Serious Gaming to Improve the Safety of Central Venous Catheter Placement

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ABSTRACT

Approximately 5 million central venous catheters (CVCs) are placed by physicians annually in the United States, with a complication rate of 15%.[1] Guidelines and recommendations are continually being established and updated regarding CVC placement.[2] While much has been done regarding training the technical skills of CVC placement using part-task trainers (i.e., mannequins), successfully finding and cannulating a central vein is but one part of the process. In fact, many steps designed to prevent untoward complications involve non-technical skills which are perhaps more important in training practitioners to safely place CVCs.

First in aviation and now in healthcare, practitioners are being trained in realistic and highly interactive simulated environments so they can learn not just technical skills , but the key management and non-technical steps which make their task safer.[3] One modality being used to improve performance is video gaming simulation, or "serious gaming." Gaming as a learning tool is being increasingly utilized in health care fields and can lead to better skill-based outcomes.[4] As such, we have developed a game based around the placement of CVCs that will be used as a new teaching modality in a pilot program for instructing residents in safe CVC placement.

Keywords:
Serious gaming, video game simulation, central venous catheter, transfer of learning, game-based learning

INTRODUCTION

Approximately 5 million central venous catheters (CVCs) are placed by physicians annually in the United States.[1] Regrettably, as with any medical procedure, complications occur. Several studies have approximated the complication rate from these procedures to range from 5%-26%.[5,6] Common complications include infection, pneumothorax, arterial puncture, thrombosis and embolism with rates that are often inversely correlated with clinical experience.[7,8] The subsequent costs of catheter-related complications are high, with a single catheter-related infection, for example, costing from $4000 - $56000.[9] Additionally, certain complications from improper placement of catheters are already affecting reimbursement rates of medical centers nationwide, placing additional value on proper placement.

Guidelines and recommendations are continually being established and updated regarding CVC placement in an attempt to minimize these complications, including the use of principles such as aseptic technique and antibiotic-coated catheters.[2] While much has been done regarding training the technical skills of CVC placement using part-task trainers (i.e., mannequins), successfully finding and cannulating a central vein is but one part of the process. In fact, many key steps designed to prevent common untoward effects such as barrier precautions involve non-technical skills, which are perhaps more important in training practitioners to safely place CVCs. Traditionally, these additional steps are learned by practitioners through an apprenticeship type method which can lead to non-standardized practices that may be a detriment to patient safety or lead to confusion as to what best practices are for a particular procedure. Additionally, given the rotation based approach of medical training, it is often the case that trainees will go through brief periods of intense training followed by long periods without placing a CVC which can lead to further skill deterioration. Simulation and gaming may be a way to standardize these practices, improve patient outcomes, and prevent technical skill decay.

Initially in aviation and now in healthcare, practitioners are being trained in realistic and highly interactive simulated environments so they can learn not only psychomotor skills (e.g., adjusting throttle on a plane or intubating a patient), but the key management and non-technical steps which make their task safer.[3] Such simulators have already been proven as effective teaching tools in a variety of healthcare environments including laparoscopy[10,11], bronchoscopy[12], and even team training exercises in areas such as ACLS.[13,14] Additionally, it has been shown that skill retention when using simulators is often superior to standard practices.[15,16] and that the use of simulators reduces the learning curve of many standardized procedures.[14,15] Likewise, it has been shown that not only can simulators improve outcomes, but they can improve efficiency of performing procedures as well.[3]

One specific modality being used to improve performance with simulators is screen-based video gaming simulation, or "serious gaming." Serious gaming as a learning tool is being increasingly utilized in health care fields and can lead to better skill-based outcomes.[4] The theoretical benefits of gaming environments include the ability of the participant to familiarize themselves with an otherwise unfamiliar environment or situation. Additionally the participants can review their progress and have the ability to make errors and learn from them without negative consequences. They can also proceed at their own pace, allowing for participants with different skill levels to learn at a speed that is comfortable for them, without added time pressure. Gaming as a training tool for physicians has not been widely available as it is relatively novel. Game development can be very time consuming and expensive. Fidelity is also a concern, as many of the video game developers have little medical and clinical experience. However, more opportunities are becoming available.

Currently, laparoscopy gaming for surgeons is the best established medical gaming application. A positive correlation has been shown between increased skill in the gaming simulator and increased skill on actual patients.[17] Additionally, Aggarwal et al showed effectiveness of their game simulator by using the standard set by the airline industry; the transfer-effectiveness ratio (TER).[3,11] Broadly speaking, the TER is means of expressing a ratio of time spent learning a skill on simulator versus normal training. Specifically, to obtain the TER, one must take the difference of the number of trials or time taken to perform the task between the control group and the simulator-trained group divided by total training time received by the simulator group(see Figure 1).

$$TER = \frac{Yo-Yx}{X}$$

Yo=Median time required by control group

Yx= Median time required by gaming group

X=Amount of time spent on simulator

Figure 1

This ratio is an approximation of cost/time effectiveness of the addition of the simulator to the standard program.[18,19] Given that serious gaming has been shown as an effective teaching tool in a variety of areas, a similar game for CVC placement might improve practitioners' ability to safely place these devices and improve patient safety.

As such, the aim of this project is to create an interactive screen-based simulation of internal jugular venous cannulation that will incorporate all aspects of the procedure including setup, sterile preparation, technique of catheter placement, and catheter maintenance. Once the game is created we aim to investigate the usefulness of our serious gaming program in enhancing the ability of the participants to place CVCs. We will do so by assessing the rate of compliance with the previously described procedural steps as measured in the simulated and actual operating room environments.[20]

METHODS

Our study will be divided into three phases: Game Development, Game Launch, Game Validation and Revision

Game Development:
The simulation group at The Mount Sinai Human Emulation, Education, and Evaluation Lab for Patient Safety and Professional Study (HELPS) Center collaborated with the Human Symbiosis Lab group at Arizona State University (ASU) for the gaming project. Staff at ASU who are expert developers of serious medical games, in consultation with the HELPS Center designed and developed the game.

Our game was developed using the Unreal Software Platform on which the ASU Team has successfully implemented and constructed games for the Nintendo Wii for surgical training.[21] The freeware developers version was used for ease of access and game construction. Graphics, templates, and sounds found in the default kit were used. After creation of the virtual world we began to design the platform for CVC placement. Our game design incorporated current best-practices for CVC placement (as outlined by the American Society of Anesthesiologists and the Institute for Healthcare Improvement Central Line Bundle)[3],[22] and current protocols used at The Mount Sinai Medical Center (MSMC) Department of Anesthesiology.[23] The central line checklist described by Dong et al[20] was the basis for the internal computerized grading scheme (See Figure 2).

CVC Proficiency Scale Checklist:

- Preprocedure ID verification
- Informed consent communication
- Trendelenberg position
- Operator maximal barrier precautions
- Hand hygeine
- Chlorhexidine skin antisepsis
- Sterile gloving and gowning
- Patient maximal barrier precautions
- Ultrasound sterile technique
- IJ compressibility by ultrasound
- Procedural pause
- Successful independent IJ Venipuncture
- Transduction/Manometry to verify venous access
- Correct securing of the catheter
- Successful independent SC venipuncture

Adopted from Dong et al

Figure 2

Users are first asked to visit a website that allows for game download and registration. They are instructed to pick a username and password for their anonymous account. After downloading the game and importing their user ID participants have access to two game modes. The first mode is a practice mode whereby their patient, CVC kit, and environment are preprogrammed to teach the participant the proper steps. At each point the participant is given prompts to the proper order of the steps and is not allowed to click on objects in the environment that are not in the correct sequence. Additionally, an information panel is displayed to guide the participant to both the step currently on the previous step completed. There is a timer in the top right corner to let the user know how long the current attempt is taking. In this game mode there is no penalty for time taken, nor any visual or audio prompts for taking more than the normal allotted time. Once completed the user is taken to a scoring screen that shows them each step completed and their score for that step. In the instruction mode they are given a perfect score since they are taken through step by step. Once the instruction mode is completed users are able to access the gaming mode. In this mode no visual or audio prompts are given to guide the user. Additionally the clock timer will give visual feedback to the user for taking too much time. Users are free to place the CVC in whichever manner they choose, since now the environment is completely unlocked to them. The internal scoring system checks which steps they perform and the order in which they perform them and awards points accordingly. For example, should the user not wash his/her hands prior to donning his gown and gloves he is given zero points for the wash hands and scrub steps, even if the user goes back later to scrub since sterile technique has already been broken. Upon completion of the task the user is directed to a scoring screen. This screen again displays the correct order of steps and shows the user which steps where done correctly and which steps where either missed or performed at the incorrect time. The score is then uploaded onto an internet server that will log the score and display it on our leader board anonymously. This way, participants can compare their scores amongst each other to foster friendly competition, without being individually targeted. We anticipate that by allowing game-like incentives within the system, we will have high retention of the users and subsequently high skill gain

Game Launch:
After over a year of game development we have launched the initial version of our game. Both medical students and anesthesiology residents have access to our game. Additionally we have begun to receive feedback on game design and effectiveness of teaching. It has thus far been very well received, with many residents and students reporting that it has helped them learn and maintain their CVC placement skills.

Game Validation and Revision:
After a brief launch phase we have begun our game validation and revision phase. We have currently enrolled twenty four anesthesiology residents from the department of anesthesiology at Mount Sinai Medical Center to validate our game. From the group of twenty four residents, two groups have been formed. They are currently being randomized either to have full access to the CVC game (gamer group) or to continue their usual practice after standard departmental training in the surgical intensive care unit using actual patients (non-gamer group). Study participants will be classified into sub groups based on years in clinical practice as well as experience and comfort with CVC placement to control for varying experience with CVC placement.

Prior to game access all participants will come to the Mount Sinai HELPS Center to perform a standardized central line placement on a mannequin (Blue Phantom, Redmond, WA). They will be timed and evaluated based on the Dong et al grading scheme that was used for the design of the gaming scoring system.[20] After baseline data collection, subjects given access to the game will have a "warm up" period to familiarize themselves with the gaming process. This will involve a group session which demonstrates the game and educates participants as to its use. Participants will then be allowed to use the game as often as they would like, with mandatory use of the game at least once per week. Use of the game will be tracked via a web-based platform which records user logins and game completion. This is the same website that hosts the leader board for participants to compare scores.

After three weeks of gaming, qualitative and quantitative analyses of the participants' abilities in CVC placement will be examined. We will bring the participants into the HELPS Center simulation lab and have them attempt CVC placement on a mannequin (Blue Phantom, Redmond, WA). These data will be ultimately be part of our primary outcome data, with raw time and an overall global assessment of performance score given by the expert raters as well. Participants will also be asked to complete a survey about how they perceived their own placement of the central venous catheter including; ease of procedure, comfort with all the steps of the procedure, adherence to safety and infection control protocols and overall performance. Those who were in the gaming group will additionally be asked if they felt the game improved their comfort and ability in placing CVCs. Additionally, to calculate the TER for the gaming group versus the control groups, the equation TER= (Yo-Yx)/X will be used, where Yo is the median time required by the control group to place a central line and Yx is the same measurement for the gaming group after using the game for X amount of time(see Figure 1).

Should we experience positive results we intend to further develop our game. We hope to develop multiple levels of central line placement to be performed once the basic level has been mastered. Once a basic line placement has been performed the user will unlock other difficulty levels wherein their knowledge of best practices are tested. These distinct difficulty levels will include minor obstacles to line placement that will allow the user to adapt to the situation while still maintaining proper techniques. Points will be awarded for adhering to standard practices and will be combined with the difficulty level to make a total score. Participants will be penalized points for skipping steps or not adhering to standard practices. Additionally, the virtual patient will now experience complications that will change the outcome of the procedure based on specific steps missed and overall score. For example, should a user not use sterile technique the patient will suffer an infection. This information will be included in the final report the participant receives after game completion. . Our online interface will continue to allow for participants to play the game as often as they would like, from any location.

CONCLUSIONS

We aim for our serious gaming project to impact different areas. First, we hope that the implementation of the game at the Mount Sinai Medical Center will improve the clinical practice of CVC placement in our department. If it is found to be an effective tool and we hope to expand the game to the medical center itself, where hopefully we can reduce the complication rate of CVC placement in actual patients throughout our institution. This might not only result in substantial financial savings for the institution, but could also save lives. Lastly, and more broadly, we hope to show that the implementation of a web-based, serious medical game which reinforces best practices for CVC placement may be an efficient, inexpensive, and widely dispersible way of reducing CVC-associated complications across multiple institutions.

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