A Virtual Reality Simulation Curriculum for Intravenous Cannulation Training

Article *in* Academic Emergency Medicine · October 2010

DOI: 10.1111/j.1553-2712.2010.00876.x · Source: PubMed

6 authors, including:

Nikolaos Nikiteas
National and Kapodistrian University of At…

Meletios A Kanakis
Onassis Cardiac Surgery Center

Argyris Moutsatsos
National and Kapodistrian University of At…

Evangelos Georgiou
Faculty of Medicine, National and Kapodis…

A Virtual Reality Simulation Curriculum for Intravenous Cannulation Training

Constantinos Loukas, PhD, Nikolaos Nikiteas, MD, Meletios Kanakis, MD, Argyris Moutsatsos, Emmanuel Leandros, MD, and Evangelos Georgiou, MD

Abstract

Objectives: Although virtual reality (VR) simulators play an important role in modern medical training, their efficacy is not often evaluated using learning curves. In this study, the learning curves of novice and intermediate users were elicited during a VR simulation–based curriculum for intravenous (IV) cannulation.

Methods: This was a prospective observational study of subjects undergoing training using a VR model of IV cannulation. Participants were divided into two groups: novices (third-year medical students with no prior practical experience in IV catheterization) and intermediates (recent graduates with limited experience). Performance was measured with two endpoints: time to completion and errors committed. Errors were categorized as critical or noncritical. Learning curves (error score and time completion vs. session number) were analyzed using the Friedman's test. Performance before and after training was compared using the Kruskal-Wallis test. The Spearman rank correlation coefficient (r_s) was used to determine the correlation between time completion and error score estimates. The number of attempts required to complete the training phase was also measured and compared between the two groups.

Results: Thirty subjects were enrolled: 17 in the novice group and 13 in the intermediate group. Learning curve plateaus of intermediates were reached in the sixth case scenario (session), whereas novices reached a plateau in the eighth session. Performance comparison of time to completion and errors showed significant improvement for both groups. Less time and fewer attempts were required by all trainees to complete a scenario while progressing through the curriculum. The overall number of IV cannulation attempts of novices was significantly higher than that of the intermediates throughout the course.

Conclusions: Significant learning curves for novice and intermediate students were demonstrated after following the VR simulation–based curriculum. Competencies acquired during this educational course may provide an important advantage for training prior to actual clinical practice.

ACADEMIC EMERGENCY MEDICINE 2010; 17:1142–1145 © 2010 by the Society for Academic Emergency Medicine

Keywords: virtual reality simulator, training curriculum, intravenous cannulation, learning curve

Typical methods of teaching intravenous (IV) cannulation include instructional videos, practice on plastic arms, and eventually IV placement on actual patients under the guidance of an experienced practitioner.[1] This model entails several pitfalls, such as high faculty-to-student ratio (an educator needs always to be present), inability to practice repeatedly on cases with idiomorphic anatomical characteristics, and failure to review the errors committed.

From the Medical Physics Lab-Simulation Centre (CL, MK, AM, EG); the First Department of Surgery, Laiko General Hospital (NN); and the First Department of Propaedeutic Surgery, Hippocration Hospital (EL), University of Athens Medical School, Athens, Greece.

Received January 18, 2010; revisions received February 22 and March 6, 2010; accepted March 8, 2010.

Supervising Editor: James Miner, MD.

Address for correspondence and reprints: Constantinos Loukas, PhD; e-mail: cloukas@med.uoa.gr.

Virtual reality (VR) simulation has opened a new era in medical education, aiming to solve several problems encountered in the traditional educational model.[2] VR simulators may be considered ethically superior to training on live patients, providing an opportunity to train repeatedly on various models and in a risk-free environment. Other advantages include robust performance monitoring, constructive feedback, and practice on rare or complex scenarios.[3–6]

This study examined the learning curve of IV cannulation for two different groups of practitioners (novices and intermediates). As opposed to other studies,[1,4,7] the proposed curriculum consists of several different case scenarios. Performance measurement included completion time and errors weighted to reflect clinical importance. To the best of our knowledge, this is the first

ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/j.1553-2712.2010.00876.x

report in the literature regarding the learning curve of IV cannulation practiced in a VR environment.

METHODS

Study Design

This was a prospective observational study of subjects undergoing training using a VR simulator of IV cannulation. The study was carried out in the Medical Physics Lab Simulation Centre of the Athens University Medical School (Athens, Greece). Institutional review board approval was obtained for the study protocol. All subjects gave informed consent prior to participation.

Study Setting and Population

The first group of subjects participating in this study consisted of 17 third-year medical students with no practical experience in IV cannulation (Group A—novices; median age 22 years, interquartile range [IQR] = 20–23 years). The second group (Group B—intermediates; age 27 years, IQR = 26–29 years) included 13 recent graduates with limited experience (fewer than 10 IV attempts[7]). Previous experience with a VR IV simulator was the only criterion for exclusion.

Study Protocol

Intravenous cannulation was performed with the aid of a commercially available VR simulator (Virtual IV, Laerdal Corp., Wappingers Falls, NY). The system comprises a computer connected to a dummy needle-catheter assembly and a haptic device for simulating skin palpation and needle insertion. A similar version was validated in the past for its educational usefulness and ability to discriminate different levels of expertise.[7]

The training was performed over a period of 1 month, with a maximum of five discrete IV attempts per day. The time interval between attempts was set to at least an hour for avoiding repetition patterns in the data collected. The curriculum consisted of four modules. *Pretraining* provided all the necessary information needed to establish vascular access and included 1-hour didactic lectures by an experienced instructor in groups of 10 trainees. *System training and preassessment* aimed to familiarize and preassess the participants. A couple of basic IV scenarios were performed by each participant with the help of a system instructor. On a subsequent day, a single cannulation was attempted for three distinct case scenarios (pediatric, trauma, and geriatric), allowing preliminary skill assessment in a distributed manner. *Competency training* was the main module where trainees performed nine different case scenarios (hereafter referred to as sessions), of equal difficulty but of varying anatomy and medical conditions (''student-level'' scenario pool). To allow trainees to elaborate more, the next session is performed only after the previous one is completed without critical errors (see below for error description). Thus, provided the discrete nature of each scenario, trainees were given the opportunity to ''learn from their mistakes'' and digest the educational content and subsequently apply their skills to the next simulation case. *Postassessment* aimed to assess the participants after training, using the same scenarios used during preassessment.

Procedure and Assessment. The virtual cannulation was attempted on the haptic-feedback arm using the dummy catheter-needle. Endpoints included the time required to complete the procedure and the total error score, calculated as the sum of critical (four points each) and noncritical (one point each) errors. This scoring scheme was based on the greater importance of critical errors and also on a post hoc analysis showing that the total number of noncritical errors committed was 3.7 times the critical ones, implying a tendency of trainees to concentrate more on the major issues of the procedure. Thus, as a counterbalance, the errors were weighted using a 4:1 ratio.

Critical errors were deemed as those having immediate relation to safety issues (e.g., essential precautions not taken) and the actual cannulation action (the main technical skill assessed). Noncritical errors related mostly to minor practical issues (e.g., stick warning, vein stabilization). Table 1 summarizes for both categories the most frequent errors recorded. The number of attempts required to complete the main training module was also compared between the two groups.

Table 1
Frequent IV Cannulation Errors and Corresponding Erroneous Actions Encountered Throughout the Procedure*

Error Categories	Example of Erroneous Action
Critical	
Standard precautions not performed correctly	Action taken without gloves
Incorrect C-band usage	C-band not removed
Incorrect vein cannulation or/and threading	Catheter buckling
Incorrect site preparation	Antiseptic agent not used near insertion site
Equipment not disposed of correctly	Gloves not disposed of
Errors during patient identification	Action taken prior to identification
Noncritical	
Extension tubing not used correctly	Extension tubing not secured correctly
Incorrect use of IV infusion	IV infusion required but not used
Incorrect catheter gauge used	Incorrect catheter gauge used for site
Incorrect vein stabilization	Vein stabilization not attempted

IV = intravenous.
*For each IV cannulation, noncritical and critical errors gain 1 and 4 point(s) each, respectively. The total sum provides the overall error score for each session.

Data Analysis

The choice of at least 10 subjects per group was based on a two-tailed test, with $\alpha = 0.05$ and power $(1 - \beta) = 0.80$ and the fact that approximately 10% of participants drop out, as reported in similar VR simulation studies.[8,9] Learning curves (error score and time completion vs. session number) were analyzed using the Friedman's test, which is a nonparametric repeated-measures analysis of variance (MATLAB Statistics toolbox, The MathWorks Inc., Natick, MA). If there was a statistically significant difference ($p < 0.05$), appropriate multiple comparisons tests were performed to identify a plateau (the session at which a point fails to show additional significant decreases). To retain a prescribed familywise error rate $\alpha = 5\%$, a Bonferroni adjustment was used to compensate for multiple comparisons. Performance comparison before and after training was undertaken using the Kruskal-Wallis test. Values are presented as medians and IQRs. The Spearman rank correlation coefficient (r_s) was used to determine the correlation between time completion and error score estimates.

RESULTS

Significant learning curves were produced for both groups of residents and for both endpoints (median values for first session vs. ninth session: error ≈ 14 vs. 2 and time ≈ 280 seconds vs. 100 seconds; see Figure 1). For the error score, the learning curve plateau of intermediates was reached in the sixth session, whereas the plateau of novices was in the eighth session (Figures 1A and 1B). The time parameter revealed a plateau at session 6 for intermediates and session 9 for novices (Figures 1C and 1D).

By conducting pre- and postassessment, measures of improvement and associated benefits of using simulation training were derived. Both groups performed faster (Group A, 286 seconds, IQR = 250–344 seconds vs. 91 seconds, IQR = 78–100 seconds, $p < 0.01$; and Group B, 246 seconds, IQR = 210–259 seconds vs. 76 seconds, IQR = 69–79 seconds, $p < 0.01$) and with fewer errors (Group A, 13, IQR = 10–15 vs. 3, IQR = 2–4, $p < 0.01$; and Group B, 9, IQR = 4–13 vs. 1, IQR = 1–2, $p < 0.01$). No difference was found between the two groups after training ($p > 0.05$ for each endpoint). We also found a strong linear correlation between completion time and error score ($r_s = 0.8$), implying that the less time is required to complete the procedure the less errors are likely to occur and vice versa. When comparing the number of cannulations attempted to complete the course, intermediates required significantly fewer attempts than novices (25, IQR = 22–27 vs. 37, IQR = 35–47, $p < 0.04$), with a median of three and four attempts, respectively.

DISCUSSION

The recent development of technologic advances in the area of medical education provides a powerful platform for advancing the cognitive and psychomotor skills of practitioners. A large number of computer-based simulators have been introduced in teaching clinical practice.[7,10–12] Although many of these devices are highly realistic, their educational value is under investigation,

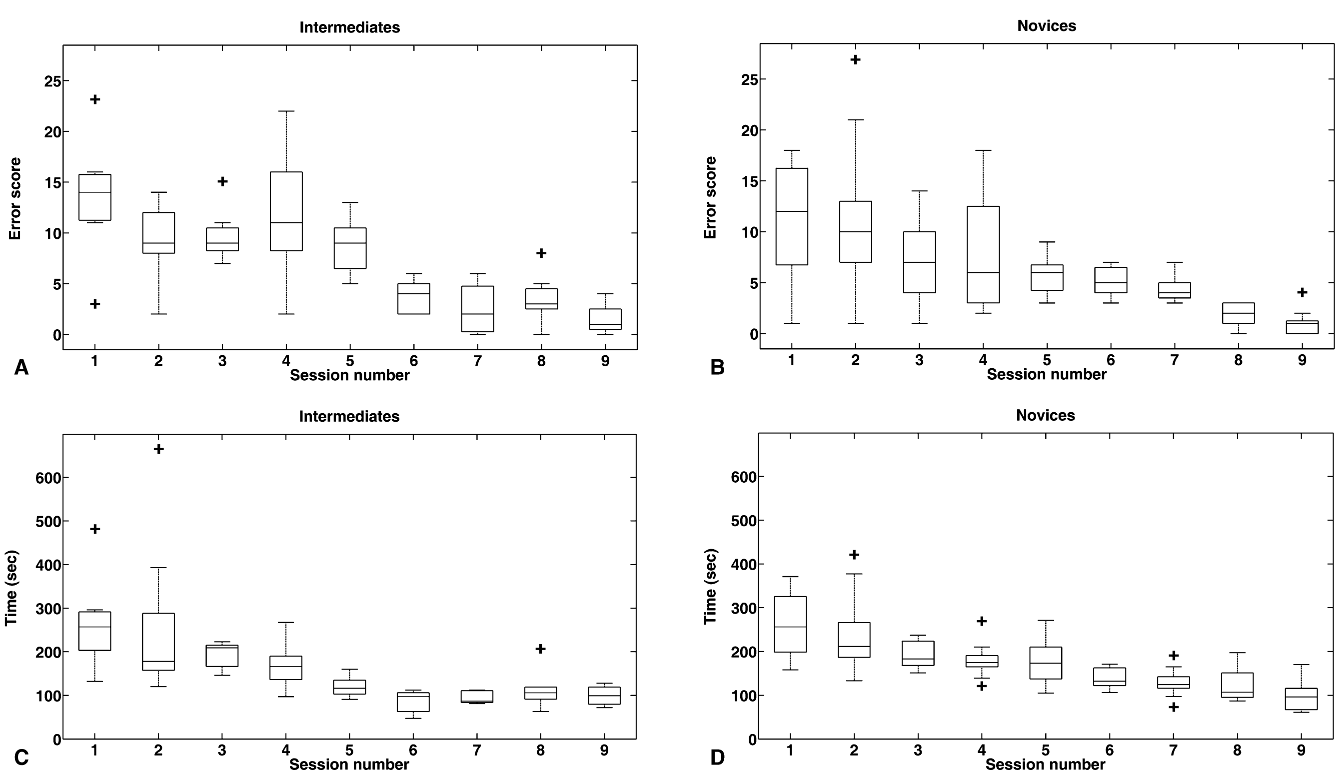

Figure 1. Learning curves (box plots) for error score (A-B), and completion time (C-D) obtained during training of the two groups. Each session corresponds to a different IV cannulation scenario. Note that different participants require a different number of attempts to complete successfully a session. Crosses correspond to outliers.

especially in terms of their learning curve assessment and role within a training curriculum. The main goal of this study was to document the learning curve of a VR simulator for IV cannulation. Such information is a prerequisite during curriculum design and development. The assessment methodology was based on previously validated endpoints such as time and error score.[4,7]

Our results showed that novices had a slightly lower learning rate than intermediates. Furthermore, the proposed curriculum reduced both the completion time and the errors committed. Intriguingly, we observed that during training most participants acquired the appropriate confidence and automation skills for performing IV cannulation in a short time and with few errors. This finding is observed also in real clinical practice, where after a certain limit, the more time is spent to perform a procedure, the more likely it is to have an unsuccessful completion, and usually the case is handed over to another health professional. Another interesting finding was that the VR simulator provided a significant aid for improving the skill level of intermediates, revealing its usefulness in skill advancement.

LIMITATIONS

Although this study focused on the learning curves, a basic limitation is the absence of an expert group. Preliminary studies on a limited sample (five experts) have shown that their performance during postassessment is comparable to that of the other two groups. However, a larger sample is required to derive definite conclusions, along with performance data on real IV procedures. Thus, an important future question will be to assess transfer of skill acquired in the VR setting to the real clinical environment, as the live patient-dependent model still remains the cornerstone for evaluating the application of the principles learned in the simulation room.

Several participants commented that the simulator's skin stretching level was slightly more sensitive than that encountered in routine practice, and the angle of catheter insertion was relatively offset to the puncture site. This observation poses some concerns about the system's generalizability to real anatomical features.

CONCLUSIONS

We have demonstrated significant learning curves of intravenous cannulation for novices and intermediates. The training course was effective for both groups after performance comparison on independent simulation scenarios. The competencies acquired provide the opportunity to achieve suitable levels of competence prior to performance on actual patients and may also serve as a functional bridge after long-term recession.

The authors thank Vassiliki Lempetzi, RN, and Anthonia Katsiapa, RN, for their participation and constructive comments throughout the study.

References

1. Engum SA, Jeffries P, Fisher L. Intravenous catheter training system: computer-based education versus traditional learning methods. Am J Surg. 2003; 186:67–74.
2. Haluck RS, Krummel TM. Simulation and virtual reality for surgical education. Surg Technol Int. 1999; 8:59–63.
3. Satava MR. Surgical education and surgical simulation. World J Surg. 2001; 25:1484–9.
4. Bowyer MW, Pimentel EA, Fellows JB, et al. Teaching intravenous cannulation to medical students: comparative analysis of two simulators and two traditional educational approaches. Stud Health Technol Inform. 2005; 111:57–63.
5. Balasundaram I, Aggarwal R, Darzi A. Short-phase training on a virtual reality simulator improves technical performance in tele-robotic surgery. Int J Med Robot. 2008; 4:139–45.
6. Aggarwal R, Grantcharov T, Moorthy K, Hance J, Darzi A. A competency-based virtual reality training curriculum for the acquisition of laparoscopic psychomotor skill. Am J Surg. 2006; 191:128–33.
7. Reznek MA, Rawn CL, Krummel TM. Evaluation of the educational effectiveness of a virtual reality intravenous insertion simulator. Acad Emerg Med. 2002; 9:1319–25.
8. Aggarwal R, Crochet P, Dias A, Misra A. Development of a virtual reality training curriculum for laparoscopic cholecystectomy. Br J Surg. 2009; 96:1086–93.
9. Aggarwal R, Grantcharov TP, Eriksen JR, et al. An evidence-based virtual reality training program for novice laparoscopic surgeons. Ann Surg. 2006; 244:310–4.
10. Hoffman H, Vu D. Virtual reality: teaching tool of the twenty-first century? Acad Med. 1997; 72:1076–81.
11. Vanchieri C. Virtual reality: will practice make perfect? J Natl Cancer Inst. 1999; 91:207–9.
12. Agazio JB, Pavlides CC, Lasome CE, Flaherty NJ, Torrance RJ. Evaluation of a virtual reality simulator in sustainment training. Mil Med. 2002; 167:893–7.