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### Authors

Shah, Sagar  
Tohmaji, Steven  
Frisch, Emily  
et al.

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## Original Article

# A comparison of simulation versus didactics for teaching ultrasound to Swiss medical students

Sagar Shah<sup>1</sup>, Steven Tohmasi<sup>1</sup>, Emily Frisch<sup>1</sup>, Amanda Anderson<sup>1</sup>, Roy Almog<sup>1</sup>, Shadi Lahham<sup>2</sup>, Roland Bingisser<sup>3</sup>, John C. Fox<sup>2</sup>

<sup>1</sup> School of Medicine, University of California, Irvine, USA

<sup>2</sup> Department of Emergency Medicine, University of California Irvine, Irvine, USA

<sup>3</sup> University Hospital Basel, Basel, Switzerland

Corresponding Author: Shadi Lahham, Email: slahham@uci.edu

**BACKGROUND:** Point-of-care ultrasound is an increasingly common imaging modality that is used in a variety of clinical settings. Understanding how to most effectively teach ultrasound is important to ensure that medical students learn pre-clinical content in a manner that promotes retention and clinical competence. We aim to assess the effectiveness of simulation-based ultrasound education in improving medical student competence in physiology in comparison to a traditional didactic ultrasound curriculum.

**METHODS:** Subjects were given a pre and post-test of physiology questions. Subjects were taught various ultrasound techniques via 7 hours of lectures over two days. The control group received 2 additional hours of practice time while the experimental group received 2 hours of case-based simulations. A physiology post-test was administered to all students to complete the two-day course.

**RESULTS:** Totally 115 Swiss medical students were enrolled in our study. The mean pre-course ultrasound exam score was 39.5% for the simulation group and 41.6% for the didactic group ( $P>0.05$ ). The mean pre-course physiology exam score was 54.1% for the simulation group and 59.3% for the didactic group ( $P>0.05$ ). The simulation group showed statistically significant improvement on the physiology exam, improving from 54.1% to 75.3% ( $P<0.01$ ). The didactic group also showed statistically significant improvement on the physiology exam, improving from 59.3% to 70.0% ( $P<0.01$ ).

**CONCLUSION:** Our data indicates that both simulation curriculum and standard didactic curriculum can be used to teach ultrasound. Simulation based training showed statistically significant improvement in physiology learning when compared to standard didactic curriculum.

**KEY WORDS:** Ultrasound education; POCUS; Switzerland; Medical education

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## INTRODUCTION

Point of care ultrasound (POCUS) is an increasingly common diagnostic imaging modality that is used in a variety of clinical settings. Over the past few decades, ultrasound machines have become more affordable, compact, and powerful. POCUS has been shown to offer physicians a rapid form of initial assessment without harmful effects. Several studies have demonstrated the potential for long term clinical skills.<sup>[1,2]</sup> As the utility

and scope of POCUS expands, it is important to ensure that physicians are competent with this technology and have a good understanding of the abilities and limitations of this imaging modality.

Many medical schools have begun integrating ultrasound education into their medical school curriculum.<sup>[3,4]</sup> Jamniczky et al<sup>[5]</sup> surveyed 108 medical students from such programs and found that students perceived learning and interpreting ultrasound images

to be of “high cognitive load”. The training required to become proficient in interpreting ultrasound images has, therefore, understandably placed focus on anatomy and structure identification. To date, many studies measuring the efficacy of ultrasound education in medical school curriculum have done so in the context of anatomy.<sup>[6]</sup> While anatomy is important in understanding ultrasound, POCUS machines also produce irremediable artifacts that are as conceptually difficult to understand as they are diagnostically significant. The interpretation of such an imaging modality leaves significant room for user error.

Given the increased utilization of POCUS in the clinical setting, it is important to introduce this skill during medical education. Many programs have attempted to integrate ultrasound into the anatomy portions of their curriculum.<sup>[6]</sup> However, measures of the efficacy of ultrasound education in anatomy are equivocal.<sup>[7]</sup> Currently, assessments of the efficacy of ultrasound education in improving competence in physiology is lacking. Furthermore, simulation-based medical education is becoming a highly touted strategy to improve clinical competence and patient safety and is perceived by medical students to be a highly positive educational experience.<sup>[7-9]</sup>

The objective of this study is to assess the efficacy of a simulation-based ultrasound education curriculum for medical physiology. We hypothesize that pre-clinical medical education is heavily classroom based. Thus, greater emphasis is placed on memorization rather than understanding. By placing students in simulated clinical scenarios and engaging them in ultrasound material, we hypothesize that medical students would retain more ultrasound knowledge, have an improved understanding of the associated physiology of each exam and would perceive the educational content to be of greater value than content taught in the standard didactic style.

## **METHODS**

### **Study design**

We performed a prospective, observational study using a convenience sample of subjects recruited from the University of Basel Medical School in Basel, Switzerland. The study was approved by the Institutional Review Board (IRB) with the support of University of Basel Medical School administration. Each participant provided verbal, informed consent before participating in the study. Study participants were randomly divided into eight cohorts and each cohort was enrolled in a two-day, focused ultrasound

course. The study spanned a period of four weeks with two full courses taking place per week.

### **Study protocol**

#### **Subject recruitment**

Research participants were recruited to participate in a focused ultrasound training course at the University of Basel via internal email correspondence prior to the arrival of the research team. A total of 116 students were approached for enrollment. Among them, 39 were male and 76 were female. One student was unable to complete the second day of the course and was thus excluded from the analysis. The 115 study subjects included medical students from the University of Basel Medical School, University of Zurich Faculty of Medicine, and University of Bern Faculty of Medicine. Medical education in Switzerland consists of six years of training after completion of secondary school and completion of a qualifying examination. Study participants were in various stages of their medical education. All research participants were provided with detailed information regarding the purpose and design of the study. Each research participant voluntarily enrolled in this study and attended the corresponding ultrasound education sessions. Participant privacy was protected by de-identifying all personal information using assigned, study-specific codes.

#### **Study site details**

The research study took place over a period of 4 weeks in July 2018 at the University of Basel Hospital in Basel, Switzerland. Study participants took part in a two-day focused medical ultrasound course over this time period. Half of the participants were randomly assigned to the didactic ultrasound education group while the other half received simulation-based ultrasound education. Prior to initiation of the ultrasound curriculum, all participants were given two separate pre-course examinations to determine baseline ultrasound and physiology competency, respectively. The same examinations were given again as at the conclusion of the teaching course to assess for differences in ultrasound and physiology competency. Education and testing were done in English.

#### **Course instructor preparation**

Courses were administered by U.S. based allopathic medical students who had successfully completed their first year of medical education. Participating medical students served as course instructors as part of a student

organized international trip to Switzerland taking place in the summer between the first and second years of their medical education. All participating medical students satisfied all mandated requirements to complete the first-year medical school curriculum. More specifically, all participating medical students achieved passing grades in human physiology, anatomy, and POCUS. As part of the POCUS curriculum, first-year medical students received ten hours of hands-on training in a small group setting. Medical students also were required to view pre-recorded lectures that taught POCUS imaging of various organ systems. First-year medical students received lectures and hands-on training on topics such as ultrasound physics and instrumentation, cardiac, hepatobiliary, renal, pulmonary, vascular, pelvic, and musculoskeletal ultrasound. Students were evaluated with multiple written examinations to assess POCUS competence throughout their first-year of medical school. A final grade of 70% or greater for each system was required to achieve a passing grade in the clinical foundations course.

All participating medical students also underwent an additional 4-hour training to simulate pre-designed clinical vignettes using standardized models. Instructors were trained on the pathognomonic signs and symptoms of particular diseases in order to role-play realistic presentations of a given clinical scenario for students receiving simulation-based ultrasound education. A total of nine unique simulation cases were presented.

### **Ultrasound curriculum**

Study participants were randomly divided into eight cohorts and each cohort was enrolled in a two-day, focused ultrasound course. All instruction was provided in English. The study spanned a period of four weeks with two 2-day courses taking place per week for a grand total of 8 classes. The focused ultrasound course covered basic ultrasound principles including ultrasound physics and instrumentation, pulmonary ultrasound, abdominal/gastrointestinal ultrasound, cardiac ultrasound, and Focused Assessment with Sonography for Trauma (FAST). The material was presented in PowerPoint format and included diagrammatic, video, pictorial, and textual content centered on spatial orientation, pathology, physiology, and physical concepts. The first day consisted of presentations on basic concepts, the abdominal exam, and the pulmonary exam. The second day consisted of cardiac and FAST scans. Following each 30-minute presentation, one hour was allotted for small group hands-on training with the presented materials. For the hands-on portions, scans were performed using

the following portable ultrasound units: Konted C9 Plus, Hitachi Aloka Noblus, and Hitachi EUB-5500. All students became proficient in using the phased array, curvilinear, and linear transducers. Following the two presentations and the two hands-on sessions, the didactic group (control group) received additional didactic ultrasound instruction for 1 hour while the simulation group (experimental group) received case-based simulation instruction for 1 hour.

The didactic group was allowed to move between several stations, each manned by an instructor. The students were given the freedom to practice any scans covered during the day. As students practiced various scans, instructors were to review associated physiology concepts. The instructors covered the same concepts underlying the case-based instruction that the simulation group was receiving. The simulation group rotated through several stations at which pairs of instructors acted out a clinical scenario. One instructor acted as the patient while the other moderated the scenario, providing necessary clinical details and interjecting when necessary to ask questions or provide instruction. The moderator reviewed associated physiology as the cases unfolded. Students developed a short differential at which point they were allowed to perform whichever ultrasound exam they saw fit. Instructors then showed videos of pathophysiological ultrasound findings to bring the case to a close. Instructors rotated weekly between didactic and simulation groups to minimize bias due to instructor variation.

### **Assessment**

Prior to the course, a 20-question multiple-choice physiology exam was given along with a 30-question multiple-choice ultrasound competency exam. At the conclusion of the focused ultrasound course, the same two examinations were again administered to evaluate each participants' mastery of ultrasound and physiology (Figures 1 and 2). Additionally, participants were asked to rate their comfort level of using ultrasound in their future medical practice and to rate the perceived value of course content on a scale of 1 (lowest) to 5 (highest). The question asked students to respond to the statement "I would feel comfortable using ultrasound in my future practice of medicine". A response of 1 meant they "strongly disagreed", a response of 2 meant they "disagreed", a response of 3 meant they felt "neutral", a response of 4 meant they "agreed", a response of 5 meant they "strongly agreed". Subjects were graded with a composite of their performance on the final ultrasound and physiology examinations. A cumulative grade of

65% qualified as a “pass”. Any score of 64% or lower was considered a “fail”.

### Data collection and statistics

We collected data from the pre-course examination, post-course examination, demographic survey, and perceived value content survey. Data was analyzed separately for the control and experimental groups. Pre- and post-course examination scores of both groups were then compared using a student's *t*-test. A *P*-value of <0.05 was used to determine statistically significant improvement in the mastery of physiology and/or ultrasound between the control and experimental group. All *t*-tests were two-tailed and assumed non-equal variances between groups.

## RESULTS

A total of 115 participants were included in the study. The year in medical school of participants ranged from year 1 to year 6. About 33.9% of participants were male and 66.1% of participants were female (Table 1). Fifty-five participants were randomized to the didactic (DID) group and 60 participants were randomized to the simulation (SIM) group. One participant was unable to complete the ultrasound course in its entirety, and was excluded from the statistical analysis.

Following randomization, the average year in medical school was 2.28 for the SIM group and 2.50 for the DID group ( $P>0.05$ ). The mean pre-course ultrasound exam score was 39.5% for the SIM group ( $n=60$ ) and 41.6% for the DID group ( $n=55$ ) ( $P>0.05$ ). The mean pre-course physiology exam score was 54.1% for the SIM group and 59.30% for the DID group ( $P>0.05$ ). When asked to subjectively assess individual comfort with ultrasound techniques, the average response was 2.7 out of 5 for the SIM group and 2.5 out of 5 for the DID group ( $P>0.05$ ). These results demonstrate that prior to the ultrasound course, there were no statistically significant differences in level of education, knowledge of physiology or ultrasound, or familiarity with ultrasound machines between SIM and DID groups.

Following the two-day course, all students were

re-administered the same ultrasound and physiology exams. All participants of the simulation group and of the didactic group achieved passing grades on both examinations. The simulation group showed statistically significant improvement on the physiology exam, going from a pre-test average of 54.12% to a post-test average of 75.32% ( $P<0.01$ ). The didactic group also showed statistically significant improvement on the physiology exam, going from a pre-test average of 59.30% to a post-test average of 70.00% ( $P<0.01$ ). These improvements correspond to an average improvement of +21.20% and +10.70% for the SIM and DID group respectively. The magnitude of improvement of the SIM group was significantly greater than that of the DID group ( $P<0.01$ ). The simulation group demonstrated statistically significant improvement on the ultrasound exam, going from a pre-test average of 39.5% to a post-test average of 71.6% ( $P<0.01$ ). The didactic group also showed significant improvement on the ultrasound exam, going from a pre-test average of 41.6% to a post-test average of 71.52%. However, for the ultrasound exam, there was no statistically significant difference in the magnitude of these improvements ( $P>0.05$ ). At the completion of the course, all participants were asked to assess the validity of the following statement on a scale from 1 to 5: “The material covered in this course was of value to my medical education”. The average response was 4.1 for the SIM group and 4.0 for the DID group. This was not statistically significant.

## DISCUSSION

Our study aimed to assess the efficacy of simulation-based ultrasound instruction in improving medical student mastery of physiology and ultrasound concepts. The specific goals of the two-day course included mastery of the abdominal/gastrointestinal, pulmonary, cardiac, and FAST ultrasound exams and underlying physiological concepts. Both the didactic and simulation groups had passing exam averages in physiology and ultrasound following the two-day ultrasound course. Additionally, both groups showed statistically significant improvement following the course, suggesting that either teaching style was sufficient to convey the basic concepts of ultrasound and associated physiology. However, our data indicates students taught in the context of simulated clinical vignettes improved their physiology scores more than students taught with standard didactics (+21.20% and +10.70% respectively). However, there was no statistically significant difference in magnitude of

**Table 1.** Participants in ultrasound course

Participant year in medical school	Male ( $n=39$ )	Female ( $n=76$ )
Year 1	17	30
Year 2	12	22
Year 3	0	0
Year 4	5	11
Year 5	2	6
Year 6	3	7

improvement on the ultrasound exam, suggesting there was no concurrent trade-off in retention of information of ultrasound mechanics due to time spent performing simulations. Because our instructors were trained to deliver the same teaching points during the didactic training sessions that were being covered during the simulated clinical vignettes, we were able to minimize the differences in the total content that didactic and simulation groups received. Therefore, our results suggest that the context provided by the clinical vignettes allows for greater understanding and retention of such physiology content. Alternatively, the simulation-based teaching may simply keep students more engaged and interested in the material, thereby improving retention.

As ultrasound is expanding into an increasing variety of clinical settings, the integration of ultrasound education into medical school curriculum has become quite prevalent.<sup>[10-12]</sup> A survey conducted in 2014 suggested that medical school curricular administrators were ambivalent in regards to placement of ultrasound education within medical school anatomy courses.<sup>[13]</sup> Our results, in conjunction with prior studies, suggest that medical students may benefit from ultrasound taught in the context of physiology.<sup>[7]</sup> Placing too much focus on anatomy may yield diminishing returns given an experienced ultrasound user can become sufficiently familiar with standard exam images without a detailed understanding of associated anatomy. Placing a focus on anatomical structure can make it difficult to capitalize on the integrative nature of ultrasound. In the context of physiology, instructors can cover structures while also discussing pathology and clinical manifestations, thereby merging content from several different medical courses. To date, no other study has looked at the relative value of case-based simulation in ultrasound education compared to didactic instruction. Our results demonstrate both non-inferiority in improving ultrasound knowledge, as well as superiority in bolstering mastery of associated physiology.

As medical schools experiment with different methods of integration of ultrasound education into their curricula, modalities of education that promote student engagement should be valued, given there exists a significant body of research demonstrating that the passive role students play in lecture-based learning contributes to poor learning outcomes.<sup>[14,15]</sup> Our results suggest that simulation-based ultrasound education is of great subjective value to students. Especially in programs that divide medical education into “pre-clinical” and “clinical” years, simulated ultrasound

scenarios provide younger students the opportunity to apply their knowledge in an environment that most resembles the clinical setting. Integrating ultrasound through case-based simulation may be helpful to improve understanding and retention of POCUS.

### Limitations and future research

There are several limitations to our study. All data was collected from a single education system utilizing a convenience sample of Swiss medical students. It is unclear if these results are generalizable to American or other international medical students. Furthermore, our relatively small sample size also limits the generalizability of conclusions drawn from our research. Additionally, our study did not longitudinally assess competence and we cannot comment on how well simulation-based ultrasound education or didactic-based education promotes long-term retention. We did not systematically assess the physical skills and techniques of the ultrasound exam. Additional studies will be required to determine the ability of POCUS to be taught using didactics and simulation. Competence in these skills may or may not be completely independent from improved understanding of underlying ultrasound concepts. Lastly, the pre-test and post-test were the same examination. Future studies may consider using different examinations to test ultrasound knowledge retention.

Future large-scale studies are needed to validate our data and further explore the efficacy of simulation-based POCUS education. In particular, a large-scale, longitudinal study that assesses long-term retention of ultrasound and associated physiology following case-based simulation sessions could benefit medical educators tasked with designing an efficient and effective medical school curriculum.

## CONCLUSIONS

Our data suggests that simulation-based POCUS training for Swiss medical students resulted in statistically significant improvement on physiology examination. However, there was no difference in ultrasound knowledge improvement between the simulation-based and didactic-based groups. Future, large-scale studies are needed to validate this promising data.

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**Ethical approval:** The study was approved by the Institutional Review Board (IRB) with the support of University of Basel Medical School administration.

**Conflicts of interest:** Dr. J Christian Fox receives stock options from Sonosim for consulting. However, no Sonosim products were used in this research project.

**Contributors:** SS, EF, AA, RA proposed the study and prepared the first draft. All authors read and approved the final version of the paper.

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## Physiology Written Exam Summer 2018

1. A penetrating trauma can introduce air into the pleural cavity, a condition known as:

- Flail chest
- Pneumothorax
- Pneumonia
- Pleural effusion
- Interstitial lung disease

2. According to LaPlace's law, the stress placed on the muscular wall of a heart is \_\_\_\_\_ (directly, inversely) proportional to the pressure within the chamber and the chamber walls thicken to \_\_\_\_\_. (decrease, increase) the stress on the heart.

- Inversely, Increase
- Directly, Increase
- Inversely, Decrease
- Directly, Decrease

3. In hemodynamically stable patients, the use of ultrasound in the identification of free fluid in the so called "dependent spaces" is indicated to determine the presence of:

- Pericardial free fluid
- Intrathoracic free fluid
- Intraabdominal free fluid
- All of the above
- None of the above

4. Which is a "potential space" within the thoracic cavity?

- Between the inner and innermost intercostal muscles
- Between the parietal pleura and innermost intercostal muscle
- Between the parietal pleura and endothoracic fascia
- Between the parietal and visceral pleurae

5. Following a high fat meal, cholecystokinin is released from the intestine leading to which of the following:

- Increased gastric emptying
- Gallbladder contraction
- Contraction of Sphincter of Oddi
- Decreased pancreatic secretion

6. What heart sound findings are common in aortic stenosis?

- Atrial gallop
- Audible S4
- Diminished S2
- All of the above

7. Where is bile produced and then stored?

- Intestine; Liver
- Liver; Gallbladder
- Gallbladder; Liver
- Gallbladder; Intestine

8. In a patient with pulmonary edema, what finding on ultrasound would you most expect to find?

- Consolidations
- Liver mirror image
- Absent lung sliding
- Acoustic shadowing
- B lines

9. In the case of a patient presenting with a blunt abdominal trauma, in which dependent space and corresponding view would free fluid be most likely to collect in the supine position?

- Hepato-renal recess (Morrison's pouch); right flank view
- Spleno-renal recess; left flank view
- Pericardial space; subxiphoid view
- Inframesocolic compartment; pelvic view

10. Which of the following symptoms is NOT a member of Beck's triad of symptoms for pericardial effusion?

- A. Hypertension  
 B. Jugular venous distension  
 C. Hypotension  
 D. Muffled heart sounds
- 11. A patient presents to the emergency department with findings concerning for bacterial pneumonia. A chest X-ray is ordered and shows a consolidation in the right middle lung lobe. What is the physiological cause for the consolidation seen on X-ray?**  
 A. Decrease in surfactant production by type II alveolar cells  
 B. Increased alveolar macrophage activity and cytokine production  
 C. Neutrophils, bacteria, and fluid from surrounding blood vessels fill the alveoli hindering oxygenation  
 D. Hyperproliferation of type I alveolar cells  
 E. Increased aeration of lung
- 12. A patient with a history of alcohol abuse presents to the Emergency Department with evidence of liver cirrhosis. He is found to have gallstones. What is the most likely composition of the gallstones?**  
 A. Bilirubin  
 B. Cholesterol  
 C. Sodium  
 D. Calcium
- 13. Under normal physiological conditions, during inspiration the left ventricle gets \_\_\_\_\_ (larger, smaller) and cardiac output \_\_\_\_\_ (increases, decreases).**  
 A. Smaller, increases  
 B. Larger, increases  
 C. Smaller, decreases  
 D. Larger, decreases
- 14. A patient presents to the emergency department with shortness of breath and is diagnosed with pneumonia. The patient is hypoventilating. Which of the following is a physiological consequence of hypoventilation?**  
 A. Decreased partial pressure of CO<sub>2</sub> in the blood and respiratory alkalosis  
 B. Decreased partial pressure of CO<sub>2</sub> in the blood and respiratory acidosis  
 C. Increased partial pressure of CO<sub>2</sub> in the blood and respiratory alkalosis  
 D. Increased partial pressure of CO<sub>2</sub> in the blood and respiratory acidosis
- 15. A patient presents with right lower quadrant abdominal pain. On ultrasound examination, the appendix measures 7 mm in diameter. Which corresponding laboratory value would you expect for this patient? (Normal WBC: 4,500 to 11,000 cells/μL)**  
 A. WBC 17,000 cells/μL  
 B. WBC 4,000 cells/μL  
 C. WBC 2,000 cells/μL  
 D. WBC 10,000 cells/μL

Figure 1. Physiology exam.

### General Ultrasound Comfort Questions

- I. I would rate my previous exposure to ultrasound as:  
 A. No previous experience with ultrasound  
 B. Learned about ultrasound, but never used it  
 C. A little hands-on ultrasound training  
 D. Some hands-on ultrasound training  
 E. A lot of hands-on ultrasound training

### Ultrasound Knowledge Questions

- 1. An object described as hyperechoic in an ultrasound exam would appear (compared to the surrounding tissue) as:**  
 A. Bright  
 B. Dark  
 C. Black  
 D. Red
- 2. What does the B in B-mode stand for in ultrasound, and what is it used for?**  
 A. Basic, general scanning  
 B. Brightness, observing blood flow  
 C. Basic, observing blood flow  
 D. Brightness, general scanning
- 3. Posterior acoustic enhancement happens when:**  
 A. Sound encounters a high attenuating artifact  
 B. Sound encounters a low attenuating artifact  
 C. Sound encounters air  
 D. Sound encounters bone
- 4. The phased array transducer is superior to the linear probe when viewing the heart in parasternal long because:**  
 A. It is smaller and causes less discomfort to the patient  
 B. It has superior resolution  
 C. It can work around the ribs  
 D. It is always the best choice
- E. All of the above
- 5. One of the advantages of ultrasound is that it can:**  
 A. See more deeply into the body than CT  
 B. Provides higher resolution than MRI

- 16. A 41-year-old woman presents for evaluation of right-sided flank pain. Evaluation shows urethral calculi constricting the right ureter. Which of the following physiological changes most likely occurred following the constriction?**

- A. Glomerular Filtration Rate (GFR) is unchanged  
 B. Glomerular Filtration Rate (GFR) increases  
 C. Glomerular Filtration Rate (GFR) decreases
- 17. In normal pulmonary capillaries of the lung, which of these forces contribute to filtration?**  
 A. Capillary hydrostatic pressure  
 B. Interstitial hydrostatic pressure  
 C. Interstitial oncotic pressure  
 D. A & B  
 E. A & C

- 18. In aortic stenosis, left ventricular emptying is impaired because of high outflow resistance caused by a reduction in the valve orifice area when it opens. This leads to an:**

- A. Decreased ventricular wall stress (afterload), increased stroke volume, increased end-diastolic volume  
 B. Increased ventricular wall stress (afterload), decreased stroke volume, decreased end-diastolic volume  
 C. Increased ventricular wall stress (afterload), decreased stroke volume, increased end-diastolic volume  
 D. Increased ventricular wall stress (afterload), increased stroke volume, increased end-diastolic volume  
 E. Decreased ventricular wall stress (afterload), decreased stroke volume, decreased end-diastolic volume

- 19. Hydronephrosis results from the inability of urine to drain from the kidney into the bladder. Which of the following describe the normal flow of urine after it is released through the renal papilla?**

- A. Major calyx, minor calyx, renal pelvis, ureters, bladder  
 B. Minor calyx, major calyx, renal pelvis, ureters, bladder  
 C. Renal pelvis, minor calyx, major calyx, ureters, bladder  
 D. Renal pelvis, major calyx, minor calyx, ureters, bladder
- 20. In mitral valve regurgitation, as the left ventricle contracts, blood is not only ejected into the aorta but also back up into the left atrium. Which of the following statements is true in a patient with mitral valve regurgitation?**

- A. Preload and ejection into the aorta are both increased  
 B. Preload and ejection into the aorta are both decreased  
 C. Preload is decreased, but ejection into the aorta is increased  
 D. Preload is increased, but ejection into the aorta is reduced

- II. I would feel comfortable using ultrasound in my future practice of medicine.

- A. Strongly disagree  
 B. Disagree  
 C. Neutral  
 D. Agree  
 E. Strongly Agree

- C. It uses less ionizing radiation than MRI  
 D. All of the above  
 E. None of the above



Case courtesy of Dr Henry Knipe, Radiopaedia.org, rID: 38664

- 6. Identify the organ that takes up the majority of this ultrasound image:**  
 A. Heart  
 B. Lungs  
 C. Liver  
 D. Kidney  
 E. Small intestine
- 7. The linear transducer, compared to curvilinear and phased array transducers, has the best:**  
 A. Sharpness  
 B. Contrast  
 C. Resolution  
 D. Color
- 8. If the image appears too bright and washed out, you should:**



- A. Turn down the brightness  
 B. Turn down the power  
 C. Turn down reverberation  
 D. Turn down the gain
- 9. M-Mode is primarily used for:**  
 A. Imaging musculature  
 B. Measuring the distance between two structures  
 C. Graphing the motion of structures over time  
 D. Detecting the direction of movement in real time
- 10. Well defined vertical hyperechoic lines caused by fluid replacing air are known as:**  
 A. Edge refraction artifacts  
 B. A-lines  
 C. Doppler artifacts  
 D. Comet tail artifacts
- 11. Which ultrasound artifact can be used to determine whether or not there is fluid in the pleural cavity?**  
 A. Gas scatter  
 B. Mirror image  
 C. High attenuation  
 D. Low attenuation  
 E. None of the above
- 12. Rib shadows can be overcome most by using:**  
 A. More ultrasound gel  
 B. Phased array probe  
 C. Higher gain  
 D. Lower depth  
 E. All of the above  
 F. None of the above
- 13. Which of the following is NOT true of A-lines?**  
 A. Each consecutive line represents a deeper layer of lung tissue  
 B. They appear as equidistant reverberation artifacts originating at the pleural line  
 C. They are visible in normal, healthy lungs  
 D. Caused by gas scatter at the air-pleura interface  
 E. All of the above are true
- 14. When fluid replaces the air of interlobular septae in the lungs, as with pulmonary edema, ultrasound imaging will show:**  
 A. 1-4 B-lines, with A-lines  
 B. 1-4 B-lines, without A-lines  
 C. 5 or more B-lines, with A-lines  
 D. 5 or more B-lines, without A-lines
- 15. Which of the following is NOT true about detecting pneumonia with ultrasound?**  
 A. Most easily diagnosed using M-mode  
 B. Consolidation can be visualized in nearly all cases  
 C. Multiple rib interspaces must be imaged  
 D. Consolidation will appear similar to liver tissue  
 E. All of the above are true
- 16. Which view would be most helpful in identifying vegetation on the anterior leaflet of the mitral valve?**  
 A. Parasternal long axis  
 B. Parasternal short axis  
 C. Apical 4 chamber  
 D. Apical 5 chamber
- 17. In order to calculate ejection fraction, which view will allow you to measure the EPSS?**  
 A. Apical 4 chamber  
 B. Apical 5 chamber  
 C. Parasternal short axis  
 D. Parasternal long axis  
 E. Sub-Xiphoid
- 18. In apical 4 chamber view and color doppler mode, you see blood is going from the left ventricle into the left atrium which cautions a suspicion of mitral regurgitation. This blood on the screen will appear as:**  
 A. Blue, because it is going towards the probe  
 B. Blue, because it is going away from the probe  
 C. Red, because it is going towards the probe  
 D. Red, because it is going away from the probe
- 19. Using pulse-wave doppler, you can measure the velocity of inflow across the mitral valve, between expiration and inspiration. If that value is more than 25% different, between inspiration and expiration, you can suspect pericardial tamponade.**  
 A. True  
 B. False
- 20. When assessing acute appendicitis and looking for the “ring of fire”, which mode of the ultrasound machine will help you determine if the appendix is inflamed?**  
 A. M-Mode  
 B. B-Mode  
 C. Color doppler  
 D. Pulsed wave doppler
- 21. A contracted gallbladder will show which of the following characteristics?**  
 A. Strongly reflective outside layer  
 B. Anechoic middle layer  
 C. Minimally reflective inner layer  
 D. A & B  
 E. All of the above
- 22. A tumor inside the kidney will show on the screen as?**  
 A. Anaechoic  
 B. Hyperechoic  
 C. Hypoechoic  
 D. Will not show
- 23. On the screen, the small intestines will have a layered appearance, will be easily compressible, and will have a wall thickness of less than 3 mm.**  
 A. True  
 B. False
- 24. Considering the depths of your GI organs which transducers should be utilized in viewing the spleen?**  
**Phased Array**  
 A. Curvilinear  
 B. Linear  
 C. A & B  
 D. All of the Above
- 25. Right ventricular strain can be identified using which technique?**  
 A. EPSS  
 B. TAPSE  
 C. eFAST  
 D. Checking for “Sky-Ocean-Beach”
- 26. When trying to identify a patients gallbladder using ultrasound . . .**  
 A. It can be useful to use the “X minus 7” technique  
 B. You should have the patient roll into the left lateral decubitus position  
 C. Look for a “wall-echo-shadow” structure  
 D. All of the above
- 27. When performing a kidney ultrasound one should scan . . .**  
 A. The coronal axis of the kidney  
 B. The transverse axis of the kidney  
 C. The sagittal axis of the kidney  
 D. A and B  
 E. B and C  
 F. All of the above
- 28. When performing a bladder ultrasound one should scan . . .**  
 A. The coronal axis of the bladder  
 B. The transverse axis of the bladder  
 C. The sagittal axis of the bladder  
 D. A and B  
 E. B and C  
 F. All of the above
- 29. The best way to confirm normal functionality of the left ventricular outflow tract is to . . .**  
 A. Perform an EPSS and find less than 7 mm septal separation  
 B. Perform an EPSS and find more than 7 mm septal separation  
 C. Perform a TAPSE and find tricuspid annular excursion of less than 16 mm  
 D. Perform a TAPSE and find tricuspid annular excursion of more than 16 mm
- 30. In the following image, which tag is the left ventricle?**  
 A. A  
 B. B  
 C. C  
 D. D

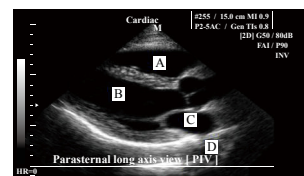


Figure 2. Ultrasound Written Exam.