A blended approach to invasive bedside procedural instruction

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Abstract

Objective: This study assessed the impact of a blended, standardized curriculum for invasive bedside procedural training on medical knowledge and technical skills for Internal Medicine residents.

Methods: The investigators developed a curriculum in procedural instruction and performance for Internal Medicine house staff, and implemented the program at a tertiary care academic medical center with a primary affiliation with a US medical school. The investigators chose procedures recommended for technical competence by the American Board of Internal Medicine: lumbar puncture, thoracentesis, paracentesis, central venous catheter insertion, and knee arthrocentesis. The program included: (1) assessment of baseline medical knowledge and technical proficiency on mannequins, (2) video instruction of procedure, (3) faculty-led discussion of critical concepts, (4) faculty demonstration of the procedure on mannequin, (5) individual practice on simulators, (6) post-intervention knowledge evaluation, and (7) post-intervention skills evaluation. The performance achieved during the initial skills evaluation on a mannequin was compared to the performance achieved on the first patient subsequent to the instructional portion.

Results: All participants with complete data demonstrated a statistically significant pre-intervention to post-intervention improvement ($p < 0.05$) in comprehensive medical knowledge and procedural skills.

Conclusion: A blended, standardized curriculum in invasive bedside procedural instruction can significantly improve performance in participants’ medical knowledge and technical skills.

Introduction

The landmark Institute of Medicine report, To Err is Human, raised the awareness and importance of patient safety (Institute of Medicine 1999). From that point on, medical errors were no longer considered as rare and benign events, as we were shown that a large number of patients annually suffer preventable harm and death. Invasive bedside medical procedures are associated with greater risks for serious errors and complications, leading to an increase in length of stay and higher associated health care cost (Reynolds et al. 2006).

Standardized procedural training has the potential to address the shortcomings of the traditional “see one, do one, teach one” approach. The apprenticeship model (learners imitating actions of skilled mentors) is inefficient because learners are exposed to numerous procedures performed by few faculty, thus competence is proved with subjective evaluations (Walter 2006). As most faculty do not undergo standardized training to teach procedures, learners receive variable experience in their performance on patients (Boots et al. 2009). Additionally, all learners do not progress at the same rate, and their ultimate performance can depend on their own confidence and competence levels.

In academic medical centers, trainees (taught through the apprenticeship model) traditionally perform the majority of bedside procedures. Recently, several Internal Medicine residency programs have abandoned this approach in favor of a more structured instructional one (Smith et al. 2004; Lenhard et al. 2008). One recently published study evaluated comfort level and self-perceived knowledge improvement after formal teaching sessions that included didactic lectures, video instruction, faculty demonstration, and observed practice (Lenhard et al. 2008). Another group reported instruction of trainees using procedure-specific, web-based, multimedia programs. These were reviewed, and an online quiz completed, prior to performing the procedure on a patient.

Practice points

- Standardized procedural training using a blended approach for instruction has the potential to address the shortcomings of the traditional apprenticeship method.
- The use of task trainers in procedural instruction allows for deliberate practice prior to patient contact.
- Experience with ultrasound improves technical proficiency.
- Bedside checklists are a proven tool to ensure patient safe practices.
- Direct supervision, combined with team training, solidifies the educational experience.
These papers contributed to the foundation of a new paradigm in procedural instruction. Simulation-based educational initiatives have increased in the recent years. Indeed, “the [American Board of Internal Medicine] ABIM strongly recommends that procedural training be conducted initially through simulations” (ABIM 2009) as it provides a safe environment for trainees to learn, practice, and hone skills without patient risk (Ziv et al. 2005). We sought to build upon the work of these investigators, and others (Wayne et al. 2008), in crafting a simulation-based, blended curriculum to teach multiple invasive bedside procedures. This would be accomplished by trainees on a dedicated rotation, supervised by a faculty member. We hypothesized that the implementation of a standardized curriculum in invasive bedside procedural training would significantly improve medical knowledge and technical skills.

**Methods**

**Course content**

The course content development team was composed of the Internal Medicine residency program director, an associate program director, and the director of the institution’s patient safety center. The team chose procedures recently recommended for technical competence by the ABIM. These included: (1) lumbar puncture, (2) thoracentesis, (3) paracentesis, (4) central venous catheter insertion, and (5) knee arthrocentesis.

**Course equipment**

For this program, we used task trainers (mannequins) for each procedure. The effectiveness of using such simulation devices has been previously described (Issenberg et al. 2005; Hutton et al. 2008). To assist the development team with the selection of task trainers, feedback was solicited from the electronic message boards of the Society for Simulation in Healthcare (http://www.ssih.org/public/) and the Association of Program Directors in Internal Medicine (http://www.im.org/About/AllianceSites/APDIM/Pages/Default.aspx), and vendors were invited for hands-on demonstrations. We obtained two task trainers for each procedure so that a back-up was available. We had an initial budget of $60,000 (USD) from the patient safety center and the Internal Medicine residency program. Table 1 lists the task trainer models purchased and utilized for this project.

Recent papers have demonstrated that ultrasound guidance during procedures reduces complications and yields higher technical success rates (McGee & Gould 2003; Nazeer et al. 2005). We also purchased a dedicated ultrasound machine (GE LogiqE; Milwaukee, WI) for procedural instruction along with the linear (12L) and curved (4C) probes for vascular access and paracentesis and thoracentesis procedures, respectively.

**Course faculty**

Our objective was to recruit a cadre of faculty from disciplines that routinely and frequently perform the selected procedures (e.g., critical care, anesthesiology, emergency medicine, gastroenterology, neurology, radiology). We e-mailed faculty from these disciplines who were previously rated highly for their ability to teach residents and invited them to participate.

**Instructor training**

Instructor candidates underwent a three-part process: (1) participate in a ‘show-and-tell’ session during which the curriculum was outlined, the evaluation tools were discussed, and they had the opportunity to practice their technique on the mannequin, all in an interactive manner; (2) they observed a teaching session led by the course director; and (3) the course director observed them leading a session. If a key point was omitted during the session, the course director interjected. Constructive verbal feedback provided to instructors was based on Kolb’s model of experiential learning as faculty were encouraged to self-reflect on previous experience and current performance to guide their teaching of procedural skills (Kolb 1984). Thus, we created a multidisciplinary team of instructors to teach a standardized method of procedural performance (e.g., neurologists for lumbar puncture, radiologists for thoracentesis, emergency medicine for central venous catheter insertion).

**Study setting and participants**

The study was conducted at an urban, tertiary care academic medical center with a primary affiliation with a US medical school. Second- and third-year Internal Medicine residents, medicine residents, and they had the opportunity to practice their technique on the mannequin, all in an interactive manner; (2) they observed a teaching session led by the course director; and (3) the course director observed them leading a session. If a key point was omitted during the session, the course director interjected. Constructive verbal feedback provided to instructors was based on Kolb’s model of experiential learning as faculty were encouraged to self-reflect on previous experience and current performance to guide their teaching of procedural skills (Kolb 1984). Thus, we created a multidisciplinary team of instructors to teach a standardized method of procedural performance (e.g., neurologists for lumbar puncture, radiologists for thoracentesis, emergency medicine for central venous catheter insertion).

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a convenience sample population whose schedule was more flexible than first-year residents, were eligible and participated from July 2007 through June 2009. After volunteering, a maximum of four residents were assigned to this 4-week elective rotation. The instructional sessions occurred at the patient safety center, and they were scheduled in the morning so that the residents could attend their continuity clinics in the afternoon.

The project was approved by the institution’s Human Subjects Research Office (Institutional Review Board). Participants read and signed a consent form that permitted us to use their information for quality improvement and academic purposes, including publication.

Course description
A master resident schedule was created in advance of the academic year, so that the procedural training course director was in contact with the chief medical resident to ascertain the number and names of participants assigned. The curriculum was divided into specific components and each procedure encompassed the same items.

(1) Introduction (5 min) – the course director provided a brief overview of the course; logistics, roles and responsibilities, and expectations were covered.

(2) Written pre-test (10 min) – participants completed a baseline medical knowledge assessment in the form of a written quiz. Questions were a mixture of true/false and single answer multiple choice. Although the total number of questions varied by procedure, the maximum possible score ranged from 10 to 14. Participants did not receive feedback on their performance.

(3) Skills check (15–20 min, depending on procedure) – participants reported the number of prior procedures and this was entered on a log sheet. Those who had performed the indicated procedures on live patients prior to their arrival had their technical skills evaluated by using a procedural checklist (Figure 1). Those without prior experience in the performance of the procedure did not undergo the initial skills assessment, and therefore their data were not included in the final checklist analysis. Each participant rotated through a task trainer (mannequin) station specific for that procedure. He/she was asked to complete the procedure on the model, beginning with reviewing the patient’s chart through the completion and documentation phase of the procedure. No feedback was provided during the evaluation. However, immediately after their attempts, participants reviewed the missed or incomplete items with the instructor.

(4) Video instruction (8–16 min depending on procedure) – following the pre-intervention knowledge and skills assessments, the entire group watched the procedural videos from The New England Journal of Medicine website (NEJM 2009) and was encouraged to ask questions or make comments at the conclusion.

(5) Faculty-led discussions of the key topics (informed consent, aseptic technique, “time-out” process) (15 min) – faculty discussed the concept, importance, and key components of the informed decision-making process. We created a consent card, a laminated index card with procedure-specific complications (Figure 2), that could be used to facilitate the process of communication with the patient. To achieve uniformity, we created standardized informed consent forms that list the procedure, its explanation in layman’s terms, and some potential complications. Faculty also provided an overview of aseptic technique with special attention given to hand washing and donning personal protective equipment and clothing. Finally, an overview of the “time out” concept, its importance, and relevance to the performance of invasive bedside procedures was presented. Specifically, we focused on identification of the three core aspects: correct patient, correct procedure, and correct site. This process has been well adopted in the operating room and is gaining acceptance on the hospital wards (The Joint Commission on Accreditation of Healthcare Organizations 2009).

(6) Orientation on ultrasound guidance (30 min) – faculty instructed the participants on the use of real-time ultrasound guidance for insertion of central venous catheters and static ultrasound imaging to facilitate the performance of paracentesis and thoracentesis. Trainees practiced their skills on the vascular access trainer blocks (Table 1).

(7) Faculty demonstration (approximately 30 min depending on procedure) – in the simulation laboratory, the instructor performed the procedure, going through the specific steps on the checklist, emphasizing those that were missed by trainees. During this session, the group had the opportunity to interact with the instructor, ask questions, and receive specific feedback.

(8) Individual practice (about 15 min depending on procedure) – participants had the opportunity to familiarize themselves with the equipment and to practice on the task trainer. They were able to practice repetitively until they felt comfortable with both the equipment and procedure.

(9) Procedural documentation (5 min) – participants were instructed on the importance of obtaining the necessary information as required by The Joint Commission on Accreditation of Healthcare Organizations standards, the federal Conditions of Participation, and other regulatory agencies. We have created standardized, fill-in-the-blank, procedure notes (Figure 3) for appropriate comprehensive documentation to be completed by the operator before including in the patients’ medical records.

(10) Post-test (10 min) – participants completed a written test, identical to the pre-test, to demonstrate intervention-based improvement of knowledge. This test was administered immediately after the practice component, without delay or other outside influence. Faculty reviewed the answers with the participants in an interactive manner.

(11) Instructor evaluation (5 min) – learners completed an anonymous, written, faculty, and course evaluation.
Clinical performance (variable) – subsequent to training, participants formed the nucleus of a dedicated procedure service. Here, the participants operated under the direct supervision of an attending physician; the checklist used during the simulation-based instruction was also employed in the clinical area.

Outcome measures
Our tests and checklists were vetted through a multidisciplinary group of faculty experts who provided evidence for their construct validity. All items were weighted equally, as they all were considered integral to the successful completion of the procedure.

Knowledge exam. Each participant completed a pre- and post-intervention written test to evaluate medical knowledge base related to each procedure. Questions were comprised of true–false and single answer multiple choice items, each of which was equally weighted. The pre-test was accomplished without subsequent immediate feedback. After the

Figure 1. Central venous catheterization performance assessment checklist developed by the institution’s patient safety center.

(12) Clinical performance (variable) – subsequent to training, participants formed the nucleus of a dedicated procedure service. Here, the participants operated under the direct supervision of an attending physician; the checklist used during the simulation-based instruction was also employed in the clinical area.
We capitalized on prior work by using a blended approach (Gordon et al. 2005) to develop a comprehensive curriculum.

### Study design

This was a case cohort before and after study designed to evaluate the impact of a simulation-based course to improve the invasive bedside procedural knowledge and skills of Internal Medicine residents. Randomization was impractical due to the large number of residents in our program and the small number of instructors, equipment, space, and time to undertake such an effort. Participants served as their own controls as we compared their prior knowledge base and skill set to that subsequent to participating in our instructional course. Each participant completed the written pre-test before undergoing a hands-on skills assessment. The pre- and post-test scores were compared, per individual participant, to ascertain a change in their post-intervention scores. The tests were administered on the same day, within hours of each other, depending on the time needed to teach the particular procedure. Similarly, we compared the checklist score during the instructional skills check portion (pre-intervention) to the score achieved during their first procedural attempt on a patient (post-intervention). The performance of the procedure in the clinical setting was accomplished within the first week following the instructional period.

**Statistical methods.** The data for the pre-tests, post-tests, and differences (post-test minus pre-test) for the knowledge tests and the performance checklists are presented as mean and standard deviation. We used a paired *t*-test to test the significance of the difference between post-test and pre-test scores. Statistical significance was set at a *p*-value less than 0.05. We used the statistical program of SAS 9.2 (SAS Institute Inc., Cary, NC) for all computations.

### Results

Summary data for the pre-tests, post-tests, and differences in knowledge tests and performance checklists are presented in Table 2. The difference between pre-test and post-test scores is significant for all scores (*p* < 0.05). The number of participants who underwent training sessions varied, and there is some crossover of participants between procedures. That is, trainee A may have participated in any or all procedures, but only did so once per procedure. Demographics of the knowledge test participants are as follows: 33 male, 52 female, 63 PGY2s (PGY, postgraduate year), and 22 PGY3s. Demographics of the performance participants are as follows: 29 male, 47 female, 55 PGY2s, and 21 PGY3s.

### Discussion

We developed a standardized method of teaching ABIM recommended invasive bedside procedures. We demonstrated that a simulation-based invasive bedside procedural curriculum improves immediate medical knowledge base and technical proficiency. The curriculum not only addresses the ABIM recommendations to require knowledge surrounding the performance of these procedures, but also the technical skills.

We capitalized on prior work by using a blended approach (Gordon et al. 2005) to develop a comprehensive curriculum.
of multiple procedures: (a) simulation-based instruction, (b) the use of a checklist to document performance and assess competence, (c) instruction and relevant use of ultrasound, and (d) direct observation by an attending supervisor (Barsuk et al. 2009). Subsequent to the training phase, residents participated on a dedicated team, performing procedures on live patients, under attending supervision. This last step of the training process allows for deliberate practice, which involves the provision of immediate feedback, time for problem solving and evaluation, and opportunities for repeated performance to refine behavior (Ericsson 2008). The improvement noted on post-intervention checklist scores on actual patients supports the translation of simulation-based teaching into the clinical setting. While the team aspect is not necessary to implement the instructional component, it provided an opportunity to evaluate the skills of the resident on the wards, with the identical checklist used during the training portion. These elements, taken together, can improve procedural instruction and performance through measurements of medical knowledge and technical skill. Further, they are critical components of a procedure-based curriculum.

**Limitations**

First, this was not a randomized controlled trial as we were limited by space and resources. Second, we did not have the participants practice on the simulator until they achieved objective mastery of the procedure. We did, however, have them practice until they reported that they were comfortable with their performance. Thus, while the course facilitated immediate self-perceived skills acquisition, future study will include the measure of skill competence on task trainers.
immediately and longitudinally after training. Finally, we have piloted this program only at our institution to date, a 1500+ bed, urban, tertiary care academic medical center, and thus the results cannot necessarily be generalized to other training programs. The month-long rotation may not be practical for community-based teaching facilities, but we believe that the instructional phase is modular and flexible enough to be incorporated at any training site.

Conclusion

Standardized curricula that provide guided learning, an available range of training tools, and opportunities for deliberate practice and feedback in a protected environment offer several advantages to the traditional apprenticeship model that is based on the teaching approach of individual faculty members. This latter system is problematic as learners progress at different rates and the number of procedures accomplished does not guarantee proficiency (Cation & Durning 2003).

We have created a formal, standardized, simulation-based procedural curriculum and have piloted it at a large, urban, tertiary care academic medical center. Our participants demonstrated a statistically significant improvement in their post-intervention medical knowledge and technical skills. We believe such a curriculum can serve as a model for others who wish to provide a successful and uniform procedural curriculum to their trainees.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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