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EDITORIAL

Orthopaedic education in the era of surgical simulation: Still at the crawling stage

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Abstract

Surgical skills education is in the process of a crucial transformation from a master-apprenticeship model to simulation-based training. Orthopaedic surgery is one of the surgical specialties where simulation-based skills training needs to be integrated into the curriculum efficiently and urgently. The reason for this strong and pressing need is that orthopaedic surgery covers broad human anatomy and pathologies and requires learning enormously diverse surgical procedures including basic and advanced skills. Although the need for a simulation-based curriculum in orthopaedic surgery is clear, several obstacles need to be overcome for a smooth transformation. The main issues to be addressed can be summarized as defining the skills and procedures so that simulation-based training will be most effective; choosing the right time period during the course of orthopaedic training for exposure to simulators; the right amount of such exposure; using objective, valid and reliable metrics to measure the impact of simulation-based training on the development and progress of surgical skills; and standardization of the simulation-based curriculum nationwide and internationally. In the new era of surgical education, successful integration of simulation-based surgical skills training into the orthopaedic curriculum will depend on efficacious solutions to these obstacles in moving forward.

Key words: Surgical simulation; Orthopaedic surgery; Education; Skills training

Core tip: Simulation-based surgical skills training outside the operating room has become essential for modern trainees due to restricted work-hours, cost pressures, emphasis on patient safety, and the increasing number of minimally invasive and technically challenging procedures. Orthopaedic surgery has fallen behind some other surgical specialties in integrating surgical simulation into its curriculum due to several obstacles. The authors aim to clarify these obstacles and suggest solutions for a smooth transformation to simulation-based curriculum in orthopaedic surgery.

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INTRODUCTION

The traditional method of teaching surgical skills in the operating rooms (OR) has been based on the master-apprenticeship (*i.e.*, learning on the patient) model for over one hundred years[1]. Although this model has been successful throughout many generations, simulation-based surgical skills training outside the OR has become essential for modern trainees due to restricted work-hours, cost pressures, emphasis on patient safety, and the increasing number of minimally invasive and technically challenging procedures[2]. In general surgery, once the need for surgical skills training outside the OR was recognized, surgical simulation was formally acknowledged as evidence-based and integrated into residency curriculum and board certification[3,4].

Orthopaedic surgery arguably covers the broadest human anatomy and related pathologies among the surgical specialties. Hence, the learning of countless basic and advanced surgical procedures during orthopaedic surgery training is required. In addition, as a specialty with a focus on both bone tissue pathologies and soft tissue disorders, trainees are expected to be familiar with a diverse range of both surgical and non-surgical equipment throughout the course of their training, which indicates a strong need for simulation-based skills training. However, orthopaedic surgery has fallen behind some other surgical specialties in integrating surgical simulation into its curriculum.

Although efforts are underway to make this training a part of orthopaedic education, issues that must be addressed include the definition of skills fundamental to orthopaedic surgery that are amenable to simulation. The optimal time period and amount of exposure to the chosen simulations during orthopaedic training must be determined. There must be objective, valid and reliable metrics to measure the effects of simulation training on both the development and progress of surgical skills. Finally, simulation-based curriculum for training in orthopaedic surgery needs to be standardized at national and international levels.

CURRENT OBSTACLES TO SIMULATION-BASED EDUCATION IN ORTHOPAEDICS

Defining areas in need of simulation-based skills training

Simulation-based training should aim to hasten the process of learning surgical skills in a safe environment that is away from the stress of the OR and also allows the opportunity to both make and learn from mistakes without causing harm to patients. Because orthopaedic surgery encompasses the broadest human anatomy, simulated orthopaedic procedures need to be defined carefully so that both basic and advanced orthopaedic surgical skills can be improved outside the OR effectively.

Currently, the majority of the educational programs in United States have already integrated simulated training of basic surgical skills in to their first postgraduate year (PGY1) either as a one-time intensive course (*i.e.*, boot camp) or as longitudinal training sessions throughout the year since this training is required by the American Board of Orthopaedic Surgery (ABOS) and Residency Review Committee (RRC) in orthopaedic surgery. However, the content of these courses is not well-defined. In addition, there is no consensus among orthopaedic training programs as to what type of advanced procedures need simulator training. Almost all advanced orthopaedic surgical skills' courses that are presently available are limited in terms of both procedure types and practiced surgical tools due to their commercial nature. As one of the first steps forward, priority will need to be given to the definition of both basic and advanced surgical skills to be trained on simulators in orthopaedic education.

Another important issue is the use of simulators for training and certification or recertification of orthopaedic surgeons already in practice. Simulation-based training might offer a valuable opportunity for practicing orthopaedic surgeons who have completed residency or fellowship training to learn new procedures and/or update their existing skills. Further, simulations may have a future role to assess surgical skills as benchmarks for certification or recertification of practicing orthopaedic surgeons. Likewise, simulators can be beneficial in selecting students for specialty training in orthopaedic surgery based on their aptitude in simulated performance of basic surgical skills. Nevertheless, all these potential areas in which simulators could have benefits need to be further identified and studied rigorously before simulators can be used in certification/recertification and trainee selection processes.

Arthroscopic surgery is an area where orthopaedic simulation is more advanced and that simulation-based training can be very effective in improving skills of orthopaedic trainees[5-7]. During the past few decades, there have been dramatic improvements in arthroscopic surgery of the knee, shoulder, hip, elbow, wrist and ankle joints. However, the amount of time that the trainees could spend for practicing arthroscopic surgery skills is limited because the duration of residency training is still the same as it was decades ago. Further, there are different arthroscopic procedure types for each joint, which makes it nearly impossible for trainees to become truly proficient in this field. Hence, simulated arthroscopic skills training could be an important learning opportunity for residents and fellows.

Current simulators are limited to mainly the knee and shoulder modules and do not include some of the commonly performed operations such as meniscectomy, rotator cuff repair, or even loose body removal. It is clear that simulation-based arthroscopic skills training needs to be integrated into the educational curriculum. However, the types of simulator devices and software, joints on which to focus, and procedures to be practiced using arthroscopy simulators are still waiting to be defined and standardized. Cost factors will be another limitation. As an example, the cost of a high-fidelity simulator can be as high as 100000 USD including the device, software, and maintenance.

After defining the skills for which training with simulators will be most effective, programs to educate and certify simulation lab instructors to supervise trainees during simulation-based skills training could be of value. Although such an initiative could only become relevant after a standard simulation based curriculum is established, this may also aid in achieving uniformity among educational programs nationwide.

Time, duration, and frequency of simulation-based skills training

Although surgical simulation in orthopaedic skills training has been recognized as a necessity, and the Accreditation Council on Graduate Medical Education recommends simulation training during residency education, specifics with regard to time, duration, and frequency of practicing with simulators are left to program directors to determine what they think is best for their residents[2,8]. Since July 2013, orthopaedic residency programs in the United States have been required to incorporate laboratory-based surgical skills training into the curriculum during the first year of residency. Currently, some orthopaedic residency programs have included a one-month period of an intensive skills training course, or boot camp, into their curriculum before interns begin their training. There are existing concerns regarding the effectiveness of short-term intensive skills training, and the degree to which skills learned in these courses are retained and achieve the goal of improved integration into the actual OR is uncertain[3]. Hence, some residency programs in the United States have decided to spread these skills training courses throughout the entire internship year *via* one or two days of simulation-based training every week. Further research is required to prove the superiority of either method in surgical skills training during residency.

Due to the tremendous number of surgical skills and procedures that must be learned after the first year of residency, incorporation of simulation-based skills training into the latter years of residency should positively influence the development of trainees' skills. Choosing the time and duration of simulation-based training as well as determining the optimal time period for reinforcing the learned skills by repeating the simulated courses are of primary concern. Although more simulation-based surgical skills training may result in better learning for residents, this would also require more time spent in education and thus away from clinical service, which might be an obstacle to conducting lab-based training for extended periods during residency. The fellowship period might be a convenient time for practicing skills that are more advanced and specific to subspecialties and offer greater opportunities for dedicated time. However, fellowship programs may vary in terms of their goals and objectives for training, and standardized educational curriculum adjustments for simulation-based training during the fellowship period do not appear to be realistic at this stage. Also more advanced skills training is necessary at the fellowship level requiring higher fidelity simulations which may be cost prohibitive for many fellowship programs.

Proficiency-based-progression training

A notable simulation-based surgical skills training approach, which was recently proposed, is proficiency-based-progression (PBP). This approach can be defined as training based on a benchmark that has been established by expert performance. The benchmark that the novice must achieve is set by the mean performance scores of experts who undergo the same course (curriculum). Thus, the training is not completed in a given amount of time but rather continues until the benchmark scores are met for two consecutive trials. In addition, tasks are presented in a progressively increasing level of difficulty. The trainees are allowed to proceed to the next step only after the previous and easier task is accomplished proficiently. This notion also matches the Dreyfus and Dreyfus model of progression of skills performance from novice to master[9]. In a prospective randomized blinded study, Angelo *et al*[5] demonstrated that the PBP protocol, when coupled with the use of a shoulder model simulator and validated metrics, produces superior arthroscopic Bankart repair skills when compared with traditional and simulator-enhanced training methods. It is evident that the integration of simulation-based surgical skills training into educational curriculum using such novel approaches will be more beneficial if certain factors, such as which skills require focus and at what point during the training they should be implemented, could be determined and organized beforehand.

MEASUREMENT OF SKILLS LEARNED IN SIMULATORS

In the process of simulation-based surgical skills training, measurement of trainees' progress in performing surgical procedures and assessment of their levels of proficiency is vital. As Rear Admiral Dr. Grace Hopper stated, "One accurate measurement is worth a thousand expert opinions"[10]. Traditional assessment of surgical proficiency, which has been based on both the observations and personal opinions of experts regarding trainees' performances, will need to be replaced with valid, objective, and standardized techniques for the measurement of the skills learned using simulators.

Current measurement methods include questionnaires, objective structured assessment of technical skills (OSATS) and global rating scale of performance (GRS) scoring systems, structured assessments using video recording, motion tracking, and direct metric measurement of task performance. Although questionnaires can be practical and low-cost assessment tools, their inherent shortcomings are subjectivity and unfeasibility in terms of standardization. Further, comfort or knowledge questionnaires as proficiency measures in surgical procedures are not validated instruments[11]. OSATS is performed by independent observers, who evaluate a trainee's performance objectively using a checklist of specific surgical maneuvers that have been deemed essential to the procedure (*e.g.*, measuring the screw length with depth gauge, verifying screw lengths, ensuring that screws securely engage the far cortex, *etc.*); GRS aims to measure characteristic surgical behaviors during the performance of any given procedure (*e.g.*, respect for soft tissues, fluidity of movements, familiarity with the instruments, *etc.*)[2,12]. Hence, subjective criteria included in GRS result in limitations including ambiguity, poor inter-rater reliability, and frequent bias. Video-based feedback is a practical method that enables the assessment of surgical performance using the same measurement tools as OSATS or GRS at a later, convenient time for the rater[13]. However, this means that the shortcomings associated with OSATS and GRS are also relevant to the video-based assessment of simulated surgical skills. Motion tracking and analysis systems can be mounted to surgical tools and attached to or worn on the hands as sensors[14]. They can also be built within a simulator to track and analyze instrument tip trajectory data[15]. Although motion analysis systems might be an objective and valid tool for assessing surgical skills in terms of precision and economy of movements during the performance of simulated surgical procedures, the impact of these metrics on a trainee's skill transfer to the OR has yet to be proven[16,17]. Directly measuring a concrete aspect of a skill using universal metric measurements holds promise for improving reliability, validity, clinical relevance, and applicability in large-scale studies or high-stakes board exams, while decreasing time and expense. Examples of such parameters include the mechanical strength of a knot or a fracture fixation construct; accuracy of reduction; or time to completion of a skill task[18-20].

The abovementioned measurement methods can be used alone or in combination based on the preferences of each research group or institution. Therefore, heterogeneity exists in the literature in terms of available evidence to draw conclusions. Formation of standardized measurement protocols using reliable, valid, and objective metrics are essential before a simulation-based orthopaedic surgery education curriculum can become standard.

STANDARDIZATION OF SIMULATION-BASED CURRICULUM AMONG RESIDENCY AND FELLOWSHIP PROGRAMS

Although simulation-based surgical skills training in dedicated laboratories is already a requirement to learn basic surgical skills during residency in United States, there are no guidelines that each residency program is required to follow. Moreover, there is no requirement to implement simulation-based training in the fellowship period, during which more advanced procedural skills, such as arthroscopic treatment of intraarticular pathologies, are taught.

As an example for standardized curriculum change, the ABOS and the Orthopaedic RRC have taken initial steps by requiring simulation based training during the PGY 1 year. Organizations that focus on education such as American Orthopaedic Association/Council of Orthopaedic Residency Directors, American Academy of Orthopaedic Surgeons or subspecialty societies could develop a more robust simulation curriculum for later years in training. However further mandatory requirements will be necessary to widely incorporate simulation in to curriculum and to uniformly advance the field. It is likely that the accrediting and certifying bodies will want to see solutions to some of the other issues identified in this article before mandating further requirements. It is clear that proposing initiatives is easier said than done. However, improving surgical education and human health is worthy of the required intensive efforts.

CONCLUSION

Orthopaedic surgery requires the comprehensive integration of simulation-based surgical skills training into its educational curriculum. Although efforts are being made toward transitioning into simulation-based educational curriculum, orthopaedic surgery lagged behind other surgical disciplines in simulation. Current obstacles that require further work and research include definition of the areas that need simulation-based skills training in orthopaedic surgery, choosing the optimal time period in orthopaedic training for exposure to simulators; the correct amount of such exposure; using objective, valid, and reliable metrics to measure the impact of the training on the development and progress of surgical skills; and standardization of the simulation-based curriculum both nationwide and internationally. A successful transition into simulation-based surgical skills training in the orthopaedic educational curriculum will depend on efficacious solutions to these obstacles.

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