The Use of a Simulation Center to Improve Resident Proficiency in Performing Ultrasound-Guided Procedures

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Rationale and Objectives: With advancements in technology and push for health care reform and reduced costs, minimally invasive procedures, such as those that are ultrasound-guided, have become an essential part of radiology, and are used in many divisions of radiology. By incorporating standardized training methodologies in a risk free environment through utilization of a simulation center with phantom training, we hope to improve proficiency and confidence in procedural performance.

Materials and Methods: Twenty-nine radiology residents from four levels of training were enrolled in this prospective study. The residents were given written, video, and live interactive training on the basics of ultrasound-guided procedures in our simulation center on a phantom mannequin. All of the teaching materials were created by residents and staff radiologists at the institution.

Results: Residents demonstrated statistically significant improvement ($P < .05$) between their pre- and posttest scores on both the written and practical examinations. They also showed a trend toward improved dexterity in the technical aspects of ultrasound-guided procedures ($P = .07$) after training. On the survey questionnaire, residents confirm improved knowledge level, technical ability, and confidence levels pertaining to ultrasound-guided procedures.

Conclusions: The use of controlled simulation based training can be an invaluable tool to improve the knowledge level, dexterity, and confidence of residents performing ultrasound-guided procedures. Additionally, a simulation model allows standardization of education.

Key Words: Simulation; ultrasound-guided Procedures; resident training; Improved proficiency.

The modifications in health care over the past few decades have changed the face of medical education training. Federal restrictions have mandated strict duty hours compliance (1) and an emphasis on shorter inpatient hospital stays, which translates into fewer training opportunities to perform and become proficient at minimally invasive procedures (2), changes which may affect patient care and safety issues. Because of these adjustments, the time-honored traditional model of medical education, which uses an apprenticeship approach to training, may need to be reevaluated and augmented with additional training. The traditional model of medical education, also known as the Halstedian model of education (3), uses patients as tools for teaching, with residents gaining an increased level of independence and responsibility through progression of training, under the supervision of faculty (2). A proficiency-based model of training may be a useful adjuvant to augment training. An example of proficiency-based training is the use of simulation, which allows a medical procedure to be learned based on a system of standard metrics, and hence progress can be recorded.

Performing an ultrasound-guided procedure is one of the basic aspects of a radiologist's training, and is essential for many therapeutic and diagnostic procedures. Ultrasound-guided procedures are performed in many divisions of radiology including mammography, body imaging, interventional radiology, and musculoskeletal imaging. Targeted needle placement requires distinct psychomotor abilities and good hand-eye coordination (4). As previously mentioned, the apprenticeship approach to training of procedures has led to no existing standards of teaching or objectively rating the radiologists’ ability to safely practice these procedures (4). We propose the development and utilization of a simulation-based model in training residents to learn and become both proficient and confident in performing ultrasound-guided procedures by utilization of a web-based model and a physical...
phantom, in hope that this will ultimately translate to improved patient care and safety.

MATERIALS AND METHODS

Informed consent was obtained from radiology residents from all 4 years of training, which permitted the review of their pre- and posttest, as well as evaluation of their simulation for both educational and research purposes.

A prospective study was performed, with absence of a control group, and the goal was to evaluate the educational benefit of a simulated ultrasound-guided procedural training model. The model was developed by the authors of this paper (residents and attending radiology staff at Henry Ford Hospital). The simulation was performed at the Henry Ford Hospital simulation center, during which time audio and video recordings were performed.

Residents began the module by completing a 20-question pretest (Appendix A). They then completed an online web-based module, which reviewed the basic indications, contraindications, and techniques to perform an ultrasound-guided procedure. The web-based module addressed the questions on the pretest and included a short 10-minute teaching video demonstrating how to perform an ultrasound-guided procedure by one of the interventional radiologists involved in the training.

The residents then received formal training in groups of four by one of two staff body interventional radiologists. It was assumed that the staff radiologist could perform the procedure more proficiently than the residents, based on years of clinical experience. The preferred technique was demonstrated by the interventional radiologist on a “blue phantom” (as described in the following section) multiple times for the training groups. During the initial training, each resident individually practiced the procedure at least four times for the staff radiologist to critique. Specific tasks which the residents trained on included technique and manual dexterity.

The procedure was performed using a 16-question checklist (Appendix B), on a blue phantom purchased from Advance Medical Technologies LLC, Kirkland WA (Fig 1). One blue phantom was used, model number BPTM130, for a cost of $429.00. This blue phantom is considered a “part-task trainer”; in other words, this trainer reproduces only a limited portion of reality, such as a model of a body part (1).

Procedures were performed using an Inrad 23 gauge needle. This specific needle was chosen to minimize visualization of prior needle tracks (Fig 2).

After this, the residents had a six-question questionnaire to complete (Appendix C). The participants were given 6 months to practice the procedure at their convenience. At the end of this period, each resident returned to the simulation center to complete the posttest and perform the simulated procedure. The procedure was monitored by one of the two body interventional staff radiologists who had provided the initial training (Fig 3). Faculty evaluation of resident performance was performed using a checklist (Appendix B). Each resident was given 10 minutes to perform the procedure. At the end of the simulation, the residents filled out another 5-point Likert scale questionnaire (Appendix C). Those residents who struggled during the procedure had a remediation course with the staff radiologist.

Results of the pre- and posttest written examinations were compared using paired t-tests. A P value of less than .05 was considered statistically significant. Average resident

Figure 1. Blue Phantom part-task trainer.

Figure 2. Ultrasound image during needle placement.
competence on the written examination demonstrated statistically significant improvement from 80% to 88% with a $P$ value of .025 (Fig 4).

Eleven random residents representing each of the four resident classes were selected to complete a pretest practical examination. All 29 residents enrolled in the study completed a practical posttest. Because of the differences in sample sizes, $t$-tests using samples of unequal variance were used to assess statistical significance. Mean practical scores improved from 12.6/20 to 17.5/20 after completion of the simulation center training, $P < .001$ (Fig 5).

In the practical examination, there were six skills on the checklist that specifically evaluated technical competence: proper handling of the transducer, sonographic localization of the lesion, correct administration of lidocaine, insertion of the needle an appropriate distance away from the transducer, visualization on the needle throughout the procedure, and identifying the needle in the center of the target lesion. Residents showed a trend toward improvement in mean technical skill from 4.3 to 5.5, which approached a statistical significance of $P = .07$ (Fig 6).

The posttest survey showed that residents found the simulation center training realistic, relevant, and helpful (Fig 7-9). Furthermore, they believed that it improved their confidence and expertise in performing ultrasound-guided procedures (Fig 10,11).

**DISCUSSION**

We present a model of training ultrasound-guided needle insertion for instructing residents, which is a basic radiologic procedure performed on a daily basis in radiology practices. One of the most important factors to simulation-based training is to create a valid training model, ensure that effective learning can occur, and creating performance metrics that accurately test one’s proficiency that ultimately measures learning.

With the evolving change in health care practices and expectations, there is a need to modify our methods of medical training. The current apprenticeship model may no longer be the optimal system for training. One key disadvantage is the presence of evaluation biases and errors when using this approach, which ultimately grants different residents different degrees of autonomy. For example, many evaluators/trainers will rate all trainees as average or rate leniently without appropriate justification. Another bias includes allowing positive characteristics of the trainee to influence a more positive performance evaluation. Finally, when a trainee has procedural skills/traits similar to the trainer, they may get a more positive rating (5).

Analysis of our study shows statistical significance in both retention of knowledge and proficiency and expertise in skills when performing ultrasound-guided procedures, as discussed in the results section. Pre- and post-written test results demonstrate statistical significance in terms of retention of knowledge. Pre- and post-practical examination using a checklist demonstrates a trend towards statistical significance in terms of improved proficiency and expertise, specifically in technical skills related to ultrasound-guided procedures. Finally, the posttest survey illustrates that residents perceive
improved confidence and expertise in performing ultrasound-guided procedures. Statistics show that 45.5% felt competent or proficient prior to training and 80% felt competent, proficient or expert after training, using a 5-point Likert scale.

Ultimately, there are many benefits with proficiency-based training in comparison to the "apprenticeship" model of training. First, from a medical and patient care perspective, improved patient safety is probably one of the most important benefits. Trainees practice on patients, so there is an inherent risk of complications for the patients. Clearly, simulation allows practice without harming others, and allows practice in responding to emergency situations (6). Second, this is a time-based model, and different trainees learn at different rates, so a proficiency-based model of advancement may be a better barometer of actual skill level. Third, there is a lack of uniformity in training. In other words, different teachers have different methods, so there is no uniformity, and therefore simulation allows for standardization of education. Fourth, conventional training may result in an inherent increased expense to the medical field because of increased level of care secondary to errors, increased procedure times, and maybe increased medical legal costs. Simulation-based training can ensure residents an opportunity to develop proficiency and efficiency and can eliminate some of these potential increased expenses and increased patient risk. Finally, because of the growing emphasis on increased throughput and productivity, there is less time to teach and learn on patients (5), a factor eliminated by simulation-based training.

The use of a simulation allows a medical procedure to be learned based on a system of metrics, which allows progress to be recorded. The individual metrics are based on each individual curriculum and the educational objectives for that training model (2). Medical simulation will therefore enhance learning by providing realistic training before actual patient care, uniform exposure to clinical material, and a flexible learning environment (7). Recent studies using simulation approach to training have shown improved trainee performance with metrics that include overall improved proficiency and patient care. Examples include two separate randomized double-blinded studies by Seymour et al that demonstrate improved technique, fewer errors, and shorter operating times by residents who trained using a simulator for laparoscopic techniques (8,9), improved laparoscopic techniques (10), improved endoscopic techniques (11), and improved laparoscopic suturing techniques (12). Finally, Erinjeri et al have shown that active learning methods results in improved learning techniques (13). These learning methods include group discussion and practice by doing and teaching others. Because simulation based training uses an active learning process, there may be improved learning and knowledge retention that, in combination with increased practice abilities and improved skills, may actually better prepare an individual for crisis situations and difficult cases (6).

Our study design allows for improved standardization for medical training and improved trainee proficiency. We have shown statistical improvement in ultrasound-guided
Fourth, it will be important to accurately design measurable performance metrics to identify individuals with different skill levels. One metric that is a missing component in our study design is that of timing the procedure from start to completion both during the pre- and posttest evaluation, and measuring improvement at completion of the course, which we feel would be an important marker of proficiency. A second parameter that could be expanded for training is testing the trainee’s understanding of the ultrasound equipment and ability to adjust parameters to better delineate the target, which is a very important aspect of performing successful procedures. Finally, it is important to have an assessment proving that simulation learned skills are not only transferable to the clinical setting, but also accurately identify future clinical competence.

A few additional limitations of this study include lack of data on the number of times each resident used the simulation center during the 6-month training period, as well as the variability in the number of practice sessions amongst the residents. Having these data would help to identify a time frame that would be necessary to improve one’s proficiency. Additionally, knowledge of the ongoing rotations a resident does during the simulation training would better define a true statistical improvement, as a resident on an interventional rotation has the added benefits of skill improvement secondary to the clinical service, which may confound the data.

In conclusion, the implication of simulator-based proficiency training in radiology is immense. Ultrasound-guidance is used on a daily basis in multiple subspecialties of radiology and is critical in accurate diagnosis and treatment for a variety of pathologic processes. Our simulation is a low-cost method of teaching the skill set necessary for accurate needle placement and the knowledge required to do so. Our prospective study has demonstrated a statistically significant benefit in simulation training in terms of improved knowledge retention, proficiency of overall procedural performance, and an increased level of confidence in the residents post-training. We also demonstrate a trend toward improvement in technical skills necessary to become proficient at performing procedures. We hope to continue to expand our program in efforts to improve patient care and safety, and believe this is an essential component of radiology education that should be considered in training programs.

REFERENCES


APPENDIX A. SAMPLE PRETEST AND POSTTEST QUESTIONS

1. Which needle is used for fine-needle aspiration?
2. Which needle is used for core biopsy?
3. What is Seldinger technique?
4. What is trochar technique?
5. Regarding core biopsy procedures, which of the following is false?
6. Which of the following is true regarding a coaxial system?
7. All of the following are true regarding fine-needle aspiration, except?
8. All of the following are true regarding core biopsies, except?
9. If too much fluid is removed during a thoracentesis, what is the potential complication?
10. All of the following are true regarding coagulation/bleeding complications, except?
11. Which of the following is not an indication for ultrasound-guided thoracentesis/paracentesis?
12. The proper needle entrance into a breast lesion under ultrasound guidance is?
13. Which of the following can be safely crossed when performing a percutaneous procedure?
14. Advantages of ultrasound-guided procedures over computed tomography–guided procedures include all but which of the following?
15. Visualization of needle tip can be improved by all of the following except?

APPENDIX B. ULTRASOUND-GUIDED PROCEDURES CHECKLIST

1. Checked coagulation/allergies
2. Consent obtained
3. Washed hands
4. Performed a “time out”
5. Appropriately turned on ultrasound devise
6. Accurately identified the target lesion
7. Prepped area in sterile fashion/placed a sterile field
8. Used proper sterile technique (mask, sterile gown, sterile gloves)
9. Demonstrated technique for local anesthetic
10. Demonstrated sterile technique when using the probe sheath
11. Inserted needle at the appropriate distance from the transducer at an appropriate angle to the lesion
12. Needle tip is visualized throughout the course of the procedure
13. Needle tip is accurately placed within the lesion
14. Demonstrates technique for applying sterile dressing
15. Sharps management
16. Filled out postprocedural forms accurately (biopsy/drainage); filled out procedure note

APPENDIX C. QUESTIONS ASSESSING THE UTILITY OF SIMULATOR TRAINING FOR ULTRASOUND-GUIDED PROCEDURES

1. The self-directed learning module(s) contained relevant information and prepared me for the Simulation Center activities.
2. The simulation activity facilitated my accurate performance of these skill sets.
3. Estimate the frequency you use (will use) the skill/knowledge presented.
4. Rate your skill/knowledge of the material before this training.
5. Rate your skill/knowledge of the material after this training.
6. My confidence in performing this procedure has improved even after this training.