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Hands-on Simulation Workshop for Obstetric Ultrasound-Guided Invasive Procedures

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Abstract

Introduction: Due to the introduction of cell-free DNA genetic testing options, the number of clinical ultrasound procedures has greatly diminished in recent years. With fewer real-life ultrasound-guided procedures being performed, it is difficult for OB/GYN and maternal-fetal medicine (MFM) trainees to achieve competency in doing them. Simulation can be utilized to address this issue and supplement a learner's real-life training. **Methods:** We developed a simulation workshop incorporating previously described ultrasound guidance task trainers and simulators of amniocentesis and chorionic villus sampling. The workshop had three parts: needle guidance basics, targeting task performance, and procedure-specific simulation. A form of this workshop has been held at the annual meeting of the Society for Maternal-Fetal Medicine since 2015 and as a regional course for MFM fellows since 2017. During the 2019 and 2020 courses, participants completed Likert-scale surveys evaluating the course. **Results:** Since the workshops began in 2015, approximately 300 people have participated. In 2019-2020, 41 MFM attending physicians, 136 MFM fellows, and three OB/GYN residents took our course and completed a postcourse survey. Participants rated the course highly and thought it was highly effective. **Discussion:** We created an introductory simulation workshop for obstetric ultrasound-guided invasive procedures that participants rated highly and thought was very effective. Objective clinical assessment of skill improvement after completion of this course is needed to verify its true impact. Repeated exposure to this introductory simulation and creation of more challenging workshops are needed to achieve a sustained high level of procedural skill.

Keywords

Ultrasound-Guided Invasive Procedures, Clinical Skills Assessment/OSCEs, OB/GYN, Simulation, Ultrasound Skills

Educational Objectives

After completing this workshop, learners will be able to:

1. Describe and explain the rationale for the psychomotor skills required to perform ultrasound-guided invasive procedures.
2. Demonstrate the psychomotor skills required to perform ultrasound-guided invasive procedures in a simulated setting.
3. Apply the psychomotor skills required to perform ultrasound-guided invasive procedures to the simulated practice of amniocentesis, chorionic villus sampling, and percutaneous umbilical blood sampling.

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Introduction

Ultrasound guidance has been shown to improve the safety of invasive procedures compared to utilization of anatomic landmarks and has become standard for a growing number of clinical procedures.[1] In addition, providers from an increasing number of medical and surgical specialties now perform ultrasound-guided needle procedures.[2] The medical education community has long recognized the challenge of objectively assessing provider skill with complex tasks, such as ultrasound-guided invasive procedures. To address this issue, there has been a move away from the historic time-based training that relies on years of training or procedure logs as proxies for procedural skill to a competency-based approach that requires a satisfactory objective assessment of skill before performing procedures independently.[3]

The ultrasound-guided invasive procedures performed in OB/GYN include chorionic villus sampling (CVS), amniocentesis, and percutaneous umbilical blood sampling (PUBS). However, conducting training for these procedures in a real-life

environment is challenging as introduction of cell-free DNA genetic testing options have greatly diminished the number of clinical procedures in recent years. Furthermore, studies have clearly demonstrated the benefit of provider experience in reducing pregnancy loss rates after these procedures.[4-7] Even in centers that perform a high volume of amniocenteses or CVSs, the number of more advanced procedures like PUBS or in utero shunt placement often remains relatively low. For these rare procedures, simulation would benefit even well-experienced providers, as it allows them to warm up specific psychomotor skills that they have not used for an extended period of time.

To improve simulation training for obstetric ultrasound-guided invasive procedures, we began constructing simulators and creating training curricula over 10 years ago. During this time, we have created and validated a task trainer for general ultrasound guidance skills[8-11] and simulators for amniocentesis and CVS.[9,12] Here, we report a hands-on workshop curriculum we use in conjunction with these devices to introduce novice learners (current maternal-fetal medicine [MFM] fellows or recent graduates with limited experience) to obstetric ultrasound-guided invasive procedures in an effort to improve their real-life ultrasound guidance skill.

Methods

Development

Our initial ultrasound guidance simulation sessions utilized a fetal pig (Carolina Biological) in an amniocentesis model[13] that needed to be replaced after 25 or more uses. We also modified an existing CVS simulator that used chicken breast as a simulated uterus, a water-filled condom as the amniotic fluid cavity, and tofu as simulated placental tissue,[14] substituting a silicone pastry bag as the simulated uterus.[9] The CVS simulators were used for both transabdominal and transcervical CVS. The silicone pastry bags could be reused indefinitely. The condoms and tofu could only be used once. Detailed instructions on how to construct the amniocentesis and CVS simulators are provided in Appendices A-C.

When first using these amniocentesis and CVS simulators, we noted that most learners did not receive specific instructions on how to select a target, position the probe and needle, or make needle course adjustments. To address this gap in training, we sought to create an easy-to-set-up simulator that would allow learners to practice specific parts of a procedure and hold their attention for extended periods of time. Our original concept was an analogue of the Fundamentals of Laparoscopic Surgery[15,16] or a set of nonclinical tasks that would allow one to practice the psychomotor skills used during ultrasound-guided invasive procedures. We named this training system the Fundamentals of Ultrasound Needle Guided Interventions, or FUNGI for short.

Around this time, the American Institute of Ultrasound in Medicine (AIUM) released its practice parameter on the performance of selected ultrasound-guided invasive procedures,[17] so we incorporated the guidance approaches and image optimization techniques outlined in that document into the new simulator's design. This process gave rise to the novel task trainer for ultrasound-guided invasive procedures and a set of targeting tasks that we have previously described.[8-11] In these studies, we devised a system to score an individual's task performance by recording the time needed to touch a prespecified number of targets in a prespecified order and noting the number of times the needle was lost from view or missed the intended target. A 5-second penalty was assessed for each of these types of targeting errors. Using this scoring system, we gathered validity evidence for the task trainer and targeting curriculum as an assessment tool based on the framework proposed by the American Educational Research Association.[18] We have described the task trainer's validity evidence in the response process,[10] its relations with other variables (specifically, an individual's level of clinical experience[11] and performance on simulated amniocentesis[9]), and its internal structure[8] domains.

Equipment/Environment

Each group of two to four learners required an ultrasound machine; three of our task trainers set up for the step, straw, and ball tasks[8-11]; one amniocentesis simulator; and two CVS simulators. Additional stations could be set up to allow for more learners to participate in each session. At a typical conference course or regional fellowship workshop, we used nine stations, which allowed approximately 30 people to participate.

Personnel

We trained several classes of our internal MFM fellows and outside practicing MFM providers to serve as instructors for the course. Fellows had to participate in one of our 4- to 6-hour workshops where they saw how the curriculum was implemented by established instructors. They also had to complete at least four 1-hour training sessions where they gained additional practice with the task trainers and procedure-specific simulators and we reviewed their responsibilities as instructors during each portion of the workshop. Established providers with significant expertise in ultrasound-guided invasive procedures had to participate in a train-the-trainer course that reviewed the use of the devices and

proper curriculum implementation prior to serving as instructors for a workshop.

We typically had one instructor per station for this course. A course director was also needed to manage the overall schedule and flow of the workshop. The course director explained and demonstrated the different concepts and exercises that would be performed to all the course attendees. Instructors at each station then reinforced the concept for the learners in their group and guided their practice of the exercises. We created skill checklists (Appendix D) and global rating scales[9] to guide the instructors during the training sessions.

Implementation

Prior to the course, we encouraged attendees to watch the self-guided introductory lecture beforehand (Appendix E). In its current form, the workshop comprised three main sections. In the first section of the course, we covered several important concepts that we referred to as *needle guidance basics*. In this section of the course, we broke down ultrasound-guided invasive procedures into a distinct set of psychomotor skills required to perform these procedures. We referred to this section as *ultrasound guidance basics.* Demonstrations of these principles are provided here as a video (Appendix F). Checklists offering lists of the key skills in each exercise are provided in Appendix D. All of the following exercises were performed with a 20- or 22-gauge 15-cm needle. The skills were introduced in the following sequence.

1. In-plane and out-of-plane guidance: We discussed how placing the needle path parallel to the ultrasound beam allowed for in-plane guidance and placing it perpendicular to the beam allowed for out-of-plane guidance. We spent most of this portion of the course focusing on in-plane guidance, as it was the one most often used for obstetric ultrasound-guided invasive procedures. The remainder of the course utilized the in-plane approach.
2. Needle and probe orientation: We discussed how the orientation of the ultrasound probe to the needle affected the appearance and location of the needle on the ultrasound screen. We reviewed how the probe could be held either perpendicular or parallel to the operator's shoulders and how the needle could appear on the right or left side of the screen. The learners practiced needle insertions in all of the different orientations to determine which one they were most comfortable using.
3. Early visualization of needle entry: We instructed learners to look down over the top of the task trainer and line up the middle of the ultrasound probe axis with the needle in preparation for insertion. They were then instructed to insert the needle while continuing to look at the probe and needle rather than the ultrasound screen. Once the needle had been inserted a few centimeters (and the participant had confirmed the needle axis was in the same plane as the ultrasound probe axis), the learners were allowed to look at the screen. If the needle was not already visualized, they were instructed to make very small adjustments with their needle hand to bring the needle into view.
4. Discrete hand movements: We focused on how discrete and purposeful movement of the needle hub towards and away from the ultrasound probe changed the needle angle and location on the ultrasound screen and had the learners practice the movements in each of the different needle/probe orientations. We talked about how moving the needle hub towards the ultrasound probe made the needle length more vertical on the monitor screen. Conversely, moving the needle hub away from the ultrasound probe made the needle length become more horizontal. The learner could than move the hub to and away from the probe, keeping the needle tip in view, with a movement like a pendulum.
5. Needle insertion distance and angle: We discussed how inserting the needle at increasing distances away from the probe could be used to change angle of the needle path on the ultrasound screen, that is, how inserting the needle further away from the probe produced an increasingly shallow angle between the ultrasound beam and the needle. The learners then practiced this concept with the task trainer.
6. Proper target positioning: In the final section of the needle guidance basics, we discussed how to position the target properly on the ultrasound screen. We instructed the learners on how to slide the probe perpendicular to the ultrasound beam to move the target from left to right on the screen and how placing the target under one of the upper corners of the ultrasound screen allowed for an easy and predictable path to the target. Once again, this concept was actively practiced by the learners with the task trainer.

In the second section of the course, we built upon the basics discussed in the first section as the learners moved on to performing the targeting tasks we have previously published.[8-11] As facilitators, we had the learners focus on the concepts of the previous section while they carried out the tasks. The tasks allowed the learners to practice the core guidance skills outlined

by the AIUM and to determine their individual preferences for needle/probe orientation, insertion distance from probe, and hand movements when performing the tasks. Instructions on how to assemble the task trainers for the different tasks are provided in Appendix G. Instructional videos on how to perform the tasks are included in Appendix H. All of the tasks were performed with a 20- or 22-gauge 15-cm needle. Although we did not formally assess participants' skill in the targeting tasks during courses or workshop, we created skill checklists to serve as a guide to instructors on how to informally assess participants' skill and provide constructive tips to participants during the course. The scales' rated an individual's skill with probe translation, probe rotation, and overall performance with each targeting task (Appendix D).

In the third section, we built upon the first two sections as the learners progressed to performing simulated amniocentesis and CVS. Their preferences from prior sections were considered as they performed the simulated procedures, so they could identify the process most comfortable for them. The simulated amniocentesis was typically performed with a 22-gauge 9-cm needle, and the simulated CVS with a 20-gauge 15-cm needle. The learners served as each other's assistants for the procedures, which allowed them to see how other learners approached the procedures and learn from each other. We did not perform a formal assessment of the participants' procedural skill during a course. However, the global rating scales we used in one of our validation studies[9] could serve as a guide for instructors on how to informally assess participants and provide constructive tips during the course.

In 2015, we started holding hands-on simulation workshops for ultrasound-guided invasive procedures at the annual meeting of the Society for Maternal-Fetal Medicine. These workshops lasted 4 hours, had nine stations, and included approximately 30 participants. The workshop participants consisted of a mix of OB/GYN residents, MFM fellows, and MFM attendings. A typical schedule for an annual meeting workshop is provided in Appendix I.

We also held regional workshops for MFM fellows in the southeast US, the New York City area, and the University of California system with a similar number of stations, instructors, and course directors. Those workshops typically lasted 7 hours (with a 1-hour lunch break) to allow the participants to spend more time practicing with each of the targeting tasks and procedure-specific simulators. For these workshops, we introduced local MFM faculty members to our training techniques during a train-the-trainer session the day prior to the actual workshop, which allowed them to serve as instructors for their own fellows during the course. A typical schedule for a regional fellows' workshop is provided in Appendix I.

Debrief

Because the instructors in each group provided ongoing feedback to the learners, a specific debrief at the conclusion of a section or the entire course was not needed.

Assessment

Surveys of the course in its current form were distributed at the workshops held at the annual Society for Maternal-Fetal Medicine meetings and the regional workshops held for the New York City and University of California programs in 2019 and 2020. A copy of the course survey is included in Appendix J.

Results

Since we began the workshops in 2015, approximately 300 people have participated. The participants in our offerings in 2019 and 2020 were asked to complete postcourse surveys (Appendix J). These participants included 52 MFM attending physicians, 149 MFM fellows, and three OB/GYN residents. Forty-one MFM attending physicians (79%), 136 MFM fellows (91%), and three OB/GYN residents (100%) completed a survey at the completion of the course. The participant responses are summarized in the Table. The responses to all survey items were uniformly very favorable.

Discussion

We constructed and then refined both a novel ultrasound guidance task trainer and procedure-specific simulators for amniocentesis and CVS. In addition, we created a hands-on simulation course built around the task trainer and simulators. To our knowledge, ours is the first such course to be held, assessed, and reported. The course surveys collected as part of the assessment indicated that participants believed the course objectives were being met. In addition, participants were very satisfied with the course and felt it was useful.

We would like to note that as we refined the course over time, we felt there was a clear benefit to simplifying the task trainers, procedure-specific simulators, and curriculum. Our initial simulators were rather complex and required a significant amount of effort and simulation know-how to construct and assemble. As we traveled to different institutions and held workshops, we found that very few programs continued to use the simulators after our initial visit because of the effort needed to maintain and assemble them. Since we introduced easy-to-assemble and easy-to-use task trainers and the simplified version of the

Table. Ultrasound-Guided Invasive Procedure Workshop Survey

Survey Item[a]	Median (IQR)
The course was organized in a way that helped me learn.	5 (5,5)
The course provided a helpful mixture of explanation and practice.	5 (5,5)
The course helped me understand the distinct psychomotor skills required to perform ultrasound-guided invasive procedures more clearly.	5 (5,5)
The course improved my ability to correctly execute the distinct psychomotor skills need to perform or teach ultrasound-guided invasive procedures.	5 (5,5)
The course improved my abilities and skills in performing or teaching ultrasound-guided invasive procedures.	5 (5,5)
The training techniques demonstrated during the course will be effective in teaching ultrasound-guided invasive procedures to novice learners.	5 (5,5)
The course developed my ability to apply theory to the performance or teaching of ultrasound-guided invasive procedures.	5 (4,5)
The course provided the opportunity to practice the distinct psychomotor skills required to perform ultrasound-guided invasive procedures.	5 (5,5)
The course gave me a deeper insight into the performance and teaching of ultrasound-guided invasive procedures.	5 (5,5)
The course improved my approach to performing and teaching ultrasound-guided invasive procedures.	5 (5,5)
How would you rate your satisfaction with this course?[b]	5 (5,5)
How would you rate the overall effectiveness of this course?[b]	5 (5,5)

Abbreviation: IQR, interquartile range.
[a]Rated on a 5-point Likert scale (1 = *Strongly Disagree*, 5 = *Strongly Agree*) unless otherwise noted.
[b]Rated on a 5-point Likert scale (1 = *Poor*, 5 = *Excellent*).

procedure-specific simulations, the programs at the University of Washington, Madigan Army Medical Center, Columbia University, and the University of San Francisco have employed our simulators and carried out fellow training independently. We believe that the simplification of the equipment and the accompanying decrease in time and energy required to properly use it are the main factors in the increased utilization of our curriculum that we have seen in more recent years outside of our institution.

We found that many MFM fellows have not been introduced to the concepts contained in the needle guidance basics of the course during their residency or fellowship training. In addition, many learners come to the course having performed ultrasound-guided procedures in only a limited number of ways. Most have only performed a procedure in a limited number of needle and probe orientations. In addition, left-handed people many times use only their right hand to guide the needle in real-life procedures. These restricted approaches to ultrasound-guided invasive procedures most often reflect the preferences of the providers at the learners' institutions who teach them, which may force them to use an approach that does not suit their individual psychomotor strengths and weaknesses. During the course, we focus on introducing learners to approaches and techniques they are unfamiliar with so that they can identify an approach that best suits them.

Although the participants' satisfaction with the course was very high, we were not able to test whether their ultrasound guidance skill improved after completing the workshop for several reasons. First, performing a skill assessment of 30 participants over the relatively short 4- to 6-hour duration of the workshops would have been logistically very difficult to carry out. However, we have carried out skill-building regimens using our task trainers with medical students and have shown objective improvement in both basic needle guidance and simulated procedural skill.[8,9]

Furthermore, the course is meant to be an introduction to the basics of ultrasound guidance, not a significant skill-building experience. Sustained skill building is best carried out over multiple sessions of increasing difficulty spread out over time. Repeated exposure to these introductory simulations and the creation of more challenging workshops will be required to sustain any improvement in procedural skill. In addition, more technically challenging simulations will have to be created and practiced to achieve the procedural skill needed to perform the most difficult procedures.

Appendices

A. Amniocentesis Simulator Construction.docx

B. Transabdominal CVS Simulator Construction.docx

C. Transcervical CVS Simulator Construction.docx

D. Procedural Checklists.docx

E. Workshop Introduction Video.mp4

F. Ultrasound Guidance Basics Video.mp4

G. Task Trainer Assembly Instructions.docx

H. Targeting Tasks Instructional Video.mp4

I. Example Workshop Schedule and Flow.docx

J. Workshop Survey.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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Disclosures

Drs. Nitsche and Brost have a patent on the ultrasound guidance task trainer and targeting curriculum presented in this publication.

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Ethical Approval

The Wake Forest School of Medicine Institutional Review Board approved this project.

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