CRESST REPORT 787

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# THE EFFECTS OF PRACTICING WITH A VIRTUAL ULTRASOUND TRAINER ON FAST WINDOW IDENTIFICATION, ACQUISITION, AND DIAGNOSIS

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**The National Center for Research on Evaluation, Standards, and Student Testing**

Graduate School of Education & Information Sciences
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# THE EFFECTS OF PRACTICING WITH A VIRTUAL ULTRASOUND TRAINER ON FAST WINDOW IDENTIFICATION, ACQUISITION, AND DIAGNOSIS

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## Abstract

In this study, we compared the effects of simulator-based virtual ultrasound scanning practice to classroom-based hands-on ultrasound scanning practice on participants' knowledge of FAST window quadrants and interpretation, and on participants' performance on live patient FAST exams. Twenty-five novice participants were randomly assigned to the simulation-practice condition and 24 participants to the classroom-practice condition. Participants were mostly medical school students, with some nursing students. Participants who received simulation-based practice scored significantly higher on interpreting static images of FAST windows. On live patient exams where participants scanned the RUQ, LUQ, and suprapubic quadrant of a normal patient and an ascites positive patient (6 quadrants total), there were no statistical differences between the two conditions on scan time, window acquisition, and window interpretation except for the following: the classroom-practice condition had shorter scan time for the LUQ, and a higher number of participants attaining high window quality on the RUQ (normal patient only) and suprapubic quadrant (positive patient only) and correct window interpretation on the LUQ (normal patient only). Performance was statistically similar on all other window quality and window interpretation measures on the other quadrants. Overall, classroom-based practice appeared to promote physical acquisition skills (e.g., acquiring a window) and simulator-based practice appeared to promote window interpretation skills. The simulator used (SonoSimulator™) was well received by participants and appears promising as a training tool not only to increase probe time, but also to increase exposure to FAST windows reflecting various anatomy and disease states.

## INTRODUCTION

Unfamiliarity with ultrasonography, the cost of training users on ultrasound-guided procedures, and the lack of training opportunities are limiting the use of this potentially beneficial technology. A cost-effective and widely applicable method for providing users with ultrasound-guided procedural training is needed. Purported simulator-based training advantages over traditional medical training include: (a) no risk to trainees or patients during practice attempts; (b) more cost-effective than current training methods; (c) provides multiple modes of sensory interaction to maximize learning; (d) user gains and maintains proficiency through unlimited repetition (avoids skill decay); (e) independent, self-directed learning; and

(f) provides a method for performance tracking. In this study, we compared simulation-based practice of ultrasound scanning to classroom-based practice of ultrasound scanning on knowledge and performance measures. We focused on one type of procedure, the *focused assessment with sonography for trauma* (FAST) exam, as the context for the comparison.

## Focused Assessment with Sonography for Trauma (FAST) Exam[1]

The FAST exam is an emergency ultrasound procedure which focuses on the detection of free fluid: hemoperitoneum, hemopericardium, pneumothorax, and hemothorax (Fox & Irwin, 2008). Unlike other trauma screening modalities such as the physical exam, diagnostic peritoneal lavage, and the CT scan, the FAST exam is non-invasive, bedside, and repeatable; requires five minutes to complete; and does not require a stable patient, making it invaluable as an initial assessment (Brooks, Davies, Smethhurst, & Connolly, 2004; Fox, 2010b; Lingawi & Buckley, 2000).

The standard windows of the FAST exam are the right upper quadrant (RUQ), left upper quadrant (LUQ), sub-xiphoid (or subcostal), and suprapubic. The quadrants are examined for fluid in the gutters or space between the organs in each window. In the RUQ (also called Morrison's Pouch), evidence of fluid may be found between the liver and the kidney. Fluid may also be found between the kidney and spleen in the LUQ view or in the pelvis in the suprapubic view (Salen, Melanson, & Heller, 2000). For the purposes of our study, the FAST exam was limited to the RUQ (Morrison's Pouch), LUQ (spleen), and the suprapubic (bladder) windows, as the model patients were ascites positive with free fluid in only these quadrants.

### Virtual Patient and Ultrasound Scanning Simulator

The simulator system we used, SonoSimulator™, was developed by Pelagique. The virtual patients used in SonoSimulator™ were modeled with real patient ultrasound scans of both normal and pathologic cases with a generic ultrasound design. The pathology in this study was limited to ascites; thus, fluid in the cardiac window was not available to participants. The SonoSimulator™ database contained a range of cases with varying amounts of free fluid: absence of fluid, and minimal, moderate, and severe amounts of fluid. The variety of patients used to populate the virtual patient database also provided scans with a range of anatomy. The system is PC-based, making it both widely accessible and transportable at a low cost.

[1] Also referred to as focused abdominal sonography for trauma exam.

## Cognitive Demands of FAST Window Acquisition and Interpretation

Recognition of anatomical landmarks is fundamental to ultrasound window acquisition. Both diagnostic medical sonographers and emergency physicians require training and proficiency in abdominal anatomy as a component of medical training and as a professional skill. To become credentialed by the American Registry for Diagnostic Medical Sonography and certified by the American Registry of Radiologic Technologists, sonographers must pass examinations requiring knowledge of normal and abnormal anatomy and physiology. The Ultrasound Task Force of the Society for Academic Emergency Medicine (SAEM), in their model curriculum for emergency physicians training in ultrasonography, also heavily emphasizes anatomy (Mateer et al., 1994).

Ultrasound scanning involves manipulating a probe or transducer against the patient's body, wherein the probe essentially acquires a 2-dimensional slice through a 3-dimensional anatomical volume. Minute changes to the pitch, yaw, and roll of the probe causes changes in the window image, and facile probe manipulation is required to acquire clear anatomical landmarks. This skill is not easily taught. Experienced sonographers use nuanced hand movements instinctively during image acquisition (Weidenbach et al., 2005). Precise verbal instructions relating the trainer's actions to the image on screen can be difficult. The FAST exam and ultrasonography in general is "operator dependent" (Robinson, 2000). To make a correct diagnosis, the sonographer must first acquire an adequate window by using anatomical landmarks and probe manipulation techniques such as fanning. Complicating the task is that the detection of fluid may depend on positioning of either the patient or the probe, with subtle changes in either required for precise window analysis (American Institute of Ultrasound in Medicine [AIUM], 2008; Salen et al., 2000).

## Use of Ultrasound Simulators for Training

The goals of FAST training are for the trainee to be able to accurately diagnose the presence of free fluid, acquire an adequate window to do so, and identify both the free fluid and the window when given a single ultrasound scan. Because window acquisition is dependent on probe movement, physical probe time is thought to be absolutely necessary to training. A typical curriculum for the FAST exam includes both didactic and hands-on instruction. Didactic training presents instruction on the principles of ultrasonography, an introduction to ultrasound mechanics or knobology, and discussion of the purpose, method, and interpretation of the FAST exam. The hands-on training component is the practical application of instruction and also the most constrained due to limitations of practicing with model patients (Salen et al., 2000; Shackford et al., 1999).

Ideally, a trainee would gain experience by performing the FAST exam on as many individuals, or cases, as possible. However, extended training experience with model patients is rarely practical. For example, to scan the LUQ, RUQ, and suprapubic quadrants would take 5 to 8 minutes in a training context per trainee. Assuming a typical class size of 20 students, with each student given two opportunities to scan, the total time required would be between 3 and 5 hours. Thus, providing trainees with the opportunity to practice scanning on different patients (to vary the anatomy) with different free fluid states (to vary the severity), and to scan multiple times to attain proficiency remains largely impractical.

One of the greatest benefits of simulators may the capability for the simulator to provide interactive learning opportunities with a large number of cases. Previous research points to the effectiveness of the simulator training in preparing trainees to both perform and interpret the FAST exam. For example, in a four-hour FAST training course for emergency medicine resident physicians, the UltraSim sonographic (mannequin) training model was found to be as effective in preparing trainees to detect the presence of intraperitoneal free fluid in various FAST windows as the training with a live patient model (using peritoneal dialysis patients) (Salen et al., 2000). In another study, the use of the SonoTrainer sonography simulation system enabled physicians trained with the system (versus theoretical training alone) to make diagnoses of second-trimester fetal abnormalities with a detection rate of 86% and specificity of 100% (Maul et al., 2004).

Thus, one advantage of simulation-based training systems for ultrasound is the capability to maximize probe time, thus aiding the acquisition of nuanced movements and virtual imaging essential in both window acquisition and identification. Various systems have been developed with a range of capabilities (e.g., UltraSim, VirUS, EchoComJ, and SONOSim3D, SonoTrainer, Maul et al., 2004). For the FAST exam, the simulator used in the current study (SonoSimulator™) focuses on providing trainees the capability to visualize free fluid in two ways: as a single ending image (e.g., snapshot of the window) and as a continuously changing window reflecting the process of window acquisition. The simulator can provide real-time imaging and visual feedback of the anatomy and gutters across multiple cases, allowing the trainee to be exposed to far more cases than would be possible in typical classroom-based training with live patients. However, there is little prior research that compares simultaneously simulator-based practice to classroom-based practice with respect to knowledge of given FAST windows and on execution of FAST exam procedures with live patients.

## Research Question

This study focused on addressing the extent to which practice using an ultrasound simulator and virtual patient affected participants' knowledge and subsequent performance on live FAST exams, compared to practice in a typical classroom context with a real ultrasound machine and live model patient. The training manipulated was the practice component of FAST scanning. The main outcomes were (a) knowledge of window identification and window interpretation, and (b) performance of a FAST exam with normal and ascites positive patients.

# METHOD

## Design

A pretest/posttest control group design was used to examine the effects of the two practice conditions on participants' knowledge of and performance on a FAST exam. Participants in the control condition received guidance and feedback from an instructor and hands-on practice with a model patient. Participants in the experimental condition practiced scanning on virtual patients using an ultrasound simulator, and received quality of scan and accuracy of diagnosis feedback from an ultrasound expert.

## Sample

Forty-nine participants participated in this study. The mean age was 25.61 years (*SD* = 3.19 years). Twenty-four participants were assigned to the group practice condition and 25 to the simulation practice condition. Forty-four participants were medical students, three were nursing students, one was a medical resident, and one was an undergraduate. The mean MCAT score was 33.63 (*SD* = 3.22). Nineteen participants reported no prior training in ultrasound scanning procedures, 15 reported a lecture or classroom training, and nine reported some hands-on practice. Overall, the sample represented novices with limited or no experience with ultrasound scanning.

### Model Patient Selection

To (visually) replicate the abdominal condition of patients with blunt trauma resulting in hemorrhage, patients with ascites were recruited to serve as model patients. Ascites is a pathological condition resulting from liver disease wherein fluid accumulates in the abdominal cavity (Runyon, 1994; Yu & Hu, 2001). For the first two waves of data collection, the same model patient (moderate degree of free fluid) was used. Scheduling conflicts required the use of a second model patient for the third data collection wave. This model patient had severe degree of free fluid. Both patients were positive for free fluid in the right upper quadrant, left upper quadrant, and suprapubic regions.

## Tasks

There were four major tasks participants engaged in: (a) answering paper-based questions related to knowledge of the FAST exam; (b) viewing computer-based training videos on the physics of ultrasound and the FAST exam procedures; (c) receiving hands-on practice with a model patient in a group-based setting typical of ultrasound training, or receiving practice scanning virtual patients with an ultrasound simulator; and (d) conducting a FAST exam on two model patients (one normal and one with ascites).

### Knowledge Measures

The knowledge measures were embedded in a 74-item pretest, which included items related to the FAST exam and participants' knowledge of abdominal anatomy. The posttest contained the same FAST exam questions (but not the anatomy questions), and in addition, questions related to participants' background. Appendix A contains a copy of the posttest, which includes the background questions, and Appendix B a copy of the pretest anatomy items. In addition, we also asked participants for their feedback on the practice tasks (Appendix C and Appendix D).

### Instructional Videos

Participants viewed two instructional video modules in sequence (Fox, 2010a, 2010b). The first video was on the physics of ultrasound and general principles of sonography. Topics covered in this module include: ultrasound instrumentation and image acquisition—mode, Doppler, echogeneity, transducer basics, image orientation, system controls (depth and gain), and artifacts (high attenuation, low attenuation, gas scatter, refraction, reverberation, mirror). The second video focused specifically on the FAST exam, describing how to view and interpret each of the four window quadrants: right upper quadrant (RUQ), left upper quadrant (LUQ), suprapubic (pelvis), and sub-xiphoid (cardiac). The video demonstrated a 3-minute FAST exam, discussed the implications of the mirror image artifact, discussed major pitfalls, and provided case study examples of conditions wherein free fluid is present.

### FAST Exam Practice

**Classroom-based practice.** In the control condition, the instructor gave participants five minutes of instruction on machine operation basics followed by a demonstration of the FAST exam. Each participant then practiced the FAST exam on the model patient while the instructor provided guidance and feedback (RUQ, LUQ, suprapubic quadrant). A normal model patient was used to demonstrate anatomic landmarks, consistent with the established training procedure used by the instructor and by other FAST educators and practitioners (Salen et al., 2000; Salen et al., 2001). Each participant was given two opportunities to conduct the FAST exam. One hour was allotted for the classroom practice session. Appendix E contains a picture of a classroom practice session, Appendix F contains a picture of the lab setup, and Appendix G and Appendix H contain copies of the observation forms used during classroom practice and during the performance test.

**Simulator-based practice.** In the experimental condition, participants were given a brief introduction to the simulator (number of cases; software features—freeze, layers, pop-up windows; and indicator/transducer positioning). For the second and third data collection waves, prior to the start of the simulation task, the sonographer gave brief instructions on locating landmarks on the body. The simulator was laptop-based and presented up to 10 cases with varying levels of normality and severity. Participants manipulated a probe, and the probe movements were mapped to corresponding ultrasound scans. The scans were updated in real-time and appeared as if the participant were using a real ultrasound machine. Appendix I contains a picture of a simulation practice session, Appendix J contains a copy of the simulator user interface, and Appendix K contains a copy of the simulation task directions.

Each case in the simulation was subdivided into three views: LUQ (Morrison’s Pouch), LUQ (spleen), and suprapubic (bladder). Participants were told to find the ideal diagnostic window and then freeze the scan. Participants were then instructed to indicate their diagnosis, window quality confidence level, and diagnosis confidence level on a pop-up window. A report with the participant’s window, diagnosis, confidence levels, time to scan, and start and end times was then printed out and given to an expert sonographer for evaluation. The expert sonographer evaluated the students’ diagnosis and window quality and determined whether the student should advance to the next view. Criteria for advancement were an accurate diagnosis and an excellent or fair window. No other instruction was given by the sonographer. One hour was allotted for the simulator session. Appendix L contains a copy of the ultrasound simulation report.

## FAST Performance Test

After practice, participants were given a performance test. The performance test required participants to conduct a FAST exam on two model patients. During the test, no help or feedback was given to the participants.

Participants examined one normal patient and one patient with ascites pathology using a portable ultrasound machine. The models used were the M-Turbo (SonoSite, 2010a), MicroMaxx (SonoSite, 2010b), and S-FAST (SonoSite, 2010c). A researcher readied the transducer and began timing when the transducer made first contact with the patient. Timing stopped when the participant indicated completion of the scan or when the participant indicated an inability to find an adequate window. After each window capture, the participants were asked to render a diagnosis. Images captured were saved to disk and later evaluated by an expert sonographer. Participants were limited to 2 minutes each for the RUQ and suprapubic scans, and 4 minutes for the LUQ.[2] Participants scanned patients in order of patient availability to expedite the testing process, minimize patient discomfort, and counterbalance model patient exposure to participants. Appendix M contains a copy of the sonographer evaluation form.

## Measures

Two major types of measures were developed for this study: (a) knowledge-based measures used to evaluate participants' knowledge of FAST-exam-related concepts; and (b) performance-based measures used to evaluate participants' skill at executing a FAST exam.

### Development of Knowledge-Based Measures

Knowledge measures were derived from information covered in the instructional videos (Fox, 2010a, 2010b) as well as FAST-exam-specific concepts. Three broad areas were sampled: prior knowledge of anatomy, basic FAST exam procedures, and window interpretation. Knowledge of the abdominal area was targeted because interpretation of FAST scans requires proficiency with abdominal anatomy. Knowledge of the FAST exam procedures was used to measure both the existing knowledge of participants prior to instruction on FAST concepts, and how much knowledge participants acquired from the instruction. Finally, window interpretation was sampled the most because this represented the most important knowledge outcome of the training.

The following types of sources were consulted to develop or adapt items for the knowledge measures: instructional materials (e.g., textbooks, guidebooks, and research [Alberto, Kelleher, & Nutt, 2007; Carnes, 2007; Noble, Nelson, & Sutingco, 2007; Reardon, 2008; Tempkin, 2009]), and computer-based instruction used in the study (Fox, 2010b). Draft

[2] These time limits were established after the first data collection wave, as one participant was taking a very long time to complete an LUQ scan. The thresholds were based on the observed timing of participants during the first data collection wave and consultation with sonographers.

items were reviewed for accuracy and interpretability by a director of emergency ultrasound, director of ultrasound and breast imaging, and a director of an emergency ultrasound department. The review resulted in revisions to 11 items. In addition, four experts experienced in sonography (director of ultrasound and breast imaging, experienced sonographer, and two emergency physicians) were administered the pretest measure. Based on their responses, two items were dropped. Table 1 shows the final distribution of the pretest items by topic.

Table 1

Knowledge-Based Measures

| Knowledge | No. of items | Pretest form question number |
|---|---|---|
| Prior knowledge of anatomy | | |
| Identification of abdominal organs | 8 | 5, 13a – 13g |
| Basic FAST scanning procedures | | |
| Scanning planes | 6 | 6, 7, 8, 15a –15c |
| Ultrasound probe placement | 5 | 11, 12, 16a – 16c |
| Echogeneity | 2 | 3, 4 |
| Artifact recognition | 2 | 33, 34 |
| Free fluid | 2 | 9, 10 |
| Window interpretation | | |
| Anatomical interpretation of FAST windows | 16 | 14a –14j, 17a –17f |
| Identification of FAST window quadrants | 14 | 18 – 22, 24 –32 (part a) |
| Diagnostic interpretation of FAST windows | 14 | 18 – 22, 24 –32 (part b) |

**Pretest of knowledge of anatomy.** As a check on prior knowledge, participants were asked to identify the organs on an abdominal diagram. This measure was intended as a basic check on participants' knowledge of anatomy of the abdominal region. There were eight items in this measure ($\alpha = .46$, $N = 49$).

**Knowledge of basic FAST concepts.** This measure contained items sampling the following concepts: basic definitions related to the FAST window, identification of anatomical parts with respect to the FAST window, identification of windows related to probe position, and identification of windows and anatomical parts related to the FAST window. There were 17 items in this measure ($\alpha = .75$, $n = 45$).

**Anatomical interpretation of FAST windows.** This scale measured participants' knowledge of the anatomical component of a given FAST window. There were 16 items in this measure (α = .80, *N* = 49).

**Identification of FAST window quadrants.** This scale measured participants' knowledge of the quadrant (LUQ, RUQ, or suprapubic) of a given FAST window. There were 14 items in this measure (α = .91, *N* = 49).

**Diagnostic interpretation of FAST windows.** This scale measured participants' knowledge of the disease state (normal, abnormal, inadequate to interpret) shown in a given FAST window. There were 14 items in this measure (α = .84, *N* = 49).

## Development of Performance-Based Measures

Measures of participants' performance were designed to gather basic information on how long participants took to acquire a window, the quality of the window, and the quality of the interpretation given the window. We recorded scan time during practice and during the live test. The evaluation of scan quality and diagnosis were performed by experts trained in sonography (either emergency medicine physicians or experienced sonographers).

## Performance Measures of FAST Exam: Practice Trials

During the practice trials participants received different types of practice depending on the condition. In the control condition, participants received one-on-one guidance and feedback from the instructor, with feedback and elaboration given to the whole group as necessary. In the experimental condition, participants received minimal feedback (knowledge of results of their scans and diagnoses), which would be typical in a fully automated system.

**Window acquisition time.** Window acquisition time was defined as the time required for a participant to acquire a window. For the control condition, the acquisition time was the period between first contact with the model patient's body and when the participant said "freeze." For the experimental condition, acquisition time was defined as the start of the procedure until the participant pressed the "freeze" button. In both conditions, the participant's judgment of an adequate window or the participant's judgment that he or she could not acquire the window determined the stop time.

The following measures were available only for the experimental condition.

**Window quality.** For each acquired window, an expert evaluated the quality of the window. In the experimental condition, an expert reviewed the window and rated the window as *excellent*, *fair*, or *poor*, then returned the rating to the participant.

**Diagnostic interpretation.** For each acquired window, the participant rendered a diagnosis of that window. An expert sonographer evaluated the diagnosis as correct or incorrect and returned the rating to the participant.

**Window and diagnosis confidence levels.** Immediately after participants acquired the window they were prompted to rate their confidence in their window acquisition and their diagnosis of the disease condition. For each factor, participants were asked to indicate, on a 5-point Likert scale (1 = *not confident,* 2 = *slightly confident,* 3 = *moderately confident,* 4 = *very confident,* 5 = *extremely confident*), their confidence in the quality of their window and the accuracy of their diagnosis.

**Number of trials to successfully diagnose a case.** The number of trials (attempts) each participant took to successfully complete a case was recorded.

**Performance Measures of FAST Exam: Live Patient Trials**

During the live trials all participants were measured using the same method.

**Window acquisition time.** Window acquisition time was defined as the time in seconds required for a participant to acquire a window. The acquisition time was the period between first contact with the model patient's body and when the participant said "stop" to indicate an adequate window or the participant's judgment that he or she could not acquire the window.

**Window quality.** For each acquired window, an expert evaluated the quality of the window. In the first wave of data collection, an expert evaluated the window quality immediately after the participant acquired the window. On subsequent data collection waves, an expert evaluated the window quality offline. The window was rated as *excellent, fair, poor,* or *other*. *Other* captured situations where the window acquired was non-diagnostic. No feedback was provided to participants.

**Diagnosis accuracy.** For each acquired window, the participant rendered a diagnosis of that window. An expert evaluated the quality of the diagnosis. In the first wave of data collection, an expert evaluated the diagnosis immediately after the participant rendered the diagnosis. On subsequent data collection waves, an expert evaluated the diagnosis after data collection. The diagnosis was rated as *correct*, *incorrect*, or *other*. *Other* captured situations where the window acquired was non-diagnostic. Note that *correct* occasionally indicated situations where an excellent scan was acquired and diagnosis based on that scan was correct, but due to patient positioning or other variability, a positive window was not acquired. No feedback was provided to participants.

**Supplementary Measures**

Additional measures were administered to gather information on individual differences, perceived benefits of the practice sessions and simulator, and general background.

**Usability.** Participants were asked several questions about their perception of how useful the practice was with respect to probe manipulation, window acquisition, and window interpretation. Participants were asked, “How well did the ultrasound practice session (either with the simulator or in the group session) prepare you to perform a ‘real’ ultrasound examination of a live patient?...”

1. ... only consider the physical aspect of scanning (i.e., manipulating the probe)
2. ... only consider the acquisition of a scan window aspect of scanning (i.e., being able to acquire a high quality window)
3. ... only consider the diagnostic aspect of scanning (i.e., being able to identify normal or abnormal conditions)

For each item, participants were instructed to indicate, on a 4-point Likert scale (1 = *very inadequate amount of practice,* 2 = *inadequate amount of practice,* 3 = *adequate amount of practice,* and 4 = *too much practice*), their perception of how adequate the practice was.

In addition, participants in the experimental condition were asked questions about their perception of how effective the simulation was in preparing them to acquire and interpret windows. Participants were instructed to indicate for each item, on a 4-point Likert scale (1 = *strongly disagree,* 2 = *disagree somewhat,* 3 = *agree somewhat,* and 4 = *strongly agree*), how much they agreed with each of the following statements:

1. Practicing with the simulator prepared me to interpret the scans during the live patient test
2. Practicing with the simulator prepared me to acquire the windows during the live patient test
3. The simulator was effective in helping me interpret scans of different kinds of conditions
4. The simulator was effective in helping me interpret scans of the different quadrants

Participants were also asked (a) What were the most useful features of the simulator? (b) How could the simulator be improved? and (c) What would have helped you improve your performance conducting the FAST scan on today’s patients? Finally, participants were asked about how confident they were with respect to conducting a FAST scan on actual patients.

**Background information.** Demographic information and prior experience with ultrasound training were gathered. Participants were asked their age, gender, current position, and MCAT scores. Participants were also asked what type of prior ultrasound training they received and the number of hours spent training on ultrasound procedures.

### Procedure

Participants were randomly assigned to the experimental or control conditions during scheduling. Each condition arrived in waves at predetermined times. One researcher introduced the research team and provided an overview of the study (3 minutes). Then the pretest of FAST knowledge was administered. Participants generally finished the pretest within 20 minutes and all participants were allowed as much time as needed to finish. Participants were then given two hours to view instructional videos on the physics of sonography and the FAST exam procedure.

Following the video instruction, participants received practice (either group-based practice with one instructor, or simulation practice with the ultrasound simulator). Following the practice session, participants were then required to conduct a live FAST exam with two patients; acquire the RUQ, LUQ, and suprapubic windows; and render a diagnosis. After the live patient exam, participants were given the knowledge posttest, and filled out the feedback form and paperwork to receive payment. The entire protocol took around 5 hours.

## RESULTS

### Preliminary Analyses

#### Checks of Assumptions

Measures used in the analyses were checked for normality and outliers, and equality of variances was checked for ANOVA-based tests. In general, the measures were normally distributed and variances were similar across conditions. Checks were conducted on the samples to examine whether there were pre-existing differences between the control and experimental conditions. $t$ tests were conducted on self-reported number of hours of prior ultrasound training, MCAT scores, prior knowledge of anatomy, and the pretest scales for anatomical interpretation, window identification, and diagnostic interpretation of FAST windows. These results suggest the conditions were equivalent on their knowledge of ultrasound scanning procedures.

## Main Analyses

The main research question in this study was to what extent does FAST exam practice using a virtual simulator affect participants' knowledge and subsequent performance on live FAST exams, compared to practice in a typical classroom context with a real ultrasound machine and live model patient? The training manipulated was the practice component of FAST scanning. The main outcomes were (a) knowledge of window identification and window interpretation, and (b) performance of a FAST exam with normal and ascites positive patients.

Table 2

Descriptive Statistics of Knowledge Measures (*N* = 49)

| | | Control (*n* = 24) | | | | Experimental (*n* = 25) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | Max. possible | *M* | *SD* | Min. | Max. | *M* | *SD* | Min. | Max. |
| Identification of abdominal anatomy | 8 | 6.50 | 1.22 | 3.00 | 8.00 | 6.57 | 1.12 | 5.00 | 8.00 |
| Basic FAST scanning procedures | | | | | | | | | |
| Pretest | 17 | 6.79 | 2.90 | 0.00 | 11.00 | 6.14 | 3.21 | 0.00 | 13.00 |
| Posttest | 17 | 14.25 | 1.51 | 11.00 | 17.00 | 14.36 | 1.85 | 9.00 | 17.00 |
| Anatomical interpretation of FAST window | | | | | | | | | |
| Pretest | 16 | 5.83 | 2.91 | 0.00 | 13.00 | 4.86 | 2.35 | 0.00 | 8.00 |
| Posttest | 16 | 12.83 | 1.79 | 10.00 | 16.00 | 12.08 | 2.29 | 6.00 | 16.00 |
| Identification of FAST window quadrant | | | | | | | | | |
| Pretest | 14 | 1.75 | 2.92 | 0.00 | 9.00 | 1.29 | 2.85 | 0.00 | 11.00 |
| Posttest | 14 | 8.50 | 2.40 | 3.00 | 12.00 | 8.92 | 2.41 | 1.00 | 13.00 |
| Diagnostic interpretation of FAST window | | | | | | | | | |
| Pretest | 14 | 1.92 | 2.89 | 0.00 | 11.00 | 0.86 | 1.59 | 0.00 | 5.00 |
| Posttest | 14 | 8.46 | 1.41 | 6.00 | 11.00 | 9.56 | 2.29 | 2.00 | 12.00 |

Table 3

Descriptive Statistics of Performance Measures (*N* = 49)

| Measure | Control ($n$ = 24) | | | | Experimental ($n$ = 25) | | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | Min. | Max. | *M* | *SD* | Min. | Max. |
| Diagnostic interpretation of FAST window[a] | 4.13 | 1.19 | 2.00 | 6.00 | 3.80 | 1.12 | 2.00 | 6.00 |
| Acquisition of FAST window[a] | 3.33 | 1.58 | 0.00 | 6.00 | 1.92 | 1.58 | 0.00 | 6.00 |
| Total scan time (sec) | 340.25 | 303.66 | 84.00 | 1644.00 | 496.96 | 214.47 | 180.00 | 934.00 |
| RUQ scan time (sec) | 125.71 | 133.04 | 17.00 | 548.00 | 139.76 | 62.64 | 33.00 | 257.00 |
| LUQ scan time (sec) | 155.00 | 132.17 | 25.00 | 548.00 | 269.16 | 178.28 | 53.00 | 673.00 |
| Suprapubic scan time (sec) | 68.87 | 105.76 | 22.00 | 548.00 | 88.04 | 47.82 | 9.00 | 180.00 |

[a]Summed across patients and quadrants. Maximum score is 6.

Table 4

Intercorrelations (Pearson) Among Posttest Measures

| Posttest measure | Knowledge measures | | | | Performance measures | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Knowledge measures | | | | | | | | | |
| 1. Basic FAST scanning procedures | – | | | | | | | | |
| 2. Anatomical interpretation of FAST window | .42** | – | | | | | | | |
| 3. Identification of FAST window quadrant | .34* | .31* | – | | | | | | |
| 4. Diagnostic interpretation of FAST window | .29* | .22 | .65*** | – | | | | | |
| Performance measures | | | | | | | | | |
| 5. No. of correct FAST window interpretations[a] | .17 | .14 | .24 | .35* | – | | | | |
| 6. No. of excellent FAST windows[a] | .06 | .15 | .01 | -.01 | .42** | – | | | |
| 7. Total scan time (sec) | .15 | .07 | -.07 | .24 | -.15 | -.20 | – | | |
| 8. RUQ scan time (sec) | .19 | .01 | .03 | .16 | -.18 | -.23 | .76*** | – | |
| 9. LUQ scan time (sec) | .14 | .08 | -.09 | .23 | -.14 | -.19 | .87*** | .57*** | – |
| 10. Suprapubic scan time (sec) | .12 | .12 | -.01 | .12 | -.12 | -.12 | .66*** | .66*** | .25 |

[a]Maximum possible is 6.
* $p < .05$ (two-tailed). ** $p < .01$ (two-tailed). *** $p < .001$ (two-tailed).

## Was there an effect of type of practice on knowledge of FAST exam procedures and FAST exam performance?

To address this question, we examined whether there were treatment effects on knowledge and performance outcomes. We checked for differences on knowledge of basic FAST procedures, anatomical interpretation of FAST windows, identification of FAST window quadrants, and diagnostic interpretation of FAST windows. Performance was examined by checking for differences on time to scan, and the quality of window acquisition and window interpretation for the RUQ, LUQ, and suprapubic quadrants.

### Effect of Instruction and Practice on Learning

Because we recruited novices for this study, we conducted pretest-posttest analyses on the knowledge measures to check whether participants learned from the instruction and practice. Separate paired *t* tests were conducted on each knowledge measure as shown in Table 5. Participants learned over instruction and practice on all knowledge measures, with percent gains of 121%, 133%, 474%, and 535% on basic FAST scanning procedures, anatomical interpretation of FAST windows, identification of FAST window quadrants, and diagnostic interpretation of FAST windows, respectively.

Table 5

Pretest and Posttest Descriptive Statistics and Paired *t* Tests ($N$ = 49)

| | Pretest | | Posttest | | Paired *t* test | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t* | *p* | effect size |
| Basic FAST scanning procedures | 6.49 | 3.03 | 14.33 | 1.73 | 20.64 | < .001 | 3.21 |
| Anatomical interpretation of FAST windows | 5.38 | 2.68 | 12.51 | 2.03 | 16.84 | < .001 | 3.39 |
| Identification of FAST window quadrants | 1.53 | 2.87 | 8.78 | 2.47 | 17.13 | < .001 | 3.24 |
| Diagnostic interpretation of FAST windows | 1.42 | 2.41 | 9.02 | 1.96 | 18.43 | < .001 | 4.26 |

### Effects of Type of Practice on Knowledge

Separate analysis of covariance (ANCOVA) procedures were conducted on the posttest knowledge scales using the pretest score as a covariate (Table 6). There was a significant effect of condition on diagnostic interpretation of FAST windows. After controlling for pretest scores, participants in the experimental condition (*Adj. M* = 9.80, *SE* = 0.40) scored significantly higher than participants in the control condition (*Adj. M* = 8.34, *SE* = 0.38), $F(1, 42) = 6.88$, $p = .01$, $d = 0.81$. Participants who received simulator-based practice scored about

18% higher on items requiring diagnostic interpretation than participants who received classroom-based practice. No other differences were found.

Table 6

Adjusted Means, Standard Errors, and Analysis of Covariance (ANCOVA) for Posttest Knowledge Measures

| | Comparison of treatment effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | | | Experimental | | | ANCOVA[a] | | |
| Knowledge of FAST exam procedure | *n* | *Adj. M* | *SE* | *n* | *Adj. M* | *SE* | *F* ratio | *p* | effect size |
| Basic FAST scanning procedures | 24 | 14.15 | 0.30 | 21 | 14.54 | 0.32 | 1.63 | .39 | – |
| Anatomical interpretation of FAST window | 24 | 12.74 | 0.41 | 21 | 12.25 | 0.43 | 0.66 | .42 | – |
| Identification of FAST window quadrant | 24 | 8.42 | 0.46 | 21 | 9.19 | 0.49 | 1.35 | .25 | – |
| Diagnostic interpretation of FAST window | 24 | 8.34 | 0.38 | 21 | 9.80 | 0.40 | 6.88 | .01 | 0.81 |

[a]Between-groups *df* = 1, pretest used as covariate.

### Effects of Type of Practice on Performance

Performance during the live patient exam was evaluated using three measures: (a) time-to-scan; (b) quality of the acquired window; and (c) quality of the interpretation of the window. Data were analyzed by type of patient and quadrant.

**Time-to-scan.** Separate analyses were conducted by type of patient (normal, positive) and for each quadrant. For each quadrant, a repeated-measures ANOVA was conducted, with type of patient (normal, abnormal) the within-subjects factor, and condition (control, experimental) the between-subjects factor. For the RUQ, an effect of type of patient was found, with participants in both conditions taking significantly longer to scan the positive patient (*M* = 79.2s, *SD* = 58.9s) compared to the normal patient (*M* = 55.8s, *SD* = 63.7s), *F*(1, 48) = 5.78, *p* = .02, *d* = 0.38. Participants in general took about 42% longer to scan the positive patient. No other differences were found.

For the suprapubic quadrant, an effect of type of patient was found, with participants in both conditions taking significantly longer to scan the positive patient (*M* = 45.4s, *SD* = 48.9s) compared to the normal patient (*M* = 33.5s, *SD* = 37.2s), *F*(1, 46) = 6.16, *p* = .02, *d* = 0.27. Participants in general took about 36% longer to scan the positive patient. No other differences were found.

For the LUQ, a significant main effect was found due to condition, with participants in the control condition taking less time to scan the patients (*M* = 80.4s, *SD* = 16.9s) than participants in the experimental condition (*M* = 140.4s, *SD* = 16.5s), $F(1, 43) = 6.45$, $p = .02$, $d = 3.59$. Participants who received simulator-based practice took about 75% longer to scan the patient compared to participants who received classroom-based practice. No other differences were found.

These results suggest differences in the time to scan between the normal and positive patients in general. The only effect of practice was on the LUQ quadrant, with participants receiving hands-on classroom-based practice performing the scan faster than patients who received only simulator-based practice (which did not include practice finding the initial anatomical landmarks).

**Window quality.** Table 7 shows the distribution of control and experimental participants who acquired high-quality windows. High quality was defined as a window quality rating of *excellent*. *Other* was defined as a window quality rating of *fair*, *poor*, or *other*.

Table 7

Comparison of Window Quality by Condition (*N* = 49)

| | Control | | Experimental | |
|---|---|---|---|---|
| Quadrant | No. of participants with high-quality windows[a] | Other[b] | No. of participants with high-quality windows[a] | Other[b] |
| Normal patient | | | | |
| RUQ* | 18 | 6 | 11 | 14 |
| LUQ | 8 | 16 | 4 | 21 |
| Suprapubic | 19 | 5 | 15 | 10 |
| Positive patient | | | | |
| RUQ | 10 | 14 | 8 | 17 |
| LUQ | 9 | 15 | 6 | 19 |
| Suprapubic*** | 16 | 8 | 4 | 21 |

[a]Window quality rating of excellent. [b]Window quality ratings of fair, poor, or other.
*$p < .05$ (two-tailed). ***$p < .001$ (two-tailed).

Separate chi-square tests were conducted for each quadrant by type of patient. For the normal patient (RUQ), the number of high-quality windows acquired was greater than expected in the control condition, and the number of non-high-quality windows was greater than expected in the simulation condition ($\varphi = -.32$, $p = .03$). Seventy-five percent of participants who received classroom-based practice were able to acquire high-quality windows, compared to 44% of participants who received simulator-based practice.

Similarly, for the positive patient (suprapubic quadrant), the number of high-quality windows acquired was greater than expected in the control condition, and the number of non-high-quality windows was greater than expected in the simulation condition ($\varphi = -.52$, $p < .001$). Sixty-seven percent of participants who received classroom-based practice were able to acquire high-quality windows, compared to 16% of participants who received simulator-based practice.

**Window interpretation.** Table 8 shows the distribution of control and experimental participants who correctly interpreted windows. *Other* was defined as a rating of *incorrect* or *other*.

Table 8

Comparison of Window Interpretation by Condition ($N = 49$)

| | Control | | Experimental | |
|---|---|---|---|---|
| Quadrant | No. of participants with correct interpretations | Other[a] | No. of participants with correct interpretations | Other[a] |
| Normal patient | | | | |
| RUQ | 24 | 0 | 24 | 1 |
| LUQ* | 17 | 7 | 10 | 15 |
| Suprapubic | 18 | 6 | 23 | 2 |
| Positive patient | | | | |
| RUQ | 18 | 6 | 17 | 8 |
| LUQ | 11 | 13 | 14 | 11 |
| Suprapubic | 11 | 13 | 7 | 18 |

[a]Rating of *incorrect* or *other*.
**p* < .05 (two-tailed).

Separate chi-square tests were conducted for each quadrant by type of patient. For the normal patient (LUQ), the number of windows interpreted correctly was greater than expected in the control condition, and the number of windows interpreted incorrectly was greater than expected in the simulation condition ($\varphi = -.31$, $p = .03$). Seventy-one percent of the participants who received classroom-based practice were able to interpret windows correctly, compared to 40% of the participants who received simulator-based practice. Conditional analyses were also conducted to examine whether there was a difference in diagnosis quality given an adequate window acquisition (i.e., a window rating of *excellent* or *fair*). There were no differences between conditions by quadrant and patient, or by overall diagnosis quality.

**Summary of performance results.** Table 9 summarizes the performance results. In general, there were no condition differences in scan time for RUQ and suprapubic quadrants, but the LUQ participants who received hands-on classroom training completed the scans faster. When window quality is examined, the control condition had more participants acquiring excellent window scans compared to the experimental condition, but only for two out of the six scans. Similarly, when window interpretation is examined, the control condition had more participants rendering a correct diagnosis compared to the experimental condition, but only for one out of the six scans.

The performance results suggest that there is little statistical difference in acquisition time between the control and experimental conditions, except for LUQ. Hands-on classroom practice appears to influence window acquisition and window interpretation only under very specific conditions: RUQ normal and suprapubic positive for window quality, and LUQ normal for window interpretation. In terms of diagnostic interpretation of acquired window scans, particularly for the positive patients, there was no statistical difference between conditions. The only difference found was in the interpretation of the LUQ scan for the normal patient; in this case, participants who received classroom-based practice were more successful at correctly interpreting the scans than participants who received simulator-based practice.

Table 9

Summary of Performance Differences

| Performance measure | FAST quadrant | | |
|---|---|---|---|
| | RUQ | LUQ | Suprapubic |
| Time to scan | No effect of condition: Positive patient takes longer to scan than normal patient. | No effect of patient: Control condition takes less time to scan than experimental condition. | No effect of condition: Positive patient takes longer to scan than normal patient. |
| Window quality | | | |
| Normal patient | control > experimental | No effect of condition | No effect of condition |
| Positive patient | No effect of condition | No effect of condition | control > experimental |
| Window interpretation | | | |
| Normal patient | No effect of condition | control > experimental | No effect of condition |
| Positive patient | No effect of condition | No effect of condition | No effect of condition |

### Summary

These results suggest that there was an impact of the type of practice on participants' knowledge of disease states given a FAST window, favoring the simulator-based practice. Hands-on practice in the classroom training setting appeared to provide participants with probe manipulation skills only on the most complex scan (LUQ), resulting in faster window acquisition times than participants in the experimental condition. Both types of practice appeared to result in similar FAST exam performance levels with respect to window quality (LUQ) and interpretation (RUQ, suprapubic). Where performance differences existed, the pattern of difference was unclear, varying by type of measure, quadrant, and type of patient.

## Participants' Perceptions of the Effectiveness of Practice

In this section we examine participants' perceptions of the utility and effectiveness of the practice received.

### Survey Responses

Participants were asked to evaluate how effective the practice session was for preparing them for the live patient exam. Participants were asked "How well did the ultrasound practice session (either with the simulator or in the group session) prepare you to perform a 'real' ultrasound examination of a live patient?" The distribution of participant responses is given in Table 10. Because participants' responses were clustered around the two middle categories, responses were collapsed into two categories: inadequate (representing the two scale points of *very inadequate* and *inadequate* amount of practice) and adequate (representing the two scale points of *adequate* and *too much* practice). Chi-square tests were conducted for each question, to test for an association between condition and participants' perceptions of the adequacy of the amount of practice.

Table 10

Distribution of Participant Responses About the Amount of Practice

| | Very inadequate amount of practice | Inadequate amount of practice | Adequate amount of practice | Too much practice |
|---|---|---|---|---|
| Physical aspect of scanning (i.e., manipulating the probe) | | | | |
| Control | 0 | 6 | 17 | 0 |
| Experimental | 0 | 14 | 11 | 0 |
| Acquisition of a scan window aspect of scanning (i.e., being able to acquire a high quality window) | | | | |
| Control | 1 | 11 | 12 | 0 |
| Experimental | 1 | 8 | 16 | 0 |
| Diagnostic aspect of scanning (i.e., being able to identify normal or abnormal conditions) | | | | |
| Control | 2 | 15 | 6 | 0 |
| Experimental | 2 | 10 | 13 | 0 |

For the physical aspect of scanning, the number of participants reporting adequate amount of practice was greater than expected in the control condition and the number of participants reporting inadequate amount of practice was greater than expected in the experimental condition ($\varphi = -.30$, $p = .04$). For the acquisition aspect of scanning, there were no differences by condition. For the diagnostic aspect of scanning, a potential effect was found. The number of participants reporting adequate amount of practice was greater than expected in the experimental condition and the number of participants reporting inadequate amount of practice was greater than expected in the classroom condition ($\varphi = -.27$, $p = .07$).

Participants in both conditions appeared to perceive the adequacy of the practice sessions differently. Participants who received classroom-based practice reported adequate practice (in general) with respect to acquiring a window compared to participants who received simulator-based practice, and inadequate practice with respect to diagnosing window scans compared to participants who received simulator-based practice.

**Written Comments**

An examination of participants' written comments on the preparedness for diagnosing a live patient suggests that participants in the control condition desired more practice with both normal (for a better grasp on anatomic variation) and abnormal (for a range of pathology and severity) cases. Participants in the experimental condition indicated that the simulator practice helped them recognize the variations in both normal and abnormal cases, and in interpreting those images.

Overall, participants in the control condition commented that both instruction on how to handle the probe and actual "probe time" were beneficial in learning the physical aspect of scanning. These participants also noted that the use of a single patient in the practice session made it difficult for them to adjust their performance on different patients. Participants in the experimental condition noted that practice with the simulator probe familiarized them with image orientation, probe movement, and visualizing major structures. The primary difficulty for these participants was locating anatomical landmarks. Both range of movement and the initial (correct) placement of the probe on the simulator model were set. Participants commented that practice placing the probe on the virtual patient would be helpful in developing skills in locating landmarks on a live patient.

Participants in the control condition reported that adequate window acquisition was dependent on the window being viewed (the LUQ was harder to acquire) and on the patient (easy on practice patient, difficult on live exam patient). Experimental condition participants noted that adequate window acquisition on a live test patient was dependent on being able to locate the proper anatomical landmarks and place the probe in the correct initial position. Participants commented that practice on the simulator increased confidence in finding and determining a good scan window once the probe was already in place.

Overall, participants viewed both the video instruction and practice sessions as helpful in answering posttest questions on window identification and interpretation. Participants in the experimental condition commented that the video instruction was useful for basic understanding but simulator practice was key in aiding spatial understanding, identification of visual patterns of structures, and increased confidence in window interpretation.

When asked what would improve performance while conducting the FAST exam, experimental condition participants perceived the simulator to be an effective means of ultrasound training but also responded that expert instruction (especially with regard to placement of the probe, amount of pressure to exert on a live patient), additional simulator practice time, and practice with a live patient were desired.

## Participants' Perceptions of the Effectiveness of the FAST Simulator (Experimental Condition Only)

In the last two data collection waves we inserted several questions into the protocol for participants receiving simulation practice. Participants in the first data collection wave had commented to us how useful the simulation practice was. The new questions were designed to gather participants' perceptions of what the simulation practice helped them with. Table 11 shows the distribution of participants' comments. In general, there was general agreement among participants that the simulation practice helped them with window interpretation, and less agreement with respect to window acquisition.

Table 11

Distribution of Simulation Participant Comments

| Question | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| With respect to the performance test | | | | |
| Practicing with the simulator prepared me to interpret the scans during the live patient test | 0 | 1 | 12 | 6 |
| Practicing with the simulator prepared me to acquire the windows during the live patient test | 1 | 6 | 9 | 3 |
| With respect to window interpretation | | | | |
| The simulator was effective in helping me interpret scans of different kinds of conditions | 1 | 3 | 12 | 3 |
| The simulator was effective in helping me interpret scans of the different quadrants | 0 | 2 | 13 | 4 |

When asked to check one of four options reflecting how confident participants were about performing a FAST examination with actual patients, one participant selected *with no further training*; 10 participants selected *with a few practice scans on a person*; three participants selected *with a training class on ultrasound scanning*; and three participants selected *other*.

### Written Comments

We also asked participants for written comments about the most useful features of the simulator. In general, participants' comments can be grouped into the following descriptions:

- The capability for real-time visualization, positioning, and manipulation of the probe
- The capability to compare their window to the four reference scans (normal, and three abnormal windows)
- The instructor evaluation of the diagnosis and quality of scan (although this is an artifact of the study procedures)
- The capability to compare windows of normal and abnormal conditions
- Practice via multiple cases
- The layers or skeleton overlay

We also asked for comments on what improvements could be made to the simulator. In general, participants' comments can be grouped into the following descriptions:

- A fixed initial probe position is helpful for beginners, but over time, the user should be responsible for positioning the transducer by locating appropriate anatomical landmarks on the body.
- Allow for lateral (superior/anterior) movement of the probe, rather than just rotational movement; expand range of motion of the probe.
- Expand the field of view of the ultrasound scans.
- In addition to the range of normal and abnormal images displayed after window selection and diagnosis, also display a "best window" image which also outlines the organs and abnormality.

## DISCUSSION

### Summary of Findings

**Participants learned from the training materials.** Evidence of the effectiveness of the training materials (the instructional videos and the practice) is seen by the significant and large gains on all knowledge-based measures. Participants more than doubled their scores on the posttest, with percent gains of 121%, 133%, 474%, and 535% on basic FAST scanning procedures, anatomical interpretation of FAST windows, identification of FAST window quadrants, and diagnostic interpretation of FAST windows, respectively. How much each training component (i.e., the instructional videos vs. the practice) contributed to the posttest gains cannot be determined because measures were not taken between the instruction and practice components of the study.

**Simulator-based practice promotes greater acquisition of window interpretation knowledge (i.e., on the paper-and pencil measure) compared to classroom-based practice.** There was clear evidence that participants in the simulator practice condition were able to interpret correctly more FAST windows than participants who received classroom practice (18% higher scores on the knowledge posttest). In general, participants in the simulator condition practiced on multiple normal and positive cases (vs. a single normal case), and were able to compare an acquired window to reference windows that represented normal and positive states (minimal, mild, severe). Participants in the simulator practice condition reported overwhelmingly that the simulation practice aided them in interpreting scans. In addition (although marginally significant, $p$ = .07), the number of participants reporting adequate amount of practice was greater than expected in the simulator practice condition and the number of participants reporting inadequate amount of practice was greater than expected in the classroom practice condition. This finding points to a major benefit of the FAST simulator-based practice: The capability to offer practice with multiple cases and conditions synchronized with the probe manipulation.

**Simulator-based practice appears to be similar to classroom-based practice in diagnostic accuracy of windows acquired during live patient exams.** The pattern of results on window interpretation during the performance test with model patients suggests no difference between practice conditions. That is, across two patient types (normal, positive), there was no difference on five of the six quadrants in the number of participants who made correct interpretations. The exception was for the LUQ (normal patient). In this case, more classroom practice participants were able to correctly diagnose the window.

**Classroom-based practice may promote greater window acquisition skills compared to simulator-based practice.** The pattern of results on the acquisition of quality windows is less clear. Acquisition of high-quality windows appeared the most challenging for the LUQ, followed by the RUQ and suprapubic quadrant. Scan time data are consistent with this ordering, with participants taking over 2 minutes to scan the LUQ, under 2 minutes for RUQ, and little over a minute for the suprapubic quadrant. Statistical differences in window quality were found that favored the classroom-practice condition for the RUQ (normal patient) and suprapubic quadrant (positive). In both cases, a higher number of participants in the classroom-practice condition were able to acquire excellent windows compared to the simulator-practice condition.[3]

These results may be pointing to one important difference between practice conditions. In the classroom-practice condition, participants received individualized guidance from the instructor on probe positioning and rotation, and sometimes included the instructor physically

[3]While not statistically significant, window quality favored the classroom-practice condition on all other quadrants/patients.

guiding the participant's hand to establish correct placement on the patient. In contrast, the simulator had the probe locked into the ideal initial positions. This difference was a major issue that surfaced in participants' self-reports. For instance, participants in the classroom-practice condition reported that they received an adequate amount of practice compared to participants in the simulator-practice condition, who reported an inadequate amount of practice. Simulation-practice participants' written comments also reflected their desire for physical practice, with one participant's comments summarizing the issue:

> I think it would have been more helpful if we had practice placing the probe onto the patient instead of having it already in place and only being able to change the angle. When I did the procedure on the patient, it was hard for me to know where to put the probe.

**There appears to be no difference in the time to scan a quadrant between the two practice formats.** For the RUQ and suprapubic quadrant, there was no effect of condition: Participants in general took significantly longer to scan the positive patient than the normal patient (RUQ: 42% longer; suprapubic: 36% longer). For the LUQ, there was an effect of condition but not an effect of patient, with the simulation-practice condition taking significantly longer to scan the patients (75% longer). While there were no statistically different scan times due to condition on two of the three quadrants, these quadrants had large standard deviations in general, with the control condition having significantly larger scan time standard deviations.

Overall, these findings suggest the general effectiveness of the simulator practice: (a) superior diagnostic interpretation on a knowledge-based test; (b) potentially similar levels of performance on live patient exams—despite having no prior hands-on practice (i.e., the first scan with a patient was the live patient test); and (c) positive perception by participants and recognized utility of the simulator.

## Limitations

There are three limitations to this study. First, the number of model patients used for the live test was limited to two for practical reasons. The low number of patients limited the range of cases and situations a participant was tested on. Thus, open questions include sampling (Do the model patients adequately represent the patients likely to be encountered under actual conditions? Are there peculiar features of the model patients that would bias the performance in some way?) and generalizability—to what extent does performance on the live test in this study adequately represent performance on actual patients likely to be encountered?

A second limitation is in the study procedures. Because of the limited availability of ultrasound machines for live patient testing (only two), the extremely limited pool of patients with ascites willing to participate in this study, and the blocking of participants (i.e., the classroom-practice participants), the procedure was designed to maximize participant throughput and minimize patient discomfort (how long the patient was being scanned). This resulted in suboptimal counterbalancing across model patients during the live patient testing (participants were assigned to patients based on patient availability which generally preserved counterbalancing but did not guarantee it), randomization at the time of scheduling the appointment for the study (vs. randomization at the time of arrival, which would mitigate against potential biases resulting from schedule availability such as only medical students in cohort X were available because the other cohorts had class), potential changes in the model patient over time resulting in blocks of participants receiving different patient conditions (e.g., if patients had to go to the restroom in the middle of the three-hour testing window, then their bladder would be empty for a while, making suprapubic window acquisition harder). We speculate that the latter situation may be a possible explanation for the advantage found for the control condition on window quality, as the control condition participants generally started the live patient exams before the experimental condition patients.

The third limitation is a potential training effect in the classroom-practice condition. We do not have information on how representative the classroom instructor was of ultrasound trainers in general. The instructor used in this study reported over 20 years of experience teaching ultrasound concepts and procedures. Our observation of the classroom instruction suggested an instructor who was able to provide clear explanations and demonstrations of procedures, and provide effective feedback and guidance to students who had difficulty acquiring a window. In addition, the class size used (about eight participants) may have been smaller than a typical training class.

## Implications for FAST Training

One of the most interesting findings of this study was that using the virtual trainer (Sonosimulator™) for practice did not result in markedly inferior performance on the physical aspects of scanning. That is, the training (the instructional videos and the simulator-based practice) was sufficiently effective to enable participants who received no hands-on practice to perform comparably to the participants who received hands-on practice on most of the performance measures across the normal and positive patients used in this study.

However, simulator-practice participants' self-reports and a general trend favoring classroom-practice (but not statistically significant) on window acquisition, point to the importance of being able to find the initial probe location for a quadrant. While in this study participants in the simulator-practice condition did not receive such practice (because of the technical complexity of the modeling), two solutions exists that are simple, straightforward, and practical. Hands-on training can be implemented in a few minutes per quadrant based on our observations of the classroom training, or a multimedia demonstration of initial probe placement could be used to mimic the hands-on training.

In the broader training context, the findings of this study are consistent with findings of design features of effective simulators. The simulator used in this study was designed around the cognitive demands of FAST window acquisition and interpretation. Through repeated exposure to cases, users are engaged in the review, identification, acquisition, and interpretation of a FAST window. High fidelity is used judiciously—only to link the real-time probe response to its corresponding window. Users can view interpolated windows of scans of actual patients with varying free fluid conditions and varying anatomy, and then compare an acquired window to windows of normal and various positive conditions. This latter capability is an important instructional feature as it helps users identify the window characteristics of the various free fluid states.

One of the most important training benefits of simulators is extended training time. Having available virtual patients to scan with various disease conditions avoids the restrictions associated with model patients, such as availability and willingness to endure long training sessions with a number of trainees. In the case of ascites, patients are often too ill to even participate in a study. Another benefit of the simulator is documented pathology—any anatomical anomalies or a specific severity of condition can be included in the simulator for an unlimited number of views.

Finally, the utility of the simulator as an anytime-anywhere refresher trainer is clear. Assuming basic competency at initial probe location and landmark identification, the use of the FAST simulator as a means to relearn procedures anytime-anywhere seems ideal as the simulator emphasizes the mapping between probe movement and the window quality. Perhaps the most powerful capability of the simulator is to provide users with practice recognizing various disease conditions or window anomalies (e.g., artifacts) that would be difficult to observe otherwise.

## Future Directions

### Simulator Design

One future direction for the SonoSimulator™ is to include the capability for users to practice finding the appropriate initial location for the probe. While this may be ideal, this capability may be cost prohibitive. A second direction for the SonoSimulator™ system may be using the image database to diagnose live scans. Given a particular quadrant, a given window image could be compared to the SonoSimulator™ image database (a volume with known anatomical and disease properties) and a similarity measure computed.

**Follow-up Studies**

One follow-up study would be to examine the relative lift in performance due to the simulator. That is, vary the sequence of simulator and classroom practice where in one condition, classroom practice precedes simulator practice, and vice versa for the second condition. This study would address the practical issue of whether to use the virtual simulator as part of a FAST training package. Alternative designs could vary degree of guidance from classroom practice as done in the current study to minimal guidance where the hands-on practice focuses on probe placement. Skill retention studies could also be conducted to examine skill decay of window acquisition and window interpretation over time.

Another study could focus on optimizing window interpretation. Given the database of patients with different diseases and quadrants, one training study could examine whether it would be more efficient to separate the exposure to different abnormal conditions from the simulator scanning activity—can window interpretation be bolstered independent of the simulator? A third study could examine the extent to which the simulator can be used as an assessment of FAST window acquisition and interpretation. Given the variation in live patients, the cost involved, and the availability of patients with different diseases, the use of a FAST simulator with a large database of cases could standardize the administration and content of FAST exams.

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# APPENDIX A:

# POSTTEST FORM (KNOWLEDGE OF ULTRASOUND AND BACKGROUND SURVEY)

National Center for Research
on Evaluation, Standards, & Student Testing
UCLA | Graduate School of Education & Information Studies

# 1015

**Ultrasound Simulator Efficacy Study**
**Summer 2010**

# Ultrasound Training Posttest

**DIRECTIONS**

You will be asked to:

1. Answer questions on anatomy and ultrasound procedures, and ultrasound scans.
2. Fill out a survey that asks about demographic information and experience with ultrasound scanning procedures.
3. If you do not know the answer to any question, write *don't know*, *DK,* or *?*.

Thank you for helping us with this study.

1. Date: ________________

2. Time now: ________________

**For each question, please circle the best answer. If you do not know the answer, select "don't know."**

3. When an organ is described as hypoechoic in relation to another organ it means ________.
   a. the organ is brighter relative to the first organ.
   b. the organ is less echogenic relative to the first organ.
   c. the organ is visualized inferior to the first organ.
   d. the organ is visualized posterior to the first organ.
   e. don't know

4. The sonographic appearance of the normal renal cortex is
   a. hyperechoic relative to the liver.
   b. heterogeneous.
   c. hypoechoic relative to the liver.
   d. highly reflective.
   e. don't know

5. The lie of the IVC (Inferior Vena Cava) within the body __________________.
   a. makes it impossible to visualize with ultrasound.
   b. is superior to inferior.
   c. is oblique.
   d. is ventral to the aorta.
   e. don't know

6. Typically, when scanning in a coronal plane, ______________.
   a. the indicator on the transducer is aimed toward the patient's left.
   b. the indicator on the transducer is aimed toward the patient's right.
   c. the ultrasound beam enters the body from a ventral to dorsal direction.
   d. the ultrasound beam can enter the body in either a right or left lateral direction.
   e. don't know

7. When scanning in a transverse plane, the ultrasound beam enters the body from
   a. any of the following: an anterior, posterior, right lateral, or left lateral direction.
   b. only an anterior or posterior direction.
   c. only a right or left lateral direction.
   d. either an anterior, posterior, or medial direction.
   e. don't know

8. When scanning in a sagittal plane, the ultrasound beam enters the body from
   a. either an anterior or posterior direction.
   b. any of the following: an anterior, posterior, right lateral, or left lateral direction.
   c. either an anterior, posterior, or medial direction.
   d. either a right or left lateral direction.
   e. don't know

9. Free fluid in the abdomen is most commonly seen ___________________.
   a. in Morrison's Pouch.
   b. behind the kidneys.
   c. under the diaphragm.
   d. in the Pouch of Douglas.
   e. don't know

10. All of the following are true regarding free fluid in the abdomen, EXCEPT:
   a. It is black.
   b. It fills potential spaces.
   c. It is hyperechoic.
   d. It is anechoic.
   e. don't know

**Please fill in the blanks for the questions below. Write "?" if you do not know the answer.**

11. When imaging the patient in a sagittal plane, aim the indicator on the transducer towards the patient's _________________.

12. When imaging the patient in a transverse plane, aim the indicator on the transducer towards the patient's ___________________.

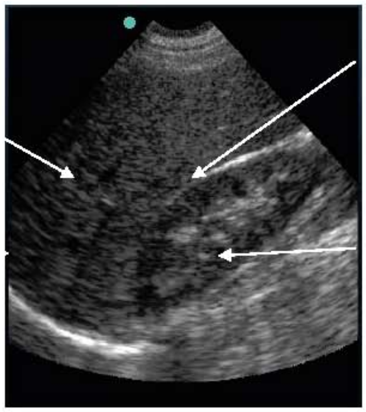
**For the questions below, please label the anatomy of the images shown. Write "?" if you do not know the answer.**

13.

a. ______________

b. ______________

c. ______________

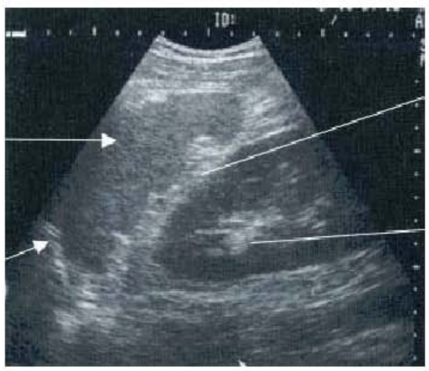


d. ______________

e. ______________

f. ______________

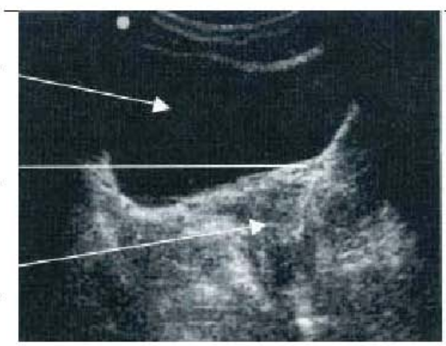
g. ______________



h. ______________

i. ______________

j. ______________

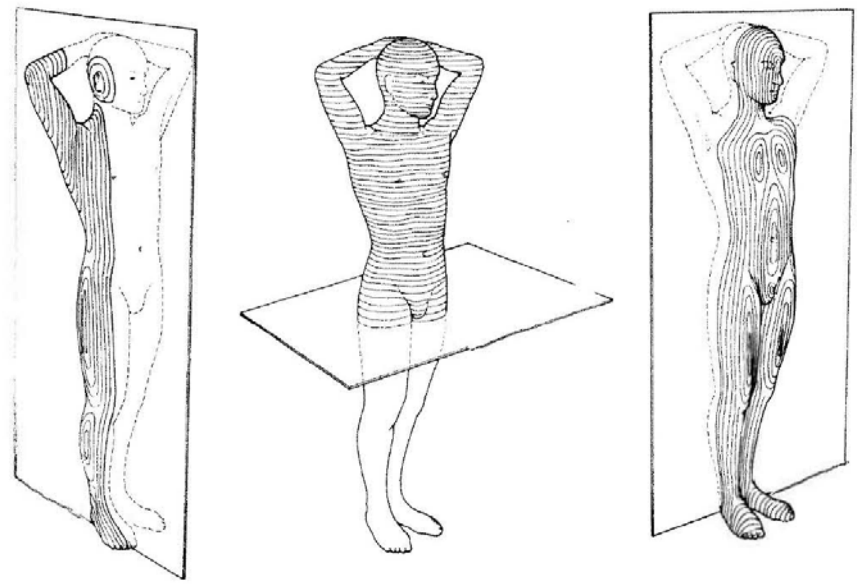


ID: 1015

**Please label the scanning planes depicted in each image below. Write "?" if you do not know the answer.**

14.

a.________________________ b.______________________ c.______________________



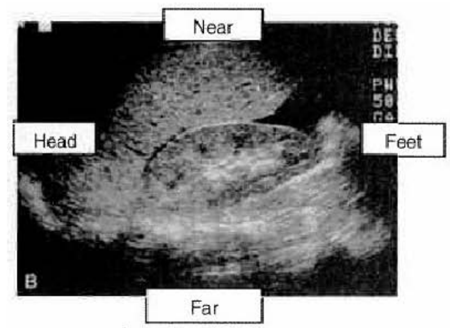


UltrasoundPosttest_100715.docx

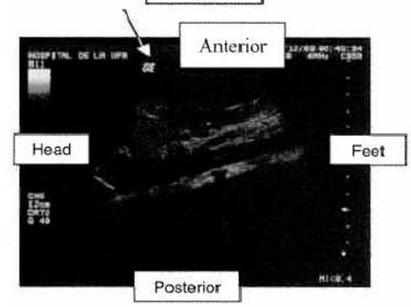
**Please match the scans images on the left to the probe position used to acquire the scan. Write "?" if you do not know the answer.**

15.

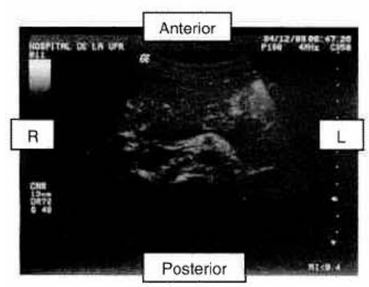
___ 

a. 


___ 

b. 


___ 

c. 

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**Please match the anatomical representations on the facing page to their ultrasound scan counterparts on this page. Write "?" if you do not know the answer.**

16.

______ 

______ 

______ 

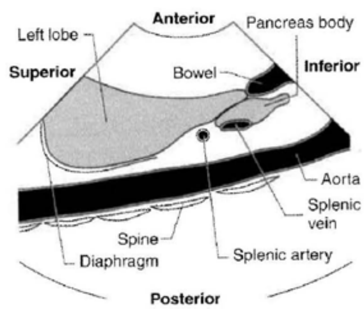
______ 

______ 

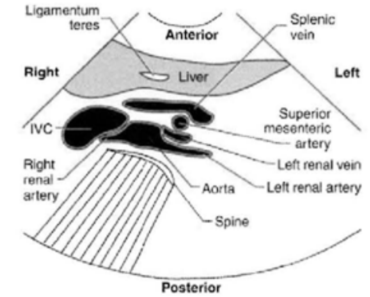
______ 

ID: 1015

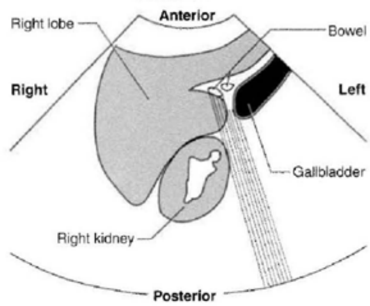
**a.**



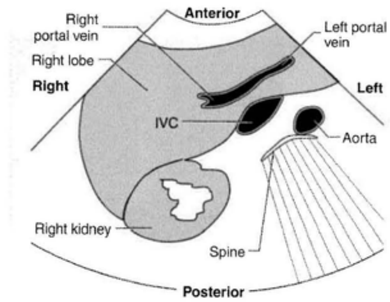

**b.**



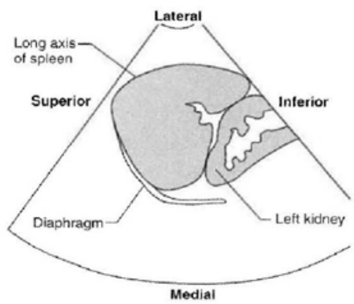

**c.**



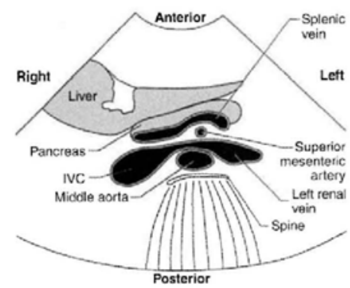

**d.**



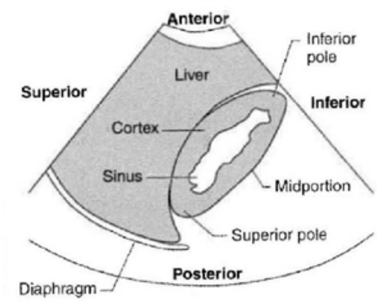

**e.**



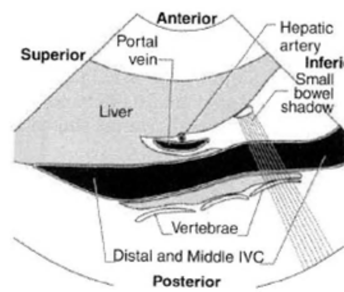

**f.**




**g.**




**h.**



**Please mark the appropriate boxes in both columns.**

17. 

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

18. 

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

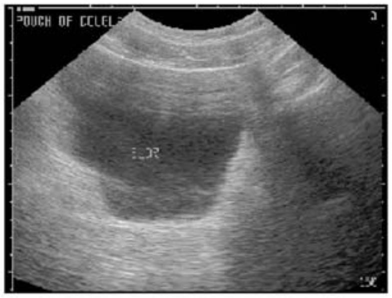
19. 


- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

ID: 1015

20.



- ☐ Normal (Negative)
- ☐ Abnormal (Positive)
- ☐ Inadequate to interpret
- ☐ Don't know

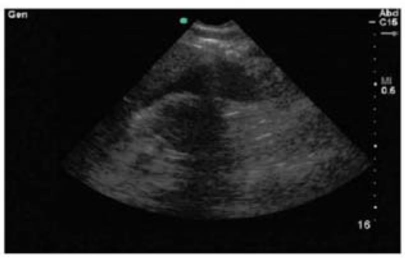
- ☐ RUQ
- ☐ LUQ
- ☐ Sub-Xiphoid
- ☐ Suprapubic
- ☐ Don't know

21.

- ☐ Normal (Negative)
- ☐ Abnormal (Positive)
- ☐ Inadequate to interpret
- ☐ Don't know

- ☐ RUQ
- ☐ LUQ
- ☐ Sub-Xiphoid
- ☐ Suprapubic
- ☐ Don't know

22.



- ☐ Normal (Negative)
- ☐ Abnormal (Positive)
- ☐ Inadequate to interpret
- ☐ Don't know

- ☐ RUQ
- ☐ LUQ
- ☐ Sub-Xiphoid
- ☐ Suprapubic
- ☐ Don't know

23.

- ☐ Normal (Negative)
- ☐ Abnormal (Positive)
- ☐ Inadequate to interpret
- ☐ Don't know

- ☐ RUQ
- ☐ LUQ
- ☐ Sub-Xiphoid
- ☐ Suprapubic
- ☐ Don't know

24. 

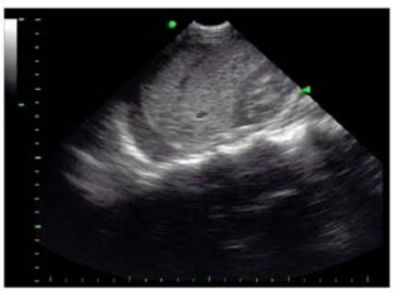
- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

25. 

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

26. 

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

27. 

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

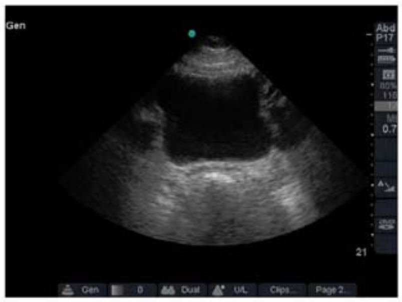
ID: 1015

28.

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

29.




- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

30.


- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

31.

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

**Please identify the type of ultrasound scanning artifact shown in the image.**

32.

- ❑ High attenuation
- ❑ Low attenuation
- ❑ Refraction
- ❑ Mirror Image
- ❑ Reverberation
- ❑ Don't know

33.

- ❑ High attenuation
- ❑ Low attenuation
- ❑ Refraction
- ❑ Rib Shadow/Image
- ❑ Don't know

34. Time now: ________________

ID: 1015

**BACKGROUND**

35. Age: ________ years

36. Gender: ❑ Male ❑ Female

37. Current position:
❑ Medical student
❑ Medical resident
❑ Physician
❑ Nursing student
❑ Other ______________

38. Specialty: ____________________________

39. MCAT Score: ________ ❑ N/A

40. **Not including today**, please describe your experience with ultrasound scanning procedures. Check all that apply.

❑ No training in ultrasound scanning procedures
❑ Lecture / classroom training. Date: _____________
❑ Hands-on practice. Date: ____________________
❑ Other:
Please describe:____________________________ Date: ___________

41. **Not including today**, how many hours of training on ultrasound procedures have you had?
❑ 0 hours
❑ 0 – 2 hours
❑ 2 – 4 hours
❑ 6 – 8 hours
❑ 8 – 10 hours
❑ More than 10 hours

Would you like to participate in this study as one of the model patients (the person getting scanned)? If so, please provide your contact information.

Would you like to participate in any future training studies? If so, please provide your contact information.

**THIS IS THE END OF THE STUDY.**

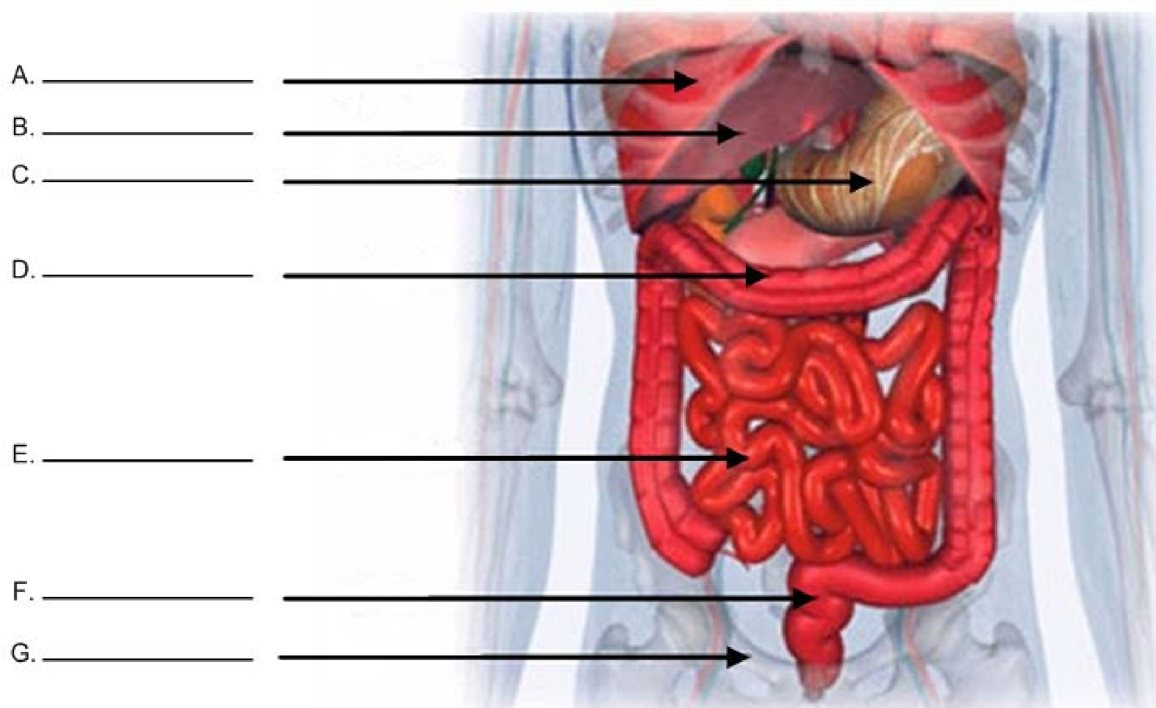
**Please hand your booklet to the researcher.**

**Thank you very much for participating.**

# APPENDIX B:

# PRIOR KNOWLEDGE OF ANATOMY ITEMS

13.



## APPENDIX C:

## PARTICIPANT FEEDBACK FORM

## Feedback on the Practice Session

**ID:** ___________

We would like to get your feedback on the ultrasound scanning practice you received in this study. By practice, we mean either the session where you and other trainees practiced scanning on a live patient, or the simulation practice where you used a computer to practice scanning a virtual patient.

We would appreciate your honest and candid comments—positive or negative.

1. How well did the ultrasound practice session (either with the simulator or in the group session) prepare you to perform a "real" ultrasound examination of a live patient?

   Only consider the **physical** aspect of scanning (i.e., manipulating the probe)

   ❑ Very inadequate amount of practice ❑ Inadequate amount of practice ❑ Adequate amount of practice ❑ Too much practice

   Please explain.

   Only consider the **acquisition of a scan window** aspect of scanning (i.e., being able to acquire a high quality window)

   ❑ Very inadequate amount of practice ❑ Inadequate amount of practice ❑ Adequate amount of practice ❑ Too much practice

   Please explain.

Only consider the **diagnostic aspect** of scanning (i.e., being able to identify normal or abnormal conditions)

- ❑ Very inadequate amount of practice
- ❑ Inadequate amount of practice
- ❑ Adequate amount of practice
- ❑ Too much practice

Please explain.

2. For questions like the one shown below on the posttest,

17.

- ❑ Normal (Negative)
- ❑ Abnormal (Positive)
- ❑ Inadequate to interpret
- ❑ Don't know

- ❑ RUQ
- ❑ LUQ
- ❑ Sub-Xiphoid
- ❑ Suprapubic
- ❑ Don't know

Which part of the training helped you the most to answer the above type of questions:

- ❑ The computer videos
- ❑ The practice session
- ❑ Both contributed equally
- ❑ Other ____________________

Please explain.

**PLEASE ANSWER THE FOLLOWING QUESTIONS ONLY IF YOU USED THE COMPUTER-BASED SIMULATOR**

3. What were the most useful features of the simulator?

4. How could the simulator be improved?

5. What would have helped you improve your performance conducting the FAST scan on today's patients?

| Indicate how much you AGREE with the following statements. | Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|---|
| 6. Practicing with the simulator prepared me to interpret the scans during the live patient test | 1 | 2 | 3 | 4 |
| 7. Practicing with the simulator prepared me to acquire the windows during the live patient test | 1 | 2 | 3 | 4 |
| 8. The simulator was effective in helping me interpret scans of different kinds of conditions | 1 | 2 | 3 | 4 |
| 9. The simulator was effective in helping me interpret scans of the different quadrants | 1 | 2 | 3 | 4 |

10. Having gone through today's training, I feel confident that I could perform a FAST scan (involving only the RUQ, LUQ, and suprapubic quadrants) with actual patients...

- ❑ With no further training
- ❑ With a few practice scans on a person
- ❑ With a training class on ultrasound scanning
- ❑ Other ____________________

Training Feedback.100716.docx Page 4 of 3

National Center for Research on Evaluation, Standards, and Student Testing

# APPENDIX D:

# PARTICIPANT COMMENTS

**How well did the ultrasound practice session prepare you to perform a "real" ultrasound examination of a live patient? Only consider the physical aspect of scanning:**

| ID | Comment |
|---|---|
| 1002 | It took 2 practice attempts, but I felt confident. |
| 1003 | The LUQ is harder to visualize and difficult to access when you're short. |
| 1004 | I think the instruction was great and I knew what I was supposed to do with the probe to obtain a good image, but more time personally using the transducer would be helpful. |
| 1005 | taught to handle probe |
| 1006 | not enough time to practice ID structures in LUQ & did not get to do it myself |
| 1008 | Need feedback from instructors on where to place probe & in which direction to rotate |
| 1009 | some of the images on a real patient (everything but bladder) were very difficult to obtain |
| 1011 | I know what I was looking for; hard to get right spot, the computer simulation was very helpful for a beginner. |
| 1012 | I had no idea where to initially place probe. What landmarks to use in computer simulator probe was already in location just had to move it up/down right/left to get image in better view. |
| 1013 | I couldn't do an UTZ at all before today & simulator I practice + learned enough to be able to do it. |
| 1014 | I think it would have been more helpful if we had practice placing the probe onto the patient instead of having it already in place and only being able to change the angle. When I did the procedure on the patient, it was hard for me to know where to put the probe. |
| 1017 | It was hard to extrapulate to the exam because the patients were different and we were only able to practice on a single person. |
| 1018 | very helpful |
| 1021 | no variation of subjects during practice session made it difficult to perform the same test on new patient |
| 1023 | Did not allow for initial approach to find the proper spot at the probe was already in the right spot (i.e. LUQ) |
| 1024 | Good practice, very helpful! |
| 1025 | I had computer practice and had trouble locating the anatomical landmarks on the patient because I had no practice doing this. |
| 1026 | I wish we had more time with using the probe and better manipulation hands-on teaching. |
| 1027 | The only other thing would be allowing the student to place the probe on the patient in the simulator, instead of having a fixed spot. |
| 1028 | In our practice session we were never told how to actual hold and manipulate the probe (i.e. no feedback from instructor upon review of our answers) |
| 1029 | I felt it was easier on the simulator. I was very uncomfortable doing it on the patient |
| 1031 | Nothing is quite like the real thing. There are no borders or artificial transducer constraints in the real live scenario and that makes things difficult. |
| 1032 | Range of manipulation of the probe is too limited in simulator. |
| 1033 | 1. The simulator provided already correct location of probe placement when placed in front of live patients, harder to get correct location. 2. Manipulation of probe had a different feeling on real person |

| ID | Comment |
| --- | --- |
| | vs. computer. |
| 1035 | I needed a little more time just to play with the machine and get comfortable with it. I improved, but I still wouldn't feel comfortable with a real patient. |
| 1038 | couldn't quite tell abnormal |
| 1039 | There is no replacement for holding the probe/muscle memory. |
| 1040 | actual practice >> computer tutorial |
| 1042 | The practice session being simplified in simulator fashion really helped me get my bearings with major structures and "which way's up." |
| 1043 | I'm good at reading scans but not at knowing where to place the actual transducer. |
| 1045 | It was good practice with orientation. |
| 1046 | Need someone to answer questions |
| 1047 | I felt comfortable moving the probe but was not always sure I was at the right height. |
| 1049 | The probe in the simulator only moves in a fixed axis so it is hard to figure out up & down movements, etc. |

**How well did the ultrasound practice session prepare you to perform a "real" ultrasound examination of a live patient? Only consider the acquisition of a scan window aspect of scanning:**

| ID | Comment |
|---|---|
| 1001 | some more techniques and tricks could have been emphasized i.e. how to get around the rib shadows |
| 1002 | It took 2 practice attempts, but I felt confident |
| 1003 | LUQ hard to visualize |
| 1004 | This is very dependent on the window I was acquiring. The landmarks for the right upper quadrant and suprapubic views were easy to obtain, while left upper quadrant was difficult for me. |
| 1005 | need smaller group & more hands on |
| 1006 | should let us experiment with moving the probe more--especially in LUQ since the location of the spleen varies |
| 1008 | did not get to practice changing settings (e.g. gain, depth, etc.) |
| 1009 | some of the images on a real patient (everything but bladder) were very difficult to obtain |
| 1011 | The computer simulation made me feel much more confident on what a good window was. |
| 1012 | The simulator was good at helping me refine this skill. |
| 1013 | I practiced & learned to improve simulator which allowed me to get better for real person. |
| 1014 | I think it was helpful to get feedback and redo it if I didn't get a good quality window. |
| 1017 | same as above |
| 1018 | very easy on practice patient, hard on test patient |
| 1023 | allowed feedback to proper window |
| 1025 | The computer program prepared me well for this. |
| 1026 | Scanning got easier throughout the process. |
| 1027 | more time. |
| 1028 | Ultrasound is a hard skill to learn, and an hour practice with no feedback didn't teach me how to adequately obtain a proper window. I just kept on teaching myself either the wrong way to go about it (or eventually teaching myself how to acquire window). |
| 1029 | I found it hard. |
| 1031 | Its easy to do in the simulation because eventually if you move your transducer around enough you'll find a window that looks like the examples. On the real patient I didn't even know where exactly to place the transducer. |
| 1032 | The feedback received during the simulation was useful. |
| 1033 | same reasons as above |
| 1035 | This was tougher than it looks. I definitely need more practice. |
| 1036 | the depth/gain setting were set for us… we didn't have to set them ourselves |
| 1037 | Didn't actually get to turn nobs and adjust window myself |
| 1040 | Takes physical practice to acquire a handle on the probe to get a feel for the slight movements in hand |

| ID | Comment |
|---|---|
| | motion w.r.t. what appears on the screen. |
| 1042 | I knew generally what I was looking for after the simulator and how to move the transducer, however, it was much more challenging on a real patient! |
| 1043 | It's luck. If I find the major landmark, I can do it well. Finding the major landmark is hard. |
| 1044 | On the practice session, the probe was already placed at a position where it was only able to rotate & not move much. On a real patient, I would be unsure of where to place the probe if it were the 1st time. |
| 1046 | Video goes through it very quickly |
| 1047 | I was confident that I could find an appropriate scan window if I found the right location. |
| 1049 | Same as above, other movements simulator doesn't allow. Also how hard to press, etc. |

**How well did the ultrasound practice session prepare you to perform a “real” ultrasound examination of a live patient? Only consider the diagnostic aspect of scanning:**

| ID | Comment |
|---|---|
| 1001 | would have been nice to practice on an abnormal or multiple normals first to get a sense of anatomic variation |
| 1002 | No abnormal findings during practice sessions. |
| 1003 | We don't really know what normal is, just that we're looking for anechoic |
| 1004 | Again, just because we didn't practice finding abnormal. On the other hand, I think the tutorials did a good job preparing us to know what to look for. |
| 1005 | 1st time seeing it. Just learned what normal looks like-but it can vary. |
| 1006 | Difficulty w/LUQ in different patients |
| 1007 | More explanations of abnormal results would have been helpful. |
| 1008 | sometimes can't tell difference between artifact & actual pathology |
| 1009 | I still feel I need practice identifying 1. anatomy and 2. normal v. abnormal |
| 1011 | I thought I did pretty well, but of course, there are so many abnormalities I still don't know. But for what was taught, I thought I got it. |
| 1012 | Computer simulator allowed me the opportunity to see many variations of normal and abnormal which I believe is key to becoming comfortable with interpreting images and making diagnosis. |
| 1013 | I practiced & learned to improve simulator which allowed me to get better for real person. |
| 1014 | It would have been more helpful if we had more "abnormal" sample images to look at. Also, it would have been nice if we could look at the sample image before choosing a diagnosis. |
| 1017 | We did not look at enough abnormal scans to be able to successfully interpret abnormal findings |
| 1021 | with a good picture quality it is adequate |
| 1022 | video adequate, live patient practice was inadequate |
| 1023 | some difficult cases allowed continuous feedback our our dx skills |
| 1025 | I did not see enough normals/abnormals to feel confident. Also I had no idea how to determine severity (minimal, moderate, severe). |
| 1026 | Just need to be able to get a better picture & see more examples to be more proficient. |
| 1027 | Need more time to continously experience multiple examples. |
| 1028 | Again, no feedback, I didn't know the diagnostic criteria for fluid quantity. Hard to differentiate among minimal/moderate/severe. |
| 1029 | I wasn't sure in my diagnosis= |
| 1030 | Needed more feedback or examples of abnormal US scans either in the videos or from computer simulator. |
| 1031 | I think this kind of thing takes many years to training to fully be able to identify abnormal vs. normal. |
| 1032 | Would have been useful to know what we were supposed to find after submitting our images. More feedback would be good. |

| ID | Comment |
|---|---|
| 1033 | Harder to come to diagnosis when difficult to obtain correct window scan. |
| 1034 | It would have been helpful to go over some abnormal images with the trainer |
| 1035 | I felt comfortable noticing abnormalities on adequate images |
| 1036 | There is a lot of anatomical variability… practicing on more sick patients would have been helpful |
| 1037 | Although, I wasn't sure to call what appeared to be ascites anterior to liver/kidney abnormal--it is but not sure if it was asking for Morrison's pouch as abnormal |
| 1038 | Couldn't see abnormal on real patient. Need more. |
| 1039 | I need to see more abnormal. |
| 1040 | Need to see quite a bit of normals prior to feeling super confident about an abnormal |
| 1041 | For the three views trained, I felt comfortable. However the paper exam had many images I could not identify. Either these are of different views/organs, or I was inadequately trained. |
| 1042 | Seeing the standard images to compare with what I saw really helped! |
| 1043 | I'm confident, but not yet overconfident. |
| 1046 | Artifacts were not explained sufficiently. |
| 1047 | The simulations provided good practice of recognizing both normal and abnormal cases. |
| 1049 | The simulator did this well. |

**Which part of the training helped you the most to answer the above type (posttest) questions? Please explain.**

| ID | Comment |
| --- | --- |
| 1017 | both types of training were helpful. |
| 1021 | mainly due to being a visual learner |
| 1023 | more didactic & good window was already given to us |
| 1025 | But both are important! |
| 1028 | Through trial and error, got to see what are minimal/moderate/severe cases. |
| 1029 | I felt the picture and the simulator looked similar. |
| 1031 | You had time to screw around and appreciate the anatoy in the computer simulations, whereas with the live patients we were being timed and I was also trying to hurry to minimize patient discomfort. |
| 1032 | Both parts were critical to understanding ultrasound procedure. |
| 1033 | There were photos of normal--abnormal conditions. I learned most when I was able to see all of those at one time and able to compare and see where differences lie. |
| 1039 | I remember better if I do it with my hand. |
| 1041 | I would agree the computer helps more because you can see more images/comparisons. However, hands on permits better spatial understanding, which judged essential for interpreting an image. |
| 1042 | The video helped me understand basics, but the simulator helped me begin to identify the visual patterns of the structures. |
| 1043 | I needed the computer and the practice making judgment calls from the session. |
| 1045 | good pictures, examples |
| 1046 | The same image was on computer test. |
| 1047 | The computer video showed me what to look for and the simulation helped me gain confidence in my ability to make accurate diagnoses. |
| 1049 | The simulator allowed some manipulation of movements. |

**What were the most useful features of the simulator? [Experimental group only]**

| ID | Comment |
|---|---|
| 1023 | feedback: instructor and self |
| 1024 | real-time visualization + positioning |
| 1025 | It was excellent, actually. The repetition, accurate probe, and continually comparing your image to standards was very helpful. |
| 1026 | Just getting used to manipulating the probe in relation to the body. |
| 1027 | multiple rounds of practice--getting feedback as to correct/incorrect and quality of scan; helpful seeing the scan with rays to know where/what you are looking at in the body. The skeleton overlay was great for that. |
| 1028 | Ability to practice manipulating the ultrasound probe in the right positions (getting comfortable with US basically); acquiring window practice |
| 1029 | I could spend a lot of time on each one. |
| 1030 | good opportunity to learn how to manipulate the probe. |
| 1031 | The fact that there was somebody to check my work. |
| 1032 | Being able to see an image very clearly with movement of the probe. |
| 1033 | 1. seeing what adequate scan window was. 2. practice manipulation of probe--especially in small movements |
| 1042 | The normal/abnormal images for comparison. |
| 1043 | quick cases, easy to pick up |
| 1044 | the multiple cases of the practice session |
| 1045 | layers |
| 1046 | It's sensitivity to motion. The images were similar to live patients. |
| 1047 | the ability to manipulate the probe in real time |
| 1048 | the layers, the comparison images |
| 1049 | Identifying abnormalities |

**How could the simulator be improved? [Experimental group only]**

| ID | Comment |
|---|---|
| 1023 | let us more inferiorly/superiorly/laterally |
| 1024 | if the sonographer could give comments. Also, having less concentration on severe v. moderate v. minimal, more important to identify (+ measure with ruler?) fluid collection than give exact severity |
| 1025 | can't think of anything. It's great! |
| 1026 | More time with the simulator. |
| 1027 | At first, having a fixed scan position is great for getting the hang of it. But perhaps with time, the simulator could make you place the probe yourself. |
| 1028 | At the moment the simulator can only be rotated to different views but cannot be manipulated (moved) superior/anterior when doing RUQ/LUQ exam and medial/lateral during suprapubic exam |
| 1030 | allow translational movement in real space |
| 1031 | Make the user responsible for positioning of the transducer on the patient's body. |
| 1032 | Allow for lateral movement of the probe, rather than just "fanning." |
| 1033 | It's good as is. It was fun & very informative. If they can give answer at the end of each case and outlined organs and abnormality--that would be very educational. |
| 1042 | In addition to the "normal" and "abnormal" standard images, also show a "best window" image for that same case! This would help me know what I could have done better (& label it!) |
| 1043 | Don't limit the field of view based on what's right. |
| 1044 | perhaps using a fake human body so we can orient ourselves better |
| 1045 | change gain, more accurate with respect to layers, shadowing. |
| 1046 | Provided as an adjunct to class. |
| 1047 | provide analyses of what the student should see after each case |
| 1048 | ability to see orientation of probe for RUQ, larger probe size (similar to real) |
| 1049 | more movements & different pressures. No fixed axis. |

**What would have helped you improve your performance conducting the FAST scan on today's patients? [Experimental group only]**

| ID | Comment |
|---|---|
| 1023 | the expert allowed to teach us as we go |
| 1024 | more time to practice, also trying at least once on a real patient first |
| 1025 | I think the best way to instruct med students would be to do the simulator and then receive some live teaching. The simulator really helps but I was unsure where to place the probe, how to solve problems, and how hard to press. I had a lot of questions and had no one to answer them. |
| 1026 | Again a little more time with hands-on teaching while using the simulator |
| 1027 | More time. Simulator was great, just needed more practice. More "real" patient practice, too. |
| 1028 | Having an instructor there telling me if I have acquired appropriate image, since I have so little experience with US. |
| 1029 | more practice on the simulator |
| 1030 | knowing history of patient |
| 1031 | Knowing where to place the transducer and not having somebody standing there timing me. |
| 1032 | Live feedback from a clinician. |
| 1033 | Practice session + teaching session on live patients after simulation. The simulator got us familiar with using an ultrasound. What was needed (at least for me) was someone there to instruct & correct me when conducting scans on real patient. |
| 1042 | Practicing on a patient some (especially with feedback from an instructor!) |
| 1043 | more patient time |
| 1045 | actual patient |
| 1046 | Having an actual instructor rather than an evaluator |
| 1047 | more practice using the probe without a limited range of motion. |
| 1048 | feedback during exam of real patient |
| 1049 | Practice on patients. Also, didn't realize till part way through the exam that the probe has things that look like indicators on both sides, so I had trouble with it. |

**APPENDIX E:**

**PICTURE OF A CLASSROOM PRACTICE SESSION**

# APPENDIX F:

# PICTURE OF THE LAB SETUP

## APPENDIX G:

## CLASSROOM PRACTICE OBSERVATION FORM

### Classroom Practice Observation Sheet

**Date / Time:** _______ / _______ **Instructor ID:** __________ **Researcher:** __________

| ID | Quadrant | Time to Scan | Notes |
| --- | --- | --- | --- |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |
| | ❑ RUQ ❑ LUQ ❑ Suprapubic | | |

Page: 1

## APPENDIX H:

## PERFORMANCE TEST OBSERVATION FORM

**Date / Time :** _______ / _______

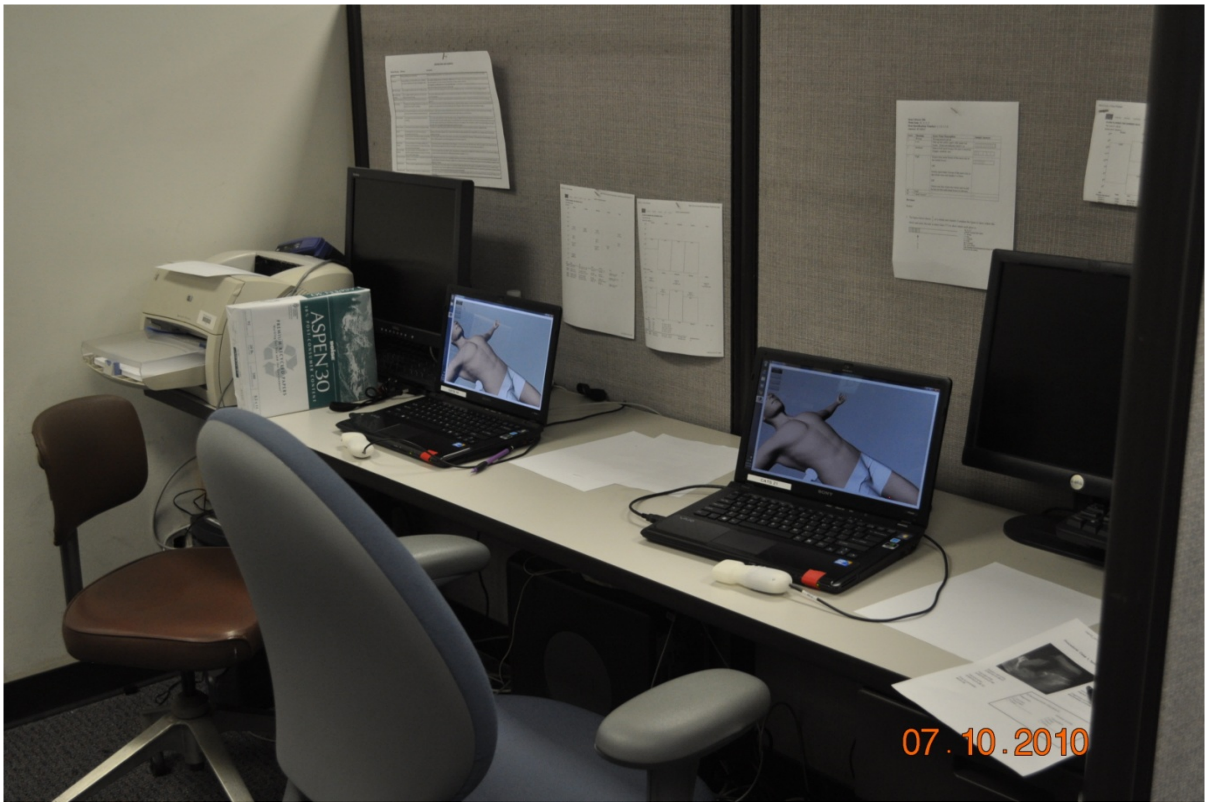
**Participant ID:** ________

**Researcher:** ________

| **UltraSound Machine:** ❑ MicroTurbo ❑ SonoSite | | | **Patient Table:** ❑ 1 ❑ 2 |
|---|---|---|---|
| **Quadrant** | **Diagnosis** | **Time to scan** | **Notes** |
| **RUQ** | ❑ Normal / negative<br>❑ Abnormal / positive<br>❑ Cannot acquire window | | |
| **LUQ** | ❑ Normal / negative<br>❑ Abnormal / positive<br>❑ Cannot acquire window | | |
| **Suprapubic** | ❑ Normal / negative<br>❑ Abnormal / positive<br>❑ Cannot acquire window | | |

## APPENDIX I:

## PICTURE OF THE SIMULATION SETUP



# APPENDIX J:

# SIMULATION USER INTERFACE SCREENSHOTS

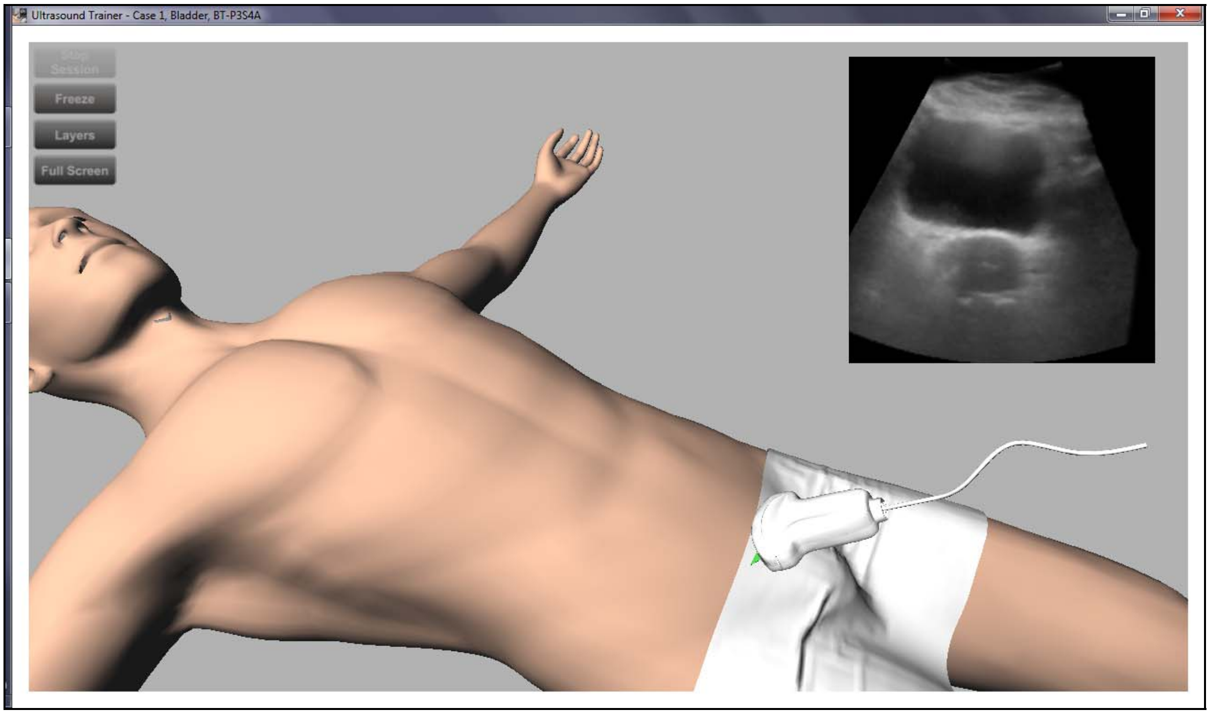



*Figure 1*. Screenshot of ultrasound simulator (suprapubic quadrant [bladder]).

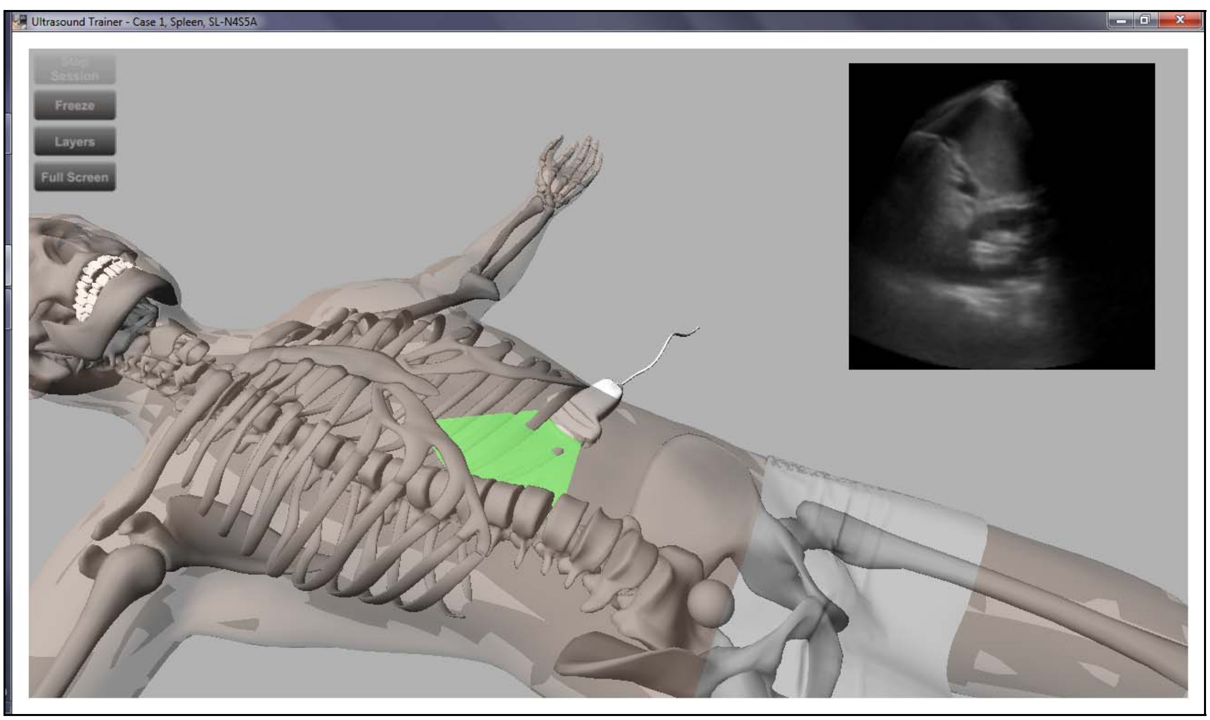


*Figure 2*. Screenshot of ultrasound simulator (LUQ/spleen) with layers shown.

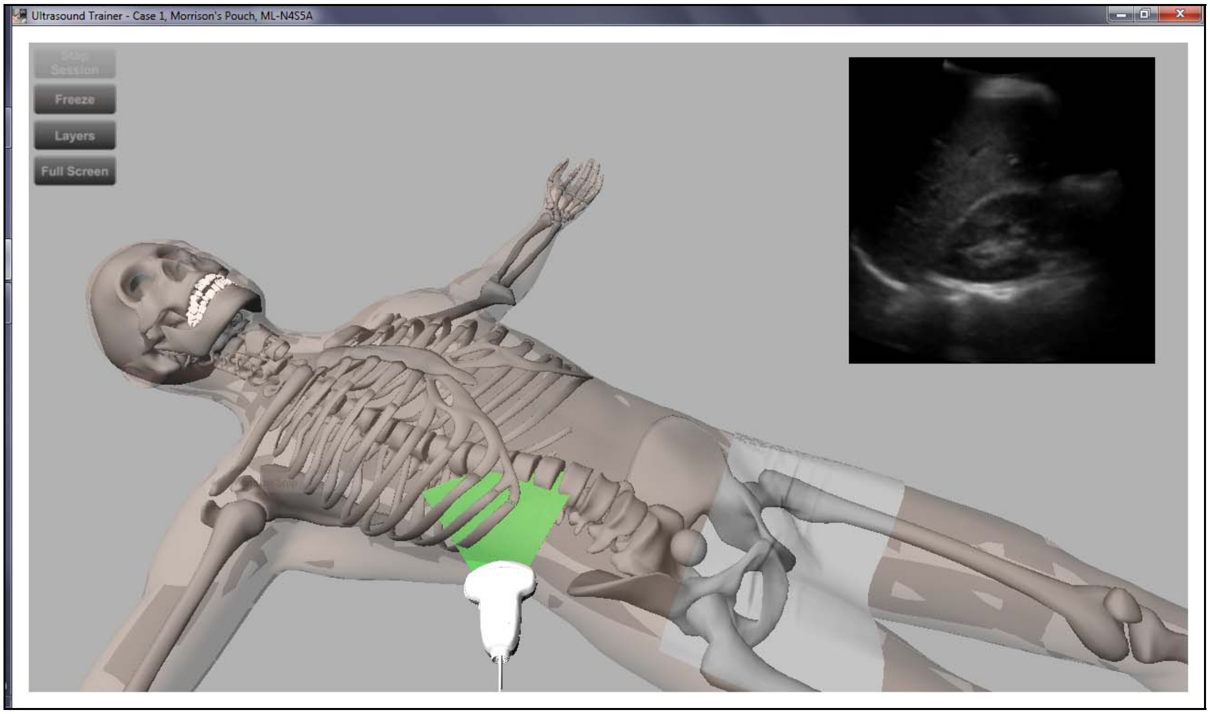



*Figure 3*. Screenshot of ultrasound simulator (RUQ/Morrison's pouch) with layers shown.

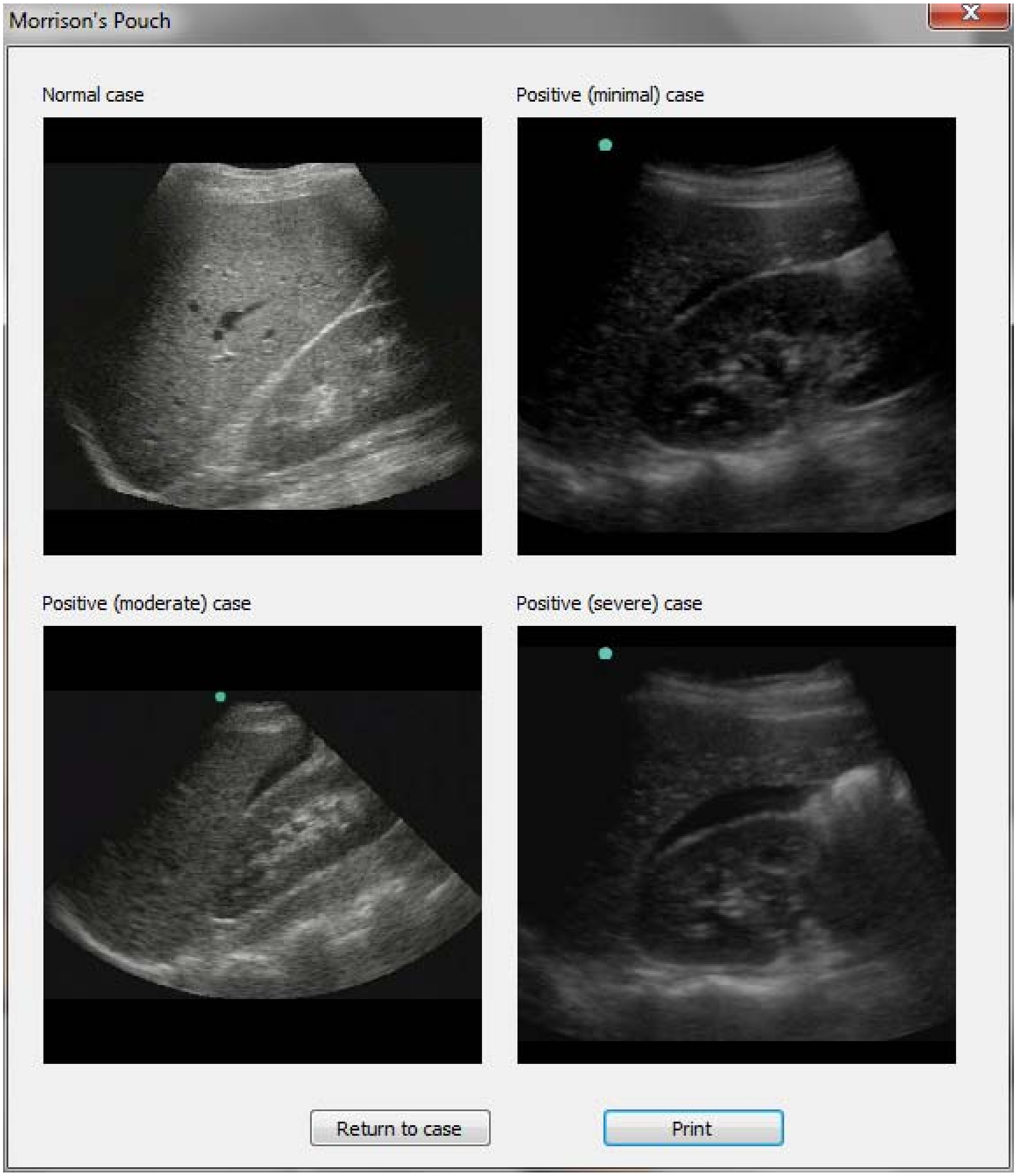



*Figure 4*. Screenshot of scans (normal, various positive) that participants could use to compare his or her scan. Displayed after participant submitted his or her diagnosis.

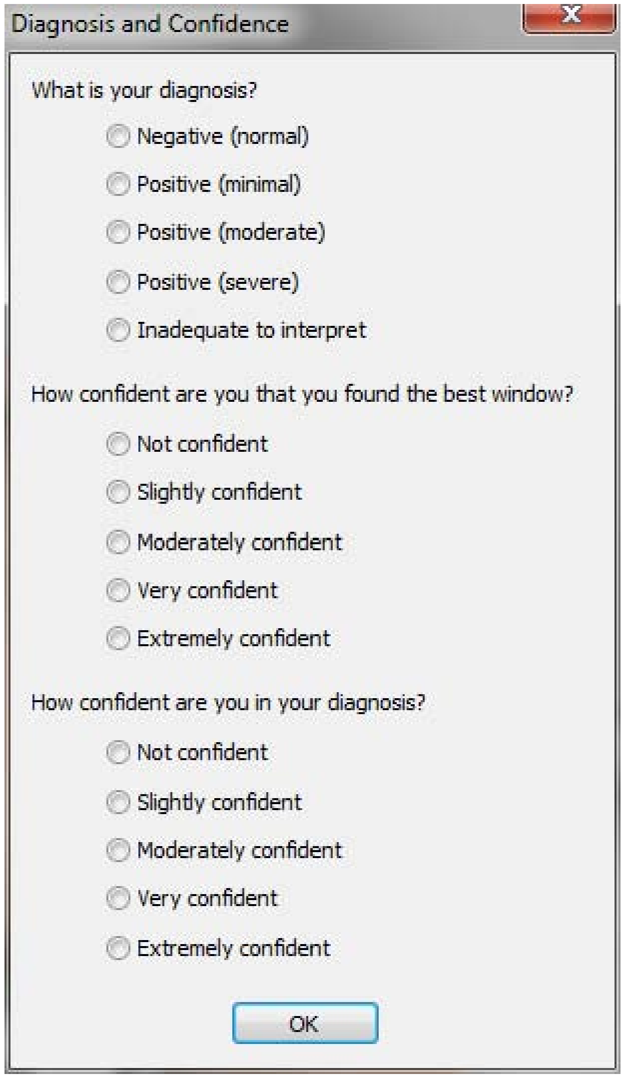



*Figure 5*. Screenshot of prompt for the participant's diagnosis and confidence ratings.

## APPENDIX K:

## SIMULATION CONDITION DIRECTIONS

**Task**

Use the simulator to practice (a) ultrasound scanning and (b) diagnosing the presence of free fluid in the abdomen.

You will have 1 hour to practice scanning 10 virtual patients.

For each patient, you will practice scanning and diagnosing three cases:

Case 1: Morrison's Pouch

Case 2: Suprapublic

Case 3: LUQ (left upper quadrant)

**Feedback**

An expert sonographer will evaluate your diagnosis, the quality of your scan window, and determine whether you can move to the next case.

The sonographer will not explain the evaluation or provide any other feedback – this is intentional and part of the research study.

Remember to **carefully compare your scan with the 4 computer-generated scans** showing

(a) negative/normal

(b) positive/moderate

(c) positive/severe

(d) inadequate to interpret

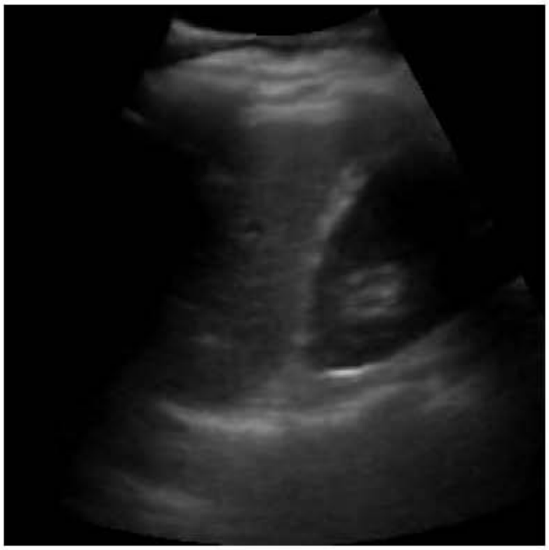
**APPENDIX L:**

**ULTRASOUND SIMULATION REPORT**

1046_20100918_123758_4C951516_0023.pdf

**1046**
**Trial 1**

**Procedure: Case 6, Spleen, SL-N3S2A**



STUDENT EVALUATION

Diagnosis: **Negative (normal)**

Window confidence level:
**Very confident**

Diagnosis confidence level:
**Very confident**

Session start time:
**09/18/10 12:37:58**

Trial start time:
**09/18/10 13:37:40**

Trial end time:
**09/18/10 13:38:16**

Time to complete:
**00:00:36**

SONOGRAPHER FEEDBACK

Diagnosis:

- ☐ Correct
- ☐ Incorrect
- ☐ Other ____________

Window quality:

- ☐ Excellent
- ☐ Fair
- ☐ Poor
- ☐ Other ____________

## APPENDIX M:

## SONOGRAPHER FEEDBACK FORM

# 1025

Patient 1: Normal




| RUQ: Normal | LUQ: Cannot acquire window | SP: Normal |
|---|---|---|

## Sonographer Feedback:

Diagnosis:
- ❑ Correct
- ❑ Incorrect
- ❑ Other ________________

Window Quality:
- ❑ Excellent
- ❑ Fair
- ❑ Poor
- ❑ Other _________________

Diagnosis:
- ❑ Correct
- ❑ Incorrect
- ❑ Other ________________

Window Quality:
- ❑ Excellent
- ❑ Fair
- ❑ Poor
- ❑ Other _________________

Diagnosis:
- ❑ Correct
- ❑ Incorrect
- ❑ Other ________________

Window Quality:
- ❑ Excellent
- ❑ Fair
- ❑ Poor
- ❑ Other _________________