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Simulation-Based Clinical Education in The Operating Room: A Review Study

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Abstract

Context: Simulation is an educational technology that has been demonstrated to facilitate learning and enhance learners' performance. The primary objective of this study is to introduce and investigate the use of simulation-based education in the context of clinical education within the operating room.

Evidence Acquisition: For this review article, the keywords "Simulation," "Education," "Clinical Education," "Operating Room Education," and "Simulation in the Operating Room" were utilized to conduct a comprehensive search of articles available on PubMed, Google Scholar, Scopus, Web of Science, and Science Direct from the period of 2000 to 2022. Articles about the introduction and implementation of simulation-based education methods in the context of the operating room were selected and examined.

Results: A total of 42 articles were scrutinized, which encompassed discussions on the historical evolution and significant role of simulation in clinical education, the approaches involved in constructing and advancing simulation-based education, the diversity of simulators employed in the operating room, and the significance and variations of models created to evaluate the efficacy of such methods. The simulators described included physical simulators with low fidelity, web-based educational tools, computer-based video training, virtual learning systems, learning management systems, the "McGill system" for laparoscopic skills training and evaluation, simulation-based surgical methods, and computer-controlled mannequins such as "Sim Man 3G".

Conclusions: The implementation of various simulators and models in the context of operating room education presents opportunities for the design, implementation, and evaluation of educational programs. With proper planning and attention to detail, many of the existing challenges can be effectively addressed.

Keywords: Simulation Training, Educational Technology, Operating Room, Clinical Education

1. Context

Simulation is an educational technology that facilitates learning and improves learner performance (1). As medical education evolved since 1900, and the need for measuring students' clinical competencies in the scopes of knowledge, skills, and behavior emerged, access to clinical skills was introduced as a critical goal in medical education (2). However, doubts about the effectiveness of these products, the lack of connection between different educational centers, and the high responsibility for proving the quality of simulation methods led to delays in accepting these methods (3). Therefore, although various simulations have been introduced over the past 50 years, widespread acceptance of some particular types, such as standardized patients, virtual reality (VR), human patient simulations, and mannequins, has only been realized in the last decade (4).

Clinical simulation is now recognized as an effective educational technique that provides clinical experiences in a safe environment, free from personal fears and weaknesses, and, through interactive activities, enhances student learning. The benefits of this method include improving patient safety, enhancing interactive learning, improving critical thinking processes, problem-solving, student-centered learning, and self-paced learning (5). The use of this method in medical education is appropriate due to the large number of clinical students, the shortage of patients, the different combinations of patients, the inactivity of patients during the examination, and the lack of constructive feedback in a suitable clinical environment (1). However, the cost of simulation equipment has always been one of the challenges of using this method (6). Nevertheless, recently, due to the expansion of collaborative simulation centers, the cost of equipment, personnel, and programs has decreased, and the popularity of this approach has led to an increase in multidisciplinary, interprofessional, and multimedia education (7).

One of the most important reasons for using simulation-based training is the reduction in equipment costs, emphasis on evidence-based practice, the creation of clinical competency, and attention to patient safety (5). On the other hand, the operating room is one of the critical medical fields that includes approximately 60% of hospital-related adverse events (8). Although most patients recover without complications, life-threatening problems may arise due to insufficient experience of personnel in these situations (9). Therefore, the use of simulation-based training in surgical environments also improves technical and non-technical skills such as interpersonal communication, judgment, leadership, and teamwork, and enables surgeons and surgical teams to operate more safely and reduce the occurrence of unintended side effects (10).

Student members of the surgical team also have an abstract mindset towards the challenges of clinical environments, as they are future personnel in the field. Therefore, the use of simulation-based training methods is recommended to improve clinical decision-making in this group (11). However, given the wide variety of simulators available, using an appropriate model for implementing and evaluating this method can increase confidence in its effectiveness (12). Therefore, considering the aforementioned points, the aim of this study is to review and introduce helpful and practical simulators for simulation-based training in the operating room.

2. Evidence Acquisition

This article presents a narrative review study aimed at introducing credible and practical simulators for operating room education. The search and selection process followed specific criteria to ensure the inclusion of relevant articles. Keywords such as simulator, simulation, education, clinical education, operating room education, and simulation in the operating room were utilized. English articles from databases including PubMed, Scholar Google, Scopus, Web of Science, and Science Direct were systematically searched within the timeframe of 2000 to 2022.

The inclusion criteria for articles were defined to establish a focused review. The search and review were conducted collaboratively by two researchers. Articles meeting the criteria and demonstrating a direct connection with the introduction and utilization of simulation-based educational methods in the operating room were selected for comprehensive review.

The criteria for acceptance and rejection of articles were established based on relevance to the topic and the extent of their contribution to understanding and implementing simulation-based educational methods in the operating room. These criteria were applied rigorously to ensure the inclusion of high-quality and pertinent literature in this review.

This narrative review employed a systematic approach to evaluate the selected articles based on predefined criteria. The criteria for article evaluation were established to ensure the inclusion of relevant and high-quality content. The evaluation process considered the following key aspects:

Relevance to the topic: Articles were assessed for their direct connection with the introduction and utilization of simulation-based educational methods in the operating room.

Methodological rigor: The methodological quality of each selected article was scrutinized to ensure a sound and reliable foundation for the information presented.

Contribution to understanding: The extent to which articles contributed to the understanding and implementation of simulation-based educational methods in the operating room was carefully evaluated.

Publication source: The reputation and credibility of the publication source were considered to ensure the inclusion of articles from reputable journals and databases.

The evaluation process was conducted collaboratively by two researchers, and any discrepancies were resolved through discussion and consensus.

3. Results

In the initial search based on the keywords used, 274 articles were found, and after removing duplicate articles, 197 articles remained. Then, by studying the titles and abstracts of the remaining articles, 155 articles were eliminated due to the lack of relevance to the study's objective, and 42 articles remained. Of the remaining articles, 14 articles discussed the history and importance of using simulation in clinical education, 5 articles discussed various types of simulators, 3 articles discussed the methods of creating and developing simulation programs in schools, 12 articles discussed the types of educational simulators used in the operating room, and 8 articles examined the importance and type of designed models for intervention and evaluation of team-based skills based on simulation, which will be discussed further in the following sections.

3.1. The Importance of Simulation-based Training in the Operating Room

Although avoiding harm to patients is one of the ethical principles in medicine, medical errors are still the most important threat to patient safety despite advances in therapeutic technologies. In the United States, approximately 210,000 to 440,000 deaths per year are preventable due to medical errors (13). One out of every 50 hospitalized patients dies due to unintended events, and two-thirds occur in the operating room (14).

Despite the belief that a significant portion of adverse events in the operating room is related to technical skills, the causes of many of these incidents are not due to skill-related errors but rather due to deficiencies in teamwork, communication skills, management, and awareness of the patient's condition, all of which are considered non-technical skills related to teamwork. Studies have shown that precise planning, repetition, and training of these skills can improve teamwork and, as a result, enhance patient safety (8, 15). Approximately half of the adverse events in the operating room can be prevented through constructive feedback, learning from past errors, and improving teamwork. Therefore, the ultimate goal of simulation-based training in the operating room should be to engage all members of the surgical team, including the surgeon, scrub and circulating personnel, anesthesiologist, nurses, and others, in order to enhance their teamwork performance (16).

3.2. Establishing and Developing Simulation Programs in Universities

According to Seropian et al., many universities use a three-stage approach to establish and develop their simulation centers: (1) assessing the willingness of faculty members to teach using simulation and how it enhances learning; (2) selecting and purchasing the necessary equipment; and (3) appointing a center director and supporting the equipment and programs (13). In addition to the necessary equipment for simulation, training based on this approach also requires the preparation of educational scenarios, which are prepared by the simulation equipment manufacturer or by faculty members in each section according to the learning objectives of students (17). That is because the focus on critical objectives and skills, attention to scenario preparation, providing feedback and evaluating performance, practical training under the supervision of faculty members, and matching simulations with professional needs all contribute to enhancing learning through simulation (18). It should be noted that effective learning in this method depends on how the interaction between the teacher and the student, their expectations, and their roles in the simulation stages are defined. The role of the teacher varies depending on the purpose of using simulation. During the implementation of the educational program, the teacher plays the role of facilitator, and during evaluation, the role of observer. Therefore, since the correct definition of the teacher's role and position in the program can affect the learning outcomes and self-efficacy of students (19), selecting skilled faculty members for simulation-based education is one of the important tasks of universities (17).

3.3. Types of Simulators

Simulators used in complex educational situations have various types and classifications. Ziv et al. classified simulators used in medical education into the following five groups: (1) low-tech/part-task simulators, (2) standardized patient simulators, (3) computer screen-based simulators, (4) computer task trainers, (5) realistic patient simulators (20).

Gaba, D M a medical professor at Stanford University and inventor of the modern patient body simulator, also categorizes educational simulators into five different groups: (1) verbal simulators for role-playing simple scenarios; (2) standardized patients for evaluating clinical examinations, taking histories, assessing communication, and professionalism of students; (3) part-task trainers, which are basically simple anatomical models of different parts of the body in normal or disease states. Although more complex modern surgical task trainers also fall into this category; (4) computer patients, which are interactive and may be computer screen-based virtual worlds or part of the real world, have replaced standardized patients, reducing costs in various educational centers; (5) electronic patients, which are mannequins or virtual realities and are capable of reflecting all clinical conditions (21, 22).

One of the most comprehensive classifications for simulation types was proposed by Nehring and Lashley in 2009, who introduced simulation as a spectrum consisting of 7 partial categories: (1) complex and straightforward skill training tools, (2) role-playing, (3) games, (4) computer-assisted instruction, (5) standardized patients, (6) virtual reality, and (7) haptic and hybrid simulation systems, which are themselves divided into high or low fidelity models (23). The term fidelity refers to the degree of closeness or accuracy of a simulation to reality. Low-fidelity simulators are suitable for demonstrating simple and cohesive movements without the need for joint movements in the training of psychomotor skills. Medium-fidelity simulators are used for listening to heart and lung sounds and examining pulses. However, they are unable to show chest movements or changes in pupillary size in response to light. High-fidelity simulators, on the other hand, are full-body computer manikins that can simulate the health and disease states of an actual human of any gender, age group, and under any conditions (17).

Another different classification exists, in which simulation models are categorized into four groups: (1) animals, (2) bodies, (3) inanimate objects, and (4) virtual realities. According to the Higher Education Accreditation Council, the most commonly used simulation in ophthalmology education for students is virtual reality, followed by animals (24).

There are two types of simulation used in operating room training to improve the clinical decision-making skills of students who have an abstract mindset toward clinical conditions (11). These two types are:

(1) Simulation-based training, which enhances clinical skills and performance in the operating room. It should be noted that these simulations are often physical with low fidelity, but their use can facilitate the transfer of cognitive processes used in simulation to actual clinical procedures.

(2) Simulation-based team training, which combines simulation-based training and teaching proper team functioning. This training focuses on establishing close communication, awareness of the situation, supportive behaviors, and support structures (24).

3.4. Simulation-based Training

Simulation-based training refers to the use of tools and techniques that simulate the real-life surgical environment to improve the technical skills of the surgical team. There are several categorizations of these tools, including (25):

(1) Web-based educational tools: These tools use symbols, images, short videos, and text to teach surgical procedures (26).

(2) Computer-based video training: This includes computer-based systems that simulate procedures such as fracture fixation or orthopedic surgical systems (27).

(3) Virtual learning environment systems: These are more complex educational systems that combine various learning tools to enhance the experience of the learners. These systems include curriculum design, student tracking, online support for teachers and students, electronic communication, and internet links to external resources (28).

(4) Learning management systems (LMS): These web-based systems allow for easy access to multimedia content that is tailored to the personal progress of each student (29).

(5) Fundamentals of Laparoscopic Surgery (FLS): This system is based on the McGill system and is designed to teach and evaluate the basic skills of laparoscopic surgery. It includes instructional materials, web-based learning, a simple and cost-effective physical simulator with specific tasks, and a recommended curriculum (30).

(6) Simulation-based surgical training: This training involves repeating the necessary clinical skills (31). Various types of virtual realities are used in this method, including simulators such as the LAP Mentor, which is used in teaching urology surgical procedures (32).

According to the study conducted by Seymour et al., the use of virtual reality-based training in surgery significantly improved the performance of surgical assistants in gallbladder removal and led to fewer errors in the study group (33).

3.5. Simulation-based Team Training

Simulation-based team training is one of the teamwork-based tools designed based on human emotions and how individuals react in different situations, to develop non-technical skills. The use of this training method promotes the improvement of clinical skills and the enhancement of fundamental competencies in performing group tasks simultaneously. Integrated Procedural Performance Instrument is one example used for teaching communication skills (34), and realistic computer-controlled mannequins such as Sim Man 3G are based on team training and simulate high-risk clinical scenarios to enhance crisis management skills in surgical teams (35). According to a study conducted by Abdelshehid et al. to evaluate the technical and non-technical performance of urology surgical residents in performing partial nephrectomy procedures using Sim Man 3G, significant changes were observed in team communication skills and technical performance of these residents before and after the intervention. It is worth mentioning that, in this study, to further enhance team communication, a feedback session was immediately held with the residents by faculty members to provide constructive feedback after each scenario (36).

3.6. The Simulation-based Model for Intervention and Evaluation of Team Skills

Despite the importance of team-based training in improving patient safety during surgery (37), prior to 2010, it had not been carried out through specific training methodologies, and its effectiveness had not been confirmed. Therefore, Weaver et al. decided to present a structured training model for conducting simulation-based interventions and evaluating team skills. According to this model, the following steps are proposed for implementing interventions and evaluating team skills: (1) identifying the training objectives, desired competencies, and target population before starting the training course; (2) determining appropriate training strategies and methods based on the content, the number of participants in each team, and the effective provision of feedback during program execution; and (3) evaluating the learning outcomes, behavioral changes, participants' reactions to the program, and achievement of the objectives at the end of the program (16).

The core competencies targeted in this educational program include enhancing communication, management, situational awareness, and role awareness skills, covering all individuals involved in operating room activities with a multidisciplinary approach (38). One of the predominant strategies in designing this program is the crew resource management (CRM) human resource management model, designed to stabilize teams, and reduce errors by improving teamwork, and utilizing all available resources (39, 40). Additionally, in designing this model, a combination of simulation-based teaching methods with conventional methods, such as instructional videos or live patient demonstrations, can be utilized (41).

The number of individuals in each team is approximately 3 - 5, and course duration may vary from about an hour to several days, depending on the volume of educational content. Feedback is preferably face-to-face and based on the individual's actual performance, and immediately following the end of each session, a brief Q&A session should be held by the instructors (42).

4. Discussion

This article discusses the importance, necessity, advantages, obstacles, and types of simulation-based training in the operating room. Simulation-based training has many advantages, such as providing a safe environment for knowledge acquisition and skills development through repetition and practice, effective learning, active participation of students in learning, improvement of critical thinking, problem-solving skills, clinical judgment, group learning, and improvement of collaboration and communication between professionals and management of emergencies (5). However, some obstacles prevent the use of this education method, such as the high cost of simulation equipment compared to other common teaching tools, the need for a large physical space, and a long time to plan, prepare scenarios and teach students in small groups (6), instructors' unfamiliarity with simulators and their proper functioning, the need to hold training courses, resistance to changing the current teaching methods towards simulation-based methods (43, 44), and creating anxiety in instructors and students when working with expensive human simulators due to fear of harming them (45). However, given the importance of using simulation in the education of clinical procedures and teamwork communication in the operating room, various methods can be used in this regard, including Web-based tools for surgical procedure training, computer-based video training, virtual learning systems, controlled learning management systems by instructors, laparoscopic and endoscopic surgery principles tools, simulation-based surgical technique training, and simulation-based training of non-technical skills in the operating room (23, 24, 27, 29, 34).

It should be noted that the implementation of simulation-based teaching methods also requires the collaboration of faculties and instructors in equipment procurement and maintenance, designing educational programs and scenarios tailored to objectives, proper execution using a suitable model, and providing performance-based feedback at the end of scenarios. Many of the challenges of using this method can be solved greatly with proper planning, and educational institutions can develop and expand simulation-based education by understanding the potential of this method. Therefore, given the clinical focus of medical education, particularly in the operating room, the extensive use of this educational method is strongly felt in Iran. It is recommended that universities provide the necessary facilities, equipment, and educational infrastructure for the implementation of this method.

4.1. Conclusions

Due to the importance of the operating room as one of the important medical treatment areas, the expansion of collaborative simulation centers, the increase in the popularity of multidisciplinary, interprofessional, and multimedia educational approaches, the high number of clinical students, the shortage of patients and their diverse composition, the inactivity of patients during the examination, and the lack of constructive feedback in clinical environments, the use of simulation methods in practical operating room education has been emphasized. If suitable simulations and models are used for designing, implementing, and evaluating educational programs, the resulting consequences will be more effective.

Additionally, it is crucial to emphasize the need for further investigation and validation of simulation training programs and their direct impact on student performance in the operating room. Future research should focus on longitudinal studies to track the progression of skills acquired through simulation training and their application in real surgical settings. Such studies could provide comprehensive insights into how simulation-based education translates to improved patient outcomes and reduced medical errors. Furthermore, the development of standardized evaluation metrics for both technical and non-technical skills acquired through simulation training will be essential in demonstrating its efficacy.

To ensure the continual improvement of simulation-based training, it is recommended that educational institutions collaborate on research initiatives aimed at optimizing simulation methodologies, integrating feedback mechanisms, and aligning training with clinical competencies required in the operating room. Emphasis should also be placed on addressing the challenges associated with simulation training, such as high costs and the need for specialized instructor training, through innovative solutions and resource-sharing among institutions.

In conclusion, while the benefits of simulation-based training in enhancing clinical and teamwork skills in the operating room are evident, a concerted effort towards rigorous research, standardized evaluation, and continuous improvement will be necessary to fully realize its potential in medical education.

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References

1. Pazargadi M; Sadeghi R. [Simulation in nursing education]. *Bimonth Edu Strateg Med Sci*. 2011;**3**(4):161-7. FA.
2. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. *Acad Med*. 2015;**90**(11):1471-86. [PubMed ID: 26375267]. https://doi.org/10.1097/acm.0000000000000939.
3. Buck GH. Development of simulators in medical education. *Gesnerus*. 1991;**48 Pt 1**:7-28. [PubMed ID: 1855669].
4. Rosenzweig M, Hravnak M, Magdic K, Beach M, Clifton M, Arnold R. Patient communication simulation laboratory for students in an acute care nurse practitioner program. *Am J Crit Care*. 2008;**17**(4):364-72. [PubMed ID: 18593836].
5. Haghani F, Ehsani M, Jafari Mianaei S. [Simulation]. *Strides Develop Med Edu*. 2014;**11**(2):272-9. FA.
6. Seropian MA, Brown K, Gavilanes JS, Driggers B. An approach to simulation program development. *J Nurs Educ*. 2004;**43**(4):170-4. [PubMed ID: 15098911]. https://doi.org/10.3928/01484834-20040401-02.
7. Bradley P. The history of simulation in medical education and possible future directions. *Med Educ*. 2006;**40**(3):254-62. [PubMed ID: 16483328]. https://doi.org/10.1111/j.1365-2929.2006.02394.x.
8. Marr M, Hemmert K, Nguyen AH, Combs R, Annamalai A, Miller G, et al. Team play in surgical education: a simulation-based study. *J Surg Educ*. 2012;**69**(1):63-9. [PubMed ID: 22208835]. https://doi.org/10.1016/j.jsurg.2011.07.002.
9. Anderson M, Leflore J. Playing it safe: simulated team training in the OR. *Aorn j*. 2008;**87**(4):772-9. [PubMed ID: 18395021]. https://doi.org/10.1016/j.aorn.2007.12.027.
10. Aggarwal R, Undre S, Moorthy K, Vincent C, Darzi A. The simulated operating theatre: comprehensive training for surgical teams. *Qual Saf Health Care*. 2004;**13 Suppl 1**(Suppl 1):i27-32. [PubMed ID: 15465952]. [PubMed Central ID: PMC1765789]. https://doi.org/10.1136/qhc.13.suppl_1.i27.
11. Lotfi M, Hasan Khani H, Fathi Azar E, Mokhtari M. [Effect of Compound Education Simulation and Critical Thinking Strategies on Clinical Decision Making in Surgical Technologist Students]. *Nurs Midwif J*. 2011;**5**(20):5. FA.
12. janighorban M, allahdadian M, Haghani F. [Simulation, a strategy for improving clinical education]. *J Nurs Edu*. 2013;**2**(1):55-65. FA.
13. Seropian MA, Brown K, Gavilanes JS, Driggers B. Simulation: not just a manikin. *J Nurs Edu*. 2004;**43**(4):164-9. [PubMed ID: 15098910]. https://doi.org/10.3928/01484834-20040401-04.
14. De Vries EN, Prins HA, Crolla RM, Den Outer AJ, Van Andel G, Van Helden SH, et al. Effect of a comprehensive surgical safety system on patient outcomes. *N Engl J Med*. 2010;**363**(20):1928-37. [PubMed ID: 21067384]. https://doi.org/10.1056/NEJMsa0911535.
15. Amiri M, Khademian Z, Nikandish R. The effect of nurse empowerment educational program on patient safety culture: a randomized controlled trial. *BMC Med Educ*. 2018;**18**(1):158. [PubMed ID: 29970054]. [PubMed Central ID: PMC6029022]. https://doi.org/10.1186/s12909-018-1255-6.
16. Weaver SJ, Salas E, Lyons R, Lazzara EH, Rosen MA, Diazgranados D, et al. Simulation-based team training at the sharp end: A qualitative study of simulation-based team training design, implementation, and evaluation in healthcare. *J Emerg Trauma Shock*. 2010;**3**(4):369-77. [PubMed ID: 21063560]. [PubMed Central ID: PMC2966570]. https://doi.org/10.4103/0974-2700.70754.
17. Jeffries PR. A framework for designing, implementing, and evaluating simulations used as teaching strategies in nursing. *Nurs Educ Perspect*. 2005;**26**(2):96-103. [PubMed ID: 15921126].
18. Ugur E, Kara S, Yildirim S, Akbal E. Medical errors and patient safety in the operating room. *J Pak Med Assoc*. 2016;**66**(5):593-7. [PubMed ID: 27183943].
19. Rambod M, Sharif F, Khademian Z. The Impact of the Preceptorship Program on Self-efficacy and Learning Outcomes in Nursing Students. *Iran J Nurs Midwifery Res*. 2018;**23**(6):444-9. [PubMed ID: 30386394]. [PubMed Central ID: PMC6178580]. https://doi.org/10.4103/ijnmr.IJNMR_67_17.
20. Ziv A, Wolpe PR, Small SD, Glick S. Simulation-Based Medical Education: An Ethical Imperative. *Academic Medicine*. 2003;**78**(8):783-8.
21. Gaba DM. The future vision of simulation in health care. *Qual Saf Health Care*. 2004;**13 Suppl 1**(Suppl 1):i2-10. [PubMed ID: 15465951]. [PubMed Central ID: PMC1765792]. https://doi.org/10.1136/qhc.13.suppl_1.i2.
22. Cooper JB, Taqueti VR. A brief history of the development of mannequin simulators for clinical education and training. *Postgrad Med J*. 2008;**84**(997):563-70. [PubMed ID: 19103813]. https://doi.org/10.1136/qshc.2004.009886.
23. Nehring WM, Lashley FR. *High-fidelity patient simulation in nursing education*. Burlington, United States: Jones & Bartlett Learning; 2010.
24. Accreditation Council for Graduate Medical Education. *Program requirements for graduate medical education in diagnostic radiology*. 2013. Available from: https://www.acgme.org/globalassets/pfassets/programrequirements/420_diagnosticradiology_2023.pdf.
25. Dietl CA, Russell JC. Effects of Technological Advances in Surgical Education on Quantitative Outcomes From Residency Programs. *J Surg Educ*. 2016;**73**(5):819-30. [PubMed ID: 27184181]. https://doi.org/10.1016/j.jsurg.2016.03.016.
26. Turina M. Multimedia Manual of Cardiothoracic Surgery: the internet-based educational tool. *Eur J Cardiothorac Surg*. 2008;**33**(1):1-3. [PubMed ID: 18023199]. https://doi.org/10.1016/j.ejcts.2007.10.001.
27. Rambani R, Viant W, Ward J, Mohsen A. Computer-assisted orthopedic training system for fracture fixation. *J Surg Educ*. 2013;**70**(3):304-8. [PubMed ID: 23618438]. https://doi.org/10.1016/j.jsurg.2012.11.009.
28. Smith FC, Greenwood SR. Modern ways to enhance surgical teaching skills. *Surgery (Oxford)*. 2012;**30**(9):471-6. https://doi.org/10.1016/j.mpsur.2012.06.006.
29. Dua A, Sudan R, Desai SS. Improvement in American Board of Surgery in-training examination performance with a multidisciplinary surgeon-directed integrated learning platform. *J Surg Educ*. 2014;**71**(5):689-93. [PubMed ID: 24776859]. https://doi.org/10.1016/j.jsurg.2014.02.007.
30. Peters JH, Fried GM, Swanstrom LL, Soper NJ, Sillin LF, Schirmer B, et al. Development and validation of a comprehensive program of education and assessment of the basic fundamentals of laparoscopic

surgery. *Surgery*. 2004;**135**(1):21-7. [PubMed ID: 14694297]. https://doi.org/10.1016/s0039-6060(03)00156-9.

31. Earle D. Surgical training and simulation laboratory at Baystate Medical Center. *Surg Innov*. 2006;**13**(1):53-60. [PubMed ID: 16708156]. https://doi.org/10.1177/155335060601300109.

32. Lucas SM, Zeltser IS, Bensalah K, Tuncel A, Jenkins A, Pearle MS, et al. Training on a virtual reality laparoscopic simulator improves performance of an unfamiliar live laparoscopic procedure. *J Urol*. 2008;**180**(6):2588-91. discussion 2591. [PubMed ID: 18950817]. https://doi.org/10.1016/j.juro.2008.08.041.

33. Seymour NE, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. *Ann Surg*. 2002;**236**(4):458-63. discussion 463-4. [PubMed ID: 12368674]. [PubMed Central ID: PMC1422600]. https://doi.org/10.1097/00000658-200210000-00008.

34. Moulton CA, Tabak D, Kneebone R, Nestel D, MacRae H, LeBlanc VR. Teaching communication skills using the integrated procedural performance instrument (IPPI): a randomized controlled trial. *Am J Surg*. 2009;**197**(1):113-8. [PubMed ID: 19101253]. https://doi.org/10.1016/j.amjsurg.2008.09.006.

35. Nicksa GA, Anderson C, Fidler R, Stewart L. Innovative approach using interprofessional simulation to educate surgical residents in technical and nontechnical skills in high-risk clinical scenarios. *JAMA Surg*. 2015;**150**(3):201-7. [PubMed ID: 25565037]. https://doi.org/10.1001/jamasurg.2014.2235.

36. Abdelshehid CS, Quach S, Nelson C, Graversen J, Lusch A, Zarraga J, et al. High-fidelity simulation-based team training in urology: evaluation of technical and nontechnical skills of urology residents during laparoscopic partial nephrectomy. *J Surg Educ*. 2013;**70**(5):588-95. [PubMed ID: 24016369]. https://doi.org/10.1016/j.jsurg.2013.04.009.

37. Khademian Z, Pishgar Z, Torabizadeh C. Effect of Training on the Attitude and Knowledge of Teamwork Among Anesthesia and Operating Room Nursing Students: A Quasi-Experimental Study. *Shiraz E-Med J*. 2018;**19**(4). e61079. https://doi.org/10.5812/semj.61079.

38. Youngblood P, Harter PM, Srivastava S, Moffett S, Heinrichs WL, Dev P. Design, development, and evaluation of an online virtual emergency department for training trauma teams. *Simul Healthc*. 2008;**3**(3):146-53. [PubMed ID: 19088658]. https://doi.org/10.1097/SIH.0b013e31817bedf7.

39. Salas E, Burke CS, Bowers CA, Wilson KA. Team training in the skies: does crew resource management (CRM) training work? *Hum Factors*. 2001;**43**(4):641-74. [PubMed ID: 12002012]. https://doi.org/10.1518/001872001775870386.

40. Khademian Z. [Teamwork Training in Healthcare Delivery System: A Review of the Literature]. *Sadra Med J*. 2017;**5**(3):173-86. FA.

41. Blum RH, Raemer DB, Carroll JS, Dufresne RL, Cooper JB. A method for measuring the effectiveness of simulation-based team training for improving communication skills. *Anesth Analg*. 2005;**100**(5):1375-80. [PubMed ID: 15845689]. https://doi.org/10.1213/01.Ane.0000148058.64834.80.

42. Shapiro MJ, Morey JC, Small SD, Langford V, Kaylor CJ, Jagminas L, et al. Simulation based teamwork training for emergency department staff: does it improve clinical team performance when added to an existing didactic teamwork curriculum? *Qual Saf Health Care*. 2004;**13**(6):417-21. [PubMed ID: 15576702]. [PubMed Central ID: PMC1743923]. https://doi.org/10.1136/qhc.13.6.417.

43. Wilford A, Doyle TJ. Integrating simulation training into the nursing curriculum. *Br J Nurs*. 2006;**15**(17):926-30. [PubMed ID: 17077785]. https://doi.org/10.12968/bjon.2006.15.17.21907.

44. Childs JC, Sepples S. Clinical teaching by simulation: Lessons learned from a complex patient care scenario. *Nurs Educ Pov*. 2006;**27**:154-8.

45. Rauen CA. Simulation as a teaching strategy for nursing education and orientation in cardiac surgery. *Crit Care Nurse*. 2004;**24**(3):46-51. [PubMed ID: 15206295].