. The commercially available trainers are expensive (ranging from $US700 to more than $US3,000), are more suited for arterial blood gas collection practice, and lack suitable anatomical accuracy. The trainer described here is cost effective, places the radial artery pulsations in an anatomically correct location, and accommodates a guide wire better using a long straight “artery,” addressing concerns faculty identified in prior years with other commercially available trainers. Initial usage of the prototype was with faculty and learners in a skills training for the Acute Care Nurse Practitioner course.

Methods

An existing, commercially available peripheral intravenous line task trainer was repurposed for this project. The latex veins were removed and replaced with a single latex tube secured in the anatomical location of the radial artery. A palpable pulse was achieved with the use of a syringe with a luer lock adapter.

Results

Learners completed a survey evaluating the anatomic and physiological fidelity after using the simulator. The learners highly recommended continued use of this model for training (mean = 4.6) learners in the procedure and identified radial artery location, ability to insert the guidewire, ability to insert the catheter, and overall anatomic accuracy as strengths of the model. Learner comfort notably increased from uncomfortable (mean = 1.8) to comfortable (mean = 4.2) after practicing radial artery catheterization on this model.

Conclusion

This novel, low-cost, radial artery catheterization task trainer is an effective task trainer for practicing the full procedure. The accuracy of anatomic location of the radial artery and the feel of the pulse even after multiple catheterizations makes this trainer superior to currently available commercial task trainers marketed for this purpose.

Introduction

Arterial lines are used for a variety of tests in ICU, PICU, NICU, CCU, and acute care settings. This lifesaving procedure is often employed when monitoring blood pressure (BP) more precisely than non-invasive BP monitoring (Pierre, et. al., 2023, Tegtmeyer, et.al., 2006, and Parandis, et.al., 2022) is needed, or frequent arterial blood draws are required (Tegtmeyer, et.al., 2006). Though complications are comparatively rare, successful first try completion can be as low as 50% (Prandis, et.al., 2022).

Wang, et al, identified arterial catheter insertion as a skill essential to the practice of the emergency physician (Wang, et al, 2008) at the EM Consensus Conference on the Science of Simulation in Healthcare. Nestel, et al, concluded that simulation results in increased knowledge and skill while the learner found simulation as a teaching tool to be highly satisfactory (Nestel, et al, 2011). Procedural skills training using training tools with the appropriate fidelity in comparison to real patients combined with the necessary anatomic and physiologic features to complete the skill being taught (Lefor, et al, 2020) allows for practice without risk to real patients, especially for skills requiring technical precision and higher patient risk (Wang, et al, 2008, Sagalowski, et al, 2016, and Sing & Restivo, 2023). The safe environment fostered in the simulation setting allows for repetition, reflective practice, nurturing feedback, and allows for skill acquisition at the pace of the individual learner to proceed to higher levels of competency, proficiency and mastery (Sagalowski, et al, 2016, and Sing & Restivo, 2023).

However, commercially available models for radial artery catheterization are costly, have debatable anatomic accuracy, and often require frequent changes to consumable parts to maintain the needed level of tactile fidelity. Commercially available trainers are also designed with short areas for catheter insertion leaving little distance or smooth pathway for the insertion of a guidewire, hindering realism and adding to the cost of practicing the procedure. The device designed and described here is less costly, repurposes materials likely already present in a simulation center, is easy to maintain, and virtually eliminates the pitfalls associated with the commercially available radial artery simulators. This design has also withstood dozens of punctures during the initial trial with comparatively little leakage and no continuous bleeding after catheter withdrawal.

Materials and Methods

An IV training arm that is no longer supported by the original manufacturer is used as the base of the trainer. However, obsolescence to recreate this model is not a requirement because this can be replicated on any IV training arm without compromising its intended purpose; the IV insertion points do not overlap with the location for radial artery catheterization and placement of the radial artery tubing as described later can be accomplished without interruption to the trainer’s venous flow. Supplies and costs are listed in Table 1.

(Continued on next page)

Table 1: Supplies and costs

Material	Manufacturer	Model Number	Number per Package	Package Cost	Number per Trainer	Cost per Trainer
IV training arm with skin	Limbs and Things	70300	N/A	No Cost*	1	N/A
3 feet of 1/4" OD, 3/16" ID latex tubing	QWORK	WD4650	33 feet	$ 11.95	3 feet	$ 1.09
2x2, 8 ply gauze pads	Covidien	REF2252	200	$ 5.40	~12	$ 0.35
Paper tape, 1/2"	McKesson	100192	24 Rolls	$ 50.15	~1/4 roll	$ 0.50
Hemostat clamp	Mabis	25-725-000	1 clamp	$ 4.18	1	$ 4.18
Luer Lock to 3/16” 4.8mm hose barb connector	RSN LLC	rsn095	10	$ 8.99	1	$ 0.89
60cc Luer Lock Syringe	Besmon Global	None Available	25	$ 20.95	1	$ 0.84
Total Cost**						$ 3.67
***Note*: Prices pulled from Amazon.com on 9/1/2023, prices may vary.**						
*** Used from previously purchased stock. Actual initial cost varies.**						
**** Total cost excludes hemostat which can be removed and used for other applications when simulator is not in use. Including the hemostat, total cost becomes $7.85.**						

Process

1. Remove the skin from the IV arm trainer. We removed the existing venous tubing to work with a fresh mandrel. Ultimately, this is not necessary as the process from this point on can be applied over the existing venous tubing depending on center needs when making the radial artery catheterization trainer. See Figure 1.
2. Measure the latex tubing. This should be long enough (approximately 3-4 feet in length) to have approximately 6 inches of tubing extend beyond the top of the skin once reapplied and run continuously down the anterior surface of the forearm, wrap around the finger area and back to the “shoulder” of the simulator. Tack into place with tape.
3. Align the tubing in the anatomic location of the radial artery – approximately at the base of the thumb running toward the antecubital fossa. The return track of the tubing should be placed in the anatomic location of the ulnar artery – anterior surface of the arm approximately at the base of the pinky. See Figure 2.
4. Take 2x2 gauze pads and fold in half. Align them along both sides of the radial artery with the folded side toward the artery. These help prevent the artery from collapsing once the skin is replaced, allow for the feeling of the soft tissue that is present in a real

arm to enhance the feeling, and help absorb internal leakage with successive cannulation attempts. Gauze pads should be approximately the same height of the tubing or fractionally higher. Repeat for the ulnar artery location. See Figure 2.

5. Secure runs of tubing in place in a straight line path with the tape. Use caution placing tape over the top of the palpable area of the radial and ulnar arteries; too much tape will reduce the pulsatile feeling later. Other areas proximal and distal to the radial artery palpation area can be secured more firmly, but not so as to pinch the tubing (use more gauze to ballast these areas if needed to prevent pinching). See Figure 2.
6. Insert the luer lock to hose barb adapter to the end of the tubing that travels first to the radial artery location. A zip tie may be used to secure the hose barb to the tubing; however, we did not find this to be needed.
7. Fill a 60cc luer lock syringe with sterile or distilled water that has been colored red with either food coloring or sufficient simulated blood. See Figure 3.
8. Evacuate remaining air bubbles from the syringe, attach to the luer lock adapter, and slowly fill the tubing. It is easiest to do this with the mandrel hand area lower than the shoulder to ensure all air bubbles are removed and the tubing fills uniformly. See Figure 3.
9. When the “blood” has filled both sides, pinch and clamp the return side with the Kelly clamp tightly to the third click, ensuring no air bubbles are trapped. The presence of large air bubbles reduces the pulsatile feeling because air is compressible as well. Minimizing these will enhance the learners’ experience of feeling a radial pulse which is essential to successful completion of the skill. See Figure 3.
10. Leave the syringe attached. There should be at least 20cc of “blood” remaining in the syringe. This is desirable because this is what will not only generate the pulse for the skill, but also replace blood that gets removed from the artery throughout the practice of placement. Add more “blood” to the syringe if there is less than 20cc of blood remaining once the system is clamped. See Figure 3.
11. Check to see that there is a palpable pulse over the radial artery. Do this by quickly compressing and releasing the plunger on the syringe. Repeat for the ulnar artery.
12. Ensure there are not any kinks or pinch points in the tubing before replacing the skin. Adjust as needed.
13. Replace the skin carefully. This can be facilitated with liberal application of standard liquid dish soap to the inside of the skin and to the stretch points on the mandrel such as the thumb area. See Figure 4.
14. Verify a pulse can be still be felt at the radial artery location now that the skin has been replaced using the same technique above. If the pulse is severely dulled, there may be too many or too few gauze pads in the area of the pulsation or that area may have been too tightly taped. Repeat for the ulnar artery. Consider these troubleshooting options:
    a. Too much tape over the radial artery: Cut the tape to loosen, careful not to cut the tubing.
    b. Too few gauze pads causing excessive compression of the tubing: Add more gauze.
    c. Too many gauze pads causing pulsation to not be transmitted through the skin: Remove some gauze pads in the area.

Figure 1: Mandrel removed from the overlying skin.

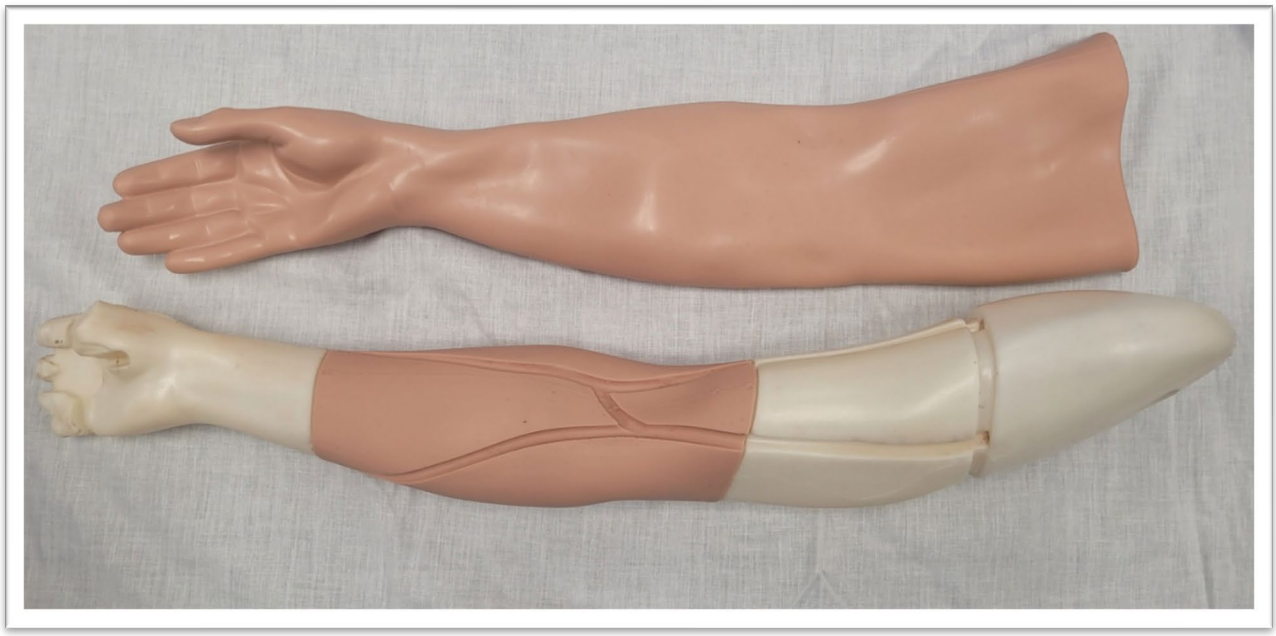


Figure 2: Radial artery in place with 2x2s and tape. Ulnar artery is hidden in this picture.

Figure 3: Line primed. Clamped at the top of the picture. Bottom of the picture shows the syringe connected to the luer lock to hose barb adapter in place with more than 20cc “blood” remaining after priming.

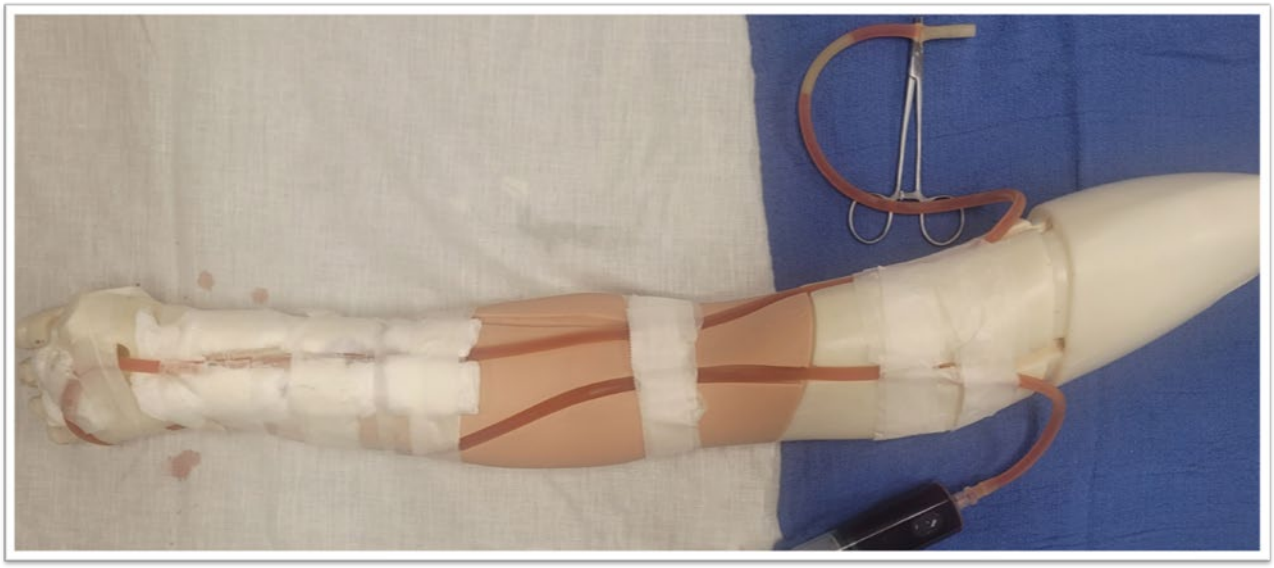
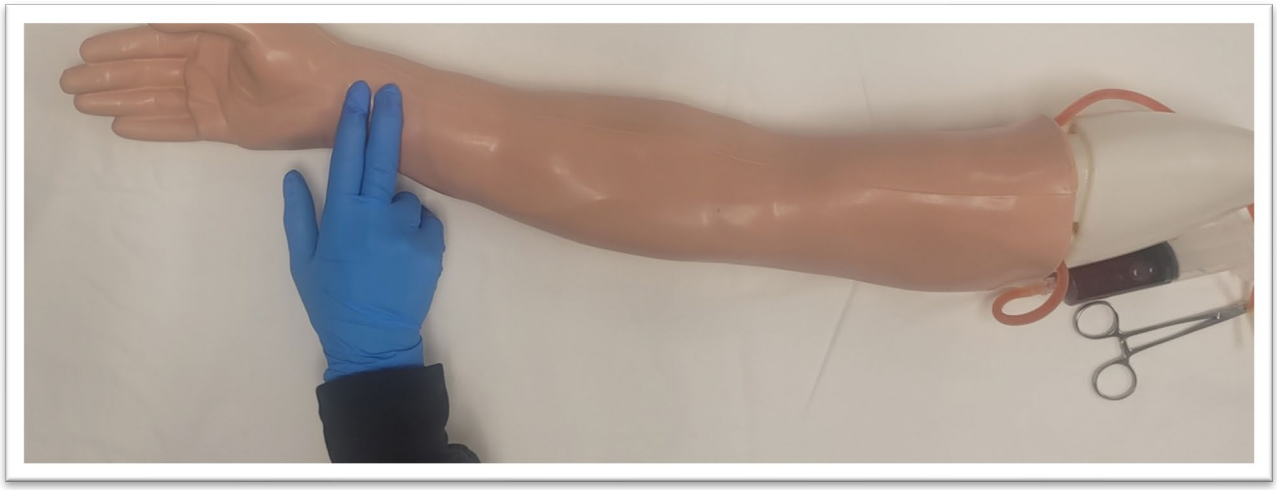


Figure 4: Final assembly showing location of radial artery.



Pilot Testing and Participants

The prototype of the radial artery catheterization trainer was pilot tested by five acute care acute gerontology nurse practitioner (ACAGNP) learners, and their instructor. The instructor is comfortable with the procedure of arterial lines and has been kept up to date on the process of creating this trainer. Learners have not performed this procedure prior to their experience with this trainer. The learners are clinically practicing nurses in acute care or emergency settings. The training occurred at one of six acute care skills stations during their acute care skills training day and attendance was required. Learners were required to practice the skill during the skills lab, however were not required to complete the survey. All learners

were anonymously, voluntarily consented according to DeSales University IRB approval number ET-88-04162023 to participate in this survey prior to the start of their skills station rotations. They completed surveys following their experience with the trainer. The five consented learners represented the entire cohort of this year's ACAGNP program.

Survey Development

The survey asked participants to rate several aspects of the realism of the trainer, their comfort with the skill before and after using the trainer, and whether or not they would recommend using this trainer for further practice of radial artery catheterization. The survey was reviewed for clarity by three experts in both simulation and radial artery catheterization. The data was summarized in a spreadsheet.

Results

The survey recorded learners' perception of realism on a 5 point scale ranging from Highly Unrealistic with a score of one through Highly Realistic with a score of 5. The five learners practiced with the trainer and all five completed a survey. The mean scores and standard deviation given can be found in Table 2. The learners rated the overall anatomic accuracy of the trainer as highly realistic with a mean of 4.6 (95%, CI = 4.11 – 5.08). The learners' comfort level increased by an average of 2.4 +/- 0.447 rising from an average of 1.8 (uncomfortable) before practicing to a 4.2 (comfortable) after using the model. The learners would overwhelmingly recommend continued use of this trainer with a mean of 4.6 +/- 0.54. Learners commented that this was very useful and worked great.

Table 2: Survey Results. n=5.

Question	Mean	Standard Deviation
1. Please rate the *location* of the radial pulse to that of a real person.	4.4	0.547
2. Please rate the *feel* of the radial pulse to that of the real patient.	4	0.707
3. Please rate the ability to insert the *needle* into the skin of the trainer.	3.6	1.140
4. Please rate the ability to insert the *guidewire* into the trainer.	4	0.707
5. Please rate the ability to insert the *catheter* into the trainer.	4	0.707
6. Overall, please rate the anatomic accuracy of this trainer.	4.6	0.547
7. Rate your comfort level initiating an arterial line *BEFORE* today?	1.8	0.447
8. Rate your comfort level initiating an arterial line *AFTER* today?	4.2	0.447
9. How likely would you be to use this trainer again for radial artery line practice?	4.6	0.547

Discussion

This trainer can be assembled in under an hour for less than $US5 per trainer and does not require specific technical skill to complete. An internet search indicated that radial artery catheterization trainers without ultrasound capabilities ranged in cost from $US700 - $US1,400 to over $US3,000 for ultrasound guided models.

We had all the supplies in house already for other course needs except the latex tubing and the luer lock to hose barb adapter. For trial purposes we also purchased silicone tubing in the same size as the latex. We opted for the latex because it transmitted the pulsations much more realistically and palpably than the silicone tubing. The pulsations felt using the silicone tubing were far too weak to be optimal for initial training, however, could be used when a weaker pulse was needed or for more advanced, experienced learners.

The trainer withstood an estimated 25 sticks over the course of the training day. At the conclusion of the day, the trainer did not leak externally during the application of pressure when providing the pulsations. The 2x2s inside were not saturated either, which could mean that internal leakage was limited, though it would be necessary to reevaluate this after more punctures were done on the trainer. Overall, this made cleanup easier, and learners were unlikely to be stained from the simulated blood.

In prior years, faculty noted that one other commercially available trainer lost palpable pulses after just two punctures. Since the pulse is essential to a realistic and successful training, this model required that the pulse be maintained with little to no loss in fidelity for all learners. This simulator still maintained a strong, palpable pulse when pressure was applied with the syringe. This indicates that larger classes or more sticks can be completed on this trainer in a relatively short period of time without an appreciable loss in anatomic fidelity. It can further be stated that this will reduce the overall cost of the trainer and training because it will require less frequent consumable supplies replacement.

Learners were able to get a blood flash in the radial artery catheter chamber which replicated a real experience over the entire day. This indicates proper placement of the needle within the vein and allows the instructor to stop the pulsations. Being able to stop the pulsations for the remainder of the procedure likely has the effect of extending the life of the simulator's current parts. Subsequently, this results in a cheaper simulator to maintain.

Faculty and learners identified the inability to float a guidewire as a confounding complication inconsistent with reality with other commercially available trainers in prior years. Using this trainer, learners were able to float the guidewire an appropriate distance into the vein because the arterial run was straight, and no kinking was observed at several points during assembly. The catheter also was able to be successfully inserted without folding through this skin in a realistic fashion.

The survey indicated the least satisfaction was with the ability to insert the needle into the skin. The researcher suspects this perception is similar to that experienced during the placement of a peripheral IV catheter in a similar trainer; however, more research would be needed. The simulator skin is necessarily thicker than that of the average forearm, particularly in the area over the radial artery at the point of insertion, and therefore presents a challenge to effectively replicate. That being said, the Limbs and Things skin for this model did not show an extensive amount of wear and was still intact, indicating that it could withstand further punctures before requiring replacement. This was of particular importance to a satisfactory design since the target area of the sticks is highly concentrated.

The presence of an ulnar artery in addition to the necessary radial artery is an added feature of this model that allows the learner to practice a component of the Allen test. The Allen test tests for collateral circulation from the ulnar artery and is performed by occluding both ulnar and radial arteries in the wrist observing for pallor to develop in the palm. The practitioner would then release the ulnar artery and, if collateral circulation is sufficient, the color returns to the palm despite continued occlusion of the radial artery (Tegtmeyer, et.al., 2006). An area of future improvement to this simulator would include the addition of a bright white LED light under the skin in the palmar area attached to pressure sensors near the radial and ulnar arteries to replicate the result of an Allen test. Occlusion of both arteries, and therefore activation of both pressure sensors, would illuminate the light, replicating the pallor. Releasing the ulnar pressure

sensor would dim the light, indicating return of collateral circulation, allowing the procedure to continue.

This simulator does not allow the procedure to be completed under ultrasound (US) guidance. This would be an area of future improvement, though would likely require an entirely different procedure rather than a simple modification to this process. US guidance for arterial line placement is increasingly becoming a standard of care, (Pierre, et. al., 2023) though the research seems to be conflicted on its utility (Zhang, et al, 2020).

Though the sample size of learners was small, it did represent this year's entire cohort, not much different in size than previous cohorts. This study can and should be replicated at larger institutions to further verify these assertions.

The survey results indicate that the users were satisfied with all aspects of the realism incorporated into this trainer. They noted that this trainer enhanced their confidence with the procedure and highly recommended it for continued future use. While all participants were clinically practicing nurses, the researcher did not determine prior experience with venous catheterization. Further, it is unlikely that any participants had ever floated a guidewire in either a simulated or real environment prior, indicating no basis of comparing the realism represented in this trainer relative to guidewire insertion. This represents an area for future evaluation from learners with experience in using a guidewire for catheter insertion to verify realism in this aspect. Although the faculty experts running this training indicated satisfaction of this trainer to address areas indicated above, it would further be of interest to have providers experienced in radial artery catheterization verify the overall utility.

Conclusion

The innovative, low-cost radial artery catheterization trainer created from an obsolete IV arm shows distinct promise as a viable alternative to more expensive commercially available trainers for radial artery catheterization. The trainer combines superior anatomic realism in the areas of location and feel of the radial artery, ability to insert the guidewire and catheter into the trainer and overall accuracy. Learners were able to increase their comfort and, by extension, confidence in performing the skill prior to entering the clinical environment and encourage the continued use of this model for repetitive practice.

Additional Information

This study was conducted in the DeSales University (DSU) Healthcare Simulation Center (Gambet Center 2755 Station Ave. Center Valley, PA 18034) when the author was employed there. The DSU IRB adjudicated this study as no more than minimal risk to study participants. The researcher identifies no conflicts of interest in conducting or publishing this study. No financial support was received to conduct this study.

References

Lefor AK, Harada K, Kawahira H, & Mitsuishi M. (2020). The effect of simulator fidelity on procedure skill training: a literature review. International Journal of Medical Education, 11, 97-106. https://doi.org/10.5116/ijme.5ea6.ae73

Nestel D, Groom J, Eikeland-Husebø S, & O'Donnell JM. (2011). Simulation for learning and teaching procedural skills: The state of the science. Simulation in Healthcare, 6(7), S10-S13.

Parandis O, Bitterman L, Park KH, Ernest S, Russell A, Bengiamin DI, & Young, TP. (2022). Arterial line placement pitfalls can be demonstrated and visualized with an inexpensive, wearable trainer. Journal of Emergency Medicine, 62(2), 210-215.

Pierre L, Pasrija D, Keenaghan M. (2023). Arterial Lines. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. Retrieved May 3, 2023, from https://www.ncbi.nlm.nih.gov/books/NBK499989/

Sagalowski ST, Wynter SA, Auerbach M, Pusic MV, & Kessler DO. (2016). Simulation-based procedural skills training in pediatric emergency medicine. Clinical Pediatric Emergency Medicine, 17(3), 169-178.

Singh M, & Restivo A. (2023). Task trainers in procedural skills acquisition in medical simulation. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. Retrieved May 3, 2023, from https://ncbi.nlm.nih.gov/books/NBK558925

Tegtmeyer K, Brady G, Lai S, Hodo R, Braner D. (2006). Placement of an Arterial Line [Video]. New England Journal of Medicine. Retrieved May 5, 2023, from https://www.youtube.com/watch?v=IRHqAl8OSkY

Wang EE, Quinones J, Fitch MT, Dooley-Hash S, Griswold-Theodorson S, Medzon R, Forley F, Laack T, Robinett A, & Clay L. (2008). Developing technical expertise in Emergency Medicine – The role of simulation in procedural skill acquisition. Academic Emergency Medicine, 15(11), 1046-1057.

Zhang W, Li K, Xu H, Luo D, Ji C, Yang K, & Zhao Q. (2020). Efficacy of ultrasound-guided technique for radial artery catheterization in pediatric populations: A systematic review and meta-analysis of randomized controlled trials. Critical Care, 24(1), 197. https://doi.org/10.1186/s13054-020-02920-8

Virtual Reality: Emerging Technology in Vascular Access Education and Training

Author

Dagoberto Salinas, MSN, ACCNS-AG, CNOR, VA-BC [1]

[1] MGH Institute of the Health Professions, Boston, Massachusetts

Conflict of Interest Statement

I have a financial interest in SimX, a company that provides virtual reality medical simulation solutions. I will receive royalties from SimX Medical for my contributions to their virtual reality simulation platform.

Corresponding Author

Dagoberto Salinas, MSN, ACCNS-AG, CNOR, VA-BC, MGH Institute of the Health Professions, Boston, MA
(Email: dagobertosalinasjr@gmail.com)

Brief Description

The dire need to educate and train more vascular access specialists in response to nursing shortages in the U.S. calls for innovative solutions that promote cost-effective, safe, and reliable educational practices. Although traditional training modalities are more prevalent in qualifying new vascular access specialists, they are expensive and have limited realism. Virtual reality (VR) has shown promising results in enhancing critical thinking and technical abilities in the health professions and can outperform traditional methodologies when strategically implemented. Augmenting traditional vascular access training with VR modalities, specifically in PICC and midline insertions, should be strongly advocated.

Introduction

Vascular access specialists are critical in supporting patient care in inpatient and outpatient healthcare settings. When properly trained, vascular access specialists can perform a variety of highly skilled procedures, including but not limited to peripherally inserted central catheter (PICC), midline, and ultrasound-guided intravenous insertions (Dabadie et al., 2016; Ostrowski et al., 2019). In the U.S., vascular access specialists insert approximately 2.7 million PICCs annually (iData Research, 2020). Ubiquitous healthcare staffing shortages, however, present a threat to maintaining pace with this effort. Estimates show that the nursing workforce will need to increase by 6% (203,000 positions per year) between 2022 and 2032 to adequately support the complex healthcare system in the U.S. (McKinsey & Company, 2023; Nicolaus et al., 2022; U.S. Bureau of Labor Statistics, 2023). These foreseen challenges will also impact the demand for qualifying more vascular access specialists.

PICC and midline insertions have become more prevalent in the U.S. because of the ease at which they are placed at the patient's bedside; however, there are inherent risks associated with these venous catheters, including venous thromboembolisms (VTEs) and central line-associated bloodstream infections (CLABSIs). To mitigate the risk of VTE and CLABSI, evidence-based practice (EBP) strategies must be adopted that not only help clinicians master the technical process but also assist in determining when it is clinically appropriate to perform these procedures (Chopra et al., 2022). Ideally, vascular access curriculums focusing on PICC and midline catheter education should integrate all elements of clinical competency to promote competency: knowledge, skills, and attitudes (Abich et al., 2021).

PICC Lines

PICC lines are long, soft, flexible vascular access devices (VADs) that are inserted in the antecubital fossa or upper arm (basilic, brachial, or cephalic veins) and terminate in the superior vena cava (above the heart). Two common indications for inserting a PICC include 1) prolonged infusion therapy (longer than two weeks) and 2) administration of irritating medications or solutions. PICC sizes range between 1.2 - 6 French in diameter and 8 - 65 cm in length (Coulter, 2022). PICCs are usually introduced via the modified Seldinger technique (MST), which entails advancing a catheter over an access needle and withdrawing the needle (Song et al., 2018). The Infusion Nurses Society (INS) recommends using "maximal sterile barrier precautions" for all PICC insertions (Coulter, 2022).

Midlines

Midlines are soft, flexible VADs inserted in the antecubital fossa or upper arm (basilic, brachial, or cephalic veins) and terminate below the axillary region. Midlines are considered peripheral access devices recommended for non-vesicant solutions smaller than 900 mOsm with infusion duration shorter than four weeks. Midline sizes range between 1.2 - 5 French in diameter and 8 - 20 cm in length. Like PICC placements, midlines are commonly inserted via an MST approach and require maximal sterile barrier precautions to prevent contamination (Coulter, 2022).

PICC and midline insertions require specialized education and training that imparts knowledge of anatomy, physiology, infusions, policies/protocols, and indications for VAD selection (CVC Healthcare, 2022). Traditional course curriculums for conducting PICC and midline insertion training consist of two segments: 1) didactic session and 2) hands-on practicum. Of these two segments, the hands-on practicum presents the most variation. It is known to be disorganized and unstructured (Kondrashova et al., 2020). Phantoms, animal and synthetic models, computer-based training, and cadavers are examples of modalities used in traditional PICC and midline training courses. Table 1 outlines the pros and cons of each training modality. Although each training modality offers a unique experience, they are limited in their ability to simulate a holistic clinical experience that covers pre-procedural, procedural, and post-procedural tasks.

Table 1: Pros and Cons of Simulation Training Modalities (Kondrashova et al., 2020).

PICC/midline training modalities	Pros	Cons
Phantoms	Easy to use	Lacks reality
Animal models	Considered useful simulators	Limited lifespan and lacks reality
Synthetic models	Realistic experience	Expensive
Computer-based training	Imparts knowledge	Unable to evaluate return demo
Human cadavers	Realistic experience	Rigid feel and potential hazard

Virtual Reality

VR technology emerged in the 21st century as an influential tool in the education of healthcare professionals. VR uses computer technology to immerse learners into simulated environments that are three-dimensional and interactive. Because of its ability to alter perception within the confines of a classroom, VR has gained popularity over traditional training methods in the health professions (Johnson, 2023). Studies have demonstrated VR's superiority

in improving healthcare professionals' knowledge and skills compared to traditional methods (Kyaw et al., 2019).

Adverse events associated with invasive procedures, such as central venous catheter insertions, are influenced by different patient conditions, anatomic variations, and unpredictable environmental stressors. Traditionally, the automatism of complex procedures is achieved through repetition using standard mannequins. However, this practice is not always practical. VR has shown strong practicality in enhancing clinical proficiency and patient safety by creating a more realistic and dynamic environment. Additionally, VR offers an advantage over traditional training with regard to cost, repeatability, and standardization capabilities (Savir et al., 2023). Through a mastery learning theory approach, VR can be leveraged to deliberately practice the essential skills needed in vascular access while maintaining cost-effectiveness (Pottle, 2019; Siddaiah-Subramanya et al., 2019).

Currently, VR simulation scenarios for PICC and midline insertions are unavailable in the marketplace. The unavailability of VR scenarios for vascular access training calls for developing an EBP-based VR vascular access curriculum with a robust simulation operations infrastructure. New VR technology can be successfully implemented by practicing interprofessional collaboration, carefully managing resources, referencing best practices for design, promoting the training of faculty and students, and sustaining a robust program evaluation process (Lie et al., 2023).

VR Clinical Scenario

VR PICC/Midline Simulation Template

To address the current competency gap that exists between the classroom setting and clinical practice, CLINSPEC Solutions, LLC invested in the development of a SimX VR vascular access curriculum that consists of two different simulation scenarios: 1) Establishing vascular access for long-term antibiotic therapy (PICC scenario) and 2) Establishing vascular access in a difficult intravenous access patient (midline scenario). The proposed VR simulation template design aligns well with INACSL best practices and intends to provide a roadmap for educators and operations specialists involved in training vascular access specialists. Figure 1 includes an example of a proposed template for a midline insertion.

The vascular access curriculum will also include key components that address assessment, debriefing, and program evaluation. The assessment plan will incorporate formative and summative elements to enhance knowledge, procedural skills, interpersonal communication, and professionalism (Kayingo & Hass, 2017). The debriefing tool is based on PEARLS principles, focusing on five basic steps: 1) setting the scene, 2) reactions, 3) description, 4) analysis, and 5) application/summary (Figure 2) (Bajaj et al., 2018). Lastly, program evaluation will be structured using two mixed methodologies: 1) Kirkpatrick's four-level evaluation model and 2) the CIPP (context/input/process/product) evaluation model (Frye & Hemmer, 2012). Assessment, debriefing, and program evaluation are critical components designed to complement the technical aspects of the VR simulation scenarios.

Figure 1: Debriefing Template for VR Vascular Access

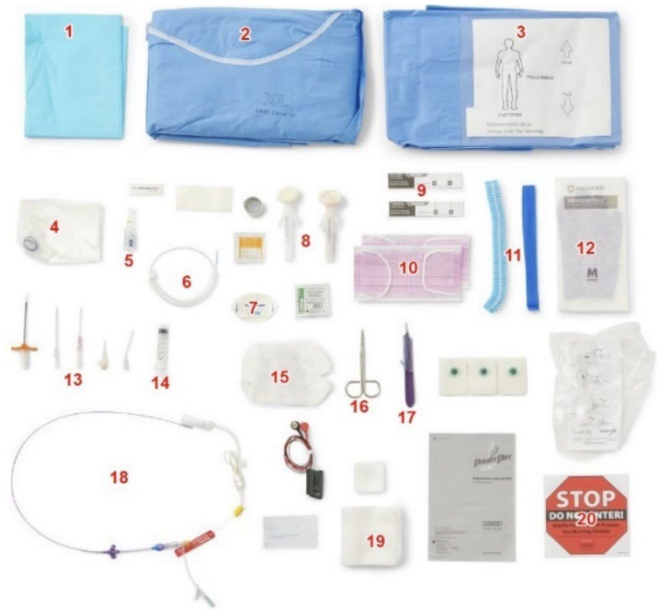
Debrief/Evaluation:
Debriefing will be facilitated by the moderator in person using the following outline:

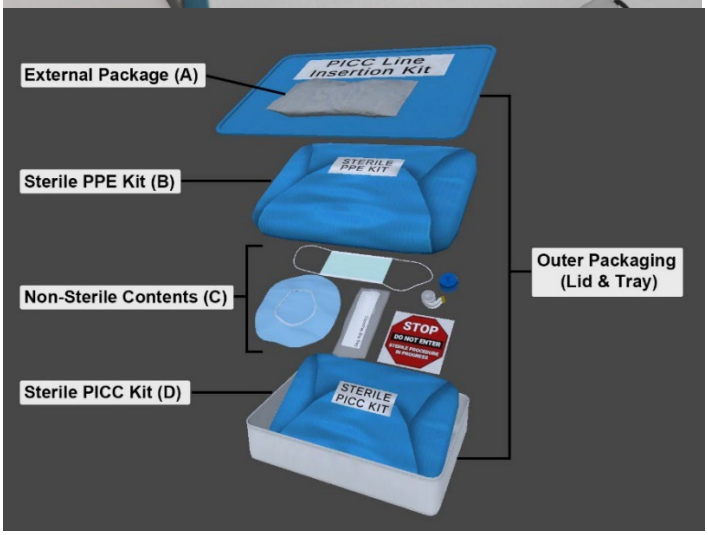
Phase	Inquiry/Script	Time allocation
Introductions	FACILITATOR: We are going to debrief together for about X minutes. During this time, I would like you to reflect on the VR scenario you just completed. I would like each of you to participate in the discussion. My role is to help facilitate, but not dominate the discussion. Before we begin, we should acknowledge that this was simulation, and we may have acted differently in real life. Now, let's focus our discussions on the process of care delivered to the patient.	5 min
Reactions	FACILITATOR: How are you feeling now that it's all over? Let's talk about how you determined which type of vascular access device would be most appropriate for this patient.	5 min
Understanding phase	FACILITATOR: [open-ended question]. What went well? What didn't go well? Specific safety learning point 1 (link to objectives) Specific safety learning point 2 (link to objectives)	10 min
Summary phase	FACILITATOR: So, to conclude, let's identify the key learning points from the scenario. What would you say are the 2-3 main take-home messages from the scenario?	5 min

Results

The proposed vascular access curriculum, which includes both PICC and midline scenarios, is expected to be released in Spring 2024 (Figure 2).

Figure 2: VR Simulation Environment and Supplies for Midline Insertion.





Discussion

VR simulation has gained significant popularity in the health professions due to its practicality – can virtually be used anywhere and at any time. Nevertheless, VR specifications must be defined clearly during its development to set realistic expectations (Kardong-Edgren et al., 2019). The upcoming release of the first-ever VR vascular access curriculum for PICC and midline insertions does not intend to replace traditional methods, but to augment them. Once released, the curriculum can be adopted by a variety of entities, including but not limited to vascular access education companies, healthcare facilities, and academic institutions. Its ground up software development will allow for compatibility with any major VR headset brand, such as Oculus and Apple products (SimX VR, 2021).

The integration of evidence-based decision-making tools like the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) within the proposed VR vascular access curriculum represents a significant advantage. This special feature addresses the crucial imperative to minimize risks associated with venous catheterization in clinical settings, specifically with PICC and midline insertions. While the primary aim of the curriculum is to enhance the qualification of vascular access specialists, its versatility also makes it a valuable resource for maintaining and advancing the clinical competencies of seasoned healthcare professionals. This innovative approach not only contributes to the growth of skilled practitioners but also ensures a sustained commitment to patient safety and quality care in the realm of vascular access.

Limitations

The use of VR simulation can be associated with cybersickness, dizziness, and nausea, which are common challenges that need to be addressed for a more seamless user experience (Park & Lee, 2020). Also, it is essential to note that the absence of haptic feedback in this product underscores the importance of considering traditional modalities as alternative methods for psychomotor skills training. Despite the lack of haptic feedback, the benefits of VR in facilitating comprehensive assessments cannot be overlooked. VR proves to be a valuable tool for integrating various aspects of learning and skill development, and its learning outcomes are comparable to those of high-fidelity simulation (Abulfaraj et al., 2021; Plotsky et al., 2021).

Future Implications

Piloting the forthcoming PICC and midline catheter insertion VR scenarios is the next step in quantifying the impact of VR in vascular access education and training. Allowing subject-matter experts to beta test the VR vascular access curriculum will further refine the proposed simulation template and serve as a roadmap for longitudinal studies exploring different outcomes (e.g., procedural confidence, time-to-insertion, appropriate vascular access device selection, success rates, etc.).

To address stakeholder concerns related to cybersickness, simulationists must advocate for VR headsets that optimize interpupillary distance fit and reduce audio/visual latency. These headset technical capabilities are known to be superior in newer headset models. Other stakeholder considerations include IT systems and support, logistics and infrastructure, and leadership engagement (Stallo et al., 2024). Consumers should consider the following when deciding if VR is a viable option in their organization:

1. Is VR an appropriate modality for addressing your existing education and training gaps?
2. Are there any infrastructure limitations in your simulation center? (e.g., recommended space is 12’x12’ and must have good internet connectivity)
3. Does your budget permit the purchase of VR headsets and licenses? If not, have you considered grants, partnerships, donations, etc.?

4. Will your leadership support the potential need to hire/contract a VR implementation consultant?

The PICC and midline catheter insertion VR scenarios discussed in this work are the first of its kind. CLINSPEC Solutions is unbiased towards any developer and disclosed its partnership with SimX as an ethical consideration and not for marketing purposes. The key take-away is that immersive VR modalities have the potential to shape the future of vascular access specialist education and training when strategically implemented.

Conclusion

A well-designed VR vascular access curriculum that incorporates EBP guidelines, assessment methods, a debriefing plan, and program evaluation will be vital to the success of future vascular access education and training programs. Pilot testing this initiative will help guide future research efforts that aim to optimize and standardize vascular access clinical competencies worldwide. The benefits of VR use in vascular access training outweigh its haptic feedback limitations. In the meantime, mixed methods that combine traditional methods with immersive VR should be explored to offer the full experience.

References

Abich IV, J., Parker, J., Murphy, J. S., & Eudy, M. (2021). A review of the evidence for training effectiveness with virtual reality technology. Virtual Reality, 25(4), 919-933.

Abulfaraj, M. M., Jeffers, J. M., Tackett, S., & Chang, T. (2021). Virtual reality vs. high-fidelity mannequin-based simulation: a pilot randomized trial evaluating learner performance. Cureus, 13(8).

Bajaj, K., Meguerdichian, M., Thoma, B., Huang, S., Eppich, W., Cheng, A. (2018). The PEARLS Healthcare Debriefing Tool. Acad Med, 93(2), 336.

Chopra, V., O'Malley, M., Horowitz, J., Zhang, Q., McLaughlin, E., Saint, S., ... & Flanders, S. (2022). Improving peripherally inserted central catheter appropriateness and reducing device-related complications: a quasiexperimental study in 52 Michigan hospitals. BMJ quality & safety, 31(1), 23-30.

Coulter, K. (2022). Session 6: clinical theory, devices & placement. [Presentation]. Infusion Knowledge VA-BC Review Program.

CVC Healthcare LLC. (2022). Standards and recommendations. [Presentation]. PICC/midline insertion class: building vascular access teams and programs.

Dabadie, A., Soussan, J., Mancini, J., Vidal, V., Bartoli, J. M., Gorincour, G., & Petit, P. (2016). Development and initial evaluation of a training program for peripherally inserted central catheter (PICC) placement for radiology residents and technicians. Diagnostic and Interventional Imaging, 97(9), 877-882.

Frye, A. W., & Hemmer, P. A. (2012). Program evaluation models and related theories: AMEE guide no. 67. Medical teacher, 34(5), e288-e299.

iData Research. (2020, February 2). Over 2.7 Million PICC Line Insertion Procedures Are Performed Each Year in the US. iData Research. Retrieved from https://idataresearch.com/over-2-7-million-picc-line-insertion-procedures-are-performed-each-year-in-the-us/

Johnson, G. (2023). Incorporating technology in teaching: a current status overlook. Nursing Education: Accelerating Learning with Virtual Reality Simulations (pp. 11-14). Independently published.

Kardong-Edgren, S. S., Farra, S. L., Alinier, G., & Young, H. M. (2019). A call to unify definitions of virtual reality. Clinical simulation in nursing, 31, 28-34.

Kayingo, G., & Hass, V. M. (Eds.). (2017). The health professions educator: A practical guide for new and established faculty (pp. 199-203). Springer Publishing Company.
Kondrashova, T., Canaan, R., Gunn, B., Pazdernik, V., & Houser, J. J. (2020). Development of competency in needle-guided procedures through the use of soft-embalmed cadavers. Missouri Medicine, 117(5), 461.
Kyaw, B. M., Saxena, N., Posadzki, P., Vseteckova, J., Nikolaou, C. K., George, P. P., ... & Car, L. T. (2019). Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration. Journal of medical Internet research, 21(1), e12959.
Lie, S. S., Helle, N., Sletteland, N. V., Vikman, M. D., & Bonsaksen, T. (2023). Implementation of virtual reality in health professions education: scoping review. JMIR Medical Education, 9, e41589.
McKinsey & Company. (2023, May 5). Nursing in 2023. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/healthcare/our-insights/nursing-in-2023/
Nicolaus, S., Crelier, B., Donzé, J. D., & Aubert, C. E. (2022). Definition of patient complexity in adults: A narrative review. Journal of multimorbidity and comorbidity, 12, 26335565221081288. https://doi.org/10.1177/26335565221081288
Ostrowski, A. M., Morrison, S., & O'Donnell, J. (2019). Development of a Training Program in Peripherally Inserted Central Catheter Placement for Certified Registered Nurse Anesthetists Using an N-of-1 Method. AANA journal, 87(1).
Park, S., & Lee, G. (2020). Full-immersion virtual reality: Adverse effects related to static balance. Neuroscience letters, 733, 134974.
Plotzky, C., Lindwedel, U., Sorber, M., Loessl, B., König, P., Kunze, C., ... & Meng, M. (2021). Virtual reality simulations in nurse education: A systematic mapping review. Nurse education today, 101, 104868.
Pottle, J. (2019). Virtual reality and the transformation of medical education. Future healthcare journal, 6(3), 181.
Savir, S., Khan, A. A., Yunus, R. A., Rehman, T. A., Saeed, S., Sohail, M., ... & Matyal, R. (2023). Virtual Reality: The Future of Invasive Procedure Training?. Journal of Cardiothoracic and Vascular Anesthesia.
Siddaiah-Subramanya, M., Smith, S., & Lonie, J. (2017). Mastery learning: how is it helpful? An analytical review. Advances in medical education and practice, 269-275.
SimX VR. (2021). Features. Retrieved from https://www.simxvr.com/features/
Song, I. K., Kim, E. H., Lee, J. H., Jang, Y. E., Kim, H. S., & Kim, J. T. (2018). Seldinger vs modified Seldinger techniques for ultrasound-guided central venous catheterisation in neonates: a randomised controlled trial. British Journal of Anaesthesia, 121(6), 1332-1337.
Stallo, P.L., Kardong-Edgren, S., & Baumann, E.B. (2024). The Influence of Technological and Design Decision Factors on the Incidence of Cybersickness: A Systematic Review. [Manuscript in preparation]. Department of Health Professions Education. MGH Institute of Health Professions.
U.S. Bureau of Labor Statistics. (2023, September 6). Occupational Outlook Handbook: Registered Nurses. Retrieved from https://www.bls.gov/ooh/healthcare/registered-nurses.htm#tab-1

Appendix 1: VR Simulation Template for Midline Insertion.

Virtual Reality Simulation Template (Vascular Access – Midline Insertion)

Introduction:

Welcome to an immersive journey through time and space as we transport you to the core of healthcare. In this virtual reality simulation, you will have the unique opportunity to apply what you have learned in your PICC/midline insertion training course. As you don your VR headset and step into the patient's room, you will find yourself immersed in the clinical setting – ready to perform an advanced vascular access procedure, as appropriate. You will enter the patient's room and systematically progress through the scenario as you would in real life.

This VR simulation is not just a game; it is an educational journey that promises to ignite your curiosity, immerse you in patient care, and promote critical thinking. So, get ready to make a difference!

Training Space: This VR scenario is intended to be used by accredited PICC/midline training programs to evaluate learner performance.

Headset: Universal, wireless (Oculus, Apple, etc.)

Case Specification:

- Case Name: Establishing vascular access in a difficult venous access patient
- Case Language: English
- Author: Dagoberto Salinas
- Learner Population: Registered nurses and healthcare providers
- Room Size Recommendation: 15' x 15'
- Basic Case Overview:
    - A 67-year-old male is recovering (hospital day #4) in the intensive care unit (ICU) after being treated for sepsis, secondary to bacterial pneumonia. Four days ago, the patient presented to the ER with signs and symptoms of respiratory failure, including rales and decreased breath sounds over lung bases bilaterally. Chest x-ray showed significant consolidation in the superior segments of the left and right lower lobes. The patient's deteriorating medical condition led to endotracheal intubation, central line placement (non-tunneled, triple-lumen catheter in the right subclavian vein), and administration of intravenous sedation and vasopressors.

During interdisciplinary rounds in the ICU on hospital day #4, the team confirmed that the patient's clinical status had improved and they no longer required mechanical ventilation or vasopressors. The interdisciplinary team agreed to discontinue central line access upon obtaining a reliable peripheral venous access device (per facility's central venous catheter maintenance bundle guidelines). After four failed attempts to obtain a peripheral IV by ICU staff, the vascular access team was consulted for further evaluation. It was noted through ultrasound visualization that the patient had limited peripheral venous access, making it difficult to insert a standard peripheral IV. After completing the venous access evaluation, the vascular team recommended placement of a midline catheter considering the patient's difficult intravenous access history and need to maintain vascular access for six more days for completion of prescribed antibiotic regimen (IV ceftriaxone and azithromycin).

- Moderator Visible Case Description:
    - A 67-year-old male with recent diagnosis of septic shock secondary to pneumonia is now recovering and no longer in need of central venous access. Unfortunately, the nursing staff

were unable to establish peripheral IV access after several attempts. The learner will evaluate the patient, review medical history, and establish vascular access using the appropriate technique.

- Learning Objectives/Critical Actions:

    - After participating in the VR scenario, learners will be able to:
        - ❖ State two clinical indications for midline placement
            - The learner will have to identify the appropriate vascular access device to use for insertion based on the clinical scenario provided (e.g., PICC vs midline vs peripheral IV)
        - ❖ Identify the three appropriate vein site locations for midline placement
            - The learner scans anatomical sites on the upper arm with ultrasound to identify appropriate veins (basilic, brachial, or cephalic veins)
        - ❖ State three potential contraindications for midline placement
        - ❖ Demonstrate correct sequence for obtaining vascular access using Seldinger's technique
            - The learner will systematically insert the midline catheter per manufacturer's recommendations
        - ❖ Document with 100% accuracy all pre-procedural, procedural, and post-procedural interventions, per The Joint Commission standards for documentation
            - The learner will need to indicate that documentation has been completed

Pre-briefing:

- Pre-briefing will be performed in real time by the moderator in person and will include the following elements:
    - Orientation to both physical and VR environments, including VR controls
    - Expectations related to learners' involvement and performance
    - Length of scenario
    - Moderator's role in facilitating during VR scenario
- Link curricular objectives to safety/organizational/practice standards:

Environment:

- VR setting is programmed with vascular access equipment/supplies (e.g., hospital bed, PICC/midline supply cart, bedside table, ultrasound machine, etc.)

Tools:

- Midline insertion kit
- Ultrasound machine
- Supply Cart
- Bedside Table

Patient(s):

- Age
- Gender
- General appearance
- Medical specifications
- Patient case notes
- Starting position
- Dialogue

Other Characters:

- Character type in VR environment: Family members, medical staff (RN, RN assist, lab tech, x-ray tech, telephone operator), or other characters with in-person speaking or action roles important to the simulation. The nurse assistant will be played by another vascular access student, and then roles will be reversed so that each student participates as both an inserter and assistant.
- Age
- Gender
- Relationship to patient
- General appearance
- Expected actions character should be able to perform
- Dialogue

Electronic Medical Record:

- General EMR information
    - Name
    - Age/DOB
    - Gender
    - Weight
    - Language
    - ID#
    - Chief complaint
    - History of present illness
    - Medications
    - Allergies:
    - Labs:
    - Past Medical History:
    - Past Surgical History:
    - Family History
    - Social History:
    - Admission Diagnosis
    - Admission Department
    - Hospital Day #
    - Lab results
    - Imaging results

Case Flow:

- Once the moderator presses the "Start Case" button, the case will progress sequentially through the states (milestones) as the learner completes all the necessary steps for completing the skill. At any point, the moderator can choose to advance to the next state by pressing the "Advance State" button. Learners cannot return to the previous state if mastery has already been achieved. Learners must advance forward once a milestone has been completed.
    - Every case should have a "Start Scenario" state without any critical actions or dialogue. Only a "Start Case" moderator button will be available on the moderator's screen. This allows all headset users to load in before starting the actual scenario.

Lessons Learned – Implementation of a Simulation Equipment Loan Guideline at a Tertiary-Care Academic Health Sciences Center

Authors

Holly D. Sarvas, MEd[1], Kyle Mispel-Beyer, MSc[1], Alexander M. Wood, BScN[1]

[1]Health Sciences North, Simulation Lab, Sudbury, Ontario

Conflict of Interest Statement

The authors Holly D. Sarvas, Kyle Mispel-Beyer, and Alexander M. Wood have no conflicts of interest to declare.

Corresponding Author

Holly D. Sarvas, MEd, Health Sciences North, Simulation Lab, Sudbury, Ontario
(Email: simeducators@hsnsudbury.ca)

Abstract

A simulation laboratory (lab) is limited in the amount of hands-on education programs it can host at any given time because of both human resources and physical space. This means task trainers, manikins, or equipment go unused, despite educators being available to implement training that day. To combat an overburdened simulation lab's schedule, our team has developed an equipment loan program for educators to take advantage of available simulation equipment. Since this new program's inception in June of 2022, it has led to the education of hundreds of learners and staff on over 15 different skills, with minimal impact to equipment condition.

Introduction

Simulation-based education is a necessary modality for learners and healthcare professionals to achieve and maintain competence in skills, through deliberate practice and mastery learning (McGaghie et al., 2014; McGaghie et al., 2011). While many institutions support simulation, the equipment to simulate skills can often be expensive or complicated to reproduce (Qayumi et al., 2014), meaning these institutions may only acquire a few pieces of equipment to support 100s to 1000s of learners and staff. To ensure the integrity and longevity of equipment, simulation labs and their technicians are often tasked with the maintenance, well-being and safeguarding of equipment (Lowther & Armstrong, 2023). By being protective with the usage of simulation equipment, institutions can lessen costs and still promote hands-on learning. However, simulation staff cannot always oversee learner groups, and the human resources or the physical space available to them often limit them (Qayumi et al., 2014). This usually means that certain manikins, task trainers, or associated equipment goes unused. Unused equipment may still have been beneficial to instructors, preceptors, or other educators who would apply them to their learning sessions.

Simulation labs and their associated institutions need to balance the risk of equipment being misused or lost against the benefit of providing ongoing deliberate practice of skills in their organization. Legitimate risk exists with certain equipment being misused for patient purposes, or becoming damaged (Raemer et al., 2018). Legitimate benefits to staff, learners, and patients also exists from task trainers and simulation equipment being available just-in-time and just-in-place for hands-on learning (Donoghue et al., 2021; Lengetti et al., 2011). This article will

describe the success of a simulation lab's design and implementation of an equipment loan program and their year in progress. Included in the discussion are key considerations for safety of equipment, coordination, and maintaining rapport with educators.

Discussion

An Overview of our Simulation Lab

When implementing simulation equipment loan guidelines, the simulation lab team must consider the user base, and feasibility of the process within their individual center. The guideline described herein was implemented at a simulation lab that services a 415+-bed tertiary-care academic health sciences center, a medical school, and a regional certifications program. Our simulation lab is situated directly on the main campus of the hospital, with direct access to the inpatient units and emergency department. One floor below us is a dedicated learner center, with two classrooms and one meeting space specifically for medical, nursing, and allied health learners. Our conveniently located simulation lab was ideal for implementing an equipment loan program. We also had long-standing relationships with our Nurse Clinician forum, Clinical Placement Advisors, and medical school Program Coordinators to promote this process. At our facility, nurse clinicians act in the role of educators and coordinators of frontline nursing and allied health staff for certifications, skills, continuing education, and policy management.

Design of Guideline

Our equipment loan guideline was co-developed with the Simulation Manager, the Simulation Educators, a Simulation Technician, and the Simulation Lab Administrative Assistant. The guideline is three pages in length, with three appendices. The appendices reference a) the signing out log kept by our administrative assistant, b) the attestation form witnessed upon sign-out of the equipment, and c) the attestation form upon sign-in of the equipment. The wording of the guideline was specifically constructed to ensure the following 5 criteria:

1. **Equipment is not required at the Simulation Lab.**

   The first concern with loaning equipment is that the needs of external educators (i.e. borrowers) could conflict with the simulation lab's programs. This would result in sub-par simulations at the lab or the inability to meet key learning objectives because of the lack of coordination of supplies/equipment. To combat this concern, a strict requesting and sign-out process was implemented to avoid conflicts with simulation supplies. All requests are required to go through the internal simulation lab email stating: the specific equipment and quantity of equipment request, the exact timeframe for the loan, the exact location where the equipment is going, and the contact information of the borrower (see Appendix A). The borrower would then attest to this information again upon sign-out, with an obligatory signature. This process allowed our administrative assistant to cross-reference the loan request with scheduled programming (in consultation with a Simulation Technician, as required) to ensure no conflicts, while also giving our simulation lab the ability to retrieve the equipment if a last-minute need arose.

2. **Equipment is used and stored in a safe location.**

   The second concern with loaning equipment is the potential for it to be lost while on loan. To combat this concern, wording in the guideline restricts equipment to be loaned out for only small periods of time (2 hours to 48 hours), unless managerial approval is sought, to minimize the risk of equipment jumping from location to location. Additionally, the borrower must indicate the exact room in which the equipment will be stored while loaned out. The guideline also states that 'The borrower will ensure the equipment is in a location away from patients and visitors, or that it is monitored when in a space accessible to the general public'. Should the equipment be stolen or lost while

loaned out, liability is placed on the borrower, which encourages them to be mindful with the equipment.

3. **Equipment is used appropriately.**

The third concern is that the simulation equipment is used inappropriately, resulting in damage to the equipment, or allowing it to be misused for patient care purposes. As such, our department made it mandatory that educators are the only individuals who can sign out the equipment, not learners. Additionally, educators must be orientated to the equipment (i.e. task trainers, manikins) prior to sign-out to ensure appropriate usage. Borrowers must attest that they will provide sufficient instruction on the use of loaned equipment to their learner group prior to starting education. The borrower must also attest they are teaching the skill to best practice guidelines or organizational policy. Finally, the borrower will attest that under no circumstances will the equipment be used for patient care purposes (see Appendix B). A not-for-human use sticker (Foundation for Healthcare Simulation Safety, n.d.), is affixed to all equipment that could be inadvertently used for patient care purposes (i.e. IV pumps). As an additional safety consideration, our equipment is routinely serviced by our Biomedical Department in case a user error does occur, or the sticker falls off.

Our simulation center also determined that only certain equipment could be loaned to mitigate risk for misuse. This means only low-fidelity manikins and task trainers would be considered loanable. Our high-fidelity manikins, VR/AR task trainers, or otherwise complex equipment would not be loaned out to minimize risk for misuse, as any damage to this equipment or subsequent downtime would be costly and/or impact upcoming simulations. We also strongly encouraged loaning out our do-it-yourself task trainer models over commercial products that were purchased by our simulation lab (i.e. homemade wound care trainers, injection pads, etc.) if it did not compromise learning objectives. This decision was made because if the models were misused or lost, it was easier to reconstruct or replace than commercial task trainers on a tight budget.

4. **Equipment does not become damaged.**

The fourth concern is that the simulation equipment becomes damaged while outside the control of our department and simulation staff. To combat this, our department required the borrower to undergo orientation to the equipment alongside a Simulation Technician prior to sign-out. As noted above, the guideline clearly stated the equipment must be in a safe place at all times while away from the simulation lab. By attesting to our guideline, the borrower agrees that should the equipment become broken or otherwise unusable, they are to immediately contact the simulation lab. The equipment will either be immediately returned, or a Simulation Technician will be deployed to the area to assess the state of the equipment. With their attestation, the borrower takes on the liability of the equipment should damage be caused due to negligent use. Finally, on return of the equipment to the simulation lab, the borrower is agreeing to an inspection by a Simulation Technician to ensure the equipment is in working order.

5. **Maintain strong rapport with educators/borrowers.**

The final concern is that any misuse or abuse of the equipment loan process could cause tension or reduced rapport with borrowers upon further engagement with the simulation team for routine simulation programs. Balancing the potential cost of damaged or lost equipment alongside positive relationships with educators needs to be weighed for each individual simulation center. To minimize the risk of degradation of relationships with educators, our simulation lab added wording that explicitly stated that the equipment loan process is a privilege that could be revoked if used improperly. This statement, alongside the liability statement, set clear expectations and boundaries for

our educators to use the program responsibly. Mandatory orientation with equipment also resulted in a lessened risk for misuse of equipment. Finally, the strict adherence to the process by our administrative assistant and simulation team meant borrowers who might have abused the process were generally deterred through email communications or first use.

Changes to Internal Processes Due to Guideline

Only two minor changes needed to occur to our internal processes to implement this program. First, a binder was created with the sign-out log and attestation forms, which was managed by our administrative assistant. The log is uploaded on a bi-monthly basis to an Excel sheet stored on our internal simulation lab drive to keep metrics on the process. The final change was an Outlook folder that was added to our internal simulation lab inbox, along with calendar reminders, to track requests and correspondences between educators.

Revisions Made to Guideline Processes

Amount of equipment borrowed.

Initially, our simulation lab had not stated in our guideline a limit on the total pieces of equipment that could be borrowed at any given time. When prompted by a particularly sizeable ask for many different pieces of equipment, we limited the number of pieces each department/educator could loan out at a time to five; ultimately to minimize risk of misuse, misplacement, or conflict between our internal scheduled programs. This change has seen no concerns since integration.

Maximum length of time to borrow equipment.

As noted above, we started with a maximum of a 48-hour window to borrow equipment, unless simulation lab managerial approval was sought. This came into conflict with weekends or statutory holidays where educators may want to borrow on the Friday evening, over the weekend, or before operational hours on the Tuesday post-holiday. To combat this concern, we extended the window to a maximum of 72-hours. This change has not seen any concerns from our simulation lab or users.

Mitigating unsupervised equipment during preceptor borrowing.

As the academic year starts up, most academic institutions are interested in having their preceptors make use of our equipment loan program to supplement their clinical placement while they are on-site. The concern arose that not all preceptors have access to protected space to lock away equipment between their placement days, placing equipment at risk of being stolen or misused when not monitored by the preceptor. To combat this concern, we distinguished preceptor-educators from hospital-based-educators. Wording was placed in our guideline that states that preceptors can only borrow during times of placement unless a departmental supervisor has consented to locking away the equipment between placement days. We have yet to see the effects of this change.

A Year in Review - Implementation of a Loaning of Equipment Guideline

Since the inception of the equipment loan program described herein (June 2022 until September 2023), 60 pieces of equipment have been borrowed via 45 separate loaning requests by educators in the organization. The most common pieces of equipment borrowed include adult CPR manikins, IV insertion arms, airway insertion task trainers, and IV pumps. Equipment was loaned to inpatient and outpatient departments, operating rooms, nursing student groups, and resident learner settings. The median time for loaning was less than 1 day with 7 instances occurring for greater than 3 days. In only 3 instances were there issues that occurred with the loaned equipment. Two minor issues occurred with urinary catheter task trainers leaking, which was rectified with further educator orientation. One larger issue arose

when the neck of a nasogastric task trainer broke from a fall while on loan. This issue was rectified with Simulation Technician repairs, and it was determined that a charge/fee was not required of the borrower. Educators continue to request access to our equipment loan process, and our guideline is now integrated into our clinical preceptor onboarding orientation to further promote its usage.

Conclusion

As demonstrated herein, an equipment loan program can be instituted at a busy academic teaching hospital simulation lab with minimal disruption to concurrent programming, minimal risk to equipment and without compromising patient care. If a simulation lab wishes to implement a similar program within their center, they must weigh the benefits of supporting deliberate practice and mastery learning outside their walls alongside the risk of equipment damage, misuse, or loss. A strong rapport with educators at the institution will promote adherence to a loaning of equipment guideline, whilst proximity to patient centers and/or learning centers will promote feasibility of returning equipment in a timely manner. This process could potentially aid institutions that are facing high staff turnover, seeing larger learner cohorts, or looking to increase skills within their organization without the need for further funding, human resources, or physical space.

References

Donoghue, A., Navarro, K., Diederich, E., Auerbach, M., & Cheng, A. (2021). Deliberate practice and mastery learning in resuscitation education: A scoping review. Resuscitation Plus, 6, 100137.

Foundation for Healthcare Simulation Safety (n.d.). Labels. https://healthcaresimulationsafety.org/labels/

Lengetti, E., Monachino, A. M., & Scholtz, A. (2011). A simulation-based “just in time” and “just in place” central venous catheter education program. Journal for Nurses in Professional Development, 27(6), 290-293.

Lowther, M., Armstrong, B. (2023, May 1). Roles and responsibilities of a simulation technician. In StatPearls. StatPearls Publishing. Retrieved September 15, 2023 from https://www.ncbi.nlm.nih.gov/books/NBK558949/

McGaghie, W. C., Issenberg, S. B., Barsuk, J. H., & Wayne, D. B. (2014). A critical review of simulation-based mastery learning with translational outcomes. Medical education, 48(4), 375-385.

McGaghie, W. C., Issenberg, S. B., Cohen, E. R., Barsuk, J. H., & Wayne, D. B. (2011). Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. Academic medicine : journal of the Association of American Medical Colleges, 86(6), 706–711. https://doi.org/10.1097/ACM.0b013e318217e119

Qayumi, K., Pachev, G., Zheng, B., Ziv, A., Koval, V., Badiei, S., & Cheng, A. (2014). Status of simulation in health care education: an international survey. Advances in medical education and practice, 457-467.

Raemer, D., Hannenberg, A., & Mullen, A. (2018). Simulation safety first: An imperative. Simulation in healthcare : journal of the Society for Simulation in Healthcare, 13(6), 373–375. https://doi.org/10.1097/SIH.0000000000000341