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Apprenticeship to simulation - The metamorphosis of surgical training

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REVIEW ARTICLE

Apprenticeship to simulation — The metamorphosis of surgical training

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Abstract

Surgery is a dynamic specialty and surgical competencies are a combination of both technical and non-technical skills. After the inception of the art of surgery, surgical education and training has undergone incredible evolution. The first model of surgical training was introduced in the 19th century and is known as the 'apprenticeship model', followed by the famous 'Halstedian' model. However, a report by the Institute of Medicine challenged the teaching institutions to formulate alternative methods of surgical education to ensure patients' safety and to reduce the fear among patients of them being practised on. Teaching surgical skills outside the operating room to ensure patient safety has laid the foundation of simulation-based training in surgical education. More recently, the focus of surgical training and residency has shifted to competency and outcome-based models. The current review article was planned to describe the evolution and transformation of surgical training over time.

Keywords: Surgical training, Technical skills, Simulation, Evolution.

Introduction

After the inception of the art of surgery, surgical education and training has undergone incredible evolution in the past few centuries. The first attempt in improving surgical education was made in the year 1210 in France where distinction was made between 'academic surgeons' and 'barber surgeons' depending upon previous training or university exposure. The College de Saint Come was established to systematically train barbers in surgery.[1] However, until the 19th century, the most well-established mode of training was the apprenticeship method in which training could start at age 12-13 and would last 5-7 years.[2] The students would learn surgery through direct observation and then by replicating the skills of the mentor in clinical settings and operating room (OR). But there were no guidelines as to what skills were to be taught, how long should the training last, who should be trained, and when training should start.

The first major shift from the apprenticeship training model to more formalised and structured model was brought by Dr. William Halsted close to the turn of the last century. Incorporating bedside teaching rounds introduced by Sir William Osler, and German way of formal surgical training with integrated basic sciences, Dr. Halsted introduced the Halstedian model.[3] This model of "see one, do one, teach one" was based on the premise of acquiring increasing responsibility that culminated in near-independence. His model not only aimed at developing a system to train surgeons, but also produced teachers and role models. He set up a formal training programme train future surgeons and passed on the skills to the coming generations efficiently. Thus, the foundation of surgical education in the 21st century is the result of significant development of educational process during the early period.

The new paradigm: The adage, "see one, do one, teach one" is the traditional method of teaching in surgery when residents after observing a procedure once were expected to perform one, followed by being able to teach one to some other trainee. The major emphasis in this model was on teaching technical skills and subsequently pass them on to the next generations. In 1999, the Institute of Medicine published its landmark report "To err is human" which stated that between 44,000 and 98,000 people in the United States hospitals die of preventable medical errors each year.[4] Furthermore, it challenged the teaching institutions to formulate alternative methods of surgical teaching to ensure patients' safety and to reduce the fear among patients of being practised on. Another incentive for change of the training model came in 1999 after Bridges et al.[5] reported the estimated financial impact of teaching residents in OR to be $53 million per year. Four years later, in 2003, the Accreditation Council for Graduate Medical Education (ACGME) implemented the 80-hour work-week restriction to ensure patients' safety owing to residents' fatigue after the death of a patient at a New York Hospital that had raised the issue of resident exhaustion.[6] These factors changed the paradigm of surgical training to avoid preventable errors

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directly harming the patient in surgery, and shifted the focus of surgical training outside the OR.

Teaching of technical skills in surgery: Teaching surgical skills outside OR to ensure patient safety has laid the foundation for simulation-based training in surgical education. Through simulation, residents are expected to reach the same level of competency as their predecessors over fewer clinical hours in low-stress environment with no real risk to patients.[7] The innovations in technology has enabled trainees to practice open and minimally invasive surgery (MIS) on synthetic models, animals or cadavers in virtual reality (VR) and augmented reality (AR). Apart from learning surgical techniques in a replicable and stepwise fashion, objective assessment of skills in simulated setting has a greater validity than assessment in OR.[8]

I. Training in open surgery

With the increasing popularity of MIS, the exposure of residents to open surgery is declining, which could potentially be critical if an operation has to be converted to open because of intra-operative complications. Trainees are required to grasp the essential skills for open procedures before attempting the more technically-demanding MIS procedures. Currently, simulation in surgical training focuses on laparoscopic surgery and the data on use of simulation for open surgery is scarce and limited to knot-tying and suturing. Fonseca et al. analysed the utilisation of simulation in open surgery and found only 31 studies dedicated to open surgery simulation.[9] Low-fidelity models, including bananas and synthetic skin tissues, are beneficial for basic surgical skill training for junior residents, but these cannot be used for advanced surgical training. Pikal in 1986 reported the earliest bench-top model used for intestinal anastomosis using freeze-dried porcine for teaching the trainees.[10] The utility of high-fidelity cadaveric or animal models for identification of anatomy, efficient surgical dissection and major bleeding control for open surgery simulation has been reported in various studies.[11] Simulation has not only helped residents improve their skills, but has also allowed the trainers to objectively assess their technical skills. Reznick et al. at the University of Toronto developed objective assessment of technical skills (OSATS) bench model using synthetic material or non-live animal tissues. OSATS has been validated for the assessment of general surgical procedures and other allied specialties, including obstetrics and gynaecology.[12]

II. Training in MIS

MIS brings in additional challenges for trainee surgeons. The learning curve in laparoscopic surgery is much longer than in open surgery, demanding more rigorous training from the residents. Advanced psychomotor skills are required for operating in a three-dimensional (3D) field with two-dimensional (2D) vision. Difficult hand-eye coordination, altered depth perception, and ergonomics of laparoscopy requires long learning curve for novice learners.[13] Simulation, including low-fidelity box trainers for basic laparoscopic skill acquisition and high-fidelity VR and AR systems for advanced laparoscopic skills training, offers alternative ways to improve laparoscopic skills in a low-pressure setting outside OR without added risk to patient safety. The effects of VR simulators to improve basic and advanced laparoscopic skills at novice level have been proven in various studies.[14,15] Apart from acquisition of skills, simulation in MIS also offers subjective and objective assessment of skills. These methods have been adopted by various residency programmes across the globe to assess the skills of surgery residents. The Society of American Gastrointestinal and Endoscopic Surgeons developed the Fundamentals of Laparoscopic Surgery (FLS) in 1997, which is a comprehensive educational module that includes a hands-on skills training component and assessment tool designed to teach the fundamental knowledge and technical skills required in basic laparoscopic surgery. The American Board of Surgery in 2008 included FLS as a necessary requisite to complete general surgery residency in the United States, and the goal was to allow the trainees to acquire and practise technical skills and then assess them to ensure competency-based skill accquistion.[16]

III. VR and AR

VR and AR are current simulation models which have upgraded surgical education and training. The VR technology generates artificial 3D world through headsets using computer software that isolates users from surroundings and immerses them in that environment in a realistic manner, while AR overlays digital interfaces, creating an environment that is both real and digital.[17] Laparoscopic surgery, robotics, neurosurgery and endoscopy have been the most popular fields for utilisation of VR and AR simulation for training purposes. VR used for laparoscopic surgery are hybrid with real instruments and virtual OR experience, providing haptic feedback to the trainees and most of them have assessment systems to measure errors during surgery, time to complete the task and economy of movements. VR simulators are equipped with modules for training simple tasks for the whole operating procedure.[18] Meta-analysis of randomised controlled trials (RCTs) showed that VR training is associated with reduction in

operating time, error rate and accuracy in laparoscopic training for new trainees.[19] VR and AR-based training has several advantages over the other simulation techniques. Despite the cost, these simulators provide reproducible costless training with different difficulty levels and no ethical considerations compared to living and animal model simulation.

Teaching of non-technical skills: Surgery is a dynamic specialty and surgical competency is a combination of both technical and non-technical skills. The Royal College of Edinburgh defines non-technical skills in surgery (NOTSS) as a collective term used to describe the skills and behaviour, including situational awareness, decision-making, communication, teamwork and leadership.[20] All these factors are serious considerations affecting patient's pathway from initial clinic visit to postoperative planning. Evidence suggests that errors in surgery are not due to technical blunders alone. Surgical outcomes of supervised trainees include complications similar to those of a skilled surgeon.[21] But poor decision-making, incomplete situational awareness, and communications errors often contribute to surgical errors.[22] Literature suggests that nearly one-half of all errors in OR are due to surgeons' behaviour and intra-operative decision-making.[23] These factors have challenged the traditional paradigm of surgical education, and stressed the need of a robust curriculum, including the training of non-technical skills for safe surgical practice. Training of NOTSS is a combination of theory, demonstration, and simulation-based training.[24]

I. Theory and demonstration-based training

Training of NOTSS focuses on three categories; social skills, like leadership, teamwork and communication, cognitive skills, like decision-making and situational awareness, and personal factors to overcome stress and fatigue which can impact the technical performance of a surgeon. Theory-based training is classroom teaching for introducing the concepts of NOTSS, their importance and how they can be replicated in OR situations. Another aspect of theory-based training is cognitive training for stress control and error detection through motor or mental imagery.[25] This approach involves mental rehearsal of a task with the assistance of a script. Studies have shown that this approach has a significant impact on teamwork, situational awareness and error handling. Demonstration-based training involves display of NOTSS along with theory. It involves observation of video-recordings of a simulated operation and discussion on problems, possible consequences and solutions. These approaches are low-cost and improve awareness and knowledge of the trainees.

II. Simulation-based training and validated tools

The most effective way of training in NOTSS is through simulation and this approach has shown superior results than didactic lectures for self-recognised improvement.[26] Hands-on training in these skills is implied with low-fidelity and high-fidelity simulators, simulated ORs, ward and clinic environment with patient simulators, manikins and hybrid models. High-fidelity-simulated setting to replicate OR, trauma and ward setting provides a face validity tool which is important to engage participants using various scenarios. The scenarios vary from uncomplicated cases to more intensive crisis resource management, including scenarios of complications and emergencies in the presence of multidisciplinary teams. These sessions are recorded with feedback from skilled facilitators for self-reflection. Concurrent use of both technical and non-technical skills in surgical curricula has proven to improve leadership, communication skills and decision-making in laparoscopic surgery and urological procedures.[27]

Individual non-technical skills, including communication skill and teamwork, have gained popularity due to their impact on patient outcome. In a review of 258 malpractice claims, 82% cases were due to system factors and 24% cases were due to communication failures.[28] Miscommunication has been reported to be the cause of near-misses in surgical practice.[20] Communication is particularly crucial during clinical handoffs, for transferring professional responsibility and accountability of patients to another trainee or healthcare professional during patient transfer from ORs, wards or emergency departments (EDs). Proper communication is vital for patient safety and continuity of care. The Institute of Medicine's reports 'To err is human' and 'Crossing the quality chasm' have emphasised the importance of continuity of care and robust exchange of information between clinicians for a safe surgical practice.[29] Team training has been found to enhance the communication skills in trainees.[30] Simulation-based team training with relevant scenarios need to be incorporated in training programmes to improve effective communication among residents to avoid unnecessary management errors in surgical patients. Surgical teamwork tool is a validated training tool to train and assess the communication skills in surgical trainees. Another significant aspect of social skills in surgery is leadership, while recently understanding and training have gained importance which has lead to the development of training tools like

Surgical Leadership Inventory and Multifactor Leadership Questionnaire.[27] Leadership is essential for safe and efficient performance of team, for setting standards, supporting other team members and coping with stress and pressure.

Situational awareness is one of the cognitive skills that has been described as a three-step model, perception being the first step, followed by comprehension of factors in current situation and, finally, projection of their implication to future situations.[31] Lack of situational awareness in surgery leads to impaired decision-making with potentially harmful patient outcomes. Way et al. reviewed 252 bile duct injuries after cholecystectomies and concluded that majority of injuries had resulted from lack of situational awareness.[32] Despite its crucial role, no validated training tool has been developed for the training of this skill-set. Another important cognitive process requiring structured training is decision-making. Surgical decisions carry high risks and can be associated with serious patient outcomes.[33] There are various training tools for surgical decision-making, including didactic teaching and simulation-based scenarios. Moreover, there is strong evidence to suggest the benefit of e-learning in enhancing this cognitive skill-set.[27] Although NOTSS training has gained importance in the past decade with the validation of various training tools, there is a need for integration of these tools in standardised curriculum for surgical residents worldwide.

Competency-based surgical education: One of the innovations in surgical education is competency-based training instead of previous time-based training, which is an outcome-based approach that identifies the abilities required for a specific level of trainee and subsequently designs the curriculum to support the acquisition of pre-defined competencies.[34] Competency-based curriculum has the potential to reduce training time with simultaneous improvement in required technical skills. Furthermore, formative assessments and feedback identify and address the deficiencies in a timely manner. These factors have influenced the regulatory bodies around the world to implement competency-based curriculum in surgical training which is further enriched with simulation-based training and assessment tools.[35]

Conclusions

Surgical education has undergone a drastic transformation from its inception and is being influenced by many factors, the most important being patient safety. The concept of "see one, do one, teach one" has widened its horizons to inculcate simulation-based training of both technical and non-technical skills that have direct impact on patient outcome. Various training tools have been developed, validated and incorporated into residency curriculum to train and to objectively assess the competency-based skills and translate them into real OR.

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