JECT. 2010;42:139–144
The Journal of ExtraCorporeal Technology

Evaluation of Basic Perfusion Techniques, ECCSIM-Lite Simulator

Asako Tokumine, PhD;* Shinji Ninomiya, DEng;* Megumi Tokaji, MS;† Tatsuya Kurosaki, MD;‡ Yasuko Tomizawa, MD, PhD§

*Department of Clinical Engineering, Hiroshima International University, †Department of Clinical Support, Hiroshima University Hospital, ‡Department of Cardiovascular Surgery, Faculty of Medicine, Hiroshima University, Hiroshima, Japan; and §Department of Cardiovascular Surgery, the Heart Institute of Japan, Tokyo Women's Medical University, Tokyo, Japan

Abstract: Although serious accidents during extracorporeal circulation are infrequent, potential adverse events with both equipment and operation do still occur and require immediate and well-coordinated responses. Hence, perfusionists need to be well trained in both standard and emergency procedures, and this would be aided by the establishment of an official education and training curriculum. In particular, the establishment of a simulator-based educational program and corresponding evaluation methods will spur development of increasingly medical simulators. ExtraCorporeal Circulation SIMulator (ECCSIM-Lite) was used during repeated sessions of undergraduate students (n = 12) using a simple training scenario. Trainees aimed to maintain reservoir volume around a constant mean, and increase or decrease the arterial flow avoiding rapid variations, and their performance was monitored. Ability to prevent backflow was also recorded as a measure of accomplishment. Skills in performances were evaluated by using a scoring system based on task accomplishment. Accomplishment score was improved in all participants after 1 week of training. Accomplishment scores reflecting ability to maintain flow improved to an average of 78%; in the third and final practice session backflow was prevented in 100% of cases. The average reservoir level maintenance score in the flow-up phase was 75%, in the flow-maintenance phase was 92%, and in the flow-down phase was 58%. During skill training, in which trainees learn methods of avoiding adverse events, the use of simulators combined with tractable skills scores can ease the transition from training session to clinical practice. Use of these training scenarios within a perfusion education system also has the advantage of providing an index of trainees' current proficiency and improvement by providing tractable skill scores. In conclusion, the use of ECCSIM-Lite simulations, together with evaluation of task accomplishment over repeated training sessions, is an effective method of basic skill training for perfusionists.
Keywords: extracorporeal circulation, education, skill training, perfusion, simulator system. *JECT. 2010:42:139–144*

In medical education, simulator-based education is gaining widespread acceptance as a teaching tool within the field of anesthesiology (1,2). The particular advantage of medical simulations is the fact that no harm can come to patients (3). Simulation training is particularly useful for learning to manage rare or infrequent events (4). To learn to manage various events, trainees have to understand basic skill.

Recent years have seen the widespread introduction of simulation training involving extracorporeal circulation (5–7). Perfusionists need to be well-trained in both standard and emergency procedures, as complications during extracorporeal circulation can be potentially fatal (8). It is therefore beneficial to establish an appropriate and official perfusion-specific education curriculum and training syllabus (9), and although many institutions recognize this, few carry out such training programs. This is in part because the educational program must adhere to the structure of the education system already in place, which differs between countries and partially as a function of culture (10). Regardless of this, simulator-based education has become common in medical education and there is speculation that the use of simulators will continue to spread in extracorporeal circulation training (3). Given this, and in the light of increasing sophistication of medical simulators (11), the establishments of validated evaluation methods are likely to be a valuable addition to the educational program of perfusionists. Ideally, parallel to advances in development of extracorporeal circulation simulator systems should be protocols for education and skill evaluation.

The goal of this study was to explore whether a simulator system could facilitate extracorporeal circulation programs within a teaching environment. We first developed the

Received for publication October 20, 2009; accepted February 15, 2010.
Address correspondence to: Asako Tokumine, PhD, Department of Clinical Engineering, Hiroshima International University, 555-36 Gakuendai, Kurose-town, Higashi-hiroshima-city, Hiroshima 724-0695, Japan. E-mail: a-tokumi@hs.hirokoku-u.ac.jp
The senior author has stated that authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

ExtraCorporeal Circulation SIMulator system (ECCSIM) (12,13) for use during basic skill training within the educational program of an undergraduate school. We then performed quantitative evaluation of the skill training incorporating the simulation training procedure, which centered on changes in task accomplishment over repeated practice sessions.

MATERIALS AND METHODS

Equipment

A simulator system (Figure 1) designed for the basic skill training relating to extracorporeal technology (ECCSIM-Lite, a non-commercial device from Ninomiya's Laboratory) was used (12).

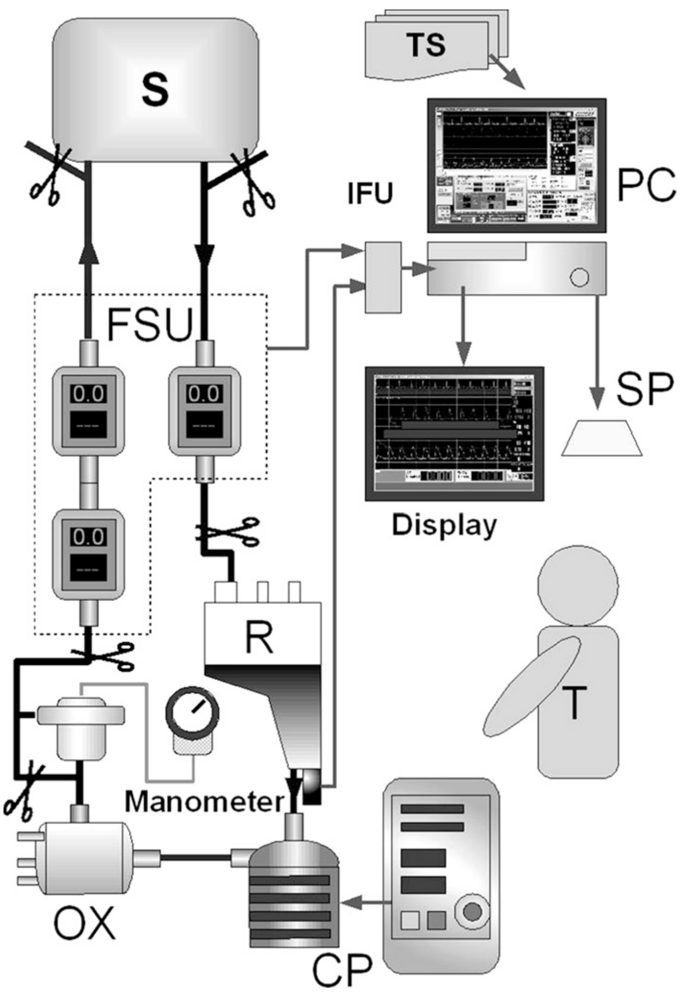

Figure 1. Schematic diagram of the simulator system ECCSIM-Lite. S, a soft bag representing the patient body; FSU, flow sensor unit; R, reservoir; PS, pressure sensor with a built-in amplifier for the measurement of water volume, which is shielded to reduce the electromagnetic noise; CP, centrifugal pump; OX, oxygenator; IFU, analog/digital interface unit; TS, training scenarios; PC, personal computer for performing the scenario and recording; SP, speaker unit; T, trainee.

This system is composed of a) a flow sensor unit with three electromagnetic flow sensors (FD-M10T, flow rate .5–10 L/min; Keyence, Osaka, Japan) for measuring arterial flow and venous return, b) a venous reservoir (Capiox RX-25, Terumo, Tokyo, Japan) with a built-in pressure sensor for water level measurement, c) a soft bag that represents the patient body, d) an interface unit that transmits sensor drive power supply and measurement signals to the computer, which simulates the patient's hemodynamic conditions and displays it on e) the screen monitor.

The system provides information to the trainee according to a pre-defined scenario in real-time, audibly, through the speakers, and visually, on the display screen. Details of arterial/venous flow and reservoir level are measured throughout. Blood flow is simulated with a centrifugal pump system equipped with an extracorporeal circulation circuit. The circuit was filled with water and gravity provided the force for venous drainage.

Procedure

To evaluate performance in basic skills, a training session involving a simple training scenario was presented to several beginners. A fully trained perfusionist must be able to maintain a patient's hemodynamic conditions adequately to accomplish the given surgical objective, and therefore students have to practice the control of arterial and venous drainage flow at the primary stages of training. In this study, the trainees' targets within the scenario were to maintain stable reservoir volume, to prevent backflow, and to prevent rapid variations in flow.

In this scenario, the trainee was instructed to first reach arterial flow of 3.5 L/min within 30 seconds ("flow-up" phase), maintain flow for 30 seconds ("flow-maintain" phase), and to reduce flow within 30 seconds ("flow-down" phase). During all periods, he/she was instructed to maintain a reservoir level of 500 mL (Table 1). The target flow rate 3.5 (L/min) was selected as representative of that of the standard patient (body surface area = 1.5, Perfusion index = 2.4). The duration of one drill was 3 minutes.

The subjects (n = 12) were undergraduate students in the clinical engineering course of Hiroshima International University who had not previously participated in any training procedure of this kind. All participants provided consent for the use of their training records in the current study.

Performance Measures of Basic Perfusion Skill

Degree of accomplishment in basic perfusion skills was defined as the largest absolute error in the arterial and venous line flow rate less than 3.5 ± .2 L/min (Table 2A), the largest absolute error on the venous reservoir level less than 500 ± 30 mL (Table 2B), and the prevention rate of backflow. To fully compare accomplishment levels across training sessions, scores were recorded as a function of phase (flow-up, flow-maintain, and flow-down). Each trainee

Table 1. Simulation scenario and tasks.

Time [sec]	Guidance	Tasks	
0 (0)	"We will start the training session. Control the arterial and venous flow rate and maintain the reservoir level. After the guidance says pump on, keep the arterial flow rate at 3.5 L/min and keep the reservoir level at 500 mL."		
35 (30)	"Pump on! Maintain the full flow at 3.5 L/min and the reservoir level at 500 mL."	Flow up (0→ 3.5 L/min)	
69 (30)	"Maintain the flow rate and reservoir level, keep the fluctuation to within 30 mL."	Flow keep (3.5 L/min)	Maintain to reservoir level (500 mL)
108 (30)	"Decrease the flow rate while maintaining the reservoir level at 500 mL."	Flow down (3.5→ 0 L/min)	
		Prevention of the backflow	
149	"Pump off and clamp the venous line."		

Table 2. Task evaluation standards and the accomplishment scores.

(A) Control of the Arterial Flow

Tasks	Standards for task achievement criteria	The transition of accomplishment scores 1st→2nd→3rd (n = 12)
Maintenance flow of the flow (Phase of flow-maintenance)	Average data of phase: 3.5 ± .2 L/min	58% →67% →67%
The prevention of the backflow (Phase of all)	Must not cause backflow	67% →100% →100%

(B) Control of Reservoir Level

Phase	Tasks	Standards for task achievement criteria	The transition of accomplishment scores 1st→2nd→3rd (n = 12)
Flow-up	Maintain the reservoir level at 500 mL	Remain in target range of 500 ± 30 mL	33% →33% →75%
Flow-maintenance			50% →75% →92%
Flow-down			58% →33% →58%

was instructed in how to operate the simulator system from an instructor with experience in cardiopulmonary bypass procedures. The first trial was performed after this instruction. After practicing freely for a period of 1 hour, trainees completed a second trial. One week later, a third trial was completed. Time courses of arterial/venous line flow and the reservoir level were recorded as quantitative data for the performance measures. The accomplishment score of the task (i.e., variation of the largest absolute error on the arterial/venous line flow, the largest absolute error on the venous reservoir level, and the prevention rate of backflow) were recorded for each phase of each session.

RESULTS

Validity of Procedures

After brief instruction for the training scenario and the manipulation procedure of the simulation circuit by an instructor, each trainee started the training session. All were able to raise flow rate and adjusted it to reach the target value and finish training correctly according to the automated guidance.

The majority of trainees found difficulty in altering blood flow within the instructed 30 seconds on this first trial, and exact manipulation was not possible for them. However, skill performance improved over trials, and on the last trial the majority of trainees achieved flow changes within 30 seconds. The flow-down phase appeared to be most demanding for the participants. These observations demonstrate that the present scenario and the training procedure are suitable for beginners.

Changes in Accomplishment over Repetitions of Training

Significant variations in operating results were observed in the time courses of arterial flow rate, venous flow rate, and blood volume of reservoir. A typical example for one trainee is shown (Figure 2A–C).

On the first training session this participant showed difficulty in controlling the arterial/venous flow and a sudden rise in the reservoir volume was observed (Figure 2A). On the second training session, held 1 hour later, the variation in arterial flow rate and reservoir level was maintained adequately and backflow was not observed (Figure 2B). On the third training session held 1 week later, this skill level was maintained (Figure 2C). The accomplishment

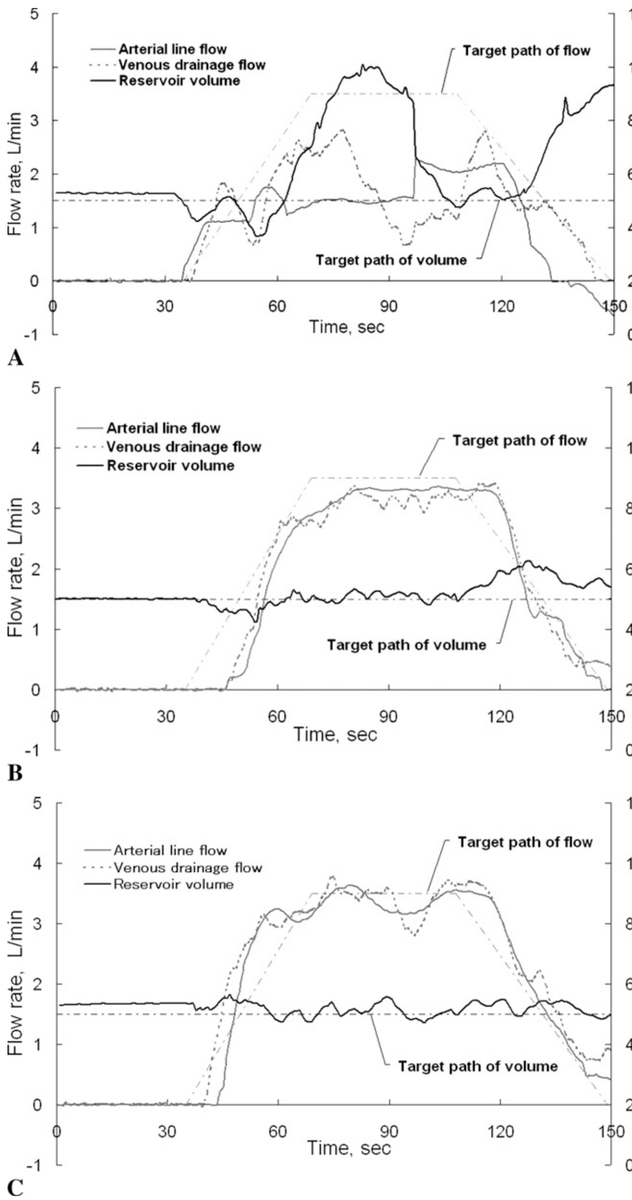

Figure 2. Trend graphs of performance over practice sessions for one trainee. During first training, a rise of the reservoir level is observed (A). During the training session 1 hour later, the reservoir level was maintained (B). The graph (C) of the training session after 1 week shows that target arterial flow rate is achieved, a stable reservoir level maintained, and backflow prevented.

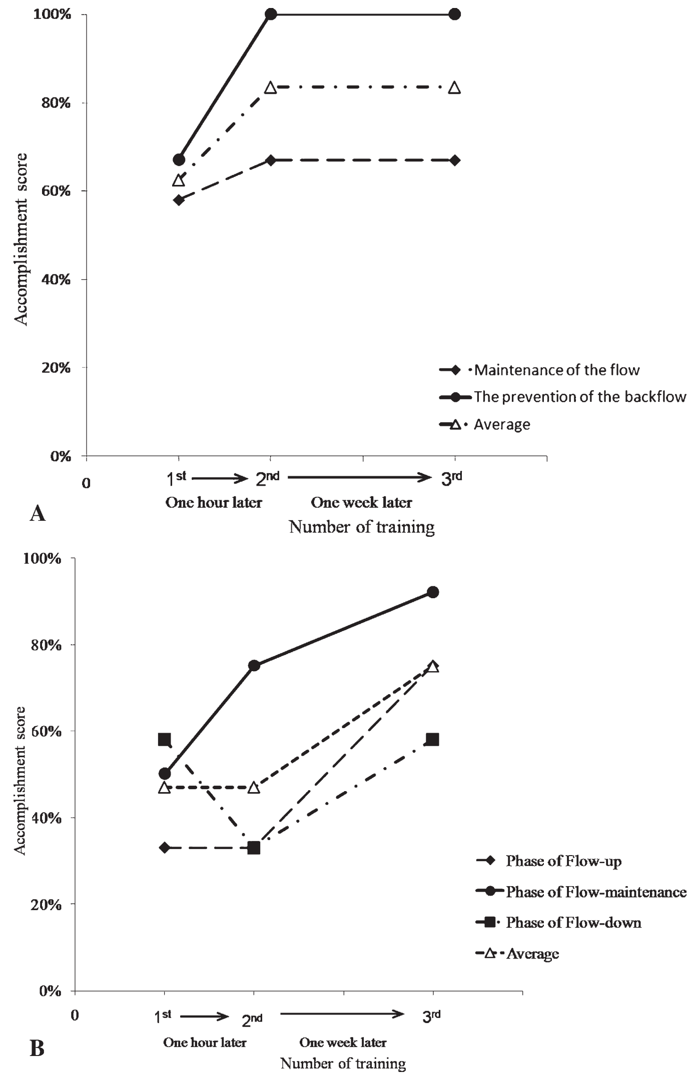

Figure 3. The improvement of the accomplishment score from first to third training session. (A) The control of arterial flow. (B) Maintenance of the reservoir level.

score was improved in all participants by 1 week training (Figure 3).

The averaged accomplishment score became 78% in the third and final training procedure. The prevention of the backflow score reached 100%. The improvement in maintenance of the flow in the flow-maintain section score was not found to differ in the second trial compared to the third. The reservoir level maintenance score became 75% in the flow-up phase, 92% in the maintain-level phase. The accomplishment score of level maintenance in the flow-down phase, 58% in the second trial, was not improved in the final trial, possibly because the trainee's attention was dedicated to prevention of backflow.

DISCUSSION

The present training procedure may be useful to trainees who may find themselves in situations where swift appropriate action is necessary during extracorporeal circulation procedures. However, scores in reservoir level maintenance during the flow-down phase did not improve. It is possible that this arose because trainees gave backflow prevention priority. Performing tasks with multiple objectives is not a simple process. The results of this study suggest that development of more effective scenarios might aid training in basic skills related to extracorporeal circulation, potentially enhancing practical skill education at the undergraduate level. Moreover, during skill training in which trainees learn about measures that can prevent adverse events, the use of a simulator can ease the transition from training scenario to actual patient (14,15).

Perfusionists are required to maintain high levels of knowledge and understanding of new equipment and techniques. Therefore knowledge and skill sets may also be taught and assessed using simulation technology. Complications during cardiopulmonary bypass procedures may be prevented or predicted, if perfusion simulators are used appropriately during the introduction of new equipment and techniques. It is likely that simulators will continue to be used and their role will grow.

Simulation equipment has broad applications throughout the health care industry and will become an integral part of teaching and training programs in most health care areas (3). Morris and Pybus developed an extracorporeal circulation simulator system in 2007 (11). The validity of this system was discussed, and it has many possible applications that include: skill training, certification and accreditation of perfusionists, development and practice of crisis and the team management protocols, and evaluation of new or existing perfusion equipment and/or techniques. However, the link between improvements in technical skills (16,17) and dexterity from simulator training has yet to be established. We suggest that the quantitative evaluation methods, such as those described here of task accomplishment, together with repeated practice of skill training, will be useful in the establishment of quantitative educational evaluation procedures.

In this study, we suggest that the use of a simulator system (ECCSIM-Lite) can provide effective skill training of new trainees through repetitive practice of a basic perfusion sequence, and can also provide quantitative indices of trainee performance for analysis and evaluation. As trainee skills improve and objectives change, complexity can be increased and the time stream made to parallel real time. Trainee proficiency and progress can be evaluated using data provided by the simulator, and this function is likely to become more sophisticated as training devices develop (18). Furthermore, extracorporeal circulation simulation may improve patient safety not only by improving skills, but also by training perfusionists to better anticipate and avoid complications and to manage them should they occur (19). Education protocols that use simulation systems over a series of training sessions may improve standards for perfusion education (20). Moreover, as perfusion simulators become more advanced, it is expected that the skill performances of perfusionists will be evaluated during the execution of standardized scenarios. In the future, perfusion simulation devices may be programmed with different input information (patient data) such as is observed in pilot simulations.

Perfusionists are required to operate the heart-lung machine within the normal physiological range in clinical settings, which differs from the simulator system described here. However, the scenario created in this research is suitable for training in the use of clamp maneuvering. Therefore, it is necessary to establish a scoring system that systematically relates performance in simulated scenarios to clinical competency.

The question of correspondence of learning from a simulator operation and the improvement of clinical skills is an important one. In this training procedure, the same scenario is repeated and practiced. Improvements in performance observed following training with a simulator may not translate into better clinical practice. Pre-clinical trainees may become very effective at completing simulation protocols, but there is potentially an enormous conceptual difference when working with a real patient. The engaging properties of the simulation may arise in part from its similarity to a game, where consequences of actions are relatively minimal: it is of course undesirable that such an attitude be generalized to clinical practice. Then validity of the developed scenario and measures of task accomplishment must be evaluated by experienced clinical perfusionists.

In this system, use of these training scenarios within a perfusion education system also has the advantage of providing an index of trainees' current proficiency and improvement by providing tractable skill scores. Quantitative evaluation methods of task accomplishment using ECCSIM-Lite over repeated practice sessions are effective in basic skill training of students and novice perfusionists.

CONCLUSION

We consider it is necessary for the development of the perfusion education system to link systematic training scenarios and evaluation methods to simulated patient information. Perfusionists play an important role in determining the outcome of cardiac surgery. Effective training of perfusionists would benefit from the establishment of a standardized syllabus and training regime, similar to the system adopted in clinical training. Repetitive practice of protocols which develop key skills is effective in the training of new trainees. A full investigation of the utility of simulation training could track the clinical progress of graduated students who used this simulator in comparison with those who received only the traditional lecture-based training.

REFERENCES

1. Holzman RS, Cooper JB, Gaba DM, Philip JH, Small SD, Feinstein D. Anesthesia crisis resource management: Real-life simulation training in operating room crises. J Clin Anesth. 1995;7:675–87.

2. Cheung V, Critchley LA, Hazlett C, Wong EL, Oh TE. A survey of undergraduate teaching in anaesthesia. Anaesthesia. 1999;54:4–12.
3. Seropian MA. General concepts in full scale simulation: Getting started. Anesth Analg. 2003;97:1695–705.
4. Scott DJ, Bergen PC, Rege RV, et al. Laparoscopic training on bench models: Better and more cost effective than operating room experience? J Am Coll Surg. 2000;191:272–83.
5. Turkmen A, Rosinski D, Noyes N. A simulator for perfusion training. Perfusion. 2007;22:397–400.
6. Toomasian JM, Searles B, Kurusz M. The evolution of perfusion education in America. Perfusion. 2003;18:257–65.
7. Tomizawa Y, Tokumine A, Ninomiya S, Momose N, Matayoshi T. Quantitative evaluation of hand cranking a roller pump in a crisis management drill. J Artif Organs. 2008;11:117–22.
8. Palanzo DA. Perfusion safety: Past, present, and future. J Cardiothorac Vasc Anesth. 1997;11:383–90.
9. Ginther R Jr, Fillingham R, Searles B, Darling E. Departmental use of perfusion crisis management drills: 2002 survey results. Perfusion. 2003;18:299–302.
10. Merkle F. Perfusion education and training in Europe. Perfusion. 2006;21:3–12.
11. Morris RW, Pybus DA. "Orpheus" cardiopulmonary bypass simulation system. J Extra Corpor Technol. 2007;39:228–33.
12. Ninomiya S, Tokumine A, Yasuda T, Tomizawa Y. Development of an educational simulator system, ECCSIM-Lite, for the acquisition of basic perfusion techniques and evaluation. J Artif Organs. 2007;10:201–5.
13. Ninomiya S, Tokaji M, Tokumine A, Kurosaki T. Virtual patient simulator for the perfusion resource management drill. J Extra Corpor Technol. 2009;41:206–12.
14. Cooper JB, Newbower RS, Long CD, McPeek B. Preventable anesthesia mishaps: A study of human factors. 1978. Qual Saf Health Care. 2002;11:277–82.
15. Williams CB, Saunders BP, Bladen JS. Development of colonoscopy teaching simulation. Endoscopy. 2000;32:901–5.
16. Morgan PJ, Cleave-Hogg D. A worldwide survey of the use of simulation in anesthesia. Can J Anaesth. 2002;49:659–62.
17. Manser T, Harrison TK, Gaba DM, Howard SK. Coordination patterns related to high clinical performance in a simulated anesthetic crisis. Anesth Analg. 2009;108:1606–15.
18. Momose N, Tomizawa Y. Incident-simulating device with wireless control for extracorporeal circulation crisis management drills. Perfusion. 2008;23:17–21.
19. Sundar E, Sundar S, Pawlowski J, Blum R, Feinstein D, Pratt S. Crew resource management and team training. Anesthesiol Clin. 2007;25:283–300.
20. Riley JB, Austin JW, Holt DW, Searles BE, Darling EM. Internet-based virtual classroom and educational management software enhance students' didactic and clinical experiences in perfusion education programs. J Extra Corpor Technol. 2004;36:235–9.