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Use of a hybrid-abdominal wound simulated patient in the ACS/ASE medical student simulation skills curriculum

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A B S T R A C T

Objective: We incorporated a hybrid-abdominal wound simulation to teach/assess the acquisition of three essential clinical skills in the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum.
Method: Third year students (N = 43) attended a workshop based on the ACS/ASE surgical skills curriculum for drain care/removal, staple removal and Steri-Strip application. Following a didactic session and demonstration using a simulated patient, student skill acquisition was assessed using the ACS/ASE module rating tool. Student interest/perceived usefulness of the workshop was evaluated using Keller's Motivational Survey.
Results: We used median scores to identify low proficiency (n = 20; scores 17–28) and high proficiency (n = 23; scores 29–35) groups. The high proficiency group was more knowledgeable, performed better drain care, had a higher global score and was more confident than the low proficiency group. The students rated the workshop highly based on the Keller's Motivational Survey.
Conclusion: All students were proficient in the procedure tasks and communication skills and most felt that the course was beneficial. The ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum was successfully integrated into our third year surgical clerkship.

Introduction

The objective of undergraduate medical education is to produce knowledgeable, proficient and safe physicians, equipped to begin their training in residency. However, multiple surveys of clerkship directors and students have revealed gaps in undergraduate education. Wu et al., in their 2005 study, noted that a majority of the third year medical students had not performed important procedures, and a quarter of the students had not performed basic procedures.[1] In their follow-up study in 2006, they received similar feedback from fourth year medical students. They reported that the final year of medical school cannot be relied upon to provide students with clinically significant additional procedural experience without an outlined curriculum.[2] An additional reason for the lack of procedural involvement was highlighted in a 2013 survey of pre-clerkship medical students and institutional administration. In this survey, student involvement was limited, in part due to concerns on patient safety, which resulted in less surgical procedural experience before graduation from medical school.[3]

To address the concern of limited student procedural involvement, great emphasis is placed on simulation in medical education. Simulation provides a safe environment for practice and errors to occur, opportunities for feedback and assessment, and standardized experience for trainees.[4–6] Simulation can be seen in many forms including standardized patients, a screen-based computer, a task simulator, or a high-fidelity mannequin simulator.[7] Yet, medical students have a varied and random simulated surgical skills experience during their clerkship, depending on access to and the quality of a simulation center. A national survey of incoming first year categorical residents revealed that only 24% of individuals had participated in a procedural-skills course. Those that did participate in a course reported a significantly higher sense of preparedness to perform basic procedural skills than those who did not.[8] To make

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simulation a powerful training tool, Gallagher and colleagues noted that integration of a validated comprehensive curriculum is essential.[9] To identify essential simulation-based procedures and skills, the American College of Surgeons (ACS) and the Association for Surgical Education (ASE) conducted a survey of surgical clerkship directors and medical students at five schools. They concluded that both clerkship directors and students concurred on the importance of specific educational topics. Clerkship directors rated basic skills high while students rated procedural skills higher.[10] These simulation-based educational topics were used to create modules, which the ACS/ASE incorporated in to the Medical Student Simulation-based Surgical Skills Curriculum.

First released in 2013, the ACS/ASE Medical Student Simulation-Based Surgical Skills Curriculum consists of 25 basic instructional and skills topics to be covered by first through thirdyear medical students. One such topic is *Surgical Drains-Care and Removal*. The module consists of two objectives: 1) Understand general theory behind the use of drains (functionality, purpose, types, limitations, maintenance and removal, etc.) and 2) Properly assess drainage and execute their removal.[11] This module was used in our study to deliver a half-day workshop for 3rd year medical students. Although acquisition of technical skills is essential for students, non-technical factors such as empathy and communication between team members, other health care providers and with patients are of equal importance. A collapse in these non-technical factors results in an increased rate of errors in the operating room.[12–15] Hybrid simulation combines patient interaction (using a standardized patient) with a task trainer that allows for procedural skill practice. The advantage of this type of simulation is that the learner, by interacting with the standardized patient, practices non-technical factors while acquiring the technical skills of the procedure. Our aim was to incorporate a hybrid-abdominal wound simulated patient in the ACS/ASE Medical Student Simulation-Based Surgical Skills Curriculum to teach and assess the acquisition of three essential clinical skills.

Methodology

Subjects/participants

All third year medical students in surgical clerkship at Drexel University College of Medicine rotating through a single hospital from June 2015 to October 2015, attended a half-day workshop (n = 43). The module was introduced at the start of the rotation and was completed by students enrolled in 2 eight-week rotation blocks. The curriculum was identical throughout the entire study period. This workshop was our initial attempt at incorporating a module from the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum into a current syllabus. This educational study was deemed exempt by the Drexel University Institutional Review Board.

Workshop

Based on the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum, Year 2, Module 7, a workshop was developed.[11] This module aimed to explain the background and general theory behind the use of drains, and to teach the assessment of drainage and removal of drains. Two other related procedures were added to this module: staple removal and Steri-Strip applications. Students received pre-course study material two weeks prior to the workshop by email. The study material was adapted from the same module allowing students to familiarize themselves with the information provided. On the day of the workshop, students attended an interactive, question-based teaching session on surgical drain and staple removal and Steri-Strip application. Subsequently, students observed a live demonstration on a hybrid simulation (Fig. 1). A clinical scenario was enacted to teach both technical procedural skills and non-technical skills of empathy and interpersonal communication skills as critical components of patient care. A didactic component related to the communications elements was added to the educational module.

Following the live demonstration, each student was evaluated on their ability to perform these skills on a hybrid simulation. Raters, who were senior surgical residents (PGY3-5), evaluated the students' interaction with these hybrid patients and assessed their skills performances. A rating tool, adapted from the ACS/ASE skills curriculum for medical students, Year 2, Module 7,[11] was used to determine proficiency (Appendix 1). All raters underwent a brief training session in which they reviewed the components of the performance rating checklist. Student information was collected on: total length of surgical rotation (months), number of drains pulled, and experience in staple removals. Students were assessed and scored in four key areas - Knowledge Based Questions (maximum score − 9), Communication and Interaction (maximum score− 6), Drain Care and Removal (maximum score − 9), and Staple and Steri-Strip Removal (maximum score − 7). A global score was given for overall technical performance and efficiency.

A final grade was given based on the total score, which was obtained by adding Knowledge-based Questions, Checklist Scores, and Global Rating Score. Using the rating tool by ACS/ASE curriculum for drain care, proficiency was set at a score greater than 15. This was a rough guide provided by the ACS/ASE curriculum, as no data are available on reliability or validity of this grading system.[11] We also used the split-half technique to divide this cohort into two levels of proficiency (low and high) to assess areas where future emphasis needs to be made in upcoming workshops. The median scores were used to identify low proficiency (n = 20; scores 17–28) and high proficiency (n = 23; scores 29–35) groups. At the end of a testing session, each student was given constructive and formative feedback on their performance by the rater and by the simulated patient. At the conclusion of the workshop, each student was asked to complete the Keller's Course Interest Survey to assess the quality of the teaching session.

Hybrid simulation

Hybrid Simulation was created by using standardized patients (SP) and a low-fidelity simulator. SP were laboratory students trained to act as patients to simulate authentic clinical encounters. They were given a script that helped them answer students' questions regarding the standard medical history (history of present illness, review of systems, past medical, surgical and OB-GYN history; current medications and allergies; psychosocial history and family history). Beside SPs, actors posing as patients' nurses were included in the clinical scenario to teach students the importance of communication between health care providers. Nurses also had essential patient information on patient's updated vital signs, medication administration details, fluid balance, and drain outputs.

A low-fidelity simulator of post-laparotomy abdominal wall, was made by recycling used laparotomy pads (Simulab Corporation®, Seattle, WA),[16] from our Basics of Open Laparotomy Training (BOLT) curriculum.[17] This model consisted of a partial abdomen including skin, subcutaneous fat, fascia, preperitoneal fat, and peritoneum (Fig. 2). As these laparotomy pads had been used in the BOLT workshop, they had a re-approximated midline incision. The simulated skin in the model was closed with staples. A Jackson-Pratt drain was placed in the simulated laparotomy pad and secured with silk sutures. The drain contained less than 5 cc of red-

Fig. 1. Workshop based on ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum, Year 2, Module 7 to teach and assess Drain care/removal, Staple removal and Steri-Strip application. a) Interactive didactic session b) Live demonstration of procedure on hybrid simulation c) Students' evaluation of patient interaction d) Corrective feedback session.

colored fluid. The simulated post-laparotomy abdominal wall was placed over the SP's abdomen underneath their gown. This model required very few resources to make and was repeatedly used throughout the session.

Clinical scenario

The first part of the clinical encounter was set on a surgical ward in a patient room. Our simulated patient was Mr. XY, a 28-year-old male post-operative day 3 status post laparotomy for a perforated peptic ulcer, which was repaired with a Graham's patch. He had no past medical or family history, his medications included vitamins.

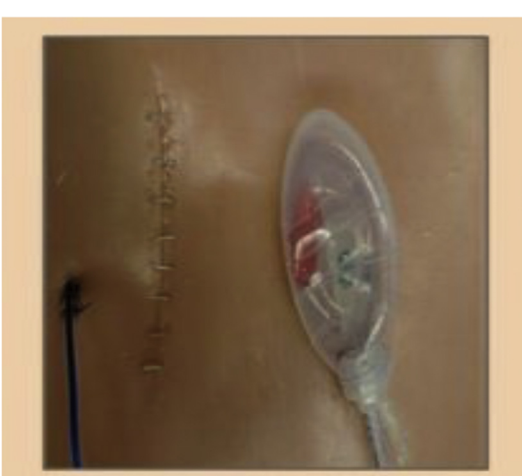

Fig. 2. Viscoelastic model of post-laparotomy abdominal wall with drain and staples.

His intra and post-operative period had been uneventful thus far. His vitals were stable and his drain output was less than 15 cc in 24 h, sero-sanguinous. He was on sips of water. Urine output had been adequate and he was passing flatus without bowel movements. In this scenario, medical students were instructed by the chief residents to pull out the drain. The medical students were expected to review the patient's charts, assess the suitability of removing the drain, communicate their plans with the nurse and ask for any important updates. Student were expected to introduce themselves to the patient and take a brief history, which includes asking about pain control and timing of pain medication intake. If the student did not ask about pain, the SP would grimace during the abdominal exam. Two other challenges were incorporated into this scenario. In the first additional challenge, the SP acted surprised and denied any knowledge of having a drain when the student conveyed the plan to discontinue the drain. In the next challenge, the SP asked the student if he/she had done this before, whether it was going to hurt and to describe the procedure. Next, the student removed the drain and was expected to dispose of it in a biohazard bin; this concluded the first scenario. In the second part of the encounter, the student met the SP in the office a week later, took a brief history, performed a physical examination, removed staples and applied Steri-Strips.

Attention Relevance Confidence Satisfaction (ARCS) survey

In our study, students' motivation and overall course satisfaction were assessed using the 1988 *Attention Relevance Confidence Satisfaction (*ARCS) survey, developed by John Keller (Appendix 2). The ARCS model of motivation is based upon the idea that there are four key elements involved in learning, which sustain a student's desire to learn. The model is centered on Tolman and Lewin's expectancy-value theory, which presumes that people are

Table 1
Overall medical students' median score and percentage (n = 43).

	Maximum Score	Median Score (IQR)	Median Percentage Score
Knowledge Based Score	9	6 (4,8)	66.6
Communication and Interaction	6	6 (6,6)	100
Drain Care and Removal	9	7 (5.5,8)	77.7
Staple Removal and Steri-Strip Application	7	6 (5,6)	85.7
Global Score	5	4 (4,4)	80.0
Total Score	36	29 (26,31.5)	80.5

Note: IQR – Interquartile range.

motivated to learn if there is value in the knowledge presented.[18,19] A student's attention, the first element of the model, is straightforward to acquire, but often difficult to maintain. Relevance, the second element, ensures that the learner's attention is held throughout the entire lesson. Confidence is the next element of the model and helps students understand their likelihood for success. Motivation decreases if students perceive they cannot meet the goals or it requires too much effort. Finally, learners must obtain some type of reward from learning. Keller suggests encouraging and supporting the intrinsic enjoyment of the learning experience to provide satisfaction to the learner through positive reinforcement and meaningful feedback. We used Keller's ‘Course Interest Survey’ from his text.[20] This survey has 34 items on the four ARCS categories, with Likert-type responses (1–5), and a minimum-maximum range of 34–170.

Data analysis

Dependent measures included ACS/ASE Year 2, Model 7 Subscales (Knowledge Based Score, Communication and Interaction, Drain Care and Removal, Staple Removal and Steri-Strip Application, and Global Score) and ARCS subscales (Attention, Relevance, Confidence, and Satisfaction scores). Mann-Whitney non-parametric tests were used to compare low and high proficiency groups on the rating tool and ARCS subsets. Number Cruncher Statistical Software (NCSS; www.ncss.com) was used for the analyses with an $\alpha = 0.05$ significance criterion for all tests.

Results

The workshop was conducted twice during the study period and each session lasted approximately 3.5 h. The interactive teaching session was 30 min long comprised of a 15-min live demonstration and a 15-min testing session per student. Forty-three third-year medical students attended the Hybrid-Abdominal Wound Simulated Patient workshop. Their surgical experience ranged from 0 to 4 months, with six students having pulled a drain and eight having removed staples.

All students scored higher than 15, achieving proficiency. Table 1 shows the median score for each of the subsets of the total score. Reviewing this data, students scored well on communication skills (100%) and performed relatively poorly on the knowledge based test (66.6%). In our group, the ranges of scores attained by students were 17–35. Table 2 illustrates the high proficiency group was more knowledgeable and performed drain care better than the low proficiency group.

At the end of the workshop students completed a Keller's Course Interest Survey (100% response and completion rates). The data was divided into the four subscales – Attention, Relevance, Confidence and Satisfaction (ARCS). Overall, students rated the workshop highly (135/170) and breakdown of subsets was as follows: Attention (29/40), Relevance (38/45), Confidence (31/40), and Satisfaction (37/45). Table 3 illustrates that medical students in both proficiency groups rated the course similarly on the Attention, Relevance and Satisfaction subscales. There was no significant correlation between the total proficiency score and the Keller's Course Interest Survey ARCS total score (Fig. 3, r = 0.115, 95% confidence interval −0.190, 0.397). The high proficiency group rated their confidence higher than the low proficiency group.

Discussion

The ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum, Year 2, Module 7 was easily incorporated into our medical students' education program. It addressed a perceived need, was comprehensive, and provided essential materials to run the workshop. The curriculum was very well received by learners as reflected by Keller's Course Interest rating scores. It was inexpensive to run the workshop as most of the material was recycled from other skills workshops or the operating room. We also included two additional procedures in the workshop: staple removal and Steri-Strip application. These procedures were included into the simulation model because there was no preexisting competency-based student education related to these essential clinical skills. Often these procedures are not taught as they are very simple; however, if not appropriately performed it can be painful for the patient and demoralizing for student. The success of the workshop can be summarized in testimony given by one of the students; "I really liked how detailed the program was. Each step of the process was taught well, not just the medicine

Table 2
Medical students' score comparison between low and high proficiency groups.

	Low Proficiency (n = 20) ACS/ASE Scores 17-28		High Proficiency (n = 23) ACS/ASE Scores 29-35		p-value[a]
	Median	IQR	Median	IQR	
Knowledge Based Score	3.5	(2,4)	7.0	(7,8)	<0.001
Communication and Interaction	6.0	(6,6)	6.	(6,6)	0.056
Drain Care and Removal	6.0	(5,7)	8.0	(7,8)	<0.001
Staple Removal and Steri-Strip Application	6.0	(5,6)	6.0	(5,6)	0.162
Global Score	4.0	(3,4)	5.0	(4,5)	<0.001

Note: IQR – Interquartile range.
[a] All tests were Mann-Whitney non parametric tests with all Z-values corrected for ties.

Table 3
Medical students' Keller's course interest survey rating subscale score comparison between low and high proficiency groups.

	Low Proficiency (n = 20) ACS/ASE Scores 17-28		High Proficiency (n = 23) ACS/ASE Scores 29-35		p-value[a]
	Median	Median CI (LL,UL)	Median	Median CI (LL,UL)	
Attention	31.5	(29,34)	31.0	(30,33)	0.999
Relevance	40.5	(36,42)	41.0	(35,42)	0.732
Confidence	32.5	(30,35)	36.0	(34,37)	0.015
Satisfaction	39.0	(37,43)	40.0	(36,41)	0.961

Note: CI – 95% confidence interval; LL – lower limit; UL – upper limit.
[a] All tests were Mann-Whitney non parametric tests with all Z-values corrected for ties.

part but all kinds of details that we really don't learn because we're usually just watching it happen. I thought overall it was very beneficial."

The suggested time to run this module is 1 h 5 min; however, it took us 3.5 h to complete a session. Our workshop was longer as we tested each student's performance, provided individualized corrective feedback and used hybrid simulation that incorporated a clinical scenario. Additional personnel were involved, including volunteers to act as our standardized patients and confederate nurses. Instead of a practice session for medical students, we created a low stakes testing condition that enabled them to retrieve information presented earlier in the workshop. Retrieval practice has been studied extensively in recent years; in their book 'Make it Stick', Brown et al., explain in detail the testing effect.[21] 'Testing effect' is described as enhanced long term memory when previously learned information is retrieved by testing a learner on the acquired information. The 'testing effect' results in better retention and reduced loss of learned information. Roediger and colleague in their review on 'The Power of Testing Memory' concluded that when increased cognitive effort is required for retrieval, it results in enhanced retention.[22] An informal review of various studies shows that even a single test produces better retention and the positive effects of testing continue to improve as the number of tests increases.[21,23,24] By giving detailed, corrective feedback at the end of workshop we aimed to reinforce long-term learning. Feedback prevents students from incorrectly retaining material that they may have misunderstood and ensures better learning of the correct responses.[21,25]

This study demonstrated that the use of hybrid simulation to teach the ACS/ASE curriculum can aid medical students in achieving proficiency in the studied tasks. Though all students achieved 100% proficiency in technical and communications skills, they scored only 66% on knowledge testing. It is possible that a single demonstration of these basic but important skills was all that was needed for students to learn the tasks to proficiency. Some students had prior experience in these tasks and it is likely that the students had observed their interns or residents performing or teaching these skills. With regard to communication, these nontechnical skills are highlighted in the preclinical years and student performance is likely a reflection of that emphasis. While one of the knowledge questions was fairly straightforward and was included in the didactic slide show, the second knowledge question required students to recall anatomical details that they may have not recently reviewed. This could explain their lower knowledge scores.

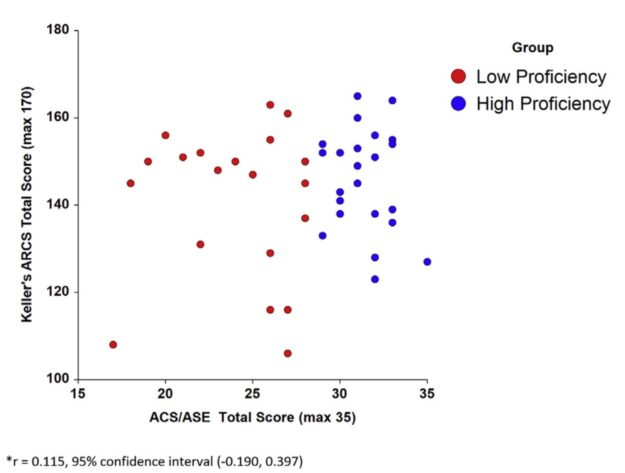

Fig. 3. Scatterlplot of Keller's ARCS total score as a Function of ACS/ASE medical student simulation surgical skills curriculum total score for the low and high proficiency groups.

In terms of comparing the high and low proficiency groups, high proficiency group was more knowledgeable, performed drain care better, had a higher global score and were more confident than the low proficiency group. The two groups were equally proficient in staple removal, Steri-Strip applications and communication/interaction. This may be a reflection of the minimal technical skills required to perform staple removal and Steri-Strip application. Furthermore, similarities in communication/interaction scores may be a result of common teaching and emphasis on these non-technical skills in the students' preclinical years. The high proficiency group demonstrated higher confidence but that may be due to bias from combining a simple skill (removing Steri-Strips and staples) with a technical skill (drain removal) in the Keller survey, which addresses and evaluates the experience as a whole.

In a hybrid simulation study performed by Goolsby et al., fourth year medical students sustained improvement in their confidence with procedural skills during an emergency medicine clerkship.[26] Similarly, there are myriad of studies that describe the usefulness of employing hybrid simulation to teach both technical and non-technical skills.[27–30] In our study, students believed that interacting with a simulated patient felt like a real patient encounter. The interaction forced them to think about the auxiliary task involved in executing a clinical procedure. These additional tasks included informing a patient's nurse, assessing a patient's present condition, evaluating the appropriateness of performing a procedure, collecting all the material to perform the procedure, and most importantly, developing the ability to explain the procedure to a patient while addressing their concerns and alleviating their fears.

As with any feasibility study, there were some limitations. The absence of a control group made it difficult to quantify the true benefits of the workshop. However, it is ethically difficult to have a control group as it would mean depriving an educational session for the control group. A better approach would have been to compare a pre and post-intervention Course Interest Survey. Another limitation of this study was the lack of assessing transfer of the acquired skills to a clinical situation. Ideally, we would like to follow-up these students through their clerkship to evaluate their technical performances and communications during patient encounters. Moreover, it would have been helpful for students to also receive feedback directly from the confederate nurse. Lastly, using a non-validated rating tool has its pitfalls. Our rating tool was adapted from the drain module of the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum, which has not been validated.

In conclusion, this curriculum was implemented successfully and with ease into our current third year surgical clerkship educational program. It was well-received by the medical students, who related the need for more procedural workshops based on the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum. Incorporation of a Hybrid Simulation enhanced the acquisition of both technical as well as non-technical skills involved with a procedure. Our future direction is to incorporate more modules from the ACS/ASE Medical Student Simulation-based Surgical Skills Curriculum in a step-wise manner into the undergraduate medical educational program.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.amjsurg.2018.07.039.

References

1. Wu EH, Elnicki DM, Alper EJ, et al. Procedural and interpretive skills of medical students: experiences and attitudes of third-year students. *Acad Med J Assoc Am Med Coll*. 2006 Oct;81(10 Suppl):S48–S51. PubMed PMID: 17001134. Epub 2006/09/27. eng.
2. Wu EH, Elnicki DM, Alper EJ, et al. Procedural and interpretive skills of medical students: experiences and attitudes of fourth-year students. *Acad Med J Assoc Am Med Coll*. 2008 Oct;83(10 Suppl):S63–S67. PubMed PMID: 18820504. Epub 2008/10/10. eng.
3. Bernholt DL, Garzon-Muvdi J, LaPorte DM, et al. A survey of current policy and practice of surgical exposure for preclerkship medical students at American medical institutions. *Am J Surg*. 2013 Sep;206(3):433–438. PubMed PMID: 23746657. Epub 2013/06/12. eng.
4. Tavakol M, Mohagheghi MA, Dennick R. Assessing the skills of surgical residents using simulation. *J Surg Educ*. 2008 Mar-Apr;65(2):77–83. PubMed PMID: 18439524. Epub 2008/04/29. eng.
5. Kneebone R. Simulation in surgical training: educational issues and practical implications. *Med Educ*. 2003 Mar;37(3):267–277. PubMed PMID: 12603766. Epub 2003/02/27. eng.
6. Moorthy K, Munz Y, Forrest D, et al. Surgical crisis management skills training and assessment: a simulation[corrected]-based approach to enhancing operating room performance. *Ann Surg*. 2006 Jul;244(1):139–147. PubMed PMID: 16794399. Pubmed Central PMCID: PMC1570602. Epub 2006/06/24. eng.
7. Okuda Y, Bryson EO, DeMaria Jr S, et al. The utility of simulation in medical education: what is the evidence? *Mount Sinai J Med New York*. 2009 Aug;76(4): 330–343. PubMed PMID: 19642147. Epub 2009/07/31. eng.
8. Promes SB, Chudgar SM, Grochowski CO, et al. Gaps in procedural experience and competency in medical school graduates. *Acad Emerg Med Offic J Soc Acad Emerg Med*. 2009 Dec;16(Suppl 2):S58–S62. PubMed PMID: 20053213. Epub 2010/01/28. eng.
9. Gallagher AG, Ritter EM, Champion H, et al. Virtual reality simulation for the operating room: proficiency-based training as a paradigm shift in surgical skills training. *Ann Surg*. 2005 Feb;241(2):364–372. PubMed PMID: 15650649. Pubmed Central PMCID: PMC1356924. Epub 2005/01/15. eng.
10. Glass CC, Acton RD, Blair PG, et al. American College of Surgeons/Association for Surgical Education medical student simulation-based surgical skills curriculum needs assessment. *Am J Surg*. 2014 Feb;207(2):165–169. PubMed PMID: 24468023. Epub 2014/01/29. eng.
11. Surgeons ACo. ACS/ASE medical student simulation-based surgical skills curriculum [cited 2016 29 Mar]; Available from: http://web2.facs.org/medicalstudents/landing.cfm; 2014.
12. Christian CK, Gustafson ML, Roth EM, et al. A prospective study of patient safety in the operating room. *Surgery*. 2006 Feb;139(2):159–173. PubMed PMID: 16455323. Epub 2006/02/04. eng.
13. Mishra A, Catchpole K, Dale T, McCulloch P. The influence of non-technical performance on technical outcome in laparoscopic cholecystectomy. *Surg Endosc*. 2008 Jan;22(1):68–73. PubMed PMID: 17479324. Epub 2007/05/05. eng.
14. Yule S, Flin R, Paterson-Brown S, Maran N. Non-technical skills for surgeons in the operating room: a review of the literature. *Surgery*. 2006 Feb;139(2): 140–149. PubMed PMID: 16455321. Epub 2006/02/04. eng.
15. Hull L, Arora S, Aggarwal R, et al. The impact of nontechnical skills on technical performance in surgery: a systematic review. *J Am Coll Surg*. 2012 Feb;214(2): 214–230. PubMed PMID: 22200377. Epub 2011/12/28. eng.
16. Corporation S. Laparotomy Replaceable Tissue. [cited 2016 29 Mar]; Available from:: https://www.simulab.com/product/suture1/laparotomy-replaceable-tissue.
17. Greenawald L, Uribe J, Shariff F, et al. Construct validity of a novel, objective evaluation tool for the basics of laparotomy training (BOLT) using a simulated model. *Am J Surg*. 2017 Jul;214(1):152–157. PubMed PMID: 28501285. Epub 2016 Mar 21. eng.
18. Keller JM. Development and use of the ARCS model of instructional design. J Instr Dev.10(3):2–10.
19. Keller JM. Using the ARCS motivational process in computer-based instruction and distance education. *N Dir Teach Learn*. 1999;1999(78):37–47.
20. Keller JM. *Motivational Design for Learning and Performance: The ARCS Model Approach*. US: Springer; 2010.
21. Brown PC, Roediger HL, McDaniel MA. *Make it Stick : The Science of Successful Learning*. 2014.
22. Roediger 3rd HL, Karpicke JD. The power of testing memory: basic research and implications for educational practice. *Perspect Psychol Sci J Assoc Psychol Sci*. 2006 Sep;1(3):181–210. PubMed PMID: 26151629. Epub 2006/09/01. eng.
23. Pastötter B, Bäuml K-HT. Retrieval practice enhances new learning: the forward effect of testing. *Front Psychol*. 2014 Apr;5:286. PubMed PMID: PMC3983480.
24. Roediger III HL, Putnam AL, Smith MA. 1 ten benefits of testing and their applications to educational practice. *Psychol Learn Motiv Adv Res Theor*. 2011;55:1.
25. Kang SH, McDermott KB, Roediger III HL. Test format and corrective feedback modify the effect of testing on long-term retention. *Eur J Cognit Psychol*. 2007;19(4-5):528–558.
26. Goolsby CA, Goodwin TL, Vest RM. Hybrid simulation improves medical student procedural confidence during EM clerkship. *Mil Med*. 2014 Nov;179(11): 1223–1227. PubMed PMID: 25373045. Epub 2014/11/06. eng.
27. Kennedy JL, Jones SM, Porter N, et al. High-fidelity hybrid simulation of allergic emergencies demonstrates improved preparedness for office emergencies in pediatric allergy clinics. *J Allergy Clin Immunol Pract*. Nov 2013;2013, 2014-03-22;1(6):608-17. PubMed PMID: 1507339641. English.
28. Goolsby C, Deering S. Hybrid simulation during military medical student field training–a novel curriculum. *Mil Med*. 2013 Jul;178(7):742–745. PubMed PMID: 23820347. Epub 2013/07/04. eng.
29. Siassakos D, Draycott T, O'Brien K, et al. Exploratory randomized controlled trial of hybrid obstetric simulation training for undergraduate students. *Simulat Healthcare J Soc Med Simulat J Soc Simulat Healthc*. 2010 Aug;5(4):193–198. PubMed PMID: 21330796. Epub 2011/02/19. eng.
30. Stewart M, Kennedy N, Cuene-Grandidier H. Undergraduate interprofessional education using high-fidelity paediatric simulation. *Clin Teach*. 2010 Jun;7(2): 90–96. PubMed PMID: 21134155. Epub 2010/12/08. eng.