SPECIAL CONTRIBUTIONS

The Use of Simulation in Emergency Medicine: A Research Agenda

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Abstract

Medical simulation is a rapidly expanding area within medical education. In 2005, the Society for Academic Emergency Medicine Simulation Task Force was created to ensure that the Society and its members had adequate access to information and resources regarding this new and important topic. One of the objectives of the task force was to create a research agenda for the use of simulation in emergency medical education. The authors present here the consensus document from the task force regarding suggested areas for research. These include opportunities to study reflective experiential learning, behavioral and team training, procedural simulation, computer screen–based simulation, the use of simulation for evaluation and testing, and special topics in emergency medicine. The challenges of research in the field of simulation are discussed, including the impact of simulation on patient safety. Outcomes-based research and multicenter efforts will serve to advance simulation techniques and encourage their adoption.

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Medical simulation promises to revolutionize health care education, and emergency physicians are actively participating in the development of this field.[1] In 2004, emergency medicine (EM) faculty helped create the new Society for Simulation in Healthcare, an international society with more than 1,000 members and growing. In 2006, *Simulation in Healthcare* was established as the first journal devoted entirely to the topic of simulation, with EM faculty serving on the founding editorial board. Given the number of EM residency programs now exploring and expanding their use of simulation,[2] there is a substantial opportunity for EM investigators to contribute new knowledge in the field. The Society for Academic Emergency Medicine (SAEM) Simulation Task Force offers this "Agenda for Research" in the belief that advanced simulation technologies will fundamentally alter the landscape of medical education and practice across specialties.

David Gaba, MD, one of the pioneers of modern health care simulation (currently Stanford's Associate Dean for Immersive and Simulation-based Learning), recommends that simulation be utilized at the individual, team, work unit, and organizational levels to improve and ensure patient safety and quality of care.[3] Gaba and other leaders in the field envision a future where health care providers (much like airline pilots) will not be able to practice medicine without first having trained and demonstrated competence using simulator technology. In many sectors of health care, this future is coming into view. The Joint Commission on the Accreditation of

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Healthcare Organizations has discussed the role of simulation in patient safety.[4] The Accreditation Council for Graduate Medical Education recently dedicated an entire bulletin to the topic of simulation.[5] The Food and Drug Administration has now approved virtual reality (VR) simulator training for carotid artery stenting, the first example of using such means for medical procedure credentialing in the United States.[6] Two of the largest insurance carriers in Massachusetts now give premium discounts for simulation-based training,[7] and in regard to research, the federal Agency for Healthcare Research and Quality recently offered the first grants targeted specifically to simulation-based research.[8]

Our working definition of simulation is quite broad, and the technology is evolving rapidly so that the boundaries of what can be simulated change frequently. For our discussion, simulation encompasses any technology or process that re-creates a contextual background in a way that allows a learner to experience mistakes and receive feedback in a safe environment.[3] Simulation tools include procedural trainers, flat-screen computer simulators, standardized patients, and high-fidelity mannequin-based simulation. When fully integrated into a curriculum, simulation creates experiences with rarely encountered pathology as well as common pathology that may not be encountered if left to random clinical experience.[9] In certain areas, such as chemical weapons preparedness, simulation training may be the only way to rehearse at the levels of emergency medical services field provider, nurse, physician, and hospital administrator. As an educational methodology, simulation helps to standardize training and can facilitate instruction in team behaviors,[10] systems-based practice issues,[11]and professionalism.[12]

Sound educational theory and design is every bit as important as technology in ensuring a valuable learner experience.[13] The cost of simulation can be substantial and should be weighed when considering alternative methods to meet learning objectives. The logistics of getting trainees to simulation centers and moving them through simulations are also considerable. From a long-term health care systems perspective, the cost of trainee time may well dwarf capital expenditures for facilities, computers, and mannequins. Given the opportunity and monetary costs of simulation training, sound research is needed to reveal the areas where simulation training adds the most value.

Increased demands by the public for patient safety, and reluctance on the part of patients to be "practiced" on, have added to the impetus for simulation and speeded its adoption. Experts in simulation have noted that the burden of proof for the adoption of simulation need not consist of randomized controlled trials.[3] In fact, to date very little evidence exists that proves the effectiveness of simulation. The most concrete evidence involves the improvement in real-world laparoscopic cholecystectomy skills after VR training.[14] A substantial body of theoretical and simulation laboratory work exists regarding the anesthesia crisis management training program,[15] but proving that such a program changes real-world outcomes in an already extremely safe system is difficult. Simulation successes noted in other fields such as anesthesia may not directly translate into the multipatient, interruption-prone setting of EM. These and other issues facing simulation researchers are discussed in the following text.

This report attempts to stimulate and prioritize EM simulation research efforts. Our discussion is organized into four components: education and training, evaluation and assessment, unique specialty topics, and overall research challenges. In each area, we will highlight opportunities for inquiry and experimentation to advance the field. A limited amount of theory in each area is discussed to provide background, highlight existing evidence, and emphasize the importance of the topic.

For further background on simulation, we refer readers to a review article by Issenberg et al.,[16] as well as the books *Simulators in Critical Care and Beyond*, edited by Dunn,[17] and *Practical Health Care Simulations*, edited by Loyd et al.[18] For a detailed discussion of research methods in education, we recommend *The International Handbook of Research in Medical Education*, edited by Norman et al.[19]

SIMULATION FOR EDUCATION AND TRAINING IN EM

Clinical Experience and Reflection

Simulation fundamentally re-creates the "experience" of patient care, giving participants an opportunity to practice a range of skills and to reflect on their performance in a safe environment. Whether the simulation is devoted to routine or rare clinical events, comprehensive self-reflection during a "debriefing" session is essential.[16,20,21] Debriefing gives learners the opportunity to think critically about their performance, deconstruct events and errors that unfold during the scenario, and acquire new information to improve subsequent practice. While educators and participants recognize the importance of debriefing, there is no consensus regarding the best approach. Many educators prefer formal debriefing sessions after simulated scenarios are completed.[17] Using this technique, clinical and behavioral errors made during the simulated case "play out" to completion, allowing practitioners to experience error-related consequences and learn from their mistakes. Although the clinical experience is simulated, this approach may produce a level of emotional realism that allows the students to learn "as if it were a real case." Instructors facilitate student-driven discussions such that the students themselves acknowledge suboptimal practices and suggest alternative approaches. The instructor must skillfully maintain an engaging, nonthreatening environment that encourages self-directed learning while teaching complex clinical and behavioral skills.[22] Compared with formal didactic instruction, adult learners are particularly suited to experiential learning and debriefing.[23] Faculty debriefers will often use video-recorded portions of the debriefing to encourage self-reflection, stimulate discussion, and identify clinical cues that were missed. While some students may be initially uncomfortable in front of a video camera, trainees quickly relax and lose their self-awareness.[21,24]

Many facets of simulation training and debriefing bring about metacognition, or "thinking about one's thinking."[25,26] Investigators have reported early attempts to study cognitive error and cognitive debiasing in the setting of simulation training.[24,27] Only recently has cognitive error as it pertains to diagnostic error been quantified.[28] The simulation laboratory is an appropriate place to develop the cognitive load and affective milieu for the study and mitigation of these types of errors. However, studying these errors will remain challenging because they often occur during cognitive processes that are hidden from the investigator. Cognitive psychologists and emergency physicians should work collaboratively to explore this topic.

One of the greatest threats to the use of simulation is the possibility of "negative learning," which occurs if the student incorrectly learns something because of an imperfect simulation. Technical (e.g., limitations in physical findings on the mannequin), instructional, or environmental factors (e.g., artificial "acceleration" of time or tasks) may imprint incorrect clinical practices or procedural skills. The presence and intervention of a clinical expert instructor during the simulation and the debriefing can mitigate this problem. An instructor can conduct standardized debriefings that incorporate preplanned PowerPoint lectures, computer-based tutorials, and videotapes depicting the "ideal" management of simulated clinical scenarios.[10,24] These remedies for negative learning during simulations are worthy of further exploration.

Instead of debriefing only at the completion of a scenario, some educators use a technique whereby the instructor suspends the clinical scenario to discuss the patient care and decision making that has occurred to that point.[16] This can be very effective with more inexperienced students who might require redirection to successfully manage a clinical case. While this technique avoids compounding error and reinforces correct information, repeated interruption might adversely impact the physical experience and emotional impact of the simulation.[9] Some educators believe that uninterrupted realism is necessary to encourage the self-reflection and abstract conceptualization that are the cornerstones of good debriefing.[29] Future studies will be needed to identify which debriefing techniques and adjuncts best enhance student learning and how the optimal approach varies with the level of learner, skill of the faculty, and specific learning objectives. As EM residency programs incorporate simulation as a teaching modality, it will be important to define such "best practices" for both teaching and faculty development.

Behavioral and Team Training

The teaching and debriefing of behavioral and team training skills in medicine deserve special mention. While other complex high-risk industries (notably the commercial airline industry) have improved their safety records through continual teamwork training and assessment, most medical training remains focused on individual skills and decision making.[30,31] Although medical faculty may be effective clinical instructors in the traditional practice domain, the approach to behavioral and team training requires specialized skill and care. If health care workers are expected to function effectively in interdependent teams, they should be trained in the principles of high-performance teamwork throughout their careers.

In aviation, the Advanced Qualification Program and Crew Resource Management training served to integrate teams and communication skills into a curriculum previously focused on technical skills.[15] There are a number of components of aviation-based training that are transferable to medicine: it is proficiency based, task or goal oriented, and focused on team performance (rather than individual performance). Team skills are combined with technical skills. Team simulation training is likely to enhance successful team performance, and training programs must be systematically developed and validated.[32] While such training principles have been transferred to the operative environment (anesthesia, obstetrics and gynecology) using courses such as MedTeams and Crisis Resource Management (CRM),[10,33] these skills are generally overlooked in other residency training programs, and they are not regularly reinforced in current continuing medical education programs.

Loosely derived from simulation-based aviation training, CRM courses train and reinforce principles of effective teamwork and problem solving in the clinical setting. CRM training often involves highly realistic, complex clinical scenarios designed to engage multidisciplinary teams in the areas of leadership and team management, situation awareness, and workload management.[32] Such training has been shown to reduce errors[33] and improve problem-solving skills[34] in real clinical practice. The debriefings of CRM-based scenarios focus less on specific medical issues and more on the behavioral principles of crisis management.[29,34] While medical debriefing may be more common for teaching novices, and team-oriented debriefing more useful for experts, ideally both concepts can be addressed simultaneously. It will be important to evaluate the optimal balance of medical and team-oriented approaches and to identify the right number and mix of participants for each set of curricular goals.

Measuring the team-oriented performance is different from measuring individual proficiency; there may be even wider variations in performance scores between teams than between individuals.[35] High performance teams should have generalized knowledge, skills, and attitudes that are shared by all members, enabling the team to function in an effective and coordinated manner.[31,36] Competencies at both individual and team levels include cognitive skills (e.g., problem solving, decision making), technical and procedural skills, and team behavior skills. Simulations with high-fidelity, whole-body mannequins allow teams to apply therapeutic interventions and respond to rapidly changing conditions under time pressures, thereby facilitating interaction among team members. The knowledge and attitudes of team members can be extracted from direct observation, review of videotapes, and debriefing sessions. Scoring across teams using standardized scenarios allows more robust assessment of actual clinical practice compared with traditional assessment methods.[37]

Can we translate the lessons of teamwork training that have been learned in aviation and anesthesiology directly to EM? Various investigators have developed taxonomies or classification systems for team behaviors and skills, instituted teamwork training curricula, and attempted validation of team training tools that could apply to EM.[21,31,33,36,38–47] The Behaviorally Anchored Rating Scales[48,49] is one example of a validated team measurement tool; other research has used measures of workload, stress, and fatigue that will be useful in

EM-based team behavior research. For example, one paradigm holds that team performance is influenced by at least four variables: external conditions, member resources, task characteristics, and team characteristics.[41] The influence of each of these variables on EM teams is unclear. We do not know which team competencies are generalizable and should be taught to all teams and which are specific to a particular clinical problem or to a particular team. Given the different styles of team interaction among specialties, the team skills that are optimal for EM must be defined. EM teams are more dynamic than most, forming and dissolving rapidly. The composition of team members often changes during a crisis. EM teams may need to be evaluated over a wide variety of conditions and at different times of the day and night. Consequently, investigators will face the challenge of developing a large repertoire of simulations to test those team skills relevant to the field of EM. We must identify the factors that impair performance and increase errors at each of three levels: the individual practitioner level, the interpersonal or team level, and the institutional level. What is the optimal team size for a cardiopulmonary resuscitation? How does the authority gradient change as a patient's condition deteriorates? Can team members recognize cognitive overload in a team leader? What events during a crisis are most likely to cause team dysfunction? Which team skills are most effective in reducing medical error in crises situations compared with routine care?

Procedural Simulation

Medical schools and residency programs are responsible for producing technically competent physicians, but not all of the necessary procedural skills are truly mastered during these training periods.[50–53] Classroom training does not always translate into effective procedural skills, and competence does not always match confidence.[54] Nadel et al. studied pediatric residents who completed a pediatric advanced life support course and found that the mean cognitive score was 93%, but only 18% correctly performed airway management skills and one third successfully inserted an intraosseous line.[55] Although residency program directors are asked to attest to the competency of recent graduates, they are unable to evaluate the performance of every procedure by every resident. Systematic evaluation using structured, objective criteria is seldom used by faculty to establish resident procedural competence.[56] Except for a few procedures, it is not known how many times a specific procedure must be repeated to attain competence.[56,57] Little is known about how quickly procedural skills deteriorate after training; consequently, there is little science behind hospital-based credentialing requirements.

In addition to traditional mechanical "task trainers," computer-based simulation technology has developed over the past decade to a point that VR now represents a realistic and highly promising modality for procedural training. The majority of VR applications available today have been designed for training in surgical and surgical subspecialty fields. Some of these applications have been validated, but few have been investigated for their applicability in EM.[58] Simulator-trained surgeons appear to perform better in particular operative environments.[14] Due to a recent decision by the Food and Drug Administration, there is now precedence for requiring the use of VR technology for certification in endovascular procedures.[6]

Ericsson[59] and others[60,61] argue that the best predictor of the quality of performance is repetitive or "deliberative" practice, with attentive supervisors providing corrective feedback until the skill is mastered. The traditional training model of trial-and-error learning, "see one, do one, teach one," is an inefficient and risky approach for acquiring technical skills. Moreover, most EM residents do not have sufficient opportunities for patient-based, deliberative practice of all relevant procedures. Simulation can provide learners with a safe, controlled, and readily accessible approach to learning and practicing procedural skills, perhaps even accelerating skill acquisition. Educators may finally have a tool for reliably assessing procedural competency. However, simulation is an incompletely tested assessment method for the range of procedural skills required of emergency clinicians. "Competency" must be defined precisely for every procedure. Each step must be identified, and the proper sequence of those steps must be established. Objective checklist and expert scoring systems must be created,[62,63] and training and assessment methodologies must be validated.

Emergency medicine procedures are sometimes taught to residents during a single session. Does skill practice that is distributed over time persist longer than multiple repetitions performed on one day? How many times should a learner repeat a procedure correctly to optimize skill retention; in other words, what is the learning curve for each procedure? The cycle of observation, practice, and feedback appears to be an effective way to learn a procedural skill initially. Is it necessary to repeat every step of a procedure with every practice session, or will review of the critical steps and sequence suffice?[57] What instructional techniques accelerate the learning process and improve retention for various procedures? Procedural skills deteriorate with lack of use over time, and the decay is proportionate to the length of time since learning or practice.[64] Assuming that competence was demonstrated at the end of a training session, how long are those skills or competencies retained if not repeated?

What simulation models are most useful for training and assessing physicians? Which components of a procedure can be taught with simulators, and which require an animal model? Difficult procedures may be learned more effectively and more rapidly if the complexity of the component skill sets is increased gradually. This may be accomplished by varying the model used for instruction.[65] With better understanding of technical skill acquisition, educators will be able to select the best model for each stage of training.[57] Partial task trainers may be the first step, high-fidelity simulators the intermediate step, and patients the last step in the mastery of a procedure. Is procedural competence that is achieved on a partial task trainer maintained when the procedure is performed during a complex medical simulation with additional distractions? Ultimately, investigators in EM will have to prove to a reasonable degree that skills developed on computer simulations, partial task trainers, or mannequin simulators, as well as on animal models, translate into competent performance of procedures on actual patients.

Computer Screen–based Simulation and Immersive Environments

The role of computer screen–based simulators in education has been explored outside of EM. Schwid and O'Donnell demonstrated improved performance in an advanced cardiac life support mega-code scenario after training with a screen-based advanced cardiac life support simulator (Anesoft Corp., Issaquah, WA) as compared with standard advanced cardiac life support textbooks.[66] Screen-based simulations have also been used as an adjunct in scenario debriefing and can improve future performance on mannequin-based scenarios.[67] Some computer screen–based simulators have the advantages of being relatively low cost and easily distributed among large groups. While computer screen–based simulators do encourage immersion into the clinical scenario, lack of fidelity and environmental cues make training certain behavioral and teamwork skills difficult. As with the area of simulation as a whole, these trainers work best when combined with multiple other teaching modalities. More research is required to determine how to optimally integrate them into existing curricula.

In addition to the procedural applications of VR, two other experiential applications warrant individual discussion and are especially promising for EM training. The first of these, the Cave Automatic Virtual Environment, is an immersive training area with dynamic real-time, virtual projections on the walls.[58,68] It has been used to simulate an emergency department, a sick bay on a Coast Guard ship, and a stadium for out-of-hospital care. Investigation into the Cave Automatic Virtual Environment or similar applications should be undertaken to determine if it improves training and is cost-effective. Another interesting concept for EM is multiuser virtual environments. A few applications now exist that enable remote users to interact in a single virtual emergency department.[58] These also require objective evaluation, but they will likely prove useful in distance learning and team training. Finally, the broad category of augmented VR holds great promise for EM. This technology allows students and teachers to virtually "see through" structures and could potentially improve training of EM procedures such as intubation, central lines, and lumbar puncture.[58] Augmented VR is relatively new, so emergency physicians now have a unique opportunity to become involved early in its development and ensure that this category of VR will optimally benefit our field.

SIMULATION FOR EVALUATION AND TESTING IN EM

Building on prior educational assessment work, there is growing literature supporting the reliability and validity of simulation as a platform on which to assess performance in medicine. The use of mannequin-assisted simulations to assess the clinical skills of EM trainees and practicing physicians is an important area for future research. Both the National Board of Medical Examiners and the Education Commission for Foreign Medical Graduates require a passing grade on the U.S. Medical Licensing Examination Clinical Skills Examination, in which data gathering skills and communication and professionalism are assessed during 12 standardized patient encounters. Similarly, the American Board of Emergency Medicine uses simulated patient encounters (role playing) as part of their oral board certification process. Extending this paradigm, the anesthesiology board certification examination in Israel recently incorporated mannequin-assisted simulations as part of the certification process.[69] While not yet used for high-stakes assessment, a growing number of EM residency training programs are using simulation as a way to teach and assess resident performance.[2]

There is a large body of literature on the objective structured clinical examination that may be helpful to investigators studying the use of other forms of simulation for assessment. As with the objective structured clinical examination format, the reliability of a simulator-based examination depends in part on the number of scenarios tested.[70] For a broad assessment of clinical skills, the number and content of simulations required to assure an acceptable level of reliability must be determined. It is possible that competencies assessed in different types of simulations (objective structured clinical examinations, standardized patients, and mannequin-assisted simulations) may overlap and that combining these different types of simulations will give us a more robust view of the construct being tested.

Validity is another measure of the utility of an educational tool. Content validity refers to how closely items match the concept being measured. Criterion validity occurs when one can draw inferences from one scale and relate it to another measure of the same quality or behavior. This can be concurrent or predictive. The most important "test" of criterion validity will be whether superior performance on simulated patient exercises predicts a high quality of patient care as measured in terms of actual patient outcomes. Construct validity involves the ability to draw inferences between an assessment and a model. For example, the association of previous experience, such as clinical rotations or coursework, or advanced levels of training, with higher scores on a given test supports the construct validity of that test. There are several reports in the literature describing a variety of simulation exercises and assessment tools that discriminate between novices and more experienced trainees.[71–76] When the goal of assessment is to provide formative feedback, locally developed scenarios and performance checklists or global rating scales that have face validity (i.e., that appear to measure what they purport to measure) are probably adequate. When the purpose of assessment is to evaluate professional competence for the purpose of promotion, certification, or licensure, the development of reproducible scenarios with reliable and valid assessment tools will be required. This is a critical area for the research agenda.

In developing assessment tools for mannequin-assisted simulations, work should be done to determine if tools that have been validated in other settings are equally valid when used to assess performance when managing simulated patients. In one published study, investigators found that evaluation tools validated for use in EM oral examinations could effectively discriminate between novices and more experienced trainees in a simulator-based testing environment.[76] Communication assessment tools validated in other settings, such as the Rochester Communication Scale[77] or the Clinical Skills Information scale[78] used by the U.S. Medical Licensing Examination, may also be valid for use in mannequin-assisted simulation exercises.

There has been debate regarding the use of checklists versus global rating tools to assess performance. The best tool may vary with the population being tested and the purpose of the examination. Checklists are often more reliable, whereas global rating systems may be better at capturing expert performance. In a comparison of checklists and global ratings during a simulation skills assessment examination, investigators found that checklist tools were more reliable than global rating tools but that global rating scales achieved an acceptable level of reliability, particularly when used to rate technical skills and judgement.[79] It is apparent in many cases that rater training is perhaps more important than the tool itself for achieving an acceptable level of reliability[80]; however, a large pool of raters randomized over many testing cases can mitigate interrater differences.[75] Questions also exist about the equivalence of live grading and video reviews. Video review is more time consuming, but it enables the review of performance by faculty not familiar with the trainee, thus decreasing the risk of bias. Video footage, however, may not capture all of the behaviors being assessed.

For high-stakes examinations, standardized patients undergo rigorous training to achieve consistency in role portrayal and an acceptable level of interrater reliability (typically reaching 0.75–0.85) in completing performance checklists and global ratings of interpersonal skills. Faculty using simulations need to assure a similar degree of reproducibility in simulator responses, situational urgency, and role portrayal by standardized nurses and other support staff. The development and validation of standardized case material, which can be reliably replicated across multiple locations and technologies, will be of paramount importance as the high-stakes agenda moves forward.

In the field of EM, investigators have begun to evaluate the use of simulation for competency assessment, but many questions must be answered. The research agenda for simulation-based assessment should focus not only on the clinical skills and Accreditation Council for Graduate Medical Education core competencies that can be assessed using simulation, but also on the elements and content of the core curriculum in EM that are best and most accurately assessed using mannequin-supported simulations.

SPECIAL TOPICS IN EM

Care Process and Organizational Design

Simulation offers the opportunity to test processes of care before their implementation.[81] Researchers should begin to study “normal operations”[82] and crises situations[83] with on-site simulation to identify vulnerabilities in both specific processes and broader systems. Simulation offers us the opportunity to test new technology, such as an intravenous pump or an information system, before an expensive, large-scale rollout of such an effort.[84] Simulation may be used to test cognitive aids, such as electronic charting systems with imbedded prompting or the Broselow–Luten tape for pediatric resuscitation.[85]

Studying and Improving Performance

One ongoing issue in medicine is the identification and remediation of individuals with substandard clinical performance. The simulation laboratory setting may help determine if an individual’s deficits lie in history taking, physical examination, other data gathering skills, data synthesis, decision making, or prioritization. Another issue that has been studied with various types of simulation is the effect of fatigue on performance.[86] Fatigue can be examined for its effect on team behaviors, decision making, communications skills, and error rates.[87,88]

Disaster Management

Descriptive work has been published on the use of simulators as part of disaster drills and in response to chemical, biological, radiological, nuclear, and explosive events.[89–92] More simulation research will be needed to define competencies and to establish programs for maintaining competencies in this area.

Undergraduate Medical Education

Because EM spans many medical disciplines, emergency physicians are well suited to help animate medical school curricula using simulation. Emergency departments can be an important force in helping medical schools to study and implement effective simulation-based teaching throughout the undergraduate medical curriculum.[93,94]

CHALLENGES IN SIMULATION-BASED RESEARCH

Because there is currently very little evidence that simulation improves patient care, we strongly advocate for studies that demonstrate and quantify the impact of simulation training on patient care outcomes. The most credible existing evidence for a cause-and-effect relationship is the success with laparoscopic VR simulator training.[14] EM has a wealth of opportunities for research on procedural competence and patient outcomes using simulation. Blike et al. have successfully developed a methodology for finding latent errors in the procedural sedation process.[83] This same methodology can be used for studying process safety after simulation training interventions, and it can provide a measure of process change that will ultimately be reflected in patient safety.

Evaluating the effect of medical simulation on actual health care outcomes remains a distinct challenge, just as formal evidence for the correlation between flight simulation and passenger safety remains elusive. There are several reasons for this problem: a relatively low rate of adverse events, the multidisciplinary context in which such events occur, the seemingly immutable nature of institutional culture, and the time and repetition required for training effects. Even for relatively small target interventions on known patient safety problems, multicenter studies may be needed to achieve sufficient statistical power. For example, in the study of difficult airway management, the cricothyrotomy rate is now approximately 1%[95]; thus, interventions designed to reduce such a low rate are exceedingly difficult to study. The outcome for difficult airway situations may need to be "appropriate adherence to the difficult airway algorithm" or "appropriate use of the airway rescue device." Surrogate markers may need to be substituted for outcomes that are difficult to measure.

Preliminary work has shown that particular types of training can improve the steepness of the learning curve (creating an earlier plateau of desired performance).[93,96–98] This work will need to be repeated in larger studies. Other industries have shown the importance of the learning curve in productivity and plan for its existence.[99] Research into learning curves and rate of skills decay could prove very fruitful in medicine. We must establish the elements of simulation training that are both necessary and cost-effective for transfer of skills to the bedside.

Emergency medicine investigators could identify the systems errors, cognitive errors, and contributing factors that produce the greatest harm to patients and that should be targeted for simulation training and testing. Multiple patient safety databases now exist at the private, state, and federal levels that contain data on the incidence of errors, the impact of errors, and the environmental contributors surrounding the error.[100] These databases will lead investigators to creative solutions, thereby "closing the loop" between patient safety databases and simulations designed to improve patient safety. Finally, on-site simulations may prove to be useful diagnostic tools for hidden flaws in emergency departments and hospital systems.

FUTURE DIRECTIONS

The work of the SAEM Simulation Task Force and the SAEM Simulation Interest Group has led to the development of a case library of simulation scenarios (http://www.emedu.org/sim). SAEM and the Association of American Medical Colleges (AAMC) are currently collaborating to publish a collection of peer-reviewed simulation cases through MedEdPORTAL, the AAMC's web-based portal for educational scholarship.[1] This will further facilitate the spread of simulation by creating an academic incentive and by providing well-made scenarios for other simulation users. The sharing of evaluation tools will also foster research and education.

Simulation patient safety efforts will also be bolstered by simulation efforts that offer both continuing medical education and "patient safety" credits, especially if they are supported or required by state licensing boards, insurance companies, and local hospital credentialing committees. Interdisciplinary team training may need to be encouraged by these same types of incentives. Such efforts have already begun; two of the largest medical liability insurance carriers in Massachusetts now offer premium discounts for simulator-trained physicians in anesthesiology and obstetrics.[7]

Multicenter simulation research efforts will be needed to further validate simulation training. Such collaboration is currently fostered through both the Simulation Interest Group and the Simulation Task Force, but to date the largest EM simulation studies have involved only two to three centers.[27,53] The SAEM Simulation Newsletter and web site will foster these collaborations (http://www.saem.org; go to education/simulators). Educational research mentoring and fellowship programs, with an emphasis on simulation-based teaching and scholarship, will accelerate the study of this exciting new field.

CONCLUSIONS

Medical simulation techniques have shown great promise in other specialties. We have outlined here the challenges and opportunities of realizing that promise in EM. Specifically, we recommend a priority emphasis for research on the following: the impact of simulation training on patient safety; the transfer of skills into real-world settings; the assessment of the validity and reliability of simulation for procedural, clinical, and behavioral competency evaluation; the assessment of various debriefing techniques; and the impact of simulation training on team function. Novel uses of simulation have been discussed, and robust collaboration will involve experts across disciplines, including psychology, psychometrics, and human factors. Given the resource demands of some simulation approaches, we should remain open to all solutions that meet desired pedagogical objectives. Multicenter studies will test reliability across institutions and add validity and statistical power to simulation research efforts.

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APPENDIX A

Simulation Task Force (2005–2006)

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