Techniques in Vascular and Interventional Radiology

Simulation-based Training for Interventional Radiology and Opportunities for Improving the Educational Paradigm

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The current model for medical education is based on the Master-Apprentice model which was adopted into practice over a century ago. Since then, there have been many changes in healthcare and the environment in which trainees learn, practice and become proficient in procedural and critical thinking skills. The current model for medical education has however, not changed considerably in this time frame, resulting in significant limitations to trainee education. Simulator-based training is a technique which can minimize the limitations of the apprenticeship model by mitigating the effect of time constraints, increased emphasis on patient safety and satisfaction and nonstandardization of Interventional Radiology (IR) curricula. Currently, simulators are utilized in some IR programs, however robust research into simulators must be performed to prove the educational validity of simulators and support formalization and widespread integration of simulation based training into a new, improved and standardized IR curriculum.
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Introduction

The current model for training in medical education, the apprenticeship model, was adopted during the formalization of medical education and residency between the years 1905 and 1910.[1] In the decades since, there have been great changes in the healthcare field, without corresponding change in the formal medical education system. This has resulted in significant limitations to the current medical training paradigm. Significant advancements in healthcare technology, changes in the physician–patient relationship, alterations to inpatient and outpatient care algorithms and adjustments in acceptable medical education training hours are some of the major factors that have limited the efficacy of the apprenticeship model. Simulation-based training offers a method by which limitations to the current educational paradigm can be addressed.

Simulation programs gained celebrity in the 1950s when they were adopted for the purpose of flight training. Over the years, other fields have come to realize the advantages of simulation-based training and introduced this methodology into their curricula. Currently, simulation training is being used in a variety of procedure-based specialties such as surgery and gastroenterology.[2] Interventional Radiology (IR) training programs have also started to utilize simulation training programs as an adjunct to traditional training methods. The use of simulators in medical training, including interventional radiology, has not reached the level of curricular integration and widespread utilization that occurred with flight simulation training decades ago.

This paper will explore both current limitations of the apprenticeship model, demonstrate ways in which simulation training can minimize these limitations and discuss what is needed for the development of effective simulation trainers that can be utilized to train, test and even certify the coming generations of interventional radiologists.

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Limitations of the Apprenticeship Model

Time

In the 1900s, trainees working in the hospital embodied the meaning of the word "resident," by spending the majority of their waking, and sleeping, hours in the hospital. Under the tutelage of an expert physician, imitation, repetition, trial and error resulted in the development of a strong knowledge base and proficiency in clinical skills. With the implementation of the ACGME's 80-hour week limit for trainees, the safety profile for both patients and trainees was potentially altered by a reduction in the chance for errors, burnout, mistakes, near misses and the like. This time decrease, while advantageous, also resulted in a limit to the amount of time trainees spend with their mentors making clinical decisions, performing procedures, and following the course of patient conditions. These experiences are essential to the efficacy of the apprenticeship model of training, and therefore suffer as a result of the current time limitations.

Patient Safety and Satisfaction

Increased emphasis on patient safety, patient satisfaction and decreased cost may translate into limited opportunities for the mentor to interact with the mentee in the angiography suite.[3,4] The emergent nature of a case may necessitate brisk and precise expert action to ensure patient safety, which makes extensive explanation, real time demonstration, and trainee practice nearly impossible. In light of residents' presumed lack of experience, some patients request a more seasoned provider to perform their procedures. As most IR procedures are usually performed under moderate sedation, patients may hear, see, and remember all the events of the angiography suite. Patients may become upset, and understandably so, if they believe something is being performed incorrectly or a mistake is being made—hearing the mentor say "no do it this way" may mean that he prefers one successful style over another, but to the layperson, undergoing a procedure and under the influence of sedation, this may be interpreted as an admission of error, suggesting that they are in the hands of a provider that does not know what they should be doing, and requires correction. Correcting trainees while upholding patient confidence in the procedure and the healthcare system is a precarious balance, one which is not always easily obtained. As a result of prior experience or general assumptions, some patients even request the exclusion of a trainee from their healthcare team altogether.[5-7] An increased emphasis on decreased costs through shorter hospital stays has also decreased the time spent following a patient through their pre-, intra- and post-procedure course of care. These factors combine to result in an overall decrease in opportunities for the IR trainee to learn and develop their procedural, interpersonal and clinical reasoning skills.

Standardization of Medical Education

In 2002, the ACGME launched the Outcome Project, an initiative with the goal of making medical training more standardized. The project identified 6 competencies for graduate medical education programs to use to evaluate their residents in training. Each of these competencies consists of different milestones that residents must master at different stages in their training.[8] The competencies and milestones are evaluated by subjective questionnaires that mentors complete. While the questionnaire may enquire about a similar set of skills and knowledge, evaluation of trainees based on these milestones does not eliminate the inherent differences in trainee education for a variety of reasons. Practices and procedures differ greatly based on geography, with patient demographics often dictating the types of cases performed in a region. Even within the same geographic region, specific procedures within each institution can vary greatly based on attending preference as well as available technology and the division of labor between specialties within the hospital. The very nature of the apprenticeship model lends toward nonuniformity as each and every mentor may be unique in their style and training. The IR educational experience is subject to this variation and as a result, trainees may matriculate with significantly variable levels of skills, experiences, and knowledge.[9]

Continuing Medical Education

In terms of maintenance of certification and the training of expert physicians on the use of new tools and procedures, once again the apprenticeship model reigns. However, a lack of time and experience again limits this method of teaching. To learn how to use a new tool or perform a new procedure, physicians may take a course over a few days or even a week. They may learn how to perform a procedure from a co-worker and be evaluated by co-workers in order to be given privileges to perform procedures or use devices in their hospital. While this approach has worked, it necessitates the use of new tools and procedures on patients. While experience, expertise, and collaboration make these efforts usually safe and effective, there is always the chance that patient safety may be compromised when new skills and tools are introduced.

Simulation-based Training and IR Education

Filling in the Gaps

Simulation-based training is a technique that replaces and reinforces real life experiences with mock experiences that reproduce substantial aspects of the real world in an interactive manner.[10] Simulators allow for repetition, identification of skills and behavior, and objective feedback that may not always be provided in the clinical setting.

Simulator programs and models can be designed to prompt trainees to mimic just a few key steps of a procedure or they can have the trainee reproduce the steps required for successful completion of an entire intervention. Simulators can also be created with the ability to recognize errors and mimic the resultant physiologic effects. These simulators may be used to evaluate trainees' proficiency in not only performing procedures but also managing common IR complications. Feedback and repeated practice can be performed almost ad infinitum, until proficiency metrics are met. In this way simulation-based training can help alleviate time limitations of the apprenticeship model by essentially creating more "time." Patent safety is not in question during practice. The loss of exposure to certain patient experiences and procedures due to the swift nature of hospital throughput, geographic or demographic limitations can be avoided as trainees can gain experience in a variety of procedures and their various outcomes, successes, or complications. During simulation training, mentors can give candid feedback and instruction on how to improve without the concern for patient interpretation or dissatisfaction. In this way, simulators do not make the mentor obsolete and indeed in most cases mentor feedback to simulator performance is an integral part of the learning experience.

Next Steps

For widespread acceptance and implementation of simulators as an adjunct to traditional training programs or as a form of certification, they must be educationally valid. Educational validity is the measure of the effectiveness of a simulation in teaching the knowledge or skills intended. Educational validity of a simulator is determined by assessing 5 different dimensions: face validity, content validity, construct validity, concurrent validity, and predictive validity (Table 1). The nature of some of these factors is objective and can be easily measured by conventional scales while others are subjectively determined by experts. These measures of validity can be assessed through a variety of methods, including: surveys, pre- and post-tests, and global rating scales.[11] The measure of validity of a simulator is determined by repeat testing and research. Valid simulators successfully teach, test, and evaluate proficiency in a variety of situations and procedures.

There are currently 4 common types of simulators used for clinical and procedural skills training: computer-based learning modules, phantom and/or part-task trainers, computer-assisted mannequins, and virtual reality (Table 2). Other types of simulators, such as animal and cadaver models, can also be incorporated into training programs. However, due to a multitude of reasons, including cost and ethics, these models are not often utilized.[14] Some of these simulators currently in use in IR have been rigorously evaluated and have demonstrated validity in one or more of the measures noted above. Coles et al[15] asked expert physicians to evaluate the face validity of PalpSim—a simulator that integrates haptics (tactile feedback) with augmented reality. Experts mentioned that the feeling of free space was slightly distorted but the physiological features, feel, and immersive environment conferred a high level of face validity upon the simulator. *Johnson* et al[16] assessed the construct validity of their Seldinger technique simulator by comparing metrics obtained when the simulator was used by trainees vs seasoned interventionalists. The metrics obtained demonstrated a difference in skill levels between experienced and inexperienced practitioners, proving a high level of construct validity of the simulator.[16] In a study by Andreatta et al[17] the concurrent validity of a PICC line simulator was evaluated. The investigators used a part-task trainer to train a group of residents to place a PICC line and the apprenticeship model to train a second group of residents to perform the same task. Results from the study demonstrated better performance by the part-task trainer group on 8 of 9 testing metrics, when compared to residents trained through the apprenticeship model.[17]

Table 1 Factors That Measure Educational Validity of a Simulator[11]

Factor	Measures
Face validity	How well a simulation replicates real life
Content validity	How well a simulation both trains and tests the skills it was designed to impart
Construct validity	How well a simulation can differentiate between the skill levels of participants
Concurrent validity	How well a simulator can teach or train a skill in comparison with standard methods
Predictive validity	How well skills on a simulator translate to real life

Toward a Standardized Curriculum

While studies have established some valid aspects of currently available interventional radiology simulators, much research is still needed to confirm the overall educational utility and functional usage of simulators across all levels of expertise. Studies have shown that novices tend to benefit more than experts from simulation-based training.[18] If valid simulators for a majority of the basic procedures integral to IR training are developed and accepted, they could be used to evaluate milestones more objectively than the current method. This in turn could lead to the formulation of a general standardized and widely accepted IR curriculum by which trainees are evaluated and certified. On the other hand, for seasoned experts, usage of simulators can serve as a method of maintenance of certification and development of new skills.[18]

Limitations of Simulation Training

Effective use of simulators requires more than a determination of educational validity and integration into a training program. Per *Issenberg,*[19] effective use of simulation requires 3 main factors: training resources, trained educators, and curricular institutionalization. Indeed, simulators must be available for use by the trainee, educators must be trained on how to use simulators and simulator training must be appropriately integrated into a trainee curriculum. A lack of any one of these factors reduces the potential effectiveness of simulator-based training.

Table 2 Simulators Utilized for Clinical and Procedural Skills Training

Type of Simulator	Description	Examples	Notes
Computer-based learning modules	Digital programs and/or collection of content on a computer used to teach individuals skills and knowledge[11].	Nightshift (Nottingham City Hospital, UK)	A program that trains residents in task prioritization, as well as how to navigate the hospital[12].
		Contrast reaction management (Wang et al[13])	Trains participants on how to manage contrast reactions
Phantoms / part-task trainers	Devices that model specific anatomical regions that are used to teach specific skills[11]	Transvaginal ultrasound simulation model (Blue Phantom, Sarasota, FL)	Used for teaching and practicing endovaginal ultrasound procedures
		Central line torso and arm models (Blue Phantom, Sarasota, FL)	Models designed to teach and practice central line placement skills
		Soft tissue biopsy ultrasound training block model (Blue Phantom, Sarasota, FL)	Model used to train ultrasound-guided needle procedures
Computer-assisted mannequins	Full body models that can simulate physiological responses[11]	SimMan (Laerdal, Wappingers Falls, NY)	A mannequin that can simulate physiological and neurological responses. SimMan can be used for crisis resource management and for contrast reaction management training[11].
		PediaSIM (CAE Healthcare, Sarasota, FL)	A mannequin that can simulate physiological and neurological responses in the pediatric population.
		Patient simulator (Medsim-Eagle Simulation, Fort Lauderdale, FL)	A mannequin that can simulate several physiological phenomena including eye and pupillary responses, and pulse. This may also be used in contrast reaction management training.
Virtual reality simulators	Simulations that attempt to create an immersive experience for the user that mimics the real world and includes visual, auditory, and haptic feedback[11].	Ultrasim (Medsim, Fort Lauderdale, FL)	An ultrasound simulator.
		ORCAMP (Orzone, Gothenburg, Sweden)	An angiography suite simulator.
		Simsuite (Medical Simulation Corporation, Centennial, Colorado)	An endovascular simulator that mimics multiple physiological responses.
		VIST-Lab (Mentice, Chicago, Illinois)	An endovascular and cardiovascular simulator that consists of a mannequin with haptics in a femoral access point.
		ANGIO Mentor (3D Systems, Littleton, Colorado)	An endovascular simulator that consists of a mannequin with a variety of haptic modules.

Institutional Support

On August 31, 2004, the US Food and Drug administration approved the use of a specific carotid stent. Due to the high complication rates from prior carotid stent use, the US FDA stipulated that before physicians are allowed to purchase the stent, they must be trained in and must demonstrate a certain level of proficiency in use of the new stent. This was the first time that the US FDA declared that a medical device, and therefore a procedure, confers too great a risk on patient safety to be learned through performance on live patients.[20] This precedent speaks volumes for what may become common practice for the institution of medical device. It also indicated another way in which simulators may be able to alter the current educational model of healthcare education.

Conclusion: Toward a New Educational Paradigm

For over a century, the apprenticeship model has been the primary method utilized for interventional radiology physician training. Due to changes in healthcare and the medical field, without corresponding changes in educational methods, significant limitations to this model of teaching have developed. Trainee regulations, an emphasis on patient safety and satisfaction as well as concerns about healthcare costs have decreased the amount of time for trainee exposure to patient care both inside and outside the angiography suite. Due to a variety of factors, including geography, patient demographics, institutional preference and mentors of differing skill levels and specialization, the current trainee education is nonuniform in structure.

Simulator-based training offers a way to bridge the gaps in the apprenticeship model of medical education. Use of simulators in interventional radiology education has the potential to save time, or more accurately, decrease the effect of time limitations on the ability of trainees to reach a significant level of proficiency during their training. Simulators promote patient safety both by decreasing patient involvement in the teaching of basic initial skills, and by making trainees proficient in certain aspects of procedures before taking these skills into the angiography suite. Simulators can be used to recreate both common and uncommon errors so that trainees learn how to manage complications without jeopardizing patient safety.

For interventional radiology simulators to play a significant part in redefining the current educational paradigm, they need to have high educational validity. Valid simulators need to train novices and experts specific skills, recognize errors, predict and display the physiological complications due to these errors and teach trainees how to manage these complications effectively. In addition, simulators and/or entire simulation training programs should be devised to evaluate individual trainees and cater to their skill level, advancing them along a stepwise path to mastery of interventional techniques and critical thinking. In this way, simulators can assist trainees in the successful completion of a standardized interventional radiology curriculum. Of note, societies such as the American Board of Radiology, the Radiological Society of North America and the Society of Interventional Radiology have banded together to advance the use of simulation in education,[1] further demonstrating a push toward a new educational paradigm which includes simulation-based training.

While experts currently maintain skills, procure new skills and learn to use new devices through the apprenticeship model, time and experience limitations beg the question as to whether there may also be a more uniform, safe and comprehensive way to approach continuing medical education.

To reach a state where simulator-based training is able to truly shift the educational paradigm from the apprenticeship model to a more hybrid form of learning, a vast body of research into simulators and simulation-based training is needed. For this to occur, simulators must first be incorporated into programs where extensive research can be performed. In the end, the goal of simulator research and utilization should be development of a new hybrid educational paradigm that bolsters the safety, efficacy, and uniformity of medical education. The integration of simulators into the current IR curriculum is a method by which the limitations of the apprenticeship model can be minimized and the simulator technology of the current century can be utilized to increase efficiency of training and ensure the continued matriculation of generations of technically proficient and clinically savvy interventional radiologists.

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