Simulation-based Procedural Skill Training

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Abstract

Procedures are a critical part of medical practice. In this report, we examine the topic of simulation-based procedural skill training. Developing competency with procedures begins in medical school and continues through residency training. After residency training, internists must maintain competency in a defined set of required procedures. Simulation plays a key role in all these stages. Learning procedural skills is influenced by an individual's ability, skill, and set. Competency in procedural skills develops through a series of five stages spanning from novice to expert. The Halstedian training model of 'see one, do one, teach one' has been replaced by a contemporary model of procedural skill training that uses simulation. The contemporary training model consisting of six stages: *Learn*, *See*, *Practice*, *Prove*, *Do*, and *Maintain*. While simulation-based procedural skill training can be applied to both graduate and continuing medical education in internal medicine, it should always be seen as a supplement to performing procedures in the clinical environment, not as a replacement

Keywords: simulation, training, procedural skills, procedural training, internal medicine

Introduction

Performing procedures is a critical part of medical practice. Acquiring competency with procedures requires education, training, and practice. Education in procedural skills begins in medical school, and training and practice commence during internship and residency. The American Board of Internal Medicine (ABIM) recognizes there is variability in the types and numbers of procedures performed by practicing internists. The ABIM, however, has identified a set of procedures in which all candidates must be competent in with regard to knowledge and understanding, and a smaller subset of procedures with which all candidates must demonstrate competency to safety perform (Table 1).[1]

Finding ways to ensure that Internal Medicine residents obtain sufficient training to become competent is a challenge for educators. The ABIM strongly recommends that procedural training be initially conducted through simulation.[1] After initial simulation-based training, residents should then perform the procedures in clinical practice with supervision for an adequate number of times to develop competency. The ABIM does not specify a minimum number of procedures needed to demonstrate competency but does state that residents should actively participate in a procedure five or more times to assure adequate knowledge and understanding.[1]

Once competency is demonstrated during initial training and certification, continued practice is essential to avoid the natural skill decay seen in all fields. The frequency in which procedures need to be performed to maintain competency has not been established. Evidence suggests that with appropriate initial training, doctors can retain procedural skills after long periods without practice.[2] This is especially true if 'mastery learning' is used during the initial training.[3] Even experienced providers, however, require refresher training at some point if they do not perform a specific procedure for a prolonged period of time. In these situations, simulation serves as a vital tool to maintain competency when performing procedures as part of clinical practice is either impractical or not feasible.[4]

In this report, we examine the topic of simulation-based procedural skill training. We begin with a discussion of procedural skill learning. Then, we explore the development of competency for a procedural skill. We conclude with a review of a proposed model of simulation-based procedural skill training and skill maintenance and an application of this mode to Internal Medicine. We hope this report will serve as a reference for Internal

Medicine educators and providers interested in the topic of procedural skill training.

Procedural Skill Learning

Procedural skills can be learned, however, some individuals learn them faster and become more proficient than others. Several intrinsic characteristics have been identified as important in procedural skill learning; these include 'ability', 'skill', and 'set'.[5,6] An 'ability' is an inherited and intrinsic characteristic that affects the ability to perform a motor task.[7] Abilities include: control precision, reaction time, manual dexterity, finger dexterity, arm-hand steadiness, wrist-finger speed, and aiming.[7] A 'skill' is the learned capacity to perform a task effectively. Abilities differ from skills in that skills are learned, whereas abilities are a product of both learning and genetic factors.[7] Learning procedural skills should focus on supporting an individual's nascent abilities and working to provide an optimal environment in which to build and develop the individual's skill with a specific procedure. A person's 'set' describes an individual's readiness to act. Sets can be mental, physical, and emotional. These sets are dispositions that predetermine a person's response to different situations and can impact the ability to perform a procedural skill in a specific setting, or at a specific time.[8] For example, a provider with a high level of nascent ability and learned skill in placing a peripheral venous line may be unable to perform the procedure on a patient if they are in a negative emotional set due to a recent traumatic event. Thus, establishing a learning environment in which the learner's mental, physical, and emotional sets are acknowledged and incorporated into their individualized learning plan is important for procedural skill training.

Procedural Skill Development

E.J. Simpson and A.J. Harrow described a five-stage developmental progression for psychomotor/procedural skills. Their taxonomy includes the stages of *guided response*, *mechanism*, *complex overt response*, *adaptation,* and *originating*.[6,8] Dreyfus and Dreyfus described a five-stage model of directed skill acquisition in medicine.[9] The 'Dreyfus model' taxonomy includes the well-known continuum of the five stages: *novice, advanced beginner, competent, proficient,* and *expert.* These 2 developmental models of skills acquisition parallel each other with learners progressing through the stages as they build competence. Table 2 outlines the alignment between the five developmental stages of the two

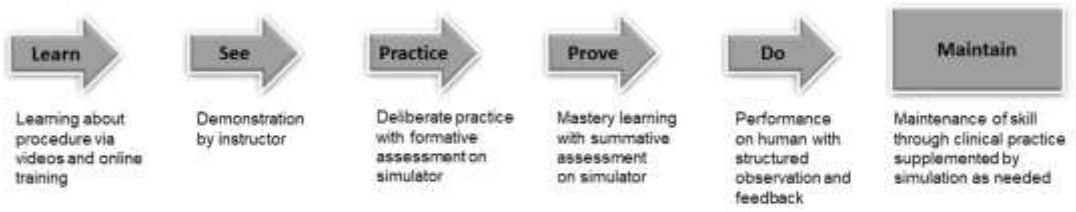
taxonomies and provides a description of each stage. In earlier stages, direct supervision is required for patient safety. In more advanced stages, the individual can teach others and can be called upon to perform a procedure in more complex and difficult settings (e.g. drawing arterial blood in a patient with septic shock). The ability to perform the procedure safely, without direct supervision, is present at the 'complex overt response'/'competent' level.

A Model of Simulation-based Procedural Skill Training

The traditional procedural skills training model of 'see one, do one, teach one' is attributed to William Stewart Halsted, who became the first Chief of Surgery at Johns Hopkins Hospital in 1890.[10] In this century-old paradigm, procedural competency is acquired through direct patient care, with trainees first observing a procedure, then performing the procedure, and then teaching the procedure to others as part of a medical apprenticeship model. Halsted's model embraces the idea of acquiring progressively increasing amounts of responsibility that culminated in independent practice; a concept that is referred to today as 'graduated responsibility'. The Halstedian training model has been scrutinized in the modern age, due to patient safety concerns, as most learners require more than one opportunity to observe a procedure before being proficient enough to perform it on a live patient and additional practice before being competent enough to teach the procedure to other learners.[11,12] Thus, a more contemporary procedural skill training model is needed to meet the needs of the modern learner and provide for adequate patient safety.

A modern procedural skill training paradigm should incorporate simulation as a fundamental component. The use of simulation offers the ability to safely develop procedural skills without the risk of harming patients during initial training. The use of simulation for training has been associated with improved patient care and patient safety,[13-19] and is supported by the Accreditation Council for Graduate Medical Education.[20] In 2015, Sawyer et al. described a procedural skills training model consisting of six stages, identified as '*Learn, See, Practice, Prove, Do,* and *Maintain*' (LSPPDM).[4] This model relies heavily on simulation both as an educational technique and as a method of skills assessment. An overview of the framework is presented in Figure 1, and the six stages are described briefly below.

Figure 1. An overview of the '*Learn, See, Practice, Prove, Do,* and *Maintain*' model[4]



Learning

The first stage of the LSPPDM model is learning about the procedure. This can be done through various methods, including traditional classroom didactic sessions, individual reading, videos, or online modules. Important learnings at this stage include the indications and contraindications of the procedure; patient preparation methods; sterile techniques; pain/sedation management; proper handling of specimens; ability to explain to the procedure to a patient; and method of obtaining informed consent. In some cases, virtual or augmented reality can be used to help learners better visualize the relevant anatomy and procedural equipment. Verification of content knowledge can be evaluated via quizzes with multiple choice, or fill in the blank, questions to ensure adequate baseline knowledge prior to moving to hands-on training.

Seeing

The second stage of the LSPPDM model is seeing the procedure performed via demonstrating and modeling. This demonstration can be done either in-person or via pre-recorded videos. The demonstration may use a simulator, which is ideally the same simulator used in the next stage: practice, so as to build familiarity with the simulator. The seeing stage starts with a deconstructed demonstration going over each step of the procedure with pauses to editorialize and explain. This is used to point out the most salient aspects of each part of the procedure and allow for clarifying questions about the details. The demonstration then proceeds to a full run through of the procedure in real time without pause. This allows the learner to get an accurate model for performing the entire procedure and a gauge of the timing of the various steps.

Practicing

The third stage of the LSPPDM model is practicing the procedure using simulation. Deliberate practice is used at this stage to maximize the learning. Ericsson defined *deliberate practice* as a regimen of effortful activity designed to optimize improvements in the acquisition of expert performance.[21] Deliberate practice involves well-defined learning objectives, focused and repetitive practice, precise measurements of performance, and formative feedback. Individualized, formative feedback is provided during this stage through coaching and sequential modification of procedural performance with a focus on specific areas for improvement.

Proving

The fourth stage of the LSPPDM model is proving procedural competency on a simulator. In this stage, the learner has his/her skill objectively assessed to ensure basic competency has been achieved. Simulation-based mastery learning (SBML) is used at this stage. SBML augments deliberate practice through the addition of a clearly defined level of performance that outlines 'mastery'.[22] Mastery is typically defined as achieving a predetermined score on an assessment tool, such as a procedure checklist or other validated scoring tool. Competency-based assessment using SBML is an important safety mechanism, as is verifies a basic level of competency prior to performing the procedure in the clinical setting on a patient.

Doing

The fifth stage of the LSPPDM model is doing a procedure on patients. This is the first stage of the training model that occurs in the clinical arena. This stage follows the four earlier stages in an effort to improve patient safety, and to avoid trainees performing procedures on patients until after some level of procedural competency has been verified through simulation. To increase the safety of this stage, all procedures are initially performed under direct supervision by someone who has mastered the procedure. During this time, real-time performance-based assessments and feedback are provided. This type of performance-based assessment in clinical practice is an important part of competency determination for training programs.[23] Creating a safe environment in which supervised practice can take place can be accomplished through one-on-one training during a clinical rotation, or during dedicated procedure rotations. Competency assessment in this stage can be done using the same procedural skills checklist used for SBML, as long as the checklist has been validated both in the simulation and clinical arena.

Maintaining

The sixth, and final, stage of the LSPPDM model is maintaining procedural competency over time. This stage starts in the later years of residency training and continues for the rest of a physician's career. This stage acknowledges the fact that procedural skill competency is perishable and degrades with time if the procedure is not practiced regularly. In the *Maintain* stage, a provider supplements clinical practice with simulation - as needed - to ensure continuous competency with a specific procedure. In this stage, the provider tracks their individual procedural experiences to identify procedures that they perform on an infrequent basis and thus may benefit from simulation training and refreshers. The need for supplemental simulation-based practice dependents on multiple factors including the prior experience of the clinician and variability in the types, difficulty, total number and frequency of procedures performed. Given the variation in procedural competency requirements, an individualized approach needs to be followed.[24]

Application of Simulation-based Procedural Skill Training to Internal Medicine

Simulation-based procedural skill training has a clear application to both graduate and continuing medical education in

internal medicine. For graduate medical education, simulation-based training can overcome some of the challenges that educators face in ensuring residents receive sufficient training to become competent in required procedural skill. Simulation provides the ability to perform 'training on demand' that is tailored to the learner's specific needs, as well as 'just in time' training when the learner is most in need of a refresher. The application of the LSPPDM model moves procedural competency assessment away from performing a set *number* of procedures, towards a more learner-central individualized approach. Creating appropriate venues within which simulation-based training can occur as part of graduate medical education takes planning and time. Resident "boot camps" are one such venue.[25] Boot camps are intensive training sessions that generally take place in the first months of training. Resident and fellow boot camps involve a focused curriculum to teach fundamental clinical skills prior to beginning clinical rotations. Using the LSPPDM model during boot camp ensures that procedural skills are not only learned but also can be performed to a set mastery standard. Such mastery-based assessment can improve patient safety at the start of the academic year.[25]

Table 1. Internal Medicine Procedural Competencies[1]

Must be competent in with regard to knowledge and understanding	**Must demonstrate competency to safety perform during residency training**
Abdominal paracentesis Advanced cardiac life support Arterial line placement Arthrocentesis Central venous line placement Drawing venous blood Drawing arterial blood Electrocardiogram Incision and drainage of an abscess Lumbar puncture Nasogastric intubation Pap smear and endocervical culture Placing a peripheral venous line Pulmonary artery catheter placement Thoracentesis	Advanced cardiac life support Drawing venous blood Drawing arterial blood Pap smear and endocervical culture Placing a peripheral venous line

For continuing medical education, simulation-based training can help safeguard continued competency in required procedures (Table 1) for practicing internists. This is especially important for providers for whom performing required procedures as part of clinical practice is either impractical, or not feasible. Simulation can also be used to provide refresher training to internists after gaps in clinical practice. Additionally, simulation can be used to as part of a hospital's privileging process when internists do not achieve a minimum threshold of patient-based experience.[26] In these cases, however, an observed patient-based assessment should occur.

Table 2. Stages of Procedural Skill Development

Simpson and Harrow Terminology[6,8]	**Dreyfus and Dreyfus Terminology**[9]	**Descriptions**
Guided response	Novice	Skills are learned through imitation and/or trial and error.
Mechanism	Advanced Beginner	Skills have become habitual and the movements can be performed with some confidence.
Complex overt response	Competent	Competency is indicated by a quick, accurate, and highly coordinated performance.
Adaptation	Proficient	Individual can *modify* movement patterns to address difficult situations.
Originating	Expert	Individual able to *create new* movement patterns to address a unique situation, or specific problems.

Conclusion

Procedures are a critical part of medical practice. Developing competency with procedures begins in medical school and continues through residency training. After residency training internists must maintain competency in a defined set of procedures. Simulation plays a key role in all these stages. The learning of procedural skill is influenced by an individual's *ability*, *skill*, and *set*. Competency to perform a procedure develops through a series of five stages from novice to

expert. The Halstedian training model of 'see one, do one, teach one' has been replaced by a contemporary, learner-centered model of procedural skill training that uses simulation. The contemporary training model consisting of six stages: *Learn, See, Practice, Prove, Do,* and *Maintain*. Simulation-based procedural skill training can be applied to both graduate and continuing medical education in internal medicine. However, simulation should always be seen as an extension to performing procedures in the clinical environment on real patients, and not as a replacement.

Conflict of Interest Statement:

There are no conflicts of interest for the authors of this manuscript.

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