The following publication Pun, S. K., Chiang, V. C. L., & Choi, K. S. (2016). A computer-based method for teaching catheter-access hemodialysis management. CIN: Computers, Informatics, Nursing, 34(10), 476-483 is available at https://doi.org/10.1097/CIN.0000000000000262.

A computer-based method for teaching catheter-access haemodialysis management

ABSTRACT

Patients undergoing haemodialysis are highly susceptible to infections, which could lead to morbidity and mortality. One of the major sources of infections stems from the mishandling of haemodialysis access sites. Although healthcare workers receive training on how to aseptically handle haemodialysis catheters, the increasing number blood infections associated with dialysis suggests that the conventional approach to training may not be sufficient to ensure a clear understanding of the necessary knowledge and skills. With advancements in digital technology, computer-assisted learning has been gaining popularity as an approach to teaching clinical skills. The purpose of this study was to evaluate the effectiveness of a computer-based training system developed to teach healthcare workers catheter-access haemodialysis management. Forty nurses were recruited and randomly assigned into two groups: the control group, which received conventional training only; and the experimental group, which received both conventional and computer-based training. A knowledge test and a skills competence test were administered to both groups before and after the intervention to evaluate their performance. The results show that the performance of the nurses in the experimental group was significantly better than that in the control group, indicating that the proposed training system is an effective tool for supplementing the learning of catheter-access haemodialysis management.

Key words: Nursing education, haemodialysis, computer-assisted learning, computer-based simulation, clinical skills

BACKGROUND

The major function of the kidney is to excrete metabolic waste and excess water from the body. For patients suffering from end stage renal disease (ESRD), such waste products will accumulate in their body and cause harmful effects. As a remedy, haemodialysis (HD) can be performed with the intent of ridding the body of these wastes, like an artificial kidney. The process involves removing blood from the body, passing it through a special filter (dialyzer) where the wastes are removed, and finally re-injecting the purified blood back into the body. The blood can enter or exit the body via an arterio-venous (AV) fistula or by the insertion of a tunnelled venous catheter, with the latter being the more common method. In either mode of access, careful haemodialysis management is required or bacteria could enter the bloodstream and lead to infection. Although using catheters for vascular access is a common practice, the approach leaves patients highly susceptible to catheter related blood stream infections (CRBSI).[1] In Hong Kong, there are currently over 7,000 ESRD patients, as many as 1,100 of whom are undergoing HD.[2, 3] Studies have shown that the survival rate for HD patients is only 34.2%, with infection being one of the most common causes of death.[4, 5]

A preventive strategy to reduce the occurrence of CRBSI is to apply aseptic techniques properly during catheter access.[6] Studies have confirmed that a stricter adherence to protocol leads to fewer infections.[7] Healthcare workers should therefore be familiar with the aseptic techniques required for handling HD catheters and be vigilant of the environment. The conventional method of HD training involves didactic face-to-face teaching and the demonstration of hands-on skills using static mannequins. However, the standard of teaching is affected by variables such as the amount of time available for training, the trainer-to-trainee ratio, and the knowledge of the trainers. Hence, providing training to healthcare workers does not mean that all of them will acquire the same level of HD knowledge and skills. The urgency of providing immediate care to patients and the heavy workload of experienced staff also makes it difficult for them to supervise novices in a clinical setting.

Many studies have been conducted to evaluate the effectiveness of educational training in reducing CRBSI. The results have demonstrated that the training sessions can increase the knowledge of nurses and improve their skills in aseptic techniques and in the handling of HD catheters.[8-10] However, CRBSI rates are increasing, revealing the need for improvement. In this regard, computer-assisted learning (CAL) offers opportunities for alternative approaches to clinical teaching. It has been shown that CAL can maintain the consistency of teaching, reduce instruction times, enhance the effectiveness of learning and the mastery of skills, and improve the retention of knowledge.[11]

CAL, also known as computer-based instruction or e-learning, is an umbrella term referring to the use of digital technologies to facilitate the educational process. Using computers as a medium, CAL fosters an engaging learning experience using multimedia with text, audio, video, graphics, or animations. In healthcare education, experiential learning is adopted to enable students to practise in simulated clinical scenarios (e.g., in teaching laboratories using static mannequins). Here, simulations can also be achieved by making use of interactive computer graphics technology to simulate the scenarios. In this paper these are referred to as computer-based simulations, a CAL approach. As in computer games, the simulated scenarios are developed by mimicking physical settings, and are displayed on the screen interactively in response to the actions of the user. These computer-generated scenarios are called virtual environments.

Computer-based simulation can provide a realistic and immersive virtual environment for teaching and learning.[12, 13] In the context of nursing, simulation can be used to replicate a clinical setting, such as a hospital ward or an emergency room, in a virtual environment. The simulation systems enable interactive self-learning to occur without constant supervision, while the performance of the trainees can be assessed automatically.[14] Computer-based simulation has been proven to be an effective tool for teaching skills related to health sciences.[15, 16]

The purpose of this study was to evaluate the effectiveness of a computer-based training system proposed for catheter-access HD training with a controlled trial. The system employed interactive multimedia and computer-based simulation for the online learning of catheter-access HD management. Two groups of nurses were recruited to participate in the study. Their performance before and after the conventional and computer-based training was measured and compared. Details of the study are discussed in the following sections.

METHODS

The Computer-based HD Training System

The proposed catheter-access HD management training system was designed based on standard guidelines adopted by the hospital in which the study was conducted. The design of the system focused on proper HD techniques, the sequence of the procedures, and the use of the materials and equipment required for managing the catheter site in an aseptic manner. The system was a web-based training system that could be executed on a personal computer using any internet browser. No additional software or hardware was required, thus maximizing the availability of the training. The training system covered seven major catheter-access HD procedures, namely: (1) preparing the patient, (2) dressing the exit site of the catheter, (3) preparing the HD trolley, (4) disinfecting the percutaneous catheter, (5) testing the blood flow in the percutaneous catheter, (6) connecting to the blood circuit, and (7) the after care procedures. Online training exercises were provided for each of the procedures. During the training, trainees were first asked to complete a set of multiple choice questions (MCQs) on their background knowledge on catheter-access HD management. They were also required to arrange the steps involved in catheter-access HD in the correct order. Next, a virtual HD trolley, along with medical materials and equipment, was displayed on the screen. The trainees were asked to choose the items required for HD, with the drag-and-drop metaphor, by dragging them onto the trolley using a computer mouse. The trainees were then presented with a video showing a nurse demonstrating step-by-step how to manage catheter-access HD for patients with renal failure.

The video was made from the viewpoint of a nurse performing the actual HD procedures on a static mannequin that simulated a renal failure patient. The setting was designed to give the trainees a greater sense of being present in the simulated environment, thereby, facilitating experiential learning.[17] The video consisted of a series of separate short clips. Each clip showed one step of the procedure and displayed subtitles describing the procedure. User-controlled buttons (“next” and "previous”) were provided to allow self-paced learning, with trainees being able to jump from one step to another according to their own progress in learning. Lastly, an interactive game was developed to enable trainees to appreciate the flow of blood in the percutaneous catheter in a virtual environment. The trainees could practise the procedures on a virtual patient, using the animated HD tools. Snapshots of the computer-based training system are shown in Figures 2 and 3.

The computer-based training system could be completed in around 15 minutes. It consisted of two modes: a *training mode* and a *testing mode*. In the training mode, trainees were provided with cues and rationales for every step of the procedure. This was to ensure that the trainees were able to master the correct operations based on rationales. The trainees could only progress to the next step after they had correctly completed the current step. Otherwise, the correct answer would be given (marked in red) with an explanation, and the trainees would be required to repeat the step. This feature was to enable trainees to genuinely understand the correct way of performing HD in each step and to discourage blind guesses. In the testing mode, the same online exercises were presented, but without the provision of hints and explanations. The answers given to all questions were accepted regardless of correctness. Only at the end of the testing mode were the trainees shown a log of all the choices they had made, as well as the correct answers if they had responded incorrectly.

Participants

Forty nurses from a sub-acute private hospital in Hong Kong were recruited for this study. The nurses were responsible for handling catheter-access sites during the HD procedure in the hospital. Information about the study and consent forms was provided to all of the participants prior to the experiment. Nurses who had experience in using computers and who had not received any previous HD training were recruited for this study. The study was approved by the Human Subjects Ethics Committee of the institution that the investigators affiliated with. Approval was also obtained from the participating hospital.

Instruments

The following four instruments were used in this study: (i) the HD knowledge test, (ii) the HD skills competence checklist, (iii) a questionnaire designed based on the Technology-Acceptance Model (TAM), and (iv) the IBM Computer System Usability Questionnaire (CSUQ). The HD knowledge test was developed based on standard guidelines already in place in the hospital. It was comprised of MCQs, sequencing, and fill-in-the-blank questions, with a total of 25 marks. To ensure content validity, the HD knowledge test was reviewed by an expert panel of six experienced renal specialty nurses in the haemodialysis unit. They were asked to rate the relevance of each question in the HD knowledge test using a 4-point scale from 1 (very irrelevant) to 4 (very relevant). All of the questions received a rating of 3 or 4, which showed good content validity, so no alterations were made to the test questions. The test-retest reliability of the instrument was also assessed with the participation of six nurses from the haemodialysis unit who met the subject recruitment criteria but were not involved in the study. Each of them completed the test at two time points, separated by two weeks. The Spearman's rho correlation co-efficient on the test scores was found to be 0.843, indicating good test-retest reliability.

The HD skills competence test was a checklist that had been developed and used by the participating hospital to rate the hands-on performance on a static mannequin. The test contained 39 items. It evaluated the performance of HD skills in terms of the correctness of the techniques, sequences, and manipulations made by a nurse during the process of the simulated catheter-access HD. The first 17 questions were about the disinfection of the percutaneous catheter, and the rest were about testing the flow of blood in the catheter. A 5-point Likert scale was adopted for the questions, with 1 indicating "unable to perform the step" and 5 indicating "performed the step accurately". Hence, the minimum and maximum score of the test was 39 and 195, respectively. The HD skills competence test was employed in the study to assess the performance of the participants. It was reviewed by the same panel of experts. A rating of 3 or 4 was given to all 39 items, indicating good content validity. A single assessor who was blinded to the study was asked to rate the performance of the participants.

In this study, a questionnaire designed with reference to TAM, thus referred to here as the *technology acceptance questionnaire* (TAQ), was used to evaluate the experimental group's acceptance of the computer-based catheter-access HD training system. The TAM is a major model that was developed to study user acceptance of a given information system technology. It aims to explain what causes users to accept a technology and their behaviour in using the system.[18, 19] The TAQ in this study consisted of two sections. The first section collected the demographic information of the participants, including their age, academic qualifications, job position, working experience in nursing, and previous experience in using computer simulation. The second section contained 13 items to collect the opinions of the participants from four aspects, namely perceived usefulness (4 items), perceived ease of use (4 items), intention to use (2 items), and attitude towards using (3 items) the computer-based HD training system. For example, the items concerned whether the training system could enhance the learning experience and the effectiveness of learning; whether it was easy and flexible to use; whether the participants intended to use it in the future; or whether they found the system a good learning approach, and whether they would recommend it to novices. A 7-point Likert scale was employed in the TAQ, with "1" referring to the strongest agreement with an item and "7" to the least. Thus, the lower the score, the more positive the comments of the participants. Written comments from the participants were also collected at the end of the questionnaire.

The IBM CSUQ is self-reported questionnaire designed by IBM to collect the opinions of participants on their satisfaction with the usability of a computer system. It has been used to evaluate CAL systems developed for clinical education.[20] The questionnaire has high reliability and validity. It contains 7 items and adopts a 7-point Likert scale, with 1 indicating "strongly agree" and 7 "strongly disagree". The experimental group was asked to complete the questionnaire in order to investigate the general usability of the computer-based training system, regarding whether the participants found the system effective and efficient, easy to use, easy to learn to use, and comfortable to use.

At the end of the post-test session, the TAQ and IBM CSUQ, which together could be completed in approximately 10 minutes, were distributed to the experimental group.

Research Design and Procedure

A randomized control trial was conducted to evaluate the effectiveness of the proposed computer-based training system. The participants were randomly divided into two groups of equal size: (i) a control group – to receive the conventional HD catheter-access management training of the participating hospital, and (ii) an experimental group – to receive the same conventional training plus computer-based training using the proposed system. A pre and post-test design was adopted to study the effectiveness of the training by comparing the performance of both groups before and after the intervention.

The design of the study is shown in Figure 1. In the pre-test phase, both groups had to complete the HD knowledge test and HD skills competence checklist in order to obtain baseline data. In the intervention phase, the participants in the control group attended a training session conventionally conducted in the hospital. The conventional training, conducted by an experienced HD nurse, included (i) a short lecture based on the HD guidelines of the hospital, (ii) a video demonstrating the procedures of catheter-access HD, and (iii) hands-on practice of the HD procedure on a static mannequin. During the training, participants could ask the lecturer questions about the HD procedure and operation. The training was conducted in four separate sessions, two times per week for two weeks. In addition to the same conventional training as described above, the participants in the experimental group used the proposed computer-based system for HD training. After a brief orientation of the features and usage of the training system, the participants were instructed to log on to the system and practise using both the training mode and testing mode independently on the same day that they attended the conventional training session. That is, the computer-based training was also conducted twice a week, for a period of two weeks. The time spent on each mode was about 15 minutes. In the post-test phase, all of the participants were again assessed using the HD knowledge test and HD skills competence checklist. In addition, the participants in the experimental group were asked to complete the TAQ and the IBM CSUQ.

RESULTS

Demographic Data

The demographic data of the 40 participants are presented in Table 1. The participants were aged between 27 and 48 years, with those in the age range from 30 to 40 years being in the majority. Thirty-four (85%) of the participants were female, 31 (77.5%) were registered nurses, and 32 (80%) had working experience of 1 to 10 years. Thirty-five (87.5%) of the participants reported having previous experience with computer simulation, largely due to playing games on smart phones or video game consoles. The statistical results indicated that there were no significant demographic differences between the control and experimental groups (see Table 2).

HD Knowledge Test

The HD knowledge test scores of the control and experimental groups in the pre-test and post-test are summarized in Table 3. For the control group, the mean score increased greatly from 4.7 in the pre-test to 17.5 in the post-test. Similarly, for the experimental group, the mean score increased greatly from 4.0 in the pre-test to 24.0 in the post-test. A statistical analysis showed no significant difference in pre-test score between the control group and the experimental group ($p = 0.169$), whereas the higher post-test score of the experimental group was statistically significant ($p < 0.001$).

HD Skills Competence Test

The HD skills competence test scores of the control and experimental groups in the pre-test and post-test are shown in Table 3. For the control group, the mean score in the pre-test was 39.0 and that in the post-test was 113.7. For the experimental group, the mean pre-test score was also 39.0 while the mean post-test score was 149.3. No statistical difference was found between the pre-test scores of the control group and the experimental group ($p > 0.05$), whereas the higher post-test score of the experimental group was statistically significant ($p < 0.001$).

Technology Acceptance Questionnaire

The statistical analysis of the TAQ scores is shown in Table 4. By averaging the ratings given to the respective items, the overall mean scores for perceived usefulness, perceived ease of use, intention to use, and attitude towards using the computer-based HD training system was respectively 2.3, 2.4, 2.0, and 1.8 out of 7 (the lower the score, the higher the acceptance). The written comments on the computer-based training system were generally positive. For example, the participants in the experimental group found the system easy to use and of help in gaining a better understanding of the HD procedure. They commented that the video and subtitles were presented clearly. Some also enjoyed using the computer simulation to practise testing the flow of blood in the catheter.

IBM Computer System Usability Questionnaire

The participants in the experimental group gave a rating of between 2 and 3 on the 7-point scale (the lower the score, the higher the satisfaction) to all seven items in the IBM CSUQ. Among the seven items, the lowest mean score was 2.10 and the highest was 2.75. The standard deviation of the mean scores ranged from 0.55 to 0.94. Similar to the findings from the TAQ, the participants were generally satisfied with usability of the computer-based HD training system.

DISCUSSION

In this study, the effect of combining CAL with conventional training in the acquisition of HD knowledge and skills was investigated. Here, CAL was delivered using the proposed computer-based training system running on a generic web browser. Based on the HD guidelines of the participating hospital, the training system was developed using multimedia to include instructional texts explaining the HD, MCQs on background knowledge on HD management, a sequencing test on the HD procedures, and a fill-in-the-blank exercise. The system further provided a series of video clips demonstrating the procedures step by step, and a computer-based simulation of the preparation of an HD trolley, the testing of the blood flow in a percutaneous catheter, and the connection of a blood circuit. The results of the randomized controlled trial demonstrated that the scores of both groups in the knowledge test and skills competence test increased significantly from the baseline, and that the improvement was more prominent in the experimental group, suggesting that the addition of CAL to conventional training could further improve the learning curve.

In the knowledge test, the pre-test scores of both groups, which were quite low, showed that the participants did not have much prior knowledge of catheter-access HD management. After the two-week intervention period, the experimental group exhibited a greater increase in score in the knowledge test than the control group, in terms of percentage, jumping from an average score of 16% in the pre-test to 96% in the post-test. Some participants even scored 100%. By comparison, the control group's score in the knowledge test rose from an average of 18.8% in the pre-test to 69.8% in the post-test, with the highest score being 84%. The higher post-test score of the experimental group was statistically significant.

In the skills competence test, the baseline score for all of the participants before the study was 39, i.e., none of them had the skills to properly handle HD catheters. Considering that there were quite a few experienced nurses among the participants and that the majority of the participants were registered nurses, the finding highlights the importance of properly training nurses in HD catheter-access management. After the training provided during the intervention, the scores of the control group, in terms of percentage, increased from an average of 20% in the pre-test to 58% in the post-test, with the highest score being 76%, whereas the average score for the experimental group increased from 20% in the pre-test to 77% in the post-test, with the highest score being 93%. The higher post-test score of the experimental group was also statistically significant.

Many previous studies on the TAM reported that the perceived usefulness and the perceived ease of use of a given technology have a positive influence on the intention to use and the attitude towards using that technology. A survey conducted to study students' behavioural intention to learn using online courses found that their perception of the usefulness of online courses had a positive effect on their behavioural intention to make use of such courses.[21] In this study, the participants gave a positive rating to the usefulness and ease-of-use of the proposed computer-based training system; their feedback on the intention to use and attitude towards using the system was also positive. Concerning the IBM CSUQ, the results showed that the participants were satisfied with the proposed training system and considered it an effective method for learning HD.

The written comments also indicated that the participants appreciated the proposed computer-based training system. The comments included the following: “the presentation of simulator was useful and clear”, “some of the features were creative and fun”, and “it helped me to memorize the steps and procedures”. Interestingly, the comments collected in the present study were similar to those obtained in a related study on the use of simulation for teaching the insertion of nasogastric tubes.[13]

Proper handling of catheter sites can significantly reduce the incidence of infections. It is therefore crucial to provide adequate and effective training to all healthcare workers involved in HD. The results of the study suggest that the proposed computer-based training system is a feasible and effective tool for enhancing conventional training, in that it provides a standardized and self-paced approach to learning, enabling trainees to learn as often as desired in the absence of instructors. The computer-based practice can increase their learning opportunities and reinforce their skills. The participants in the study, who were of different age groups and different ranks in nursing, and who possessed different kinds of work experience and educational backgrounds, considered the use of computers for training catheter-access HD management to be an effective method.

Despite the promising results, the size of the sample was relatively small and the study was only conducted in a single haemodialysis unit. The sample size was limited by the number of nursing staff in the hospital. Further studies will be conducted with a larger sample size by extending the research to other hospitals in order to obtain more conclusive evidence to substantiate the training effectiveness of the computer-based system. In addition, to evaluate the real benefits of the system in practice, a further study will be conducted to monitor the incidence of infections over time after the subjects have received the training. The effectiveness of the training system will then be demonstrated if a decrease in infections is observed. The ability of the participants to retain their knowledge and skills of HD management over time can also be assessed after the training to evaluate whether the proposed computer-based method improves such retention.

For ethical and practical considerations, the demonstration video clips in the proposed system were made using a static mannequin instead of a real patient. As such, the clips may not clearly portray actual situations, making it difficult for trainees to anticipate the issues that could occur in real situations. The computer-based training was also tailored to the protocols of the hospital where the study was conducted; thus, it may not be applicable to the settings of other hospitals where local protocols for catheter-access HD management are used. In this regard, flexibility to customize or fine-tune the content in the proposed computer-based training system is required to adapt it to the training needs of different hospitals.

When compared to conventional face-to-face training, computer-assisted learning is particularly advantageous for its availability and accessibility to trainees. However, in order to make a fair comparison between the control and experimental groups, the amount of training was controlled so that the participants received the same number of sessions of both conventional and computer-based training. Therefore, the relationship between the frequency (dosage) of computer-based training and the acquisition of HD knowledge and skills was not investigated. A further study will be conducted to study the effect of the amount of computer-based training on the performance of the trainees. While this study focused on the use of computer-based training as an adjunct to conventional training, it is worthwhile to study the effectiveness of the proposed approach as an independent training method in order to further explore those settings and features of the computer-based method that are optimal for facilitating the teaching of catheter-access HD management.

CONCLUSION

The study showed the effectiveness of computer-based simulation in training nurses in catheter-access HD management. The system complemented the conventional training approach and helped to further promote aseptic techniques in HD for reducing the occurrence of CSBRI. The availability of the system and its ease of use also made it a convenient tool for training. The findings from the study indicated that the nurses had a positive perception of the computer-based training programme and were open to accepting it. The findings suggest that student nurses could benefit from the adoption of more computerized training in the traditional nursing curriculum. In designing and implementing computer-based training approaches, it is important to include the opinions of nurses as an integral part of the process. Indeed, this nurse-led multi-disciplinary project, which crosses the fields of infection control and information technology, exemplifies the value of informatics in nursing. The findings of this study were encouraging and provided insights into the development of more innovative, flexible CAL approaches to complement conventional teaching methods in nursing education. Large-scale studies involving a broader range of participants will be conducted to further affirm its applicability.

REFERENCES

1. Joshi A, Hart P. Antibiotic catheter locks in the treatment of tunneled hemodialysis catheter-related blood stream infection. *Seminars in Dialysis.* 2013;26(2):223-226.
2. Authority H. Smart Patient. Chronic renal failure. June 25, 2015. Available at: http://www21.ha.org.hk/smartpatient/en/chronicdiseases_zone/details.html?id=120. Accessed June 29, 2015.
3. Office CaPR. CUHK releases research results on employment status of Hong Kong chronic kidney disease (CKD) dialysis patients and promotes predialysis education systemme for mid to late stage CKD patients. *Chinese University of Hong Kong*, October 27, 2013. Available at: https://www.cpr.cuhk.edu.hk/en/press_detail.php?id=1669. Accessed June 29, 2015.
4. Network NHS. Tracking infections in outpatient dialysis facilities. April 13, 2015. Available at: http://www.cdc.gov/nhsn/dialysis/. Accessed June 29, 2015.
5. Ho W, Chau K, Choy B. Hong Kong renal registry report 2010. *Hong Kong J Nephrol.* 2010;12(2):81-98.
6. Protection CfH. Recommendations on prevention of intravascular catheter associated bloodstream infection. *Department of Health* January, 2010. Available at: http://www.chp.gov.hk/files/pdf/recommendations_on_prevention_of_intravascular_catheter_associated_bloodstream_infection_r.pdf. Accessed June 29, 2015.
7. Chu G, Adams K, Crawford S. Improving catheter-related blood stream infection in haemodialysis patients using a practice development framework. *Ren Soc Australas J.* . 2013;9(1):16-21.
8. Deshmukh M, Shinde M. Impact of structured education on knowledge and practice regarding venous access device care among nurses. *Int J Sci Res.* . 2014;3(1):895-901.
9. Shrestha R. Impact of educational interventions on nurses' knowledge regarding care of the patient with central venous line. *J Kathmandu Med Coll.* 2013;2(3):28-30.
10. Bianco A, Coscarelli P, Nobile C, Pileggi C, Pavia M. The reduction of risk in central line-associated bloodstream infections: knowledge, attitudes, and evidence-based practices in health care workers. *Am J Infect Contr.* 2013;41(2):107-112.
11. Ruiz JG, Mintzer MJ, Leipzig RM. The impact of e-learning in medical education. *Academic Medicine.* 2006;81(3):207-212.
12. Lateef F. Simulation-based learning: just like the real thing. *J Emerg Trauma Shock.* 2010;3(4):348-352.
13. Lai F, Luo R, Zhang L, Huang X, Rozelle S. Does computer-assisted learning improve learning outcomes? Evidence from a randomized experiment in migrant schools in Beijing. *Econ Educ Rev.* 2015;47:34-48.
14. Summer L, Gonzalez L, Jimeno M, Christensen K. Development of a nasogastric tube insertion simulator: a collaborative interdisciplinary effort. *Comput Inform Nurs.* 2009;27(2):105-113.
15. Harder B. Use of simulation in teaching and learning in health sciences: A systematic review. *J Nurs Educ.* 2010;49(1):23-28.
16. Roh Y, Lee W, Chung H, Park Y. The effects of simulation-based resuscitation training on nurses' self-efficacy and satisfaction. *Nurse Educ Today.* 2013;33(2):123-128.

17. Kamin C, O'Sullivan P, Deterding R, Younger M. A comparison of critical thinking in groups of third-year medical students in text, video, and virtual PBL case modalities. *Acad Med.* 2003;78(2):204-211.
18. Holden RJ, Karsh B-T. The technology acceptance model: its past and its future in health care. *Journal of Biomedical Informatics.* 2010;43(1):159-172.
19. Pai F-Y, Huang K-I. Applying the technology acceptance model to the introduction of healthcare information systems. *Technological Forecasting and Social Change.* 2011;78(4):650-660.
20. Hung P-P, Choi K-S, Chiang VC-L. Using interactive computer simulation for teaching the proper use of personal protective equipment. *Computers, Informatics, Nursing.* 2015;33(2):49-57.
21. Tung F, Chang S. Nursing students' behavioral intention to use online courses: A questionnaire survey. *Int J Nurs Stud.* 2008;45(9):1299-1309.

List of Figures

List of Tables

FIGURES

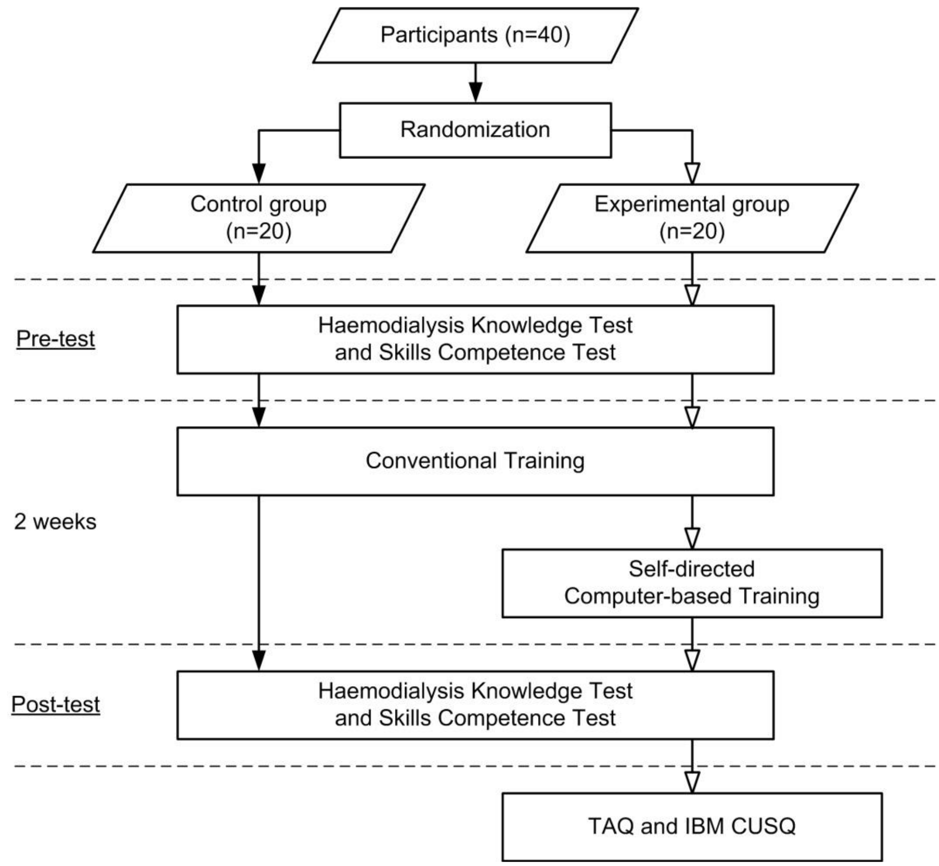
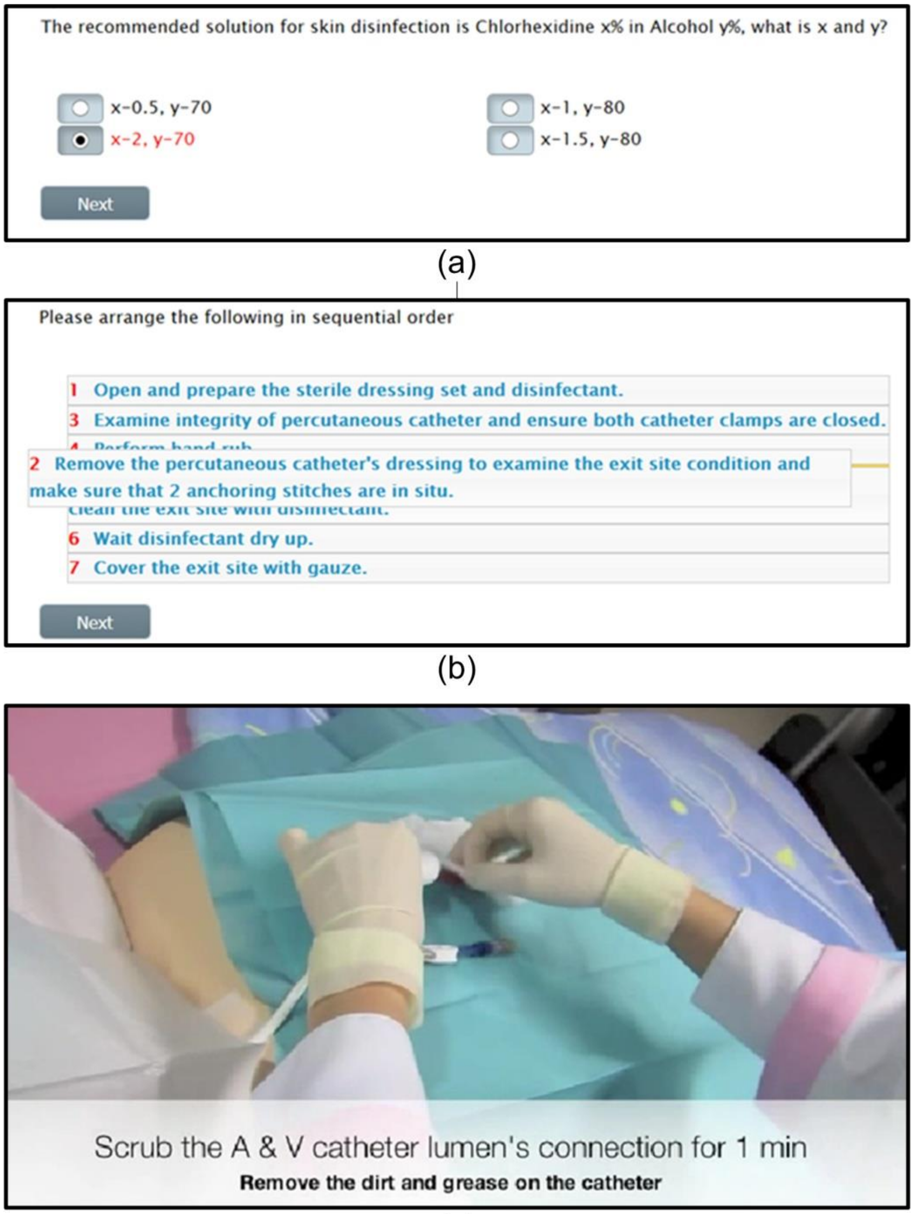
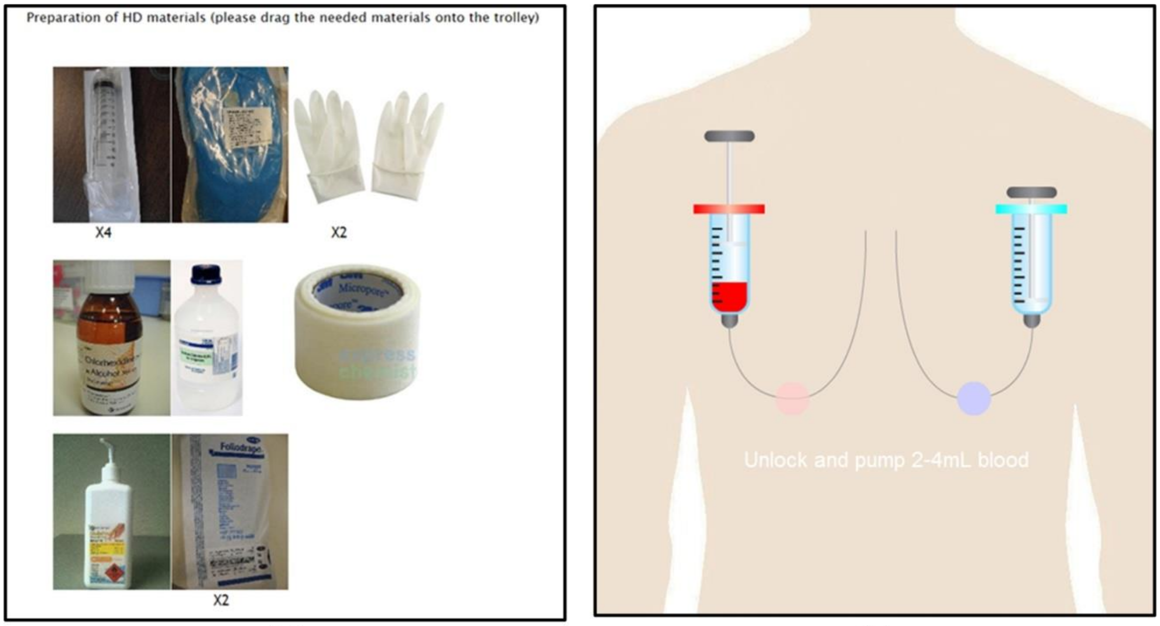


Figure 1. Research design.



(c)

Figure 2. Screenshots of the computer-based HD training system: (a) MCQs, (b) ordering questions, and (c) video demonstration.



(a) (b)

Figure 3. Interactive simulations of the computer-based HD training system: (a) preparing the HD trolley with the drag-and-drop metaphor, (b) testing the blood flow in the percutaneous catheter in a virtual environment.

TABLES

Table 1. Demographic data of the participants.

Demographics	Category	Frequency	Percentage
Gender	Male	6	15%
	Female	34	85%
Age (years)	20-29	13	32.5%
	30-39	21	52.5%
	40-50	6	15%
Academic qualification	Higher diploma	4	10%
	Degree	33	82.5%
	Master’s or above	3	7.5%
Working experience in nursing (years)	1-10	32	80%
	11-20	6	17%
	21 or above	2	5%
Nurse ranking	Enrolled nurse	4	10%
	Registered nurse	31	77.5%
	Senior registered nurse	3	7.5%
	Nursing officer	2	5%
Previous experience with computer simulations	Yes	35	87.5%
	No	5	12.5

Table 2. Demographics of the control group and the experimental group.

Demographic	Category	Control Group	Experimental Group	χ^2	p-value
Gender	Male	3	3	0	1.00
	Female	17	17		
Age (years)	20-29	7	6	0.13	0.94
	30-39	10	11		
	40-50	3	3		
Academic qualification	Higher diploma	1	3	1.36	0.51
	Degree	17	16		
	Master's or above	2	1		
Working experience in Nursing (years)	1-10	15	17	0.79	0.67
	11-20	4	2		
	21 or above	1	1		
Nurse ranking	Enrolled nurse	2	2	0.37	0.95
	Registered nurse	15	16		
	Senior registered nurse	2	1		
	Nursing officer	1	1		
Previous experience with computer simulations	Yes	18	17	0.23	0.63
	No	2	3		

Table 3. Statistical analysis for the HD knowledge test and the HD skills competence test.

Measures	Time	Control group		Experimental group		Between groups
		Mean	SD	Mean	SD	p
Knowledge test	Pre	4.70	1.59	4.00	1.49	0.169
	Post	17.45	2.74	24.00	1.03	< 0.001
Skills test	Pre	39.00	0.00	39.00	0.00	1.000
	Post	113.65	21.23	149.30	19.42	< 0.001

Table 4. Overall response of the 20 subjects in the experimental group to the TAQ.

	Mean	SD
Perceived usefulness	2.28	0.20
Perceived ease of use	2.41	0.13
Intention to use	2.03	0.17
Attitude towards using	1.83	0.03