The importance of simulation training in surgical sciences

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Received: 01 April 2022
Accepted: 30 April 2022

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ABSTRACT

Simulators have been used throughout history to practice complicated procedures before performing them on human beings. The earliest simulation attempts were in cadavers. Donor bodies are still used for teaching and research but involve costly infrastructure, ethical and legal issues, as well as animal models. Training models need to be purposefully designed. These can be physical models, 3-D printed, simulators with virtual reality, augmented reality, or a hybrid simulation. The inert model is an alternative for animal tissue models, based on a trial-and-error method, the learning curve is approximately 65 procedures for a laparoscopist. Simulations models with virtual and augmented reality have shown that can reduce the time of practitioners with experience in laparoscopy, with an approximate reduction of 30 to 58%. Video-based learning method has been adopted in recent years but has shown to be less effective than hand-on learning using a simulator. Simulation can be involved to simulate specific scenarios, recreate simulated trauma patients, help develop a doctor-patient relationship and prepare complex approaches. Patient safety concerns call for the need to train medical personnel in simulated settings to reduce cost and patient morbidity because the ability to acquire surgical skills requires consistent practice. Simulation represents ideal teaching methods to optimize the knowledge and skill of residents before they are entrusted with procedures with real patients.

Keywords: Simulation, Surgical simulation, Surgical training, Surgical education

INTRODUCTION

The phrase by Francis D. Moore states that- ‘You can’t learn to play the piano by attending concerts’.

The use of simulators has been used by novices and experts to learn, perfect, and simulate surgical skills for basic and complicated procedures. A surgeon can rehearse specific, uncommon, or difficult maneuvers before performing them directly on the patient. The earliest simulation attempts were with cadavers in the sixth century BC.1 Currently, donor bodies are still used for teaching and research, however, these require costly infrastructure, and involve ethical and legal issues.2,3 Animal models have similar challenges and must be rightfully justified.4,6 The use of technology-enhanced simulators and models has provided a viable option to imitate real-life scenarios and for learners to acquire experience and confidence.5,7,8

Training models must be purposefully designed. These can be physical models, 3-D printed, simulators with virtual reality, augmented reality, or a combination of these for hybrid simulation.9-11 These allow for a greater number of trainees to participate, and the repetition of maneuvers. However, the models do not depend only on their design. They must transfer knowledge and skills, develop confidence, precision, and decision-making, and have supervised performance for feedback and mentoring.12-15
HUMAN BODY MODELS

Dissection of the human body is considered essential in the unique ethical and technical formation of future physicians and surgeons, both in undergraduate and postgraduate medical education.6,16-18 Dissection is extremely useful in a variety of ways: it aids understanding of the three-dimensional organization of the human body, appreciation of the body, develops practical skills, promotes teamwork, introduces students to the physician-patient relationship, reinforces familiarization with and respect for the human body, and establishes the concepts of humane care and understanding of the phenomena of death and of dying. However, due to elevated costs, many universities are decreasing funding for these types of laboratories.13,19

Body donation programs for medical education and research are essential. However, many countries still lack the legal fundamentals to establish these, and those with well-established programs currently have the challenge of justifying costs and ethical issues.3,20-22

ANIMAL MODELS

Animal models have been used in centers allowing trainees to perform complex laparoscopic procedures outside the clinical setting.23,24 The animals providing the organs usually are specially bred for these purposes elevating their cost, their anatomy may vary from human, along with the ethical implications it carries due to its limited use, and therefore are not used frequently.25 However, there is a superiority in the use of these tissues. The similarity to human tissue brings elevates the fidelity, allowing detailed abilities to be developed. With the animal anesthetized, local and generalized complications and bleeding are incorporated into the procedure, providing value to the development of confidence in surgical training.7,13,26

INERT MODELS

Synthetic models are anatomic but can be divided into those with life-like characteristics, and with non-life appearance. They provide an alternative for biological tissue models and are frequently used for basic surgical skills such as knot tying, suturing, and laparoscopic technique training.7,13,27 These models may increase simulation with added electronic components such as video, virtual reality, augmented reality, others. They may also include tactile feedback to increase fidelity and flatten the learning curve, making clinical settings safer. With costs of technology decreasing, these are available with greater ease, providing objective performance measurements, and reliable feedback.13

Mannequins and mechanical simulators have proven equivalent in terms of outcome for obtaining skills such as neonatal intubation, laparoscopy, animal anatomy, human anatomy, and training of emergency medical procedures, such as insertion of a chest tube, and cricothyroidotomy, without the harmful use of animals.25

Although these models include a high initial investment, they can be used with more trainees and for longer periods of time. These result in cheaper, durable, and readily available training that can be implemented in any training center.27,28 Training has been shown to reduce operating time and error while improving performance and confidence.10,23,29,30 However, structured training is needed, as formal training programs are still lacking.11,18

VIDEOS AND WEBSITES

Video-based learning (VBL) integrates different teaching skills based on the technique “see one, do one, teach one.” This way, apprentices can be provided with knowledge through visualization, obtain feedback once encountering the skill challenges, and be exposed to understanding enough to teach others what was learned. Surgeons have embraced online videos for skills acquisition and case preparation.31,32 In recent years, surgical videos and video-based online platforms have increased rapidly, with worldwide reach, allowing viewers to learn and repeat videos in a safe environment, according to the time disposition, and learning pace. However, these must be used with caution. Studies examining content on YouTube, the most common source for surgical videos, report substantial variability in educational value due to nonuniform production quality, unclear intent (education or marketing), lack of a peer-review process, and many times suboptimal techniques and maneuvers.33-35

The learning method using instructional videos has shown to be less effective than hand-on learning using a simulator for microsurgery training, especially in understanding the procedure. However, traditional video instruction can increase the effectiveness of the training curriculum for novices when videos follow recommendations such as the LAP-VEGaS practice guidelines for surgical educational videos.36,37

IMPLEMENTATION OF TRAINING

Simulation is a practice involved in many areas of medical education. It can be used to simulate patients with specific clinical scenarios, help cultivate doctor-patient relationships, recreate simulated trauma patients, prepare for complex approaches or anatomical variants, among others. These benefit the patient as well, primarily its safety.38 Student and resident training with simulation prior to engaging patients decreases mala praxis. Users can learn and understand anatomy better and make fewer mistakes.39,40 Time is better spent with higher exposure and repetition which may be limited in the operating room due to restrictions both in residency duty-hours hospital protocols.1,41 Operating times can also be reduced due to practice and the confidence developed by the surgeon.11,40,42,43
Although many programs around the world have implemented these strategies, resources in low- and middle-income countries may be narrow primarily in public institutions, with access to students and residents limited.\(^4\)\(^4\)\(^5\) Although easily accessible or economic adaptations have been described, many are still not practiced. This forces residents to perform and acquire experience directly from the patients with techniques such as “learning as they go” practicing their first procedures trans-operatively, without validating their knowledge or ability. This is not only unethical in today’s medical practice, but also dangerous. Residents should acquire a specific level of skill and knowledge before being allowed to practice on patients, and not only from visualizing surgeries repetitively as an aid.\(^4\)\(^6\)\(^7\)

**ETHICAL CONCERNS**

Patient safety concerns call for the need to train medical personnel in simulated settings to reduce cost and patient morbidity. Technological innovations had led to consistent improvement in learning outcomes, and already play a role in surgical training programs.\(^8\)

The ability to acquire surgical skills requires consistent practice, and evidence suggests that many of these technical skills can be learned away from the operating room.\(^1\)\(^3\)\(^4\)\(^1\) Simulation represents ideal teaching methods to optimize the knowledge and skill of residents before they are entrusted with procedures in real patients. However, which method is better? How can we confirm the skills are being properly learned and performed? Are they properly supervised? Can simulation replace the lack of exposure? Is consent needed from the patient to have a resident perform a procedure?

**CONCLUSION**

Using simulators in different surgical areas, for the training of novices or already expert surgeons is crucial for patient management and reducing the margin of error, surgery time, and providing confidence in the learner, perfecting the techniques and maneuvers. Thanks to technological advancements and innovation, there is a wide range of various types of simulators that can be used for surgical training. Training hospitals and universities should make simulation training mandatory in their curriculums, both for medical students and residents. Programs should have a formal structure, feedback, and be purposefully designed.

**Funding:** No funding sources  
**Conflict of interest:** None declared  
**Ethical approval:** Not required

**REFERENCES**

1. Rehder R, Abd-El-Barr M, Hooten K, Weinstock P, Madsen JR, Cohen AR. The role of simulation in neurosurgery. Child's Nervous System. 2016;32(1):43-54.
2. Quiroga-Garza A, Reyes-Hernández CG, Zarate-Garza PP, Esparza-Hernández CN, Gutierrez-de la OJ, de la Fuente-Villarreal D, et al. Willingness toward organ and body donation among anatomy professors and students in Mexico. Anatomical Sciences Education. 2017;10(6):589-97.
3. Salinas-Alvarez Y, Quiroga-Garza A, Martínez-Garza JH, Jacobo-Baca G, Zarate-Garza PP, Rodríguez-Alánis KV, et al. Mexican Educators Survey on Anatomical Sciences Education and a Review of World Tendencies. Anatomical Sciences Education. 2021;14(4):471-81.
4. Quiroga-Garza A, Delgado-Brito M, Bazaldúa-Cruz JJ, Villarreal-Silva E, Velázquez-Gauna SE, Elizondo-Omaña RE, et al. Nuevo modelo microquirúrgico para el estudio de la respuesta morfológica adaptativa de injertos venosos [New microsurgical model for the study of the morphological adaptive response of venous grafts]. Revista de investigación clínica; órgano del Hospital de Enfermedades de la Nutrición. 2011;63(4):399-406.
5. Velázquez Gauna SE, Soto Domínguez A, Quiroga Garza A, Reyes Hernández CG, Chávez Reyes A, Morales Avalos R, et al. Histomorphometric and immunohistochemical study of early adaptive response of the vascular wall in a termino-terminal microsurgical model of femoral vessels in Wistar rat. Int J Morphol. 2017;35(2):479-87.
6. De la Garza-Castro O, Sánchez-González SG, De La Garza-Pineda O, Espinosa-Uribe AG, Quiroga-Garza A, Elizondo-Omaña RE, et al. Dermatology surgery training in a live animal model. J Morphol Sci. 2018;35(03):187-90.
7. Gonzalez-Navarro AR, Quiroga-Garza A, Acosta-Luna AS, Salinas-Alvarez Y, Martínez-Garza JH, de la Garza-Castro O, et al. Comparison of suturing models: the effect on perception of basic surgical skills. BMC Med Educ. 2021;21(1):250.
8. Krebs C, Quiroga-Garza A, Penenefather P, Elizondo-Omaña RE. Ethics behind technology-enhanced medical education and the effects of the COVID-19 pandemic. Eur J Anat. 2021;25(4):515-22.
9. Muñoz-Leija MA, Paul BR, Shi G, Dixit I, Quiroga-Garza A, Elizondo-Omaña RE, et al. THE HIVE: a multidisciplinary approach to medical education. Eur J Anat. 2021;25(1):101-6.
10. Taba JV, Cortez VS, Moraes WA, Iuamoto LR, Hsing WT, Suzuki MO, et al. The development of laparoscopic skills using virtual reality simulations: A systematic review. PloS One. 2021;16(6):e0252609.
11. Vilchez-Cavazos JF, Simental-Mendía MA, Peña-Martínez VM, Acosta-Olivo C, Quiroga-Garza A, Elizondo-Omaña RE, et al. Simulador de artroscopia de rodilla para desarrollar habilidades artroscópicas en los residentes de ortopedia y traumatología. Orthotips. 2022.
12. Sutherland LM, Middleton PF, Anthony A, Hamdorf J, Cregan P, Scott D, Madder GI. Surgical simulation: a systematic review. Ann Surg. 2006;243(3):291-300.
13. Sarker SK, Patel B. Simulation and surgical training. Int J Clin Pract. 2007;61(12):2120-5.
14. Waran V, Narayan V, Karuppiah R, Panchatnatm D, Chandran H, Raman R, Rahman ZA, Owen SL, Aziz TZ. Injecting realism in surgical training-initial simulation experience with custom 3D models. J Surg Educ. 2014;71(2):193-7.
15. Snyderman CH, Gardner PA, Lanisnik B, Ravnik J. Surgical telementoring: A new model for surgical training. The Laryngoscope. 2016;126(6):1334-8.
16. Gilbody J, Prasthofer SW, Ho K, Costa ML. The use and effectiveness of cadaveric workshops in higher surgical training: a systematic review. Ann Royal Coll Surgeons England. 2011;93(5):347-52.
17. Macchi V, Porzionato A, Stecco C, Tiengo C, Parenti A, Cestrone A, De Caro R. Body parts removed during surgery: a useful training source. Anatomical Sciences Education. 2011;4(3):151-6.
18. Robles-Torres JJ, Zapata-González JA, Lozano-Salinas JF, Montelongo-Rodriguez FA, Elizondo-Omahá RE, Guzman-Lopez S, et al. A Novel Cadaveric Training Model for Percutaneous Renal Access. Bol Col Mex Urol. 2022.
19. McLachlan JC. New path for teaching anatomy: living anatomy and medical imaging vs. dissection. Anatomical record. Part B, New Anat. 2004;281(1):4-5.
20. Garment A, Lederer S, Rogers N, Boult L. Let the dead teach the living: the rise of body bequeathal in 20th-century America. Academic Medicine. 2007;82(10):1000-5.
21. Riederer BM. Body donations today and tomorrow: What is best practice and why? Clinical Anatomy (New York, N.Y.). 2016;29(1):11-8.
22. Habicht JL, Kiessling C, Winkelmann A. Bodies for Anatomy Education in Medical Schools: An Overview of the Sources of Cadavers Worldwide. Acad Med. 2018;93(9):1293-300.
23. Aggarwal R, Boza C, Hance J, Leong J, Lacy A, Darzi A. Skills acquisition for laparoscopic gastric bypass in the training laboratory: an innovative approach. Obes Surg. 2007;17(1):19-27.
24. Kobayashi E, Hishikawa S, Teratani T, Lefor AT. The pig as a model for translational research: overview of porcine animal models at Jichi Medical University. Transplant Res. 2012;1(1):8.
25. Zemanova MA, Knight A. The Educational Efficacy of Humane Teaching Methods: A Systematic Review of the Evidence. Animals (Basel). 2021;11(1):114.
26. Gaitanidis A, Simopoulos C, Pitaikoudis M. What to consider when designing a laparoscopic colorectal training curriculum: a review of the literature. Tech Coloproctol. 2018;22(3):151-60.
27. Botden SM, Christie L, Goossens R, Jakimowicz JJ. Training for laparoscopic Nissen fundoplication with a newly designed model: a replacement for animal tissue models? Surgical Endoscopy. 2010;24(12):3134-40.
28. Suguita FY, Essu FF, Oliveira LT, Iuamoto LR, Kato JM, Torsani MB, Franco AS, Meyer A, Andreus W. Learning curve takes 65 repetitions of totally extraperitoneal laparoscopy on inguinal hernias for reduction of operating time and complications. Surg Endosc. 2017;31(10):3939-45.
29. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg. 2004;91(2):146-50.
30. Gurusamy KS, Aggarwal R, Palanivelu L, Davidson BR. Virtual reality training for surgical trainees in laparoscopic surgery. Cochrane Database Syst Rev. 2009(1):CD006575.
31. Rapp AK, Healy MG, Charlton ME, Keith JN, Rosenbaum ME, Kapadia MR. YouTube is the Most Frequently Used Educational Video Source for Surgical Preparation. J Surg Educ. 2016;73(6):1072-6.
32. Yee A, Padovano WM, Fox IK, Hill EJR, Rowe AG, Brunt LM, Moore AM, Snyder-Warwick AK, Kahn LC, Wood MD, Coert JH, Mackinnon SE. Video-based Learning in Surgery: Establishing Surgeon Engagement and Utilization of Variable-duration Videos. Ann Surg. 2020;272(6):1012-9.
33. Rodriguez HA, Young MT, Jackson HT, Oelschlager BK, Wright AS. Viewer discretion advised: is YouTube a friend or foe in surgical education? Surg Endosc. 2018;32(4):1724-8.
34. deAngelis N, Gavrilidis P, Martínez-Pérez A, Genova P, Notarnicola M, Reitano E, et al. Educational value of surgical videos on YouTube: quality assessment of laparoscopic appendectomy videos by senior surgeons vs. novice trainees. World J Emerg Surg. 2019;14:22.
35. Jackson HT, Hung CS, Potarazu D, Habbobh NS, DeAngelis EJ, Amdur RL, Estroff JM, Quintana MT, Lin P, Vaziri K, Lee J. Attending guidance advised: educational quality of surgical videos on YouTube. Surg Endosc. 2021.
36. Celentano V, Smart N, McGrath J, Cahill RA, Spinelli A, Obermaier A, et al. LAP-VEGaS Practice Guidelines for Reporting of Educational Videos in Laparoscopic Surgery: A Joint Trainers and Trainees Consensus Statement. Ann Surg. 2018;268(6):920-6.
37. Sakamoto Y, Okamoto S, Shimizu K, Araki Y, Hirakawa A, Wakabayashi T. Hands-on Simulation versus Traditional Video-learning in Teaching Microsurgery Technique. Neurologia medico-chirurgica. 2017;57(5):238-45.
38. Clifton W, Damon A, Nottmeier E, Pichelmann M. The importance of teaching clinical anatomy in surgical skills education: Spare the patient, use a sim! Clin Anat. 2020;33(1):124-7.
39. Dee EC, Alty IG, Agolia JP, Torres-Quinones C, van Houten T, Stearns DA, et al. A Surgical View of Anatomy: Perspectives from Students and
Instructors. Anatomical Sciences Education. 2021;14(1):110-6.
40. Huri G, Gülşen MR, Karmuş EB, Karagüven D. Cadaver versus simulator based arthroscopic training in shoulder surgery. Turkish J Med Sci. 2021;51(3):1179-90.
41. Tan SS, Sarker SK. Simulation in surgery: a review. Scottish Med J. 2011;56(2):104-9.
42. Walliczek-Dworschak U, Schmitt M, Dworschak P, Diogo I, Ecke A, Mandapathil M, Teymoortash A, et al. The effect of different training exercises on the performance outcome on the da Vinci Skills Simulator. Surg Endosc. 2017;31(6):2397-405.
43. Jokinen E, Mikkola TS, Härkki P. Simulator training and residents’ first laparoscopic hysterectomy: a randomized controlled trial. Surg Endosc. 2020;34(11):4874-82.
44. Tosam MJ, Chi PC, Munung NS, Oukem-Boyer O, Tangwa GB. Global health inequalities and the need for solidarity: a view from the Global South. Developing World Bioethics. 2018;18(3):241-9.
45. Quiroga-Garza A, Garza-Cisneros AN, Elizondo-Omaña RE, Vilchez-Cavazos JF, Montes-de-Oca- Luna R, Villarreal-Silva EE, Guzman-Lopez S, et al. Research Barriers in the Global South: Mexico. J Global Health. 2022;12:03032.
46. Raja AJ, Levin AV. Challenges of teaching surgery: ethical framework. World J Surg. 2003;27(8): 948-51.
47. Tapia-Nañez M, Quiroga-Garza A, Guerrero-Mendivil FD, Salinas-Alvarez Y, Jacobo-Baca G, De la Fuente-Villarreal D, et al. A review of the importance of research in Anatomy, an evidence-based science. Eur J Anat. 2022. 26;4.
48. Graafland M, Schraagen JM, Schijven MP. Systematic review of serious games for medical education and surgical skills training. Br J Surg. 2012;99(10):1322-30.