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The Effects of Simulation with Cooperative Learning Strategies in a College Sonography Lab

Christopher W. Kopp

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Christopher W. Kopp

Saint Catherine University

St. Paul, Minnesota

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Acknowledgements

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Abstract

This action research study investigated adding a combination of learning strategies to a sonography lab course and its impact on student performance. The study was conducted in a junior college level sonography lab with 20 female participants between the ages of 20 to 29. The duration of the study was six weeks. Both qualitative and quantitative data tools were utilized. A pre- and post-survey, instructor lab journals, peer review exercises, quizzes, and competencies scores were used to measure effectiveness. The findings indicated an increase in sonography competency scores when compared to the previous year and an increase in the students' perceived value of the various strategies. The addition of simulation, rehearsal, and peer review exercises yielded positive results. The implications for results, study limitations and further research are discussed.

Keywords: sonography, simulation, rehearsal strategies, peer review

Diagnostic medical sonography is a very challenging imaging modality. Sonography students must develop their knowledge of human anatomy, physiology, and pathology. Students also require a strong understanding of physics, hemodynamics, and cross-sectional anatomy. Sonography students develop their ability to conceptualize two-dimensional slice imaging of the human gross anatomy in any given plane. This requires strong psychomotor skills along with diagnostic level imaging recognition of normal anatomy and abnormal anatomy with pathology.

In the school-based laboratories, students typically scan one another learning how to survey through various anatomy capturing images as per specific protocols. Students survey each organ to provide documentation of normal and abnormal anatomy along with any pathological findings. A typical sonography lab has a limited number of diagnostic machines and simulators due to the high cost of equipment. One lab has 3 diagnostic machines and 1 simulator to be shared by 20 sonography students. This is a common ratio of machines to students, which can be cause for uneven distribution of scanning hours for each student in developing high-level psychomotor and patient care skills.

Sonography students perform competency exams on live patients throughout the semester to demonstrate their ability to perform high-quality diagnostic exams. Most sonography students do not have previous patient care experience, adding to a host of new challenges in their first sonography lab course. For 20 all-female entry level sonography students in the midwestern region of the United States, applying their new-found sonography knowledge while obtaining scanning and patient care skills can be rather daunting and cause anxiety.

Implementing a synergistic combination of rehearsal, simulation, and peer review strategies may build student confidence and increase overall competency scores. Adding a schedule for each diagnostic ultrasound machine and simulator in the structured labs ensures that

each student will receive an equal amount of time on each machine and may also contribute to overall higher competency scores. The purpose of this project was to quantify the value of sonography simulator use combined with rehearsal and peer review strategies in developing student abdominal scanning performance.

Theoretical Framework

Diagnostic medical sonography is a very focused imaging modality that challenges its adult learners. The value of performing live sonography scans and simulation directly correlates to the success of sonography students. If we work to meet the needs of our adult sonography learners, we will greatly increase their chances for success in a very challenging field. In 1990 Malcom Knowles proposed the foundation stones of modern adult learning:

> (1) Adults are motivated to learn as they experience needs and interest that learning will satisfy, (2) Adults' orientation to learning is life-centered, (3) Experience is the richest resource of adult learning, (4) Adults have a deep need to be self-directed and (5) Individual differences among individuals will increase with age. (p.127)

Knowles foundation stones of modern adult learning theory inspired the application of a set of synergistic learning strategies to meet the needs of the adult sonography student learning in the lab setting. Rehearsal strategies prior to clinical internship motivate sonography learners to prepare for their internships and career as they discover the rewards of scripting and role playing. Because sonography learners are adults entering a narrowly focused career, the researcher oriented their learning towards what will be a life-long career choice. The hands-on experience itself is a rich learning experience but may be enhanced even more when combined with additional learning strategies. The researcher considered that sonography learners are self-directed and will eventually be working independently. For this reason, this study included

exercises that allowed students to work as individuals and in small groups. To accommodate individual differences with adult sonography learners, a variety of learning strategies were implemented synchronously to benefit the class as a whole and as individuals. Adding rehearsal, simulation and peer review strategies to a level-one sonography abdominal lab course may yield overall better outcomes for sonography learners.

Literature Review

Sonography is a very operator dependent imaging modality. Sonography imaging utilizes sound waves that travel through soft tissues and fluid in order to create a diagnostic image on a screen. Handheld transducers, using a very thin scan plane are directed by a trained technologist to investigate 2 and 3D slice images. There is a practical component that works to develop autonomous use of high-level psychomotor skills, combined with higher order cognitive elements of sonography, such as image pattern recognition and clinical interpretation (Thoirs & Coffee, 2012). Educating sonography students is a complex process, students may acquire their scanning skills in a school-based student laboratory or develop their scanning skills during their clinical internship (Pessin & Tang-Simmons, 2018).

Most sonography education programs have their own labs and ultrasound equipment where they can practice and simulate actual sonography exams. It is in this environment that students can make use of simulation, rehearsal strategies, and peer review assessments to prepare them for their clinical internships. Sonography internships involve partnerships with healthcare clinics and hospitals to acquire many hours of scanning actual patients. Live patient scanning has been the preferred method of training students; but as technology has been advancing, so have sonography simulators. High fidelity ultrasound simulators include life-like mannequins which are linked to a makeshift transducer that has positional sensors, and an image is displayed

on a computer monitor (Osborne, Parange, & Thoirs, 2015). Simulators allow sequential development and scaffolding of skills to occur in a low stress environment, rather than opportunistic training which occurs in clinical departments with live patients (Osborne et al., 2015).

Rehearsal strategies may benefit sonography students. Simple role playing and rehearsal of obtaining a patient's history, symptoms, and previous imaging may build student confidence. Rehearsing an entire exam could be even more beneficial. Other medical learning institutions have been successfully using rehearsal strategies. Cognitive rehearsal has shown promise as a training tool to improve performance quality, and increase knowledge, comfort, and confidence with surgical residents (Kovacevic et al., 2016).

When rehearsing an ultrasound exam scenario, this learning strategy allows the learner to develop their knowledge, skills, and attitudes while practicing the clinical experience (Kloc, Ballor, Boldt, & Curry, 2018). Peer assessment can be an effective feedback tool that is also inexpensive (Sun, Harris,Walther,& Baiocchi, 2015). A typical sonography lab has one instructor providing feedback to multiple students simultaneously performing exams. Having sonography lab students evaluate each other's scanning allows for a greater amount of feedback per student without having to hire additional staff. Rehearsing an ultrasound exam while being peer reviewed provides feedback on the scanning performance along with patient care skills.

Ultrasound simulator machines alone may be a beneficial learning strategy to enhance a sonography student's diagnostic scanning skills. To what extent can simulation activities combined with rehearsal strategies increase sonography lab competency? The addition of role playing an entire sonography exam and having the exercise immediately reviewed by

sonography student peers, may formulate a learning method that could maximize student lab competency.

Simulators

Simulators have not become a replacement for actual live patient scanning in sonography. Currently, the JRC-DMS Joint Review Commission of Diagnostic Medical Sonography does not recognize simulation as an acceptable format for student competency evaluation (2020). However, this does not imply that there is no perceived value in training with sonography simulators. Simulation is becoming recognized as an innovative pedagogic approach that has gained much popularity in health care education more recently (Gibbs, 2015). Have sonography educational programs kept up with the technological advancements in simulation to properly integrate simulator training into their curriculum? The available literature indicates that there is a lack of empirical research determining the effectiveness of simulation, and whether the skills acquired through simulation are transferred into clinical practice (Prion, 2008).

Historically, sonography professionals have regarded ultrasound simulator machines as a poor substitute compared to scanning live patients on a diagnostic ultrasound machine. This is in part, due to the inability to simulate live patient attributes with a mannequin or virtual subject. In addition, simulator technology was not able to adequately replicate actual diagnostic machine capabilities such as real time scanning. A fundamental psychomotor skill needed by all sonographers is being able to view 3-dimensional anatomy in real-time on a 2-dimensional screen (Nicholls, Sweet, & Hyett, 2014).

In a survey completed by 230 program directors, that was focused on simulator usage by Commission on Accreditation of Allied Health Education Programs (CAAHEP) accredited sonography programs, 75% of the programs reported usage of simulators (Pessin & Tang-

Simmons, 2018). Of those programs, 89% of the respondents stated that simulation was a useful teaching tool (Pessin & Tang-Simmons, 2018). Additionally, 81% of the students reported positive feedback after participating in the simulation exercises (Pessin & Tang-Simmons, 2018). Of the programs that responded to the survey, only 11% reported negative feedback regarding the use of ultrasound simulators because they preferred that students scan each other (Pessin & Tang-Simmons, 2018). These are very positive statistics, but how many of these programs are using high-fidelity simulation that is more comparable to an actual diagnostic machine? Only 20% of programs provide faculty with low-fidelity phantom scanning workshops, and 30% provide their faculty with high-fidelity simulation (Pessin & Tang-Simmons, 2018).

In 2014 at the University of the West of England, a research study was conducted with 25 diagnostic medical sonography students that had interacted with a Medaphor ScanTrainer ultrasound simulator (Gibbs, 2015). In addition to the students, 14 sonography mentors agreed to participate in the study. A qualitative research approach was taken using interview surveys to collect data from each individual. Students stated that they particularly benefited from the time spent on the simulator where they could repeat the scan without the clinical pressures of working in a busy department (Gibbs, 2015).

Many positive responses were received from students and mentors about the advantages of using the simulator to comprehend orientation and improve hand-eye coordination (Gibbs, 2015). These are skills that many students struggle to master and are pertinent to becoming a competent sonographer (Gibbs, 2015). Sonography students develop these skills at varying rates and simulators allow students to work at their own speed and perform exams with little pressure (Gibbs, 2015). With a simulator, students do not have the pressure of a live patient that may be in pain, or uncomfortable from having a full bladder. In addition, the student working on a

simulator could have less fear of a misdiagnosis. Ultrasound simulators have the ability to prompt the student to find the appropriate sonography window for optimal angle of insonation. Feedback from mentors also noted improvements in students' psychomotor skills after time spent with the simulator (Gibbs, 2015). Recent developments in high fidelity sonography simulators may reduce the need for live models or patients in actual clinical settings (Osborne et al., 2015). For now, there seems to be a place for ultrasound simulator machines in conjunction with traditional training methods.

Rehearsal Strategy

Rehearsal strategy has been used in many forms of training and teaching. Sonography is an imaging modality that involves some exams that may be uncomfortable for both the patient and sonographer. Despite the common association of sonography exams being performed only in obstetrics, other common exams include: abdomen, pelvis, examinations of the legs and arms, scrotal exams, and in the body's soft tissues. Role-playing can be quite valuable in helping students become more comfortable with handling exams that may make the student or patient feel uncomfortable. Scenario-based simulation can help students develop affective behaviors needed in their profession (Kloc et al., 2018). This practice may boost student confidence, which could also result in increased patient confidence and assuredness. Practicing scenarios that can be uncomfortable, risky, or rarely seen in the clinical setting will best prepare the student for when they encounter similar situations in the clinical setting (Kloc et al., 2018).

A scenario-based simulation study was conducted in a diagnostic medical sonography program in 2017 with 11 female students from a midsized community college (Kloc et al., 2018). The study involved four simulated patient care rooms divided by a control room with two-way glass into each patient care room, video surveillance, and microphones (Kloc et al., 2018). These

scenarios were design-based by students' answers to questions on what made them uncomfortable in the clinical setting.

Each scenario was constructed to enhance affective behaviors and not actual scanning psychomotor skills. The first simulation room had students performing a scrotal exam, the second was a first-trimester obstetrics exam, the third room had a second trimester obstetrics exam, and the fourth room was a control room where the instructors observed and recorded each student's performance and behaviors (Kloc et al., 2018).

Prior to and after each simulation study, students were given surveys to describe their level of confidence with each exam. Survey data indicated student confidence levels in their ability to explain the exam to patients improved in all three examinations and most notably in the first-trimester OB and second-trimester OB (Kloc et al., 2018). Results of the pre-simulation survey indicated that students were unconfident or neutral regarding their confidence with the two OB exams. All of the students showed significantly improved confidence with the scrotal exam (Kloc et al., 2018).

Peer Assessment

Peer assessment and feedback have been used in a wide range of teaching modalities to have students evaluate and give one another constructive critique. Student peer assessment (SPA) consist of students evaluating the work of other students in structured environments where students can rate one another in an evaluation based on performance skills (Elderidge Bear, Wayne, & Perea, 2013). An evaluation of their peer's performance most often represents a formative assessment rather than a summative assessment, as the assessment primarily focuses on feedback intended to enhance learning (Elderidge et al., 2013). SPA includes the use of rubrics to ensure consistent and transparent feedback between students (Elderidge et al., 2013).

In medical education SPA is primarily used when assessing professional skill competencies, particularly in assessing professional behaviors (Elderidge et al., 2013). Peer assessment is an excellent way to obtain feedback as it reduces instructor burden with minimal sacrifice to quality (Sun et al., 2015).

In a randomized control study conducted at Stanford University in a large statistics class, students received peer feedback on their homework assignments over a ten-week period (Sun et al., 2015). The peer assessments were a combination of feedback from 3 peers for each student and were anonymized prior to being collected online (Sun et al., 2015). Results were measured by a quiz after each unit was completed. The students who participated in peer assessment during a given unit performed significantly better on the unit quizzes, when compared to the students that did not. Students who participated in peer assessment also had higher final exam scores indicating peer assessment benefits over time (Sun et al., 2015). A similar strategy could be utilized for sonography students in the lab setting. Sonography students may largely benefit from peer reviewing their fellow students while role playing an entire sonography exam from beginning to end.

Discussion

Sonography is a very challenging field that requires a great deal of effort, faculty time, and equipment, and it has a substantial learning curve (Pessin & Tang-Simmons, 2018). With such a challenging learning curve in a very operator modality, practicing in the clinical setting alone may be rather daunting for the sonography student. Ultrasound simulator machines are still viewed as inferior training when compared to live patient scanning on a diagnostic sonography machine. However, ultrasound simulators have become more advanced and may be considered a valuable training aid rather than replacement. Simulators have proven to enhance

sonography student psycho-motor skills. Rehearsal strategies may allow students to practice in a low-pressure environment, develop their own routine and cognitive skills. Peer assessment strategies could be a reliable way to evaluate student skills and development. Combining an ultrasound simulator with live patient scanning, role playing an entire exam from beginning to end, and peer reviewing the activity may result in a superior synergistic learning experience.

Methodology

Classroom action research is defined as a form of action research that instructors perform in their classroom for the purpose of improving practice (Hendricks, 2017). The classroom action research method was used to improve educational practice in the sonography laboratory setting. Multiple strategies were combined synergistically to raise the overall competency scores of college juniors enrolled in an abdominal diagnostic medical sonography lab course. This study introduced peer review, rehearsal, and ultrasound simulation strategies into the lab curriculum. Data collection tools included pre- and post-assessment surveys and lab journals. Research participants were between 20 to 29 years of age. All 20 students who identify themselves as female elected to participate in the research study and signed an informed consent.

The researcher has been a diagnostic medical sonographer for over 15 years, instructing ultrasound students as a preceptor for six years, and teaching at the college level for just under two years. The researcher is registered with the American Registry for Diagnostic Medical Sonography and holds credentials in abdomen, obstetrics/ gynecology, and vascular ultrasound. Prior to the research study, the researcher had worked with this group of students for five weeks in abdominal 1 lab and lecture.

Figure 1 compares the total available open lab hours to the students in each year. In 2019 the students had a total of 53 open lab hours per week. The 2020 class only had 18 open lab hours per week due to COVID-19 restrictions.

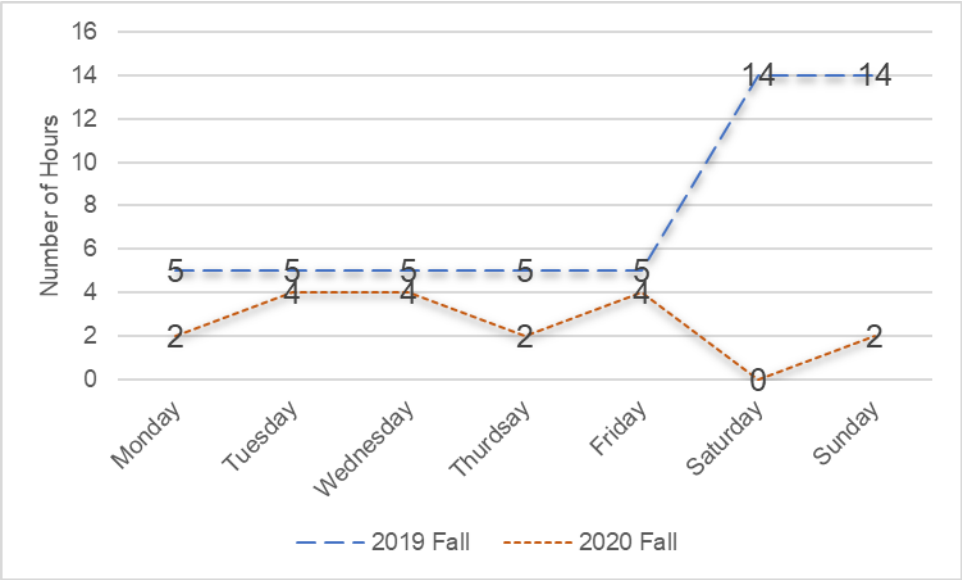


Figure 1. Abdomen 1 Lab Open Hours in 2019 and 2020 Fall. Each line represents…

The COVID-19 pandemic caused a significant decrease in total open lab hours for the 2020 sonography students in weekly available hours and caused two weeks of complete lab shut downs. There were two separate weeks in November where the 2020 sonography class lost all of their open lab hours and both scheduled instructed lab sessions. If we take into account the two weeks of the lab being closed in November and COVID restricted instructed lab schedule, the 2020 class had nearly 250 less hours of scanning practice time available in their fall semester.

Equipment

The students used multiple hospital-grade diagnostic ultrasound machines. Two of the ultrasound machine models were Acuson NX3 (Siemens, 2015) series models. The third ultrasound machine was a Siemens Acuson Redwood (Siemens, 2019) model. All three sonography machines are state-of-the-art machines utilizing the latest technology available to

sonographers. The Redwood model is less than a year old and offers the most recent advances in diagnostic capabilities, making it somewhat more desirable than the NX3 series models. Defined student sessions ensured that all students would receive equal time on each machine. A Simbionx U/S Mentor (3D Systems, n.d) simulator machine was the fourth machine being used in the sonography laboratory.

Pre and Post Survey

A pre- and post-survey (Appendix A) were collected to determine student opinion and perceptions before and after the research strategies were implemented in this course. Each survey measured students' perceptions of using peer evaluations, simulation, instructor evaluation of student imaging, and rehearsal strategy. Each survey had the same four questions and provide answers on a 5-Point Likert Scale (Appendix A). Students were also given an area to add explanations to their answers and add comments. An analysis of the data indicated positive student perception of the added interventions.

Student Machine Schedule

In instructor led-sonography labs, it is common for students to decide which ultrasound machine they will scan on and how long their scanning duration will be in the lab session. This often results in less assertive students losing out on scan time to their more assertive peers. An informal schedule may also cause disproportionate scan time on higher quality sonography machines and ultrasound simulators.

A time schedule (Appendix B) was utilized in each lab class over the entire six weeks to ensure students had an equal amount of time on each sonography machine and ultrasound simulator. Each student was allocated 20-minute intervals in each lab session, and the student schedule evenly rotated each student between all four machines.

Rehearsal Strategy

Rehearsal strategy techniques were used to replicate entire ultrasound examinations from beginning to end. Students were required to practice meeting and greeting a patient from the radiology waiting area, escorting patients to the exam room, obtaining patient identifiers, patient history, thoroughly explain the exam, perform the exam, and explain when the patient would receive results along with exiting the patient. AIDET (Acknowledge, Introduce, Duration, Explanation, Thank You) (Appendix C) scripting was provided to each student to study before participating in the rehearsal strategy techniques. The AIDET scripting provided a platform for the students to know how to properly room the patient, provide sensitivity to the patient's needs, explain the exam, respond to questions and concerns, and explain when results would be provided. Rehearsal strategies were executed throughout the entire duration of the research study.

Peer Review Strategy

Peer review strategy was conducted weeks four and six during the rehearsal sessions. Because the scanning skill is progressive and the first few weeks incorporate more demonstration time by the instructor, peer review strategies were not incorporated during the first few weeks. Students were placed into groups of three. One student performed a rehearsal of an entire ultrasound exam, while two students observed and completed a peer-review competency rubric (Appendix D). Students participated in peer reviewing one another on a gallbladder/ biliary exam and an abdomen complete exam. The rubric allowed students to provide feedback on their ability to complete and properly demonstrate all aspects of the exam protocols. To ensure honest feedback, students received points based on participation rather than performance. The peer-review included all aspects of the rehearsal strategy: sonographic evaluation of the pancreas,

liver, proximal inferior vena cava and aorta, gallbladder, biliary ducts, and kidneys. The evaluation also involved properly breathing the patient, timely completion of the exam, degree of confidence, and proper use of equipment and settings.

Simulator

The Simbionx U/S Mentor (3D SYSTEMS, n.d.) machine simulates live patient scanning while scanning a mannequin. This allows students to learn in a lower pressure environment as the machine offers guidance to obtaining needed protocol images. In addition, the Simbionx U/S Simulator (3D SYSTEMS, n.d.) machine provides students with an introductory guide to ultrasound machine knobology and offers numerous simulated case-studies with pathology. Students are presented with a clinical scenario that provides information regarding patient description, symptoms, and history. Students must use all patient clinical information in conjunction with the sonographic findings to detect and document any pathology. Students completed a one question closed-ended quiz (Appendix E) to determine the correct case study findings at the end of each simulation module. Eight simulator case studies and quizzes were used in this study, assigned weekly during the six-week study. Simulator case studies included patients with and without pathologies. Pathological findings included: abdominal aortic aneurysm, hemangioma, appendicitis, hydronephrosis, cholelithiasis, pancreatic malignancy, liver metastases, and cholecystitis.

Lab Instructor Journals

Lab instructor journals (Appendix F) were used daily to collect information in six key areas. The journal worksheets documented observations (e.g., noting benefits and challenges) and reflections. The first key area of observation indicated whether students were adhering to

their scheduled time. Did the student start and end their exam "on time" to prevent overlapping into the next student's session?

The second area documented student engagement, protocol, and performing a proper AIDET. Scanning progression was the third area to be documented. This included noting which students were provided with formative feedback and students that were experiencing scanning difficulties. The fourth area documented relates to observations and reflections. Number five included observations and reflections on what went well during the session and needed improvement. Lastly, the sixth key area of observation and reflections summarized what changes should be made based on today's results and what did the instructor learn?

Analysis of Data

Abdominal lab sonography students were requested to participate in an anonymous pre-course and post-course assessment of select learning strategies. The objective of these assessments was to determine student perceptions/ value of learning strategies prior to and after engaging in select learning strategies. Eighteen of the 20 sonography students enrolled in the lab course elected to complete the pre-course assessment, while 16 students completed the anonymous post-course assessment. Students were asked to rank four different learning strategies on a scale from one to five. One was the lowest available score on the scale indicating the learning strategy offered no benefit. Five was the highest possible score indicating that the learning strategy was extremely beneficial.

Figure 2 demonstrates the students' value of the implementation of peer evaluation exercises prior to and after participating in the activity. Peer review exercises were conducted in week four and six of the research study laboratory sessions. Only 16.7% of the student participants perceived peer evaluation learning strategies in the lab as being extremely beneficial

in the pre-course assessment. In the post-course assessment 50% of the student participants perceived peer evaluation learning strategies as being extremely beneficial. In the post course survey, there was a decrease in neutral scores and slight increase number two selection. Lab journals documented that only six of the 20 students were able to complete the abdomen right upper quadrant peer review in week six due schedule changes due COVID-19 pandemic. This may have caused some students to perceive the peer review exercises as less favorable. The overall response in student perception indicates a 33.3% increase in the perceived value of peer evaluation learning strategies in the sonography lab after having engaged in the peer evaluation activities.

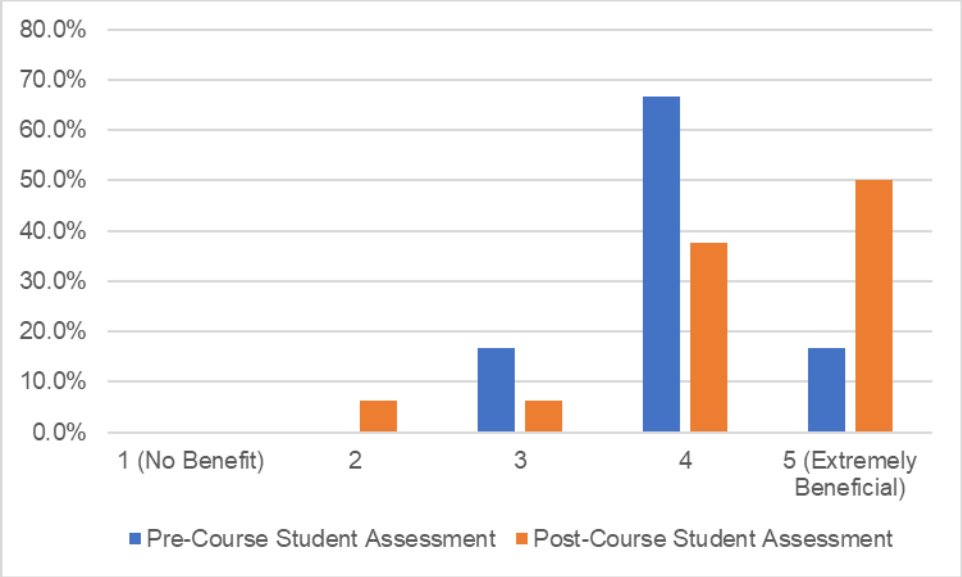


Figure 2. Students' Perceptions of Peer Evaluation Exercises.

Students were asked to score their perception of the value of using an ultrasound simulator machine in combination with case study assignments. In the pre-course assessment, only 27.8% of the students scored the ultrasound simulator machine case study assignment as being extremely beneficial. In the post-course assessment, students that scored the value of simulation as neutral decreased by 15.3%. Additionally, student perception of simulation being

somewhat beneficial decreased by 19.4%. Whereas in the post-course assessment 62.5% scored the ultrasound simulator case study assignment as being extremely beneficial, an increase of 34.7%.

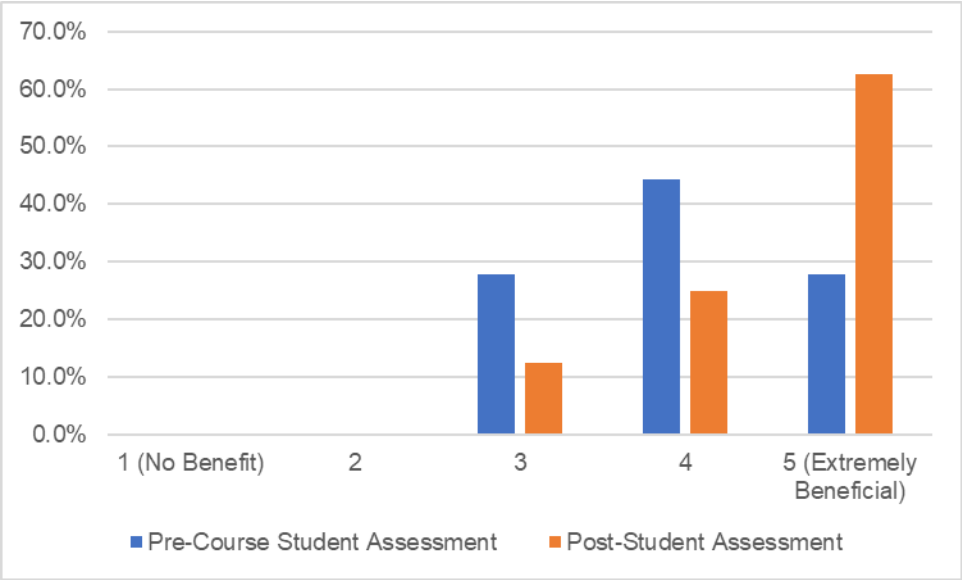


Figure 3. Students' Perceptions of Weekly Ultrasound Simulation Assignment.

The third question in the student assessment surveys pertained to student perception of image evaluation by the instructor. This learning strategy involves sonography students performing exams independently and sending the images to their instructor for an evaluation. In the pre-course assessment, all students rated this exercise as extremely beneficial (Figure 4). In the post-course assessment, 87.5% of students perceived this activity as being extremely beneficial. Prior to the study, peer review strategies had not been implemented. The addition of peer review strategies may have impacted student perception of image evaluation by the instructor alone.

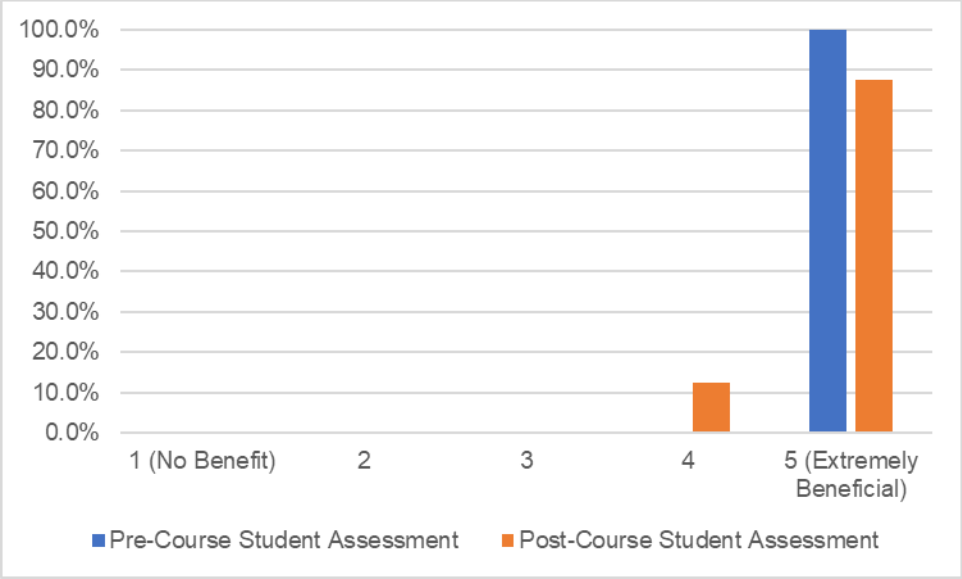


Figure 4. Students' Perceptions of Image Evaluation Completed by Instructor.

The final student assessment question asked the students to rate their perceived value of rehearsing and role playing an entire sonography exam from beginning to end. As depicted in Figure 5, the pre-course assessment indicated 77.8% of students perceived this exercise as being extremely beneficial, while 87.5% of students perceived this learning strategy as being extremely beneficial in the post-course student assessment.

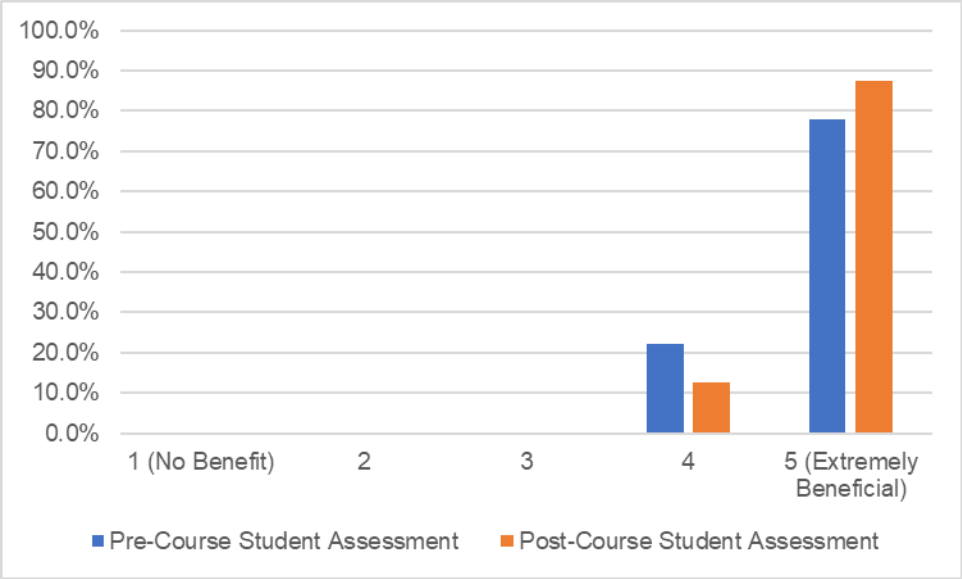


Figure 5. Students' Perceptions of Rehearsing and Role-Playing Sonography Exams.

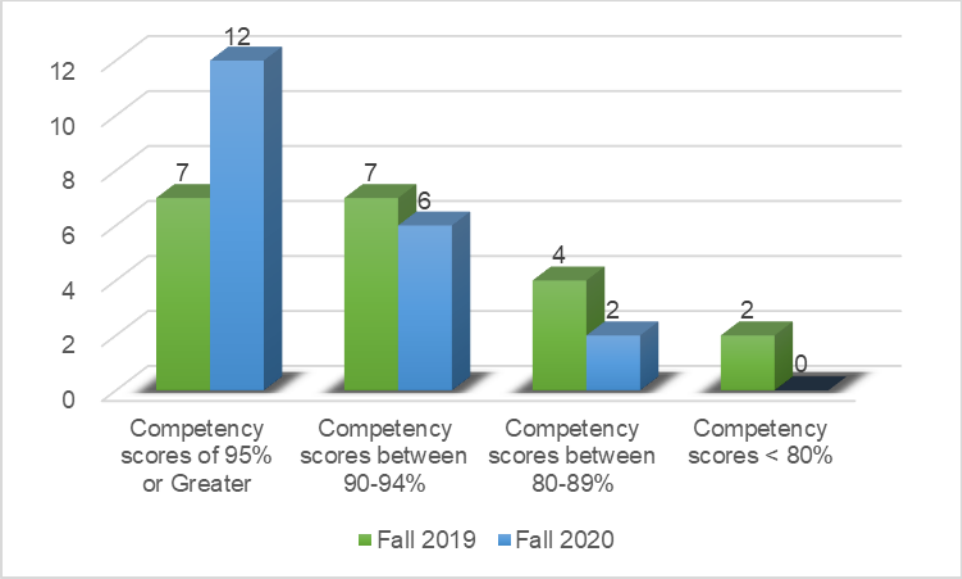
Table 1 compares 2019 and 2020 class competency exam total scores. The 2020 class that participated in the research action plan had increased overall scores on each competency exam. The mean competency score of all exams in 2019 was 90%, this number increased by 4% in 2020.

Table 1

Competency Score Comparison

	2019 Abdomen 1 Class	2020 Abdomen 1 Class (Action Research Plan Participants)
Competency	Average Competency Score	Average Competency Score
Liver	89%	91%
Gallbladder	90%	95%
RUQ (Right Upper Quadrant)	90%	95%
Mean Competency Scores	90%	94%

Figure 6 represents sonography student liver competency scores in the abdomen lab course for 2019 and the 2020 class. The class of 2020 participated in a research action plan including simulation, rehearsal, and peer review strategies along with scheduled machine times. The class of 2019 did not participate in these activities. In 2019 the average competency score was 89%, compared to the average score in 2020 which was 91%. In 2019 seven sonography students had a score of 95% or better on their liver competency exams. In 2020 twelve of the sonography students had scores in the same category. A significant increase of five additional students producing high scoring exam results was documented in 2021. Furthermore, in fall 2020 there were no students with a liver competency score lower than 80%.



Figures 6. Abdomen 1 Lab – Student Liver Competency Scores.

Figure 7 demonstrates the differences in gallbladder competency scores between the 2019 and 2020 classes. The gallbladder competency scores were similar to that of the liver scores. Both the liver and gallbladder competency scores indicated an increase of 5 students with a competency score of 95% or better in 2020 compared to the class of 2019. The 2019 class had gallbladder competency score of 90%, whereas the 2020 class had an average score of 95.1%. This pattern continued to the final right upper quadrant competency that was performed in the last week of the semester ending the research study (Figure 8).

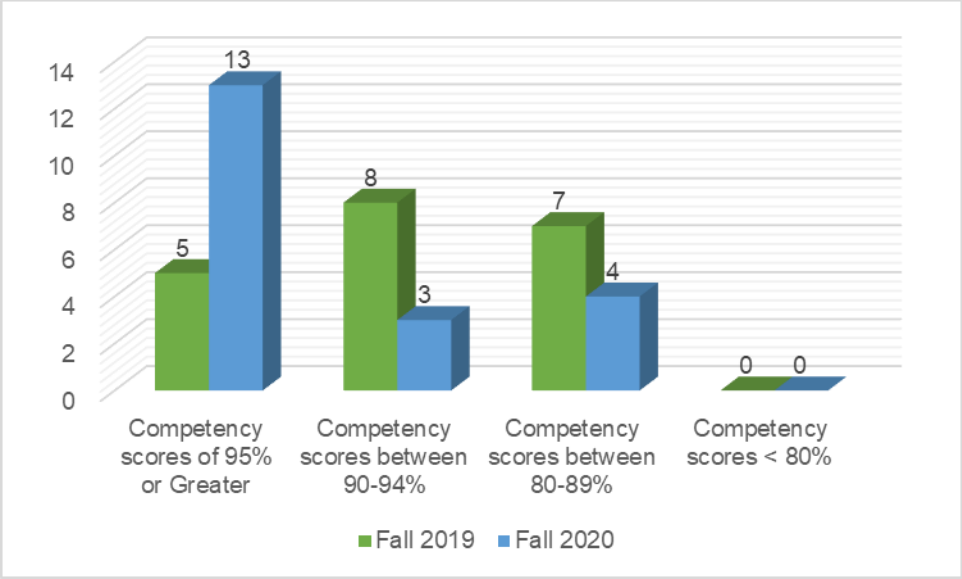


Figure 7. Abdomen 1 Lab – Student Gallbladder Competency Scores.

Figure 8 depicts a comparison of right upper quadrant competency scores. The average student score on the right upper quadrant competency exam was 90% in 2019. In the 2020 class the average score was 95%. When calculating the total competencies scores, the mean competency score for 2019 was 90% and the mean competency score for 2020 was 94%.

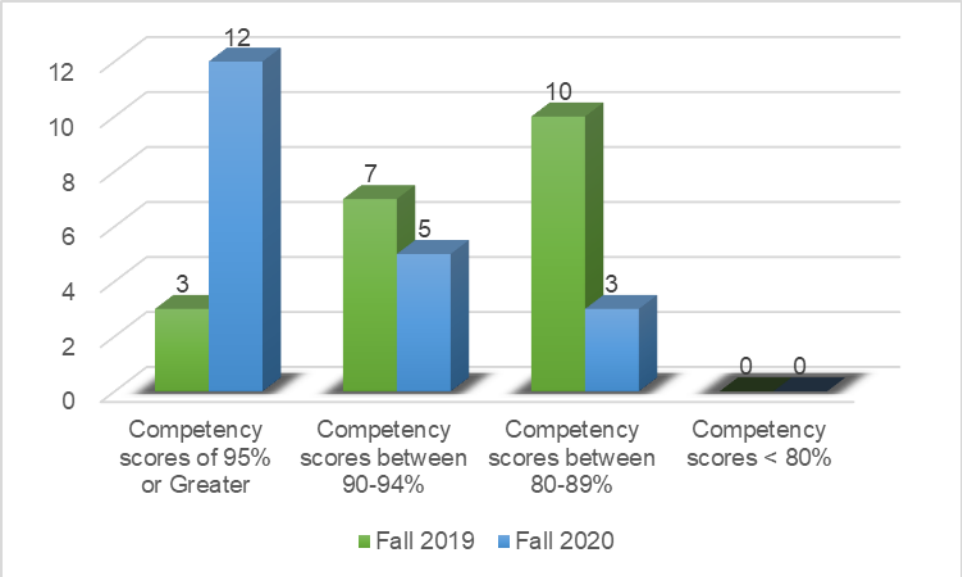


Figure 8. Abdomen 1 Lab – Student RUQ Competency Scores.

Students were required to rehearse an entire sonography exam during each instructor-led weekly lab session. A core aspect of the student rehearsal was performing a scripted AIDET (Appendix C). To measure student progress of their ability to perform the AIDET properly, students were evaluated on their performance in their gallbladder peer review assignment (Appendix D) and in their gallbladder final competency exam. Figures 9 & 10 demonstrate student performance in being able to properly perform AIDET in their peer review assignment and one week later in their gallbladder final competency.

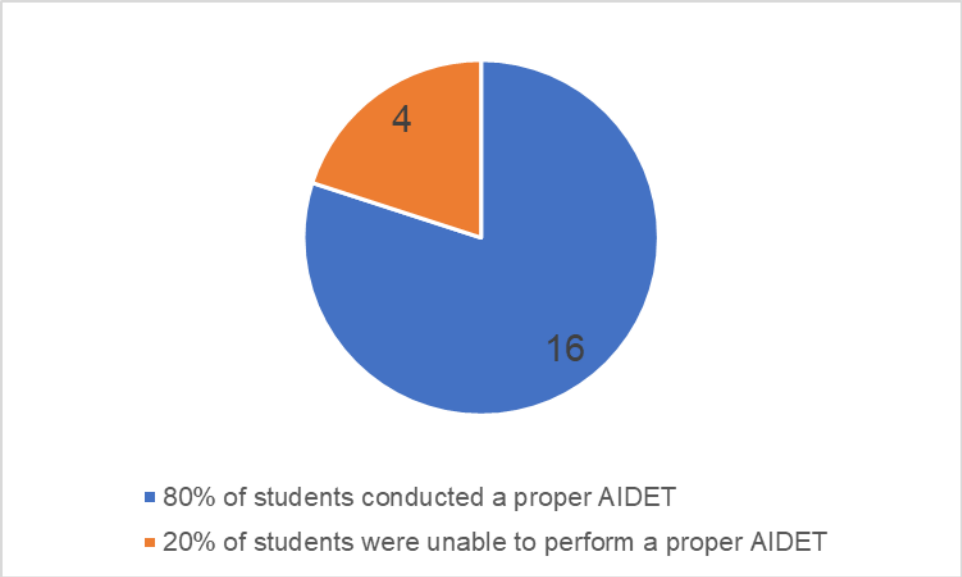


Figure 9. Gallbladder Peer Review AIDET Demonstration

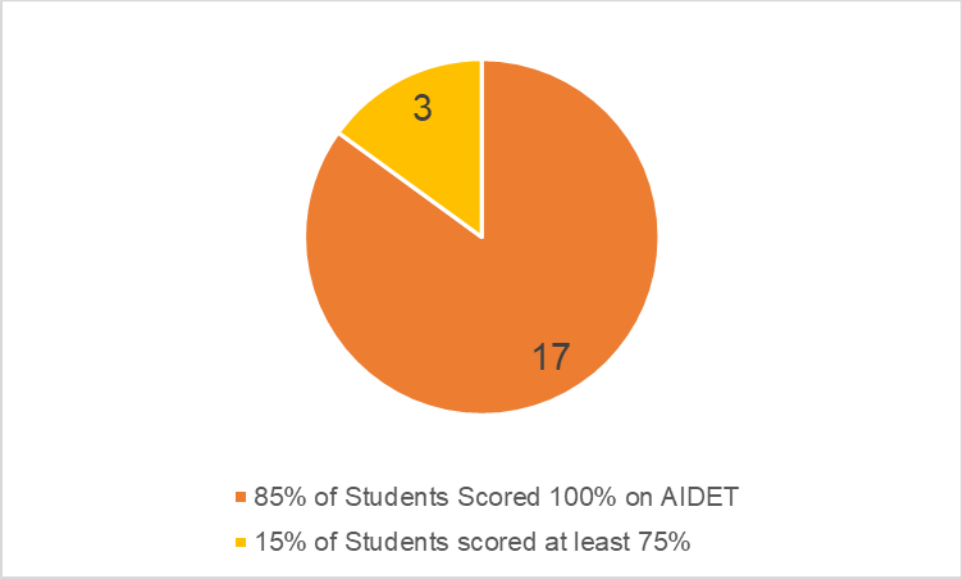


Figure 10. Gallbladder Proficiency AIDET Scores

Students were also assigned eight simulator case study units with quizzes on the Simbionx U/S Mentor simulator machine. Figure 11 depicts the number of students that were able to properly diagnose each case. A progression from the first case of 13 out of 20 students having the correct diagnosis, to 19 out of 20 making a proper diagnosis in their final case study. Regular weekly use of the Simbionx U/S Mentor simulator machine demonstrated an increased ability to properly diagnose individual case studies.

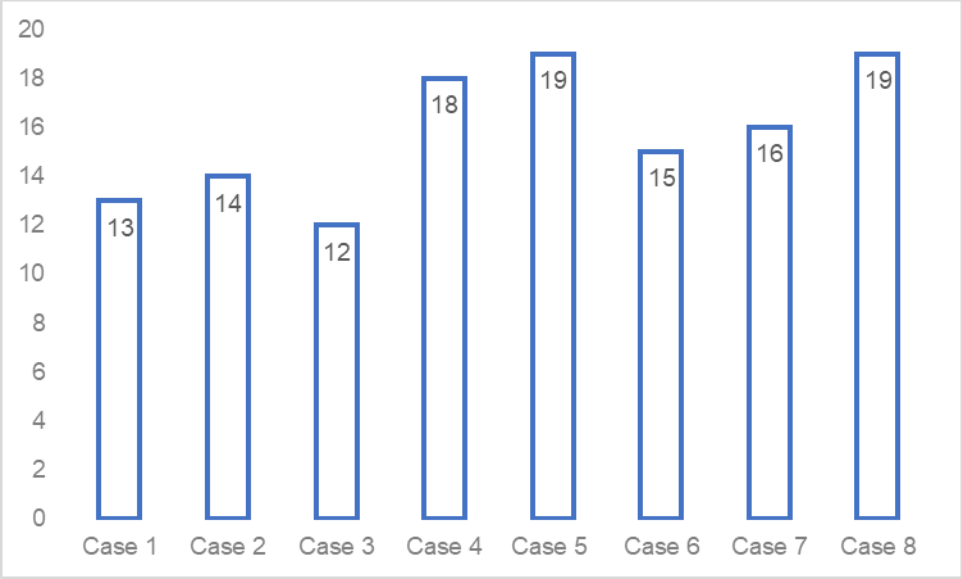


Figure 11. Number of Students with Correct Simulator Case.

A review of the analysis of student competency scores and simulation quizzes, indicates positive outcomes for students. Students who participated in rehearsal, peer review and simulation strategies also had an increase in perceived value of these interventions. These results may incentivise sonography educators to add one or more of these interventions into their own curriculum.

Action Plan

This action research study investigated adding a combination of learning strategies to a sonography lab course and its impact on student performance. Prior to conducting this action research study, the researcher has witnessed sonography student challenges in scanning protocols, effective use of AIDET, and communication with patients in the clinical internship setting. The researcher had also previously observed students in the university lab setting lacking confidence and skills resulting in lower competency scores.

Adding the use of an ultrasound simulator machine, along with rehearsal and peer review strategies can build student confidence and possibly reduce anxiety associated with competency

exams. Adding a defined machine schedule in the laboratory setting ensures that each student receives an equal amount of time on each piece of equipment during instructor-led lab sessions. A more organized teaching approach where students can rehearse and simulate their clinical experience will lead to increased student competency scores and confidences better preparing them for their clinical internship experience.

Conducting an action research project during a world-wide COVID-19 pandemic had posed several notable challenges. COVID-19 social distancing, positive COVID cases, quarantined students, the use of PPE's (personal protective equipment), and restricted laboratory hours presented some difficulties while conducting this study. Sonography students were to (whenever possible) remain a minimum of six feet apart during our in-person lab sessions. This makes it difficult for students observing exams to visualize machine monitors and learn from their peers that are scanning live patients. Several students tested positive for COVID-19 or had exposures that resulted in being removed from the sonography lab for up to 14 days. The use of PPE's made for difficult communication between students and their instructor. Donning a N95 mask and face shield not only makes oral communication difficult but makes it impossible to read one another's facial expressions.

The restricted lab hours in 2020 due to the pandemic, will always cause the researcher to question how different the study results would have been if the 2020 class would have had comparable hours to the 2019 class. Future recommendations for an action research study exploring the effectiveness of learning strategies of this nature would include performing the study when there are no lab restrictions or abnormal variables such as a pandemic that could affect the study. Having a research action group that has a comparable working environment to the normal status quo would make for a more accurate data analysis.

Peer review exercises could be implemented each week as opposed to one every three weeks. Protocols could be broken down so that students could work their way up to a complete protocol while preventing a decrease in student/ instructor interaction during the lab. More defined instructor lab journals would be beneficial when documenting individual student progress. Adding sections for noting individual progress rather than just sections for open comments may be a more effective way to document formative feedback and provide future assistance.

In addition, having multiple researchers may be beneficial when performing this type of action research study. For a single researcher implementing the strategies, providing each student with adequate formative feedback and data collection can be rather demanding. Despite the challenges of conducting this action research study during a world-wide pandemic, notable positive results were documented. As stated earlier, the 2020 abdominal 1 sonography lab class had a mean competency score of 94% compared to the 2019 class score of 90%. This increase is quite surprising considering the 2020 class had approximately 250 less hours of open lab time to practice their scanning skills.

Reviewing the statistical data alone indicates this action research study was able to demonstrate positive effects when adding simulation, peer review, and rehearsal strategies. Student feedback in the post-course student assessment adds validation to the statistical results. One student commented in the post course assessment validating positive perceptions of simulator use and rehearsal strategy: “What we are doing is extremely helpful to find liver abnormalities and also getting comfortable with communicating to the patient and feeling more confident when scanning”. Another student’s comment read: “I thought all the things that were implemented in lab were very helpful to improve scanning”. A third student commented:

"Absolutely loved these changes in lab and greatly benefited". The researcher added the rehearsal and peer review strategies, and a defined lab schedule into his spring lab course, as this is now becoming a student expectation.

In Summary, the researcher found that adding simulation, rehearsal, and peer review strategies in sonography lab to be beneficial. Collected data indicated increases competency scores. Student perception revealed that the addition of these learning strategies better prepared them for sonography competencies with actual live patients.

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Appendix A
Pre and Post-Course Student Assessment

Abdominal 1 Lab (2020 Fall) Pre-course student assessment

Form description

This form is automatically collecting email addresses for St. Catherine University users. Change settings

Rate the following activity: Peer evaluation learning strategy. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rate the following activity: Weekly ultrasound simulator machine case study assignments. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rate the following activity: Instructor evaluation of my sonography exam images. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rehearsing and role playing sonography exams from the very beginning (patient introduction) to exam end (exiting the patient). *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Please explain any of your answers here.

Long answer text

Abdominal 1 Lab (2020 Fall) Post-course student assessment

Form description

Rate your experience with the following activity: Peer evaluation of my lab scan process. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rate your experience with the following activity: Weekly ultrasound simulator machine case study modules. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rate your experience with the following activity: Instructor evaluation of my sonography exam images. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Rate your experience with the following activity: Rehearsing and role playing during sonography exams. *

	1	2	3	4	5	
Offers no benefit	○	○	○	○	○	Extremely beneficial

Please explain any of your answers here:

Long answer text

Appendix B
Lab Rotation Schedule

Tuesday abdominal lab (Week 1, Week 3, and Week 5)

	Machine 1 (Redwood)		Machine 2		Machine 3
8:00-8:20	Student 1	8:00-8:20	Student 2	8:00-8:20	Student 3
8:20-8:40	Student 4	8:20-8:40	Student 5	8:20-8:40	Student 6
8:40-9:00	Student 7	8:40-9:00	Student 8	8:40-9:00	Student 9
9:00-9:20	Student 10	9:00-9:20	Student 1	9:00-9:20	Student 2
9:20-9:40	Student 3	9:20-9:40	Student 4	9:20-9:40	Student 5

Simulator time	Student assignment
8:00-8:10	**Student 4**
8:10-8:20	**Student 10**
8:20-8:30	**Student 8**
8:30-840	**Student 2**
8:40-8:50	**Student 3**
8:50-9	**Student 5**
9-9:10	**Student 6**
9:10-9:20	**Student 7**
9:20-9:30	**Student 9**
9:30-9:40	**Student 1**

Thursday abdominal lab (Week 2, Week 4, and Week 6)

	Machine 1 (Redwood)		Machine 2		Machine 3
8:00-8:20	Student 6	8:00-8:20	Student 7	8:00-8:20	Student 8
8:20-8:40	Student 9	8:20-8:40	Student 10	8:20-8:40	Student 1
8:40-9:00	Student 2	8:40-9:00	Student 3	8:40-9:00	Student 4
9:00-9:20	Student 5	9:00-9:20	Student 6	9:00-9:20	Student 7
9:20-9:40	Student 8	9:20-9:40	Student 9	9:20-9:40	Student 10

Highlighted= additional 20 minutes

Simulator time	Student assignment
8:00-8:10	**Student 10**
8:10-8:20	**Student 3**
8:20-8:30	**Student 4**
8:30-840	**Student 5**
8:40-8:50	**Student 6**
8:50-9	**Student 8**
9-9:10	**Student 9**
9:10-9:20	**Student 1**
9:20-9:30	**Student 2**
9:30-9:40	**Student 7**

Appendix C
St. Kate's Communication Prep Outline for Internship

AIDET (Acknowledge, Introduce, Duration, Explanation, Thank You)

Rooming the Patient

- Avagard as you approach your patient.
  This assures the patient you have cleaned your hands, especially, if you greet them with a handshake. Patients need to see hand hygiene performed to know it was done.
- Perform the AI (acknowledge and identify) of AIDET.
  This is a good time to introduce yourself, but do not discuss confidential patient information until you are in the exam room. Identify yourself as an Intern (not a student) from St. Kate's and introduce your preceptor.
- Direct the patient to the exam room and shut the door.
  DO NOT discuss any confidential information in the waiting area or hallway!
- If needed, explain to the patient where they may place their belongings.
- Offer your patient a chair to sit down, help the patient on and off the exam table.
- Perform the DE of AIDET.
  Have you ever had this exam before? Explain the exam or procedure you are about to perform and the duration of the exam.

Provide Sensitivity to the Patient's needs

- Ask your patient if they have any special needs related to the procedure.
  Some patients have a physically limited range of motion or may be unable to be positioned in a certain manner. They may have poor hearing, vision, circulation, language barrier, etc.
- Obtain patient history prior to beginning the imaging exam.
  Along with obtaining the patient history, ask the patient why their physician ordered this exam today (Are you having pain in a particular area? Did you recently have some abnormal lab results? Etc.)?

Response to Concerns and Questions

- Ask the patient before the exam – "Before we begin, do you have any questions that I should be aware of or that I can help to address?"
  Directly asking the patient will give the patient a comfortable opportunity to bring forth their concerns prior to the exam and help to ensure that we are being sensitive to any concerns or questions that they may have.
- If the patient has a concern or question – ask the patient if you have addressed their concern to their satisfaction. If not, offer to let them speak with your preceptor.

Post-Exam/Procedure

- Explain to the patient how and/or when they will get their results.
- Ask your patient if they have any questions about today's visit.

- THANK THE PATIENT FOR COMING TODAY! (This completes your Aidet)

Appendix D
Gallbladder
PEER REVIEW ASSIGNMENT

Student: _____

Protocol	**Good**	**Adequate**	**Needs Improvement**	**Comments**
Longitudinal GB supine				
Transverse GB supine				
Longitudinal GB LLD				
Transverse GB LLD				
Wall of GB with measurement				
CBD with measurement				
AIDET comments: Introduction Identified patient (name/DOB) Reason for exam Patient History Previous Imaging Previous Labs When can patient expect results? Overall communication.				

Abdomen Complete Peer Review

Name: _____ Date:_____Patient and Anatomy Scanned:_____

Evaluator: _____ Start time:_____ Finished: _____

Add comments in the appropriate box.

Skill	Accomplished	Unable to demonstrate
Sweeps through anatomy prior to beginning study		
Long Liver		
Demonstrates pancreas		
Demonstrates long image of left lobe with aorta posterior		
Demonstrates long image of left lobe with caudate & LV		
Demonstrates long image of left lobe with IVC		
Demonstrates long kidney/liver interface		

Demonstrates long image of right lobe with diaphragm		
Demonstrates long image of dome		
Trans Liver		
Demonstrates trans image of left lobe with tip		
Demonstrates trans image of caudate & LV		
Demonstrates trans image of dome (right/mid lobe)		
Demonstrates trans image of a minimum of 2 hepatics draining into IVC		
Demonstrates trans image of right lobe with portal vein & IVC		

Demonstrates trans image of liver/right kidney interface		
Gallbladder		
Demonstrates long image of GB supine		
Demonstrates trans image of GB supine		
Demonstrates long image of GB LLD		
Demonstrates trans image of GB LLD		
Demonstrate GB wall trans with measurement		
Demonstrate & measure CBD		
Kidneys		
Demonstrate long right kidney mid with measurements		
Demonstrate long right kidney medial		
Demonstrate long right kidney lateral		
Demonstrate trans right kidney mid with measurement		

Demonstrate trans right kidney superior pole		
Demonstrate trans right kidney inferior pole		
Demonstrate long left kidney mid with measurements		
Demonstrate long left kidney medial		
Demonstrate long left kidney lateral		
Demonstrate trans left kidney mid with measurement		
Demonstrate trans left kidney superior pole		
Demonstrate trans left kidney inferior pole		

Aorta		
Demonstrate long proximal aorta with measurement		
Demonstrate long mid aorta with measurement		
Demonstrate long distal aorta with measurement		

Demonstrate trans bifurcation with measurements		
Spleen		
Demonstrate long spleen		
Demonstrate trans spleen		
Miscellaneous		
Breathes patient		
Finishes in allowed time		
Degree of confidence		
Effectively used equipment overall: TGC, depth, OVG/patient positioning, etc.		
Maintains professionalism & communicates effectively using AIDET		

Pass/Fail

Total Points: Pass / Fail

Example comments for scanning performance:

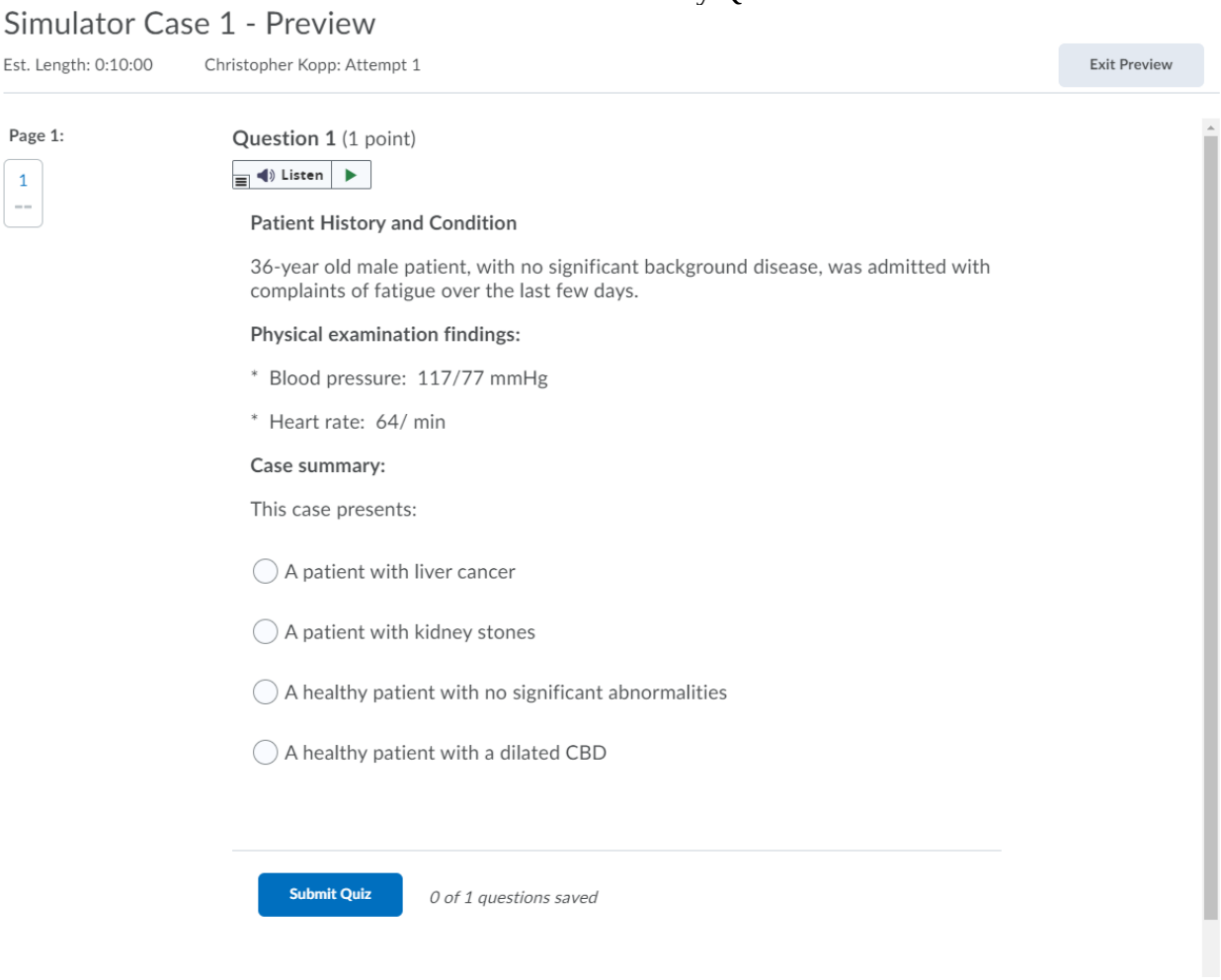
Accomplished image and diagnostic quality. Image quality is consistent with student progression in scanning: TGC, TZ, depth, gain, RES/Zoom, and anatomy centered. Good patient care skills. Proper ergonomics.

Intermediate image and diagnostic quality. Image quality is good. Good patient care skills. Proper ergonomics.

Developing image and diagnostic quality. Image quality is degraded.

Beginning image quality with minimal diagnostic quality. Image quality suboptimal.

Appendix E
Simulator Case Study Quiz



Simulator Case 2 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1

Question 1 (1 point)

Listen

Patient History and Condition

45-year old male patient, heavy smoker with a history of high blood pressure, was admitted with complaints of a new onset of lower back and abdominal pain.

Physical examination findings

Blood pressure: 141/97 mmHg

Heart rate: 85/ min

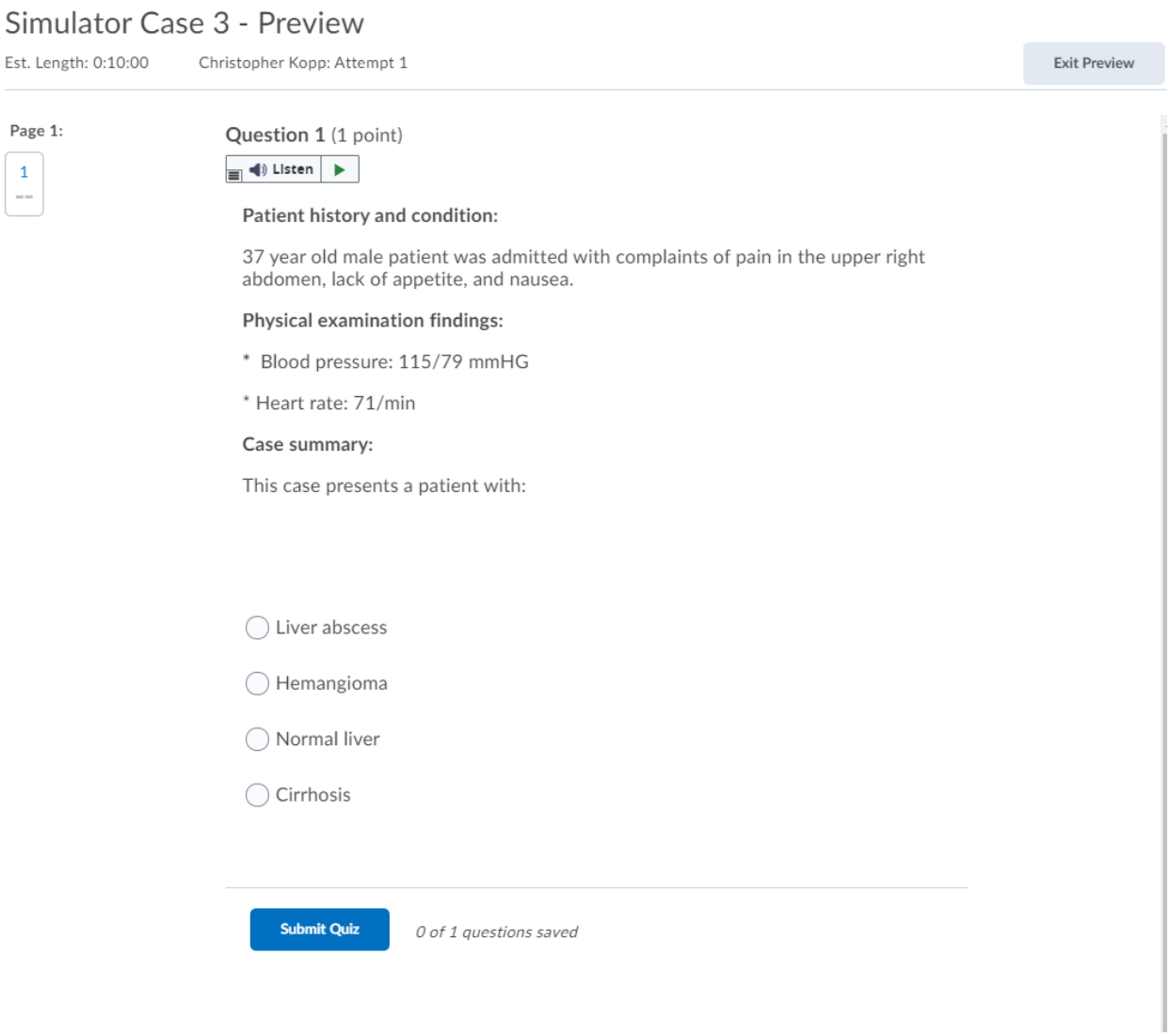
Respiration rate: 16/min

Case summary

This case presents a patient with:

- ◯ Dilated IVC
- ◯ Normal aorta
- ◯ Liver cyst
- ◯ Abdominal aortic aneurysm (AAA)

Submit Quiz *0 of 1 questions saved*



Simulator Case 3 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1

Question 1 (1 point)

Listen

Patient history and condition:

37 year old male patient was admitted with complaints of pain in the upper right abdomen, lack of appetite, and nausea.

Physical examination findings:

* Blood pressure: 115/79 mmHG

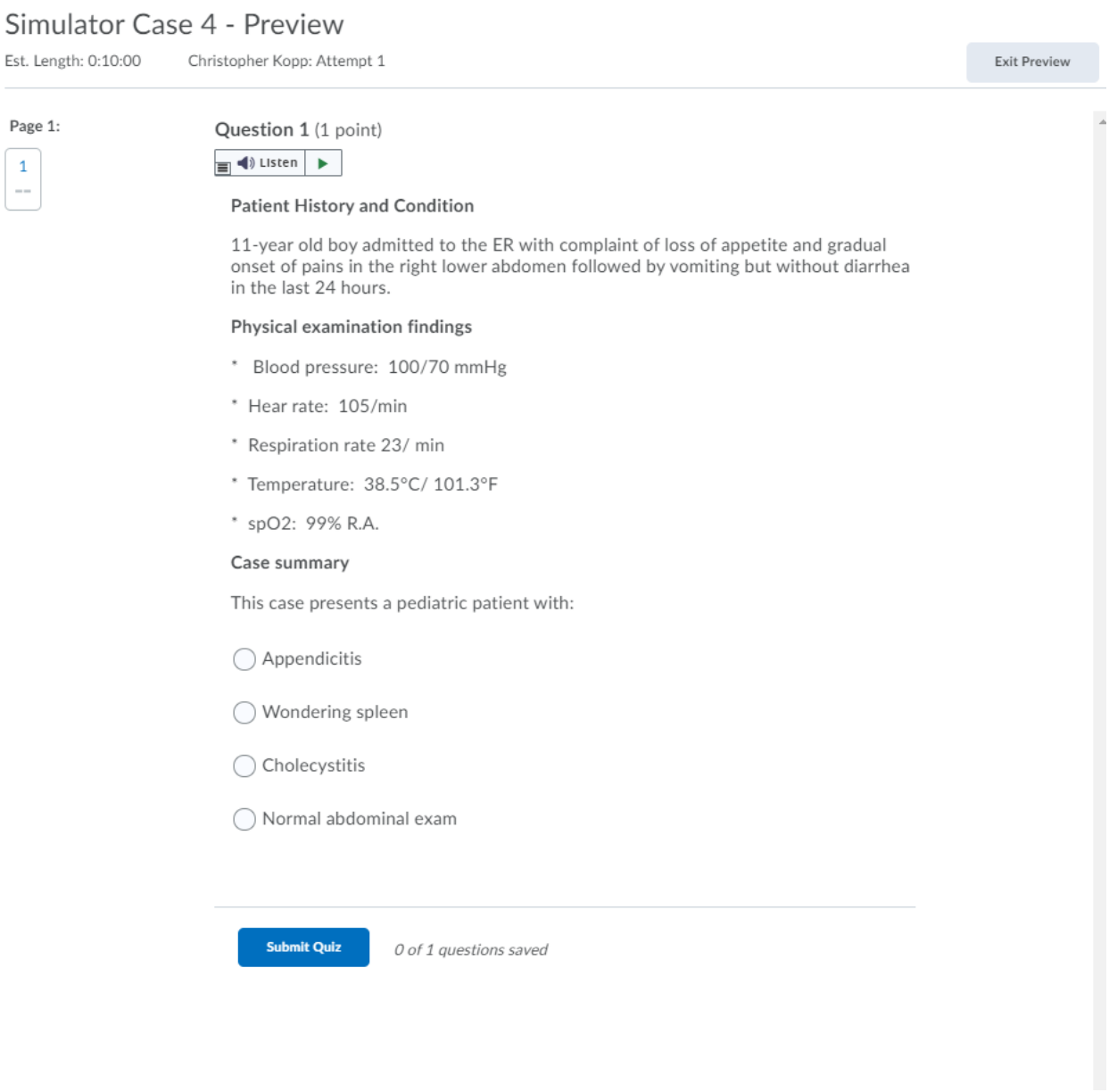
* Heart rate: 71/min

Case summary:

This case presents a patient with:

- Liver abscess
- Hemangioma
- Normal liver
- Cirrhosis

Submit Quiz *0 of 1 questions saved*



Simulator Case 4 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1

Exit Preview

Page 1:

1

Question 1 (1 point)

Listen

Patient History and Condition

11-year old boy admitted to the ER with complaint of loss of appetite and gradual onset of pains in the right lower abdomen followed by vomiting but without diarrhea in the last 24 hours.

Physical examination findings

* Blood pressure: 100/70 mmHg
* Hear rate: 105/min
* Respiration rate 23/ min
* Temperature: 38.5°C/ 101.3°F
* spO2: 99% R.A.

Case summary

This case presents a pediatric patient with:

- ◯ Appendicitis
- ◯ Wondering spleen
- ◯ Cholecystitis
- ◯ Normal abdominal exam

Submit Quiz 0 of 1 questions saved

Simulator Case 5 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1

Question 1 (1 point)

Listen

Patient History and Condition

A 50-year old male patient was admitted to the emergency room with right colic flank pain for the past 48 hours. There were no urinary symptoms. Past medical history is unremarkable.

Physical examination findings

* Blood pressure: 120/80 mmHg
* Temperature: 37°C/ 98.6°F
* Right flank region is mildly tender upon palpation.

Lab tests:

* WBC: 8000/ mm3
* Creatinine: 2 mg/L
* RBC>60/mm3

Case summary

This case presents:

- ◯ A patient presenting with right kidney hydronephrosis due to kidney stone in the UPJ
- ◯ A patient presenting with right kidney mass
- ◯ A healthy patient with a normal right kidney

Submit Quiz *0 of 1 questions saved*

Simulator Case 6 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1
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Question 1 (1 point)

Listen

Patient History and Condition:

A 47-year old male patient with complaints of abdominal pain, malaise, fatigue, and diffuse abdominal discomfort. Past medical history is unremarkable.

Physical examination finding:

* Blood Pressure: 150/87 mmHg
* Heart rate: 80/ min
* Temperature: 37°C/98.6°F
* Right upper quadrant abdominal tenderness and hepatomegaly

Lab tests:

WBC: 4700/ mm3

AST, ALT and ALP are elevated

Case summary:

This case presents a patient with:

- ◯ Fatty liver and normal gallbladder
- ◯ Multiple gallstones and fatty liver
- ◯ Multiple gallstones and normal liver
- ◯ Normal liver and gallbladder

Submit Quiz *0 of 1 questions saved*

Simulator Case 7 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1

Question 1 (1 point)

Listen

Patient History and Condition

A 72-year old man arrived at the outpatient clinic complaining of lower abdominal pain, constipation and 15 kg weight loss during the last 3 months with a gradual onset of anorexia, malaise, nausea, loss of appetite and fatigue during the last month.

Patient is not on any medications. Past medical history is unremarkable.

Physical examination findings

* Blood pressure: 130/85 mmHg
* Pulse rate: 85/ min
* Temperature: 37°C/98.6°F
* Mild suprapubic tenderness. The patient is destressed.

Lab tests:

* CBC showed mile anemia
* WBC: 10630/ mm3
* Hematocrit: 31%
* Bilirubin 5.0 mg/dl; SGOT: 109 U/L; SGPT: 145 U/L; yGT: 517 U/L; ALP: 467 U/L; LDH: 503 U/L; CA125: 244.50 U/L; CA19.9: 5130 U/L

Case summary

This case presents a patient:

- ◯ With normal liver exam
- ◯ With cholelithiasis and dilated ducts
- ◯ With pancreatic malignancy and liver metastases
- ◯ With retrograde Main portal vein flow

Submit Quiz *0 of 1 questions saved*

Simulator Case 8 - Preview

Est. Length: 0:10:00 Christopher Kopp: Attempt 1 Exit Preview

Page 1:

1

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Question 1 (1 point)

Listen

Patient History and Condition

A 45-year old male patient with a history of hypertension was admitted to the emergency department complaining of abdominal pain, nausea, and vomiting. He stated that he had prior similar episodes which resolved spontaneously; however, the current pain has persisted for five hours and is more severe. The pain is located in the upper right quadrant of the abdomen and is radiating to the upper back, described by the patient as dull and cramping.

Physical examination findings:

* Blood Pressure: 148/96 mmHg

* Heart rate: 108/ min

* Respiration rate: 18/ min

* Temperature: 38.5°C/ 101.3°F

* Right upper quadrant abdominal tenderness and guarding. Murphy's sign is positive.

Lab tests:

* WBC: 15,000/ mm3

* AST, ALT and ALP are mildly elevated

Case summary

This case presents a patient with:

- ◯ Cholecystitis due to gallstone in the neck of the gallbladder
- ◯ Fluid in Morrison's pouch
- ◯ Normal gallbladder exam
- ◯ Polyps in the gallbladder

Submit Quiz *0 of 1 questions saved*

Appendix F
Lab Instructor Journal

Lab Instructor Journal

1. Are students beginning and ending their scanning sessions in a timely manner? (The students have been allocated equal time on each sonography machine and the ultrasound simulator. If they do not begin and end their sessions on time, some students will get less time on the machines.)

Observations: (please include noted benefits and challenges).	Reflections:

2. Are students engaged in their exam? (Do they know the protocol? Have they performed a proper AIDET? Are they staying on-task (not socializing or being distracted etc.)?

Observations: (please include benefits and challenges).	Reflections:

3. Scanning progression. Which students did I provide formative feedback on their patient scanning? Did any individuals have difficulty with transducer positioning/ placement and optimizing 2D images being projected on the monitor? What did I notice that students needed assistance with?

Observations: (please include noted benefits and challenges).	Reflections:

4. Did I have personal interaction with each student? If not, who was missed? What did I learn about individual students today that I can remember for personalizing interactions in the future?

Observations: (please include noted benefits and challenges).	Reflections:

5. What went well? What didn't go well/could've gone better?

Observations: (please include noted benefits and challenges).	Reflections:

6. What changes will I make based on today's results? What did I learn?

Observations: (please include noted benefits and challenges).	Reflections: