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ORIGINAL ARTICLE

SimLife: face validation of a new dynamic simulated body model for surgical simulation

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Abstract

Background: Surgical trainees face many barriers when learning anatomy and surgical techniques. Many teams describe the use of cadaveric simulators, and most of the time cadavers are used fresh or embalmed. These models, although realistic, are far from the physiological reality. For more realistic surgical training, we have proposed a dynamic cadaveric model mimicking an anaesthetized patient. **Aim**: A face validation study of SimLife, a new dynamic cadaveric simulated body model for acquisition of operative skills by simulation. The objectives of this study were to measure the realism of the model, the satisfaction of learners, and the ability of the model to facilitate a learning process. **Methods**: Simulation training in surgery requires realism very close to that found in the operating room. This is what SimLife technology brings. It is based on a fresh body (frozen/thawed) donated to science, made dynamic with a pulsatile vascularization with simulated blood heated to 37°C and ventilation in a patented technical module. This model allows performance of both open and laparoscopic surgical approaches. **Results**: Surgical trainees (n = 103) from gastrointestinal, cardiothoracic, transplantation, gynaecology, and orthopaedic surgery departments were enrolled in this study. Based on their evaluation, the overall satisfaction of the cadaveric model was rated as 8.43, realism as 8.89, anatomic correspondence as 8.65 and the model's ability to be a learning tool as 8.87. **Conclusion**: The use of the SimLife model is a realistic surgical simulation model to train and objectively evaluate the performance of surgical trainees.

Keywords: *Surgical simulation; cadavers; reperfusion*

Introduction

In the last two decades, the surgical community has stated that mentorship, as described since the 19th century, is no longer the method of instruction that best prepares trainees to enter the modern field of surgery.[1–5] The advent of assisted video surgery, possibly associated with robotics, has shifted learning from the operating theatre to a preclinical model well known in the aeronautics industry: simulation-based teaching. Aircraft pilots and crews can benefit from electronic high-fidelity simulators and analyse their teamwork using the technique of simulation known as "crisis resource management". This simulation-based education is not the norm in the health care field where education is very heterogeneous from one country to another and even from one university to another.[2–5]

If we focus on surgery, the learning of basic technical skills can be compared with the simulation training of pilots. Just like a pilot in his cockpit, the novice surgeon must be immersed in an operating room-type universe to acquire an optimum level of performance before practicing in a real situation.

Although computer models can perfectly simulate a long-distance flight with all possible anomalies, the same cannot be said for computerized surgical simulation. It is necessary to adapt simulation models to anatomic and/or physiological variations that cannot be perfectly programmed in a computerized scenario.[6,7] Anatomic models or human fresh or embalmed cadavers have been used for centuries for practical surgical training and interventional medicine.[8–10]

Whether by open or laparoscopic approaches, the benefits and performance acquisition have been highlighted using cadaveric models in pilot studies.[11–15] Furthermore, the hyper-specialization of the surgical world leads to the emergence of complex procedures that require training on a hyper-realistic model.[9] For many medical students, the use of human cadavers can lead to both ethical reflection and emotional and psychological analysis, and as such contributes to their behavioural training.[16,17] Training on a cadaveric model seems to be the best compromise between learning in the operating room, the animal model and/or virtual simulators.[12]

One of the main shortcomings of the cadaveric model is that, in most cases, it does not correspond to a pathological situation and when using embalmed or even fresh bodies, the pulsatile nature of the vessels and even the appearance and texture of the tissues is very far from clinical reality.[9] To offer a high degree of face validity, the cadaveric model must offer a realistic replication of human anatomy, tissue consistency, and physiology.[9] Also, it is very difficult or even impossible to find a pathological situation with cadaveric models.[9] It seemed possible to improve realism by proposing a reperfused and reventilated cadaveric model that mimics a patient in the operating room.

The objectives of this study were to evaluate the realism of this model, the satisfaction of learners and the ability of this model to facilitate the learning process.

Materials and methods

The model

The SimLife model combines a cadaver from a body donation that arrived at the Centre de Dons de Corps (Body Donation Center) of the Faculty of Medicine of Poitiers and was prepared for surgical simulation (Fig. 1). Cannulas were placed in both femoral arteries and in the left common carotid artery (input) in both femoral veins and in the left internal jugular vein (output). The vascular axes of the limbs can be excluded to vascularize only the trunk, but one or two limbs can be irrigated. A pressure recording catheter in the arterial system was introduced into the right common carotid artery and pushed into the aortic arch. A tracheotomy or intubation tube provides ventilation. A gastric tube was used to aspirate the stomach. Emptied of its native blood, the body was frozen for conservation and then thawed a few days before the simulation session.

A specific technical module animating the body (patent 1 560488, deposit 1 000318748) was adapted to cannulas.[18,19] The blood-mimicking fluid circulated in the arterial system in a pulsating manner, recoloured and warmed the organs, restored venous turgor and was eliminated from the body by the venous catheters. The physiological hemodynamic data, correlated with the pressure data of the right common carotid artery, could be mechanically adapted by a technician at the head of each model.

This teaching programme on a cadaveric model was covered by the approval of the Ethics Committee of the French Ministry of Health under the number: DC-2008-137.

The training programme

The main purpose of this work on this cadaveric model was to highlight its relevance and all the possibilities it offers, and we set up training sessions for several specializations.

Study design and participants

A total of 125 participants, comprising residents, experts and faculty members, consented to take part in this study on a total of 20 occasions. The training days were hosted at the Anatomy, Biomechanics and Simulation Lab of the Medical School of the University of Poitiers. Before performing each procedure, all participants were given an introduction, which included lectures, videos, description of the technique, and an introduction to the reperfused cadaver model. This was followed by hands-on training on SimLife. The number of participants in the practical sessions depended on the surgical specialty. Our wish to demonstrate the extent of the model's possibilities has led us to set up training courses for many of the specialties specified in Table 1. Except for multi-organ procurement sessions, where there could be up to five learners per station, we assigned two learners per station with at least one supervising expert.

Evaluation survey

At the end of each session, all surgical trainees were invited to complete a voluntary and anonymous evaluation. Feedback from the trainees included considerations on their learning experience and the realism of the model. A feedback form was distributed at 20 subsequent training sessions to evaluate the model on Likert scale from 0 to 10 (0, not at all; 10, perfect). Questions involved (1) facilitation to learn a technical procedure with this model; (2) accuracy of the corresponding anatomic landmarks in comparison with clinical reality; (3) degree of realism of the model; and (4) overall satisfaction with the training model.

Statistical analysis

Analysis was performed using SAS 9.3 software. Means and standard deviations (SDs) of the scores are reported in Table 2.

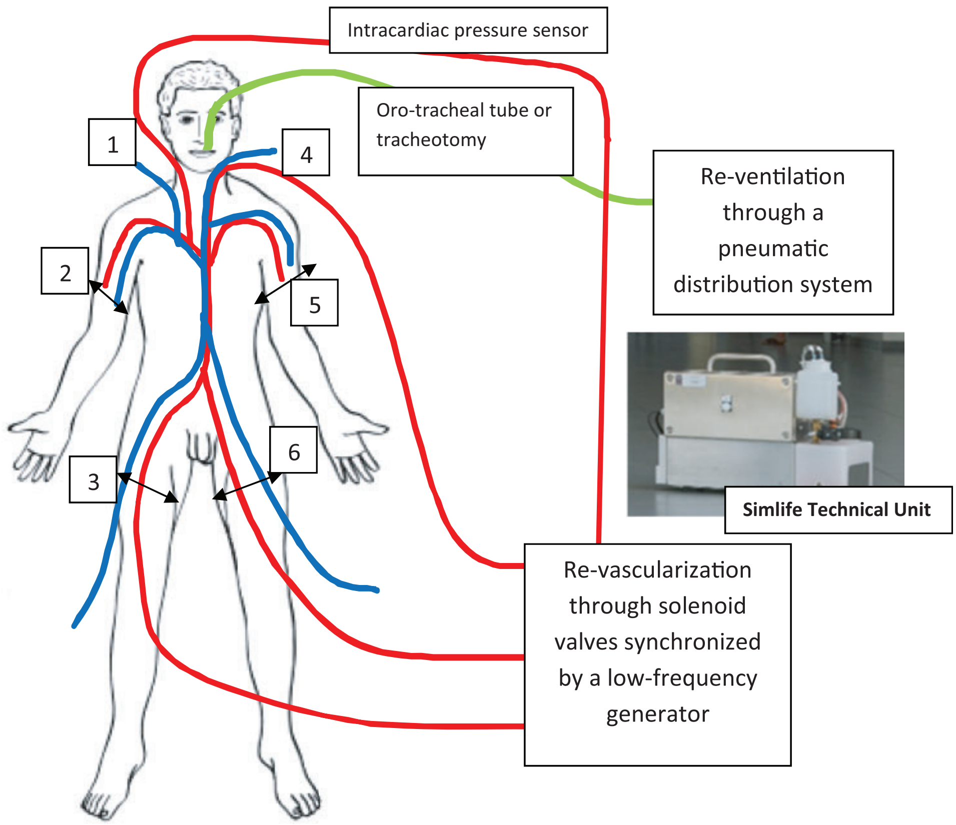

Figure 1. Schema of global vascular and arterial access of SimLife in the model of trunk surgery and the connections with the SimLife technical system. (1 and 4) Dissection of carotid arteries and internal jugular veins: input cannula in the left artery, output cannula in the two veins, and an intracardiac pressure sensor through the right carotid artery. (2 and 5) Dissection for ligation of bilateral humeral arteries and veins. (3 and 6) Dissection of femoral veins and arteries: input cannula in the arteries, output cannula in the veins. Double arrows indicate ligation of the vessels to avoid limb revascularization.

Results

Of the 125 participants, 103 surgical trainees completed and returned the evaluation survey (Table 2). Among faculty, all 22 received an oral debriefing with the module designers to discuss any technical changes. In total, 103 evaluation surveys were received for a response rate of 100% from the trainees.

Participants consisted of French surgery residents and fellows: residents were aged from 25 to 33 years, in year 4–5 of training and fellows were aged between 29 and 40 years, with 1–4 years post residency (Table 3). In the multi-organ harvesting session, participants included residents and fellows who had been practicing for 4 to 8 years. Faculty members were qualified as senior surgeons in their specialty and were from different French institutions.

The evaluation survey was carried out at the end of each session. Data were collected from 20 training sessions, and 103 participants answered the four survey questions relating to face validity of the SimLife model. Each question was scored on a Likert scale of 0 to 10 (0, not at all; 10, perfect). Based on these evaluations, the overall satisfaction of the cadaveric model had a mean score of 8.43 (SD, 0.87), realism had a mean score of 8.89 (SD, 0.96), anatomic correspondence had a mean score of 8.65 (SD, 0.98) and the model's ability to be a learning tool had a mean score of 8.87 (SD, 0.86).

Discussion

Teaching future health professionals constitutes a pedagogical challenge that must take into account the development of new training methods. Theoretical training, thanks to e-learning, poses fewer problems. Until now, the practical training of surgical residents has been done according to the companionship method: on the one hand in the anatomy laboratory (preclinical practical training), and on the other hand in departments and operating rooms (clinical practical training). This model of surgical companionship was based on principles defined in the 19th century by William Halsted and by Theodore Billroth.[20]

The following reasons are currently forcing the rethinking of surgeons' education at national and international level "away from the patient" and on to other models: the current evolution of socio-economic constraints ("never the first time on the patient"), the increase in number and changes in the status of residents with a decrease in the duration of clinical training, the evolution of surgical procedures and techniques with the advent of videoscopy and robotics, and the increase in medico-legal pressure on the surgical world, which is considerably modifying the conditions and legitimacy of clinical companionship.[16,17,21,22]

Surgical residents must undergo preclinical technical surgical training outside the operating room. It may integrate several simulation methods on electronic or synthetic simulators, and on animal or human models.[23] Some of these traditional preclinical and procedural training courses using cadavers are carried out in an anatomy laboratory in medical faculties. Most of the time, these include technical procedures, approaches, dissection of vessels,[11,12] endourology,[14] and emergency procedures: packing the pelvis, emergency nephrectomy,[14] tracheostomy, splenectomy,[13] and insertion of surgical equipment such as the placement of spinal screws.[9] After a short theoretical reminder (anatomy, indications, technique or operating method), the procedures performed on human cadavers are supervised and corrected by senior anatomists from the specialty concerned.[20] This process of short training courses of a technical nature is similar to the method of behaviourism whereby the expected result is the observable manifestation of the mastery of knowledge corresponding to an algorithm of actions.[24]

For surgical skills training, the fidelity of the model with reality is essential for the transfer of skills and technical and psychological retention by trainees.[6,7] Although cadaveric models are anatomically near identical to the live patient, reproducing realistic physiology is a difficult task. With the SimLife model, we focused on circulation and ventilation.

With regard to circulation, we developed a computerized programme that changes the flow rate of the pumps

Table 1. The different surgical procedures performed to date using the SimLife model

	Open procedure	Laparoscopy
Urology		
Nephrectomy	X	X
Prostatectomy	X	X
Thoracic and cardiac surgery		
Aortic valve replacement	X	
Aortic arch surgery	X	
Lung resection		X
Transplant surgery		
Multi-organ procurement (lung, heart, liver, kidney and pancreas)	X	
Orthopaedic surgery		
Spine	X	
Gynaecological surgery		
Breast, uterus, pelvic floor	X	X
Pelvic lymph node resection	X	X
Visceral surgery		
Bariatric surgery		X
Endocrine surgery : adrenal gland resection, thyroid and para thyroid	X	X
Cervical lymph node resection	X	

Table 2. Characteristics of the trainees

	Residents (n = 87)		Fellows (n = 16)	
	Number of trainees	Years of experience	Number of trainees	Years of experience
Age (years)	25–33		29–40	
Surgical specialty				
Urology	8	3–5	2	1–4
Orthopaedic surgery	8	2–5	2	1–2
Digestive surgery	11	4–5	4	1–2
Gynaecology	8	4–5	1	1–2
Cardiothoracic surgery	8	4–5	1	1–4
Transplantation	38	3–5	6	1–4
Damage control	6	4–5	0	

Table 3. Trainees' responses (*n* = 103) to the questionnaire (on a Likert scale of 0 to 10) about the quality of the model

Questions	Score, mean (SD)
Learning a procedure with this model	8.87 (0.86)
Anatomic correspondence	8.65 (0.98)
Realism	8.89 (0.96)
Overall satisfaction	8.43 (0.87)

according to the pressure. Using a pulsatile pump with warmed blood-like liquid and a catheter into the aortic arch through the right carotid, the blood pressure is adjusted automatically according to possible bleeding accidents during surgery. Thus, a moderate haemorrhage induces an increase in flow up to a threshold where the flow decreases until it stops. Concerning coagulation, we worked on the blood-like liquid to obtain a realistic colour and make coagulation possible when surgeons needed to use coagulation devices.

With regard to ventilation, the cadaveric model has been validated for simulation-based training on the approach to the upper airways in anaesthesia resuscitation.[25] It is important to be able to offer the possibility of ventilation of corpses for multi-professional simulation sessions. In surgery, the thorax approach has been proposed for resuscitation thoracotomy.[15] We have developed a ventilated model for thoracic surgery; when lung expansion is sometimes limited, it perfectly mimics a pulmonary cavity during surgery with lung exclusion.

Fundamentally, all simulated cadaver models have been developed by specialized teams taking into account the specificities of their own activities. For example, vascular surgeons focus on circulation, allowing for the repetition of approaches and vascular sutures. As shown by Bellier et al.[26] in their review, most models have used pumps to perfuse the cadaver and maintain the mean arterial blood pressure in the physiological range. They concluded that perfusion techniques on cadavers were heterogeneous and imperfect, but as proposed in Gnunakumar's paper,[9] "the simulator or training device is actually teaching or evaluating what it is intending to teach or measure".

For thoracoscopy workshops, where the main goal is to dissect the pedicles and control pulmonary stapling, the cadaveric model is perfectly relevant; even if the expansion of the pulmonary parenchyma is not perfect, the model's realism is relevant, and the model validation process should be adapted to this concept.

In the late 1950s, Kirkpatrick and Kirkpatrick[27] defined a training evaluation model based on four levels of evaluation. Each level is built on the information from the previous levels. In other words, a higher level is a finer and more rigorous assessment of the previous level: level 1, assessment of reactions; level 2, learning assessment; level 3, evaluation of transfer; and level 4, outcome evaluation.

Level 1, or face validation in the case of the cadaver model, is the most common evaluation because it is the easiest to implement. After each training session, participants are asked to complete an evaluation questionnaire. However, a positive evaluation does not indicate successful learning. Only one study, about the use of cadavers in training, has evaluated the trainee's future performance when transferred to the operating room[9] in one specialized model on neurosurgery. Face validation is an assessment of the participants' level of satisfaction with the training programme and their perception. The evaluation goes beyond simple learner satisfaction; for example, this anatomically or physiologically realistic model can also facilitate immersion, and will make it possible to measure the acquisition of new skills in relation to the training objectives.

There has been a notable step forward in procedural simulators with the introduction of virtual reality and augmented reality simulators, and these have been shown to be effective for surgical training using videoscopy.[28,29] It is difficult to objectively compare virtual simulators or the animal model with training using cadavers. Thus, it is difficult to establish a hierarchy between surgical simulation models. Each model must find its place within a curriculum specific to each specialty. The SimLife model is a demanding model with regard to preparation and infrastructure, and training must be integrated into an educational curriculum to limit the cost. It is not desirable to learn the basic procedures on the SimLife model. Those must be acquired on simpler models. For example, performing running sutures is learned on a simple laparoscopic trainer. The use of the SimLife model must be reserved for training just before transfer to the operating theatre; it can be a dress rehearsal for the theatre.

Conclusion

SimLife seems to be a relevant cadaveric model that could have a positive effect on the training of young surgeons. In accordance with the objectives of each element of training, the acquisition of new skills could be implemented with this cadaveric model.

References

1. Tan SS, Sarker SK. Simulation in surgery: a review. Scot Med J 2011; 56: 104-109 https://doi.org/10.1258/smj.2011.011098.
2. Scott DJ, Cendan JC, Pugh CM, Minter RM, Dunnington GL, Kozar RA. The changing face of surgical education: simulation as the new paradigm. J Surg Res 2008; 147: 189-193. https://doi.org/10.1016/j.jss.2008.02.014.
3. Zahiri HR, Park AE, Pugh CM, Vassiliou M, Voeller G. "See one, do one, teach one": inadequacies of current methods to train surgeons in hernia repair. Surg Endosc 2015; 29: 2867-2872. https://doi.org/10.1007/s00464-015-4411-7.
4. Di Saverio S, Catena F, Birindelli A, Tugnoli G. "See one, do one, teach one": education and training in surgery and the correlation between surgical exposures with patients outcomes. Int J Surg 2016; 27: 126-127. https://doi.org/10.1016/j.ijsu.2016.01.085.
5. Krell RW, Birkmeyer NJ, Reames BN, Carlin AM, Birkmeyer JD, Finks JF. Michigan Bariatric Surgery Collaborative. Effects of resident involvement on complication rates after laparoscopic gastric bypass. J Am Coll Surg 2014; 218: 253-260. https://doi.org/10.1016/j.jamcollsurg.2013.10.014.
6. Tsuda S, Scott D, Doyle J, Jones DB. Surgical skills training and simulation. Curr Probl Surg 2009; 46: 271-370. https://doi.org/10.1067/j.cpsurg.2008.12.003.
7. Norman G, Dore K, Grierson L. The minimal relationship between simulation fidelity and transfer of learning. Med Educ 2012; 46: 636-647. https://doi.org/10.1111/j.1365-2923.2012.04243.x.
8. Aziz MA, McKenzie JC, Wilson JS, Cowie RJ, Ayeni SA, Dunn BK. The human cadaver in the age of biomedical informatics. Anat Rec 2002; 269: 20-32. https://doi.org/10.1002/ar.10046.
9. Gnanakumar S, Kostusiak M, Budohoski KP, Barone D, Pizzuti V, Kirollos R, et al. Effectiveness of cadaveric simulation in neurosurgical training: a review of the literature. World Neurosurg 2018; 118: 88-96. https://doi.org/10.1016/j.wneu.2018.07.015.
10. Magee R. Art macabre: resurrectionists and anatomists. ANZ J Surg 2001; 71: 377-380. https://doi.org/10.1046/j.1440-1622.2001.02127.x.
11. Simmerman E, Simmerman A, Lassiter R, King R, Ham B, Adam BL, et al. Feasibility and benefit of incorporating a multimedia cadaver laboratory training program into a didactics curriculum for junior and senior surgical residents. J Surg Educ 2018; 75: 1188-1194. https://doi.org/10.1016/j.jsurg.2018.03.012.
12. Reed AB, Crafton C, Giglia JS, Hutto JD. Back to basics: use of fresh cadavers in vascular surgery training. Surgery 2009; 146: 757-762; discussion 762-763. https://doi.org/10.1016/j.surg.2009.06.048.
13. Sharma G, Aycart MA, O'Mara L, Havens J, Nehs M, Shimizu N, et al. A cadaveric procedural anatomy simulation course improves video-based assessment of operative performance. J Surg Res 2018; 223: 64-71. https://doi.org/10.1515/sem-2018-0047.
14. Ahmed K, Aydin A, Dasgupta P, Khan MS, McCabe JE. A novel cadaveric simulation program in urology. J Surg Educ 2015; 72: 556-565. https://doi.org/10.1016/j.jsurg.2015.01.005.
15. Kim SC, Fisher JG, Delman KA, Hinman JM, Srinivasan JK. Cadaver-based simulation increases resident confidence, initial exposure to fundamental techniques, and may augment operative autonomy. J Surg Educ 2016; 73: e33-e41. https://doi.org/10.1016/j.jsurg.2016.06.014.
16. Tseng WT, Lin YP. "Detached concern" of medical students in a cadaver dissection course: a phenomenological study. Anat Sci Educ 2016; 9: 265-271. https://doi.org/10.1002/ase.1579.
17. Rizzolo LJ. Human dissection: an approach to interweaving the traditional and humanistic goals of medical education. Anat Rec 2002; 269: 242-248 https://doi.org/10.1002/ar.10188.
18. Delpech PO, Danion J, Oriot D, Richer JP, Breque C, Faure JP. SimLife a new model of simulation using a pulsated revascularized and reventilated cadaver for surgical education. J Visc Surg 2017; 154: 15-20. https://doi.org/10.1016/j.jviscsurg.2016.06.006.
19. Faure JP, Breque C, Danion J, Delpech PO, Oriot D, Richer JP. SIM Life: a new surgical simulation device using a human perfused cadaver. Surg Radiol Anat 2017; 39: 211-217. https://doi.org/10.1007/s00276-016-1715-9.
20. Varas J, Mejia R, Riquelme A, Maluenda F, Buckel E, Salinas J, et al. Significant transfer of surgical skills obtained with an advanced laparoscopic training program to laparoscopic jejunojejunostomy in a live porcine model: feasibility of learning advanced laparoscopy in a general surgery residency. Surg Endosc 2012; 26: 3486-3494. https://doi.org/10.1007/s00464-012-2391-4.
21. Garment A, Lederer S, Rogers N, Boult L. Let the dead teach the living: the rise of body bequeathal in 20th-century America. Acad Med 2007; 82: 1000-1005. https://doi.org/10.1097/ACM.0b013e318149e986.
22. Nutt J, Mehdian R, Parkin I, Dent J, Kellet C. Cadaveric surgery: a novel approach to teaching clinical anatomy. Clin Teach 2012; 9; 148-151. https://doi.org/10.1111/j.1743-498X.2012.00536.x.
23. Boet S, Granry JC, Savoldelli G. La simulation en santé. De la théorie à la pratique. Paris: Springer-Verlag; 2013, 442 p. https://doi.org/10.1007/978-2-8178-0469-9.
24. Barussaud ML, Roussel B, Meurette G, Sulpice L, Meunier B, Regenet R, et al. French intensive training course in laparoscopic surgery (HUGOFirst) on live porcine models: validation of a performance assessment scale and residents'

satisfaction in a prospective study. J Visc Surg 2016; 153: 15-19. https://doi.org/10.1016/j.jviscsurg.2015.10.005.

25. Ruetzler K, Leung S, Chmiela M, Rivas E, Szarpak L, Khanna S, et al. Regurgitation and pulmonary aspiration during cardio-pulmonary resuscitation (CPR) with a laryngeal tube: a pilot crossover human cadaver study. PLoS One 2019; 14: e0212704. https://doi.org/10.1371/journal.pone.0212704.
26. Bellier A, Fournier J, Faure Q, Snyman S, Mirallie C, Chaffanjon P. Development of cadaver perfusion models for surgical training: an experimental study. Surg Radiol Anat 2019; 41: 1217-1224. https://doi.org/10.1007/s00276-019-02204-z.
27. Kirkpatrick DL, Kirkpatrick JD. Evaluating training programs: the four levels. San Francisco, CA: Berrett-Koehler; 2006. 379 p.
28. Palter VN, Grantcharov TP. Virtual reality in surgical skills training. Surg Clin North Am 2010; 90: 605-617. https://doi.org/10.1016/j.suc.2010.02.005.
29. Diesen DL, Erhunmwunsee L, Bennett KM, Ben-David K, Yurcisin B, Ceppa EP, et al. Effectiveness of laparoscopic computer simulator versus usage of box trainer for endoscopic surgery training of novices. J Surg Educ 2011; 68: 282-289. https://doi.org/10.1016/j.jsurg.2011.02.007.