Increasing Technologists' C-Arm Confidence And Competence in the Operating Room

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The operating room (OR) is a fast-paced environment that often can be stressful and daunting.[1] Proper and adequate education for all members of the diverse OR team, including the radiologic technologist, is essential in ensuring delivery of excellent patient care.[1] Radiologic technologists' role in the surgical environment is multifaceted; they must take precise and accurate images to help guide the surgical team while using their knowledge of radiation safety to minimize radiation exposure to staff and patients.[2] The C-arm is used to take images during surgical procedures, and its operation and management are the responsibility of the radiologic technologist.

The C-arm can be used to take static radiographs and perform live fluoroscopy. This functionality makes it an invaluable tool in helping guide surgeons' accuracy while keeping procedures minimally invasive.[3] Although C-arms generate radiation that could endanger patients and OR staff, particularly when used for continuous fluoroscopy, the radiation exposure is lower than that of a computed tomography (CT) scan.[3,4] In addition to potentially lower radiation doses compared with CT, fluoroscopy offers the ability to continually reposition a patient and only expose the localized region of interest to radiation.[4] CT might be superior for its 3-D imaging, but the C-arm is preferred because of its reduction in radiation exposure and high quality 2-D images.[3] Sonography can be considered an even safer option because it does not produce radiation; however, sonography does not create the proper visualization needed to guide a surgeon safely through a procedure.[3] Therefore, C-arms have become accepted as the preferred method for keeping procedures minimally invasive and are used in orthopedic, pain management, and interventional radiology procedures,[5] as well as vascular, urological, and gastrointestinal cases.[1] Another advantage of the C-arm is its varied ranges of motion, or kinematics.[3] C-arms have 6 ranges of motion, making them highly flexible and functional in the confines of the OR. C-arms can be moved in and out, up and down, and left or right on their axis (wag), as well as rotated over and under for lateral imaging and left and right for oblique imaging.[3]

Being familiar with these C-arm operations and able to perform them quickly and competently is key to the radiologic technologist's role in the OR.[1] However, OR radiography is known to be among the most intimidating and challenging rotations for students, as well as for registered technologists, particularly because of the lack of hands-on C-arm instruction before clinical rotation through the OR.[1-3,5,6] Current C-arm education is mostly didactic or theoretical, with students reading and studying C-arm operation but having no hands-on experience before rotating through the operating suite.[1,2] This lack of clinical skill development has several consequences, including causing stress and lack of confidence in the student,[5] which then affects their competence.[7] Furthermore, inadequately trained technologists in the OR might generate additional radiation exposure to the patient and the OR staff by needing to potential to cause anxiety and confusion for students and registered technologists whose primary language differs from that used in the OR.[11]

The OR also has no standardized imaging or positioning protocols for C-arm radiography; necessary images and projections are dependent on the surgeon.[12] The technologist works to learn each surgeon's preferences and to react accordingly when asked to produce images.[12] Mistakes can be made if technologists forget which images a particular surgeon prefers, leading to prolonged procedures and additional radiation exposure.[12] For students, this is another potential barrier to confidence and competence because learning each surgeon's preferred projections is particularly difficult when they have limited competence using the C-arm.

Potential Solutions

Several potential solutions were identified to counter the challenges to increasing technologists' confidence and competence when using C-arms in the OR. C-arm education must include hands-on C-arm instruction before surgical rotation.[3] Didactic and theoretical lessons are not sufficient when a clinical hands-on skill is being taught.[1-3] Simple hands-on device instruction familiarizes a student with the various kinematics involved in moving and operating a C-arm,[3] building familiarity and muscle memory. This can reduce student anxiety when rotating through the OR because they feel more prepared, which fosters confidence and competence via enabled learning acquisition.[8,15] Furthermore, being more prepared and more competent ensures proper positioning of the C-arm, which reduces repeat imaging, overall radiation exposure, and dose to the patient and OR staff.[2]

Although hands-on C-arm instruction before OR clinical rotations in a stress-reduced and safe environment is key to building initial confidence and competence, additional rotations and exposure to the OR environment and the C-arm also help build student's confidence.[5] Kerns and Clark found that students who completed additional rotations that required C-arm use reported more confidence than those who completed fewer rotations.[5] Kerns and Clark's sample indicated that students who rotated through 4 or more rotations requiring C-arm use felt significantly more confident than those who completed fewer C-arm rotations.[5] This is evidence that additional C-arm rotations help to build C-arm confidence and might be necessary to ensure student technologists are prepared for work in the OR.[5]

Several types of C-arm and OR simulations have been found to reduce anxiety and promote confidence and competence. Simulations in radiography have been found to bolster clinical skills and skill retention, in part because simulations are performed in a safe environment where confidence can be fostered and learning acquisition increased.[14] Simulations in a controlled environment also foster better communication between trainer and trainee, where skills can be constructively critiqued, repetitions can be performed without fear of radiation exposure, and a thorough debriefing can occur after the simulation.[16] Debriefing is a central feature that gives the trainee the ability to reflect on their work and actions and to hear feedback on how to improve.[16] Learning occurs as the trainees apply feedback to future actions, building competence.[16] Debriefing and feedback are difficult to do during an actual OR case because there is no time for discussions, and the atmosphere often is poor for learning and building competence.[1] The instructor in these situations typically is an experienced technologist who must manage the surgeon's expectations and the student's inexperience; therefore, instruction becomes difficult.[1]

Simulation programs such as the Artificial X-ray Imaging System (AXIS) use digitally reconstructed radiographs to help C-arm users with little or no experience successfully position the C-arm for accurate images.[6] Participants had more confidence when using AXIS and took 53% fewer radiographs overall, supporting the notion that AXIS helps beginner C-arm users with using the C-arm more effectively and competently.[6] These results support the evidence that repetition and simulation help to reduce radiation dose by reducing the number of images required.[6] Another simulation program that has been shown to improve C-arm education is the computer-based virtual reality simulator for intraoperative x-ray imaging (virtX) created at Flensburg University of Applied Sciences in Germany.[2,17] VirtX gives students an opportunity to position a virtual C-arm in a safe environment and, using digitally reconstructed radiographs, see what their images would look like based on where they positioned the virtual C-arm in relation to a virtual patient.[2] Bott et al surveyed participants in a virtX simulation study and found that 89% of the participants found virtX to be a useful tool in addition to hands-on C-arm instruction.[2] Although virtX does not replace hands-on instruction, this supplemental simulation program can improve positioning skills and thereby reduce potential radiation exposure by strengthening competence and confidence.[2]

Simulations also might reduce challenges created by the OR hierarchy.[13] Naylor et al identified 4 themes that could help boost confidence, competence, and intercommunication in the OR suite by observing various simulations performed with radiologic technology students.[13] The first theme was identification; if a student or trainee is present in the OR, this should be made known to all so that unreasonable demands are not placed on the trainee, and stress is kept at a minimum. The second theme is clarity; the technologist should know details of the OR case so that they can react accordingly when needed. The third theme is preparation, which is required to keep the parts of the OR moving smoothly. For example, all staff must have protective radiation gear on, a space for the C-arm must be maintained, and the technologist must be made aware of the case well in advance. If anything is unprepared, delays in the case and disruption to the staff ensue. The last theme was respect; radiologic technologists' expertise in radiation safety must be respected because they are the gatekeepers who make sure the principle of as low as reasonably achievable are maintained.[13] These 4 themes highlight ways to improve technologist confidence and competence, as well as OR harmony, while reducing radiation exposure.[13]

Creating a universal or standardized system for C-arm commands has been suggested to reduce miscommunication and errors.[10,11] In a study by Yeo et al, several pairs of radiologic technologists and surgeons were timed while trying to achieve perfect circles during an orthopedic simulation.[11] Perfect circles refer to when an orthopedic device or implantation is positioned with the circles or screw holes on either side perfectly superimposed and properly aligned so that perfect round circles appear on the x-ray image vs ellipses.[18] The same pairs then were asked to memorize a common standardized set of C-arm commands and perform another simulation. There was a 50% reduction in the time it took to achieve perfect circles after the standardized commands were introduced, supporting the notion that when communication is improved by using a clear set of common commands, surgical time and amount of radiation exposure are reduced.[11] De Muinck et al created a standardized set of C-arm commands in Dutch because of the unhappiness technologists and surgeons expressed regarding the amount of miscommunication that occurred.[10] They found a decrease in surgical time and number of images required, as well as a reduction in discontentment when testing these commands.[10] Furthermore, a clear and unambiguous set of universally agreed on commands benefits nonnative speakers, who might struggle with the different commands given by surgeons.[11]

Lastly, radiography programs can improve their C-arm curricula to better prepare their graduates for OR work. Tay et al suggested a new curriculum that is competency based and uses simulations to enhance clinical skill application.[1] They also suggested faculty development to better enable educators to pass these skills along to their students.[1] Kerns and Clark showed that more clinical C-arm rotations promotes more student confidence;[5] this evidence supports the suggestion that radiologic technology education programs might need to require additional rotations that use the C-arm for students and to test their competence more rigorously. Jeyandrabalan et al called on radiologic technology programs to promote student well-being by adequately preparing them and by evaluating the effectiveness of all educational resources to monitor what works and what new services are needed to foster student confidence and competence.[7]

Discussion

Current literature supports the idea that gaps in proper C-arm preparation and instruction negatively affect the confidence and competence of radiologic technology students and trainees. However, additional questions and differing paths for research emerge when reviewing the current literature. Although this report highlights the gaps in C-arm education, it does not venture into the reasons why the gaps exist. Allen pointed out that simple device instruction is all that is needed for proper C-arm preparation.[3] However, as highlighted by Kerns and Clark, approximately one-third of students received C-arm preparation before starting OR rotations; for students who receive no preparation, a lack of confidence when they begin using the C-arm in the OR suite might inhibit learning and skill development.[5] There might be a few reasons for lack of hands-on C-arm instruction. C-arms are expensive, and radiography education programs might not be able to afford C-arms for instruction and simulation purposes.

Simulations also were cited as a reliable way to increase C-arm confidence and competence, but simulation software also can be expensive and might require additional hardware to operate, as well as additional space and resources, all of which cost money. Additional research might explore diverse ways that radiography programs could gain access to a C-arm. For example, hospitals that provide clinical rotations could donate older C-arms to those radiography programs. Grant programs in allied health education could help radiography programs procure C-arm machines for simulations and practice. Although C-arm simulations have been shown to improve learning, they are not without fault. As with all simulations, they can never fully recreate reality, and so a true-to-life experience with live patients with various illnesses will never be obtained in a simulated setting.[2]

The literature also discussed the lack of preparedness of OR technologists to train student technologists.[1] These experienced OR technologists are pressured to provide the surgeon with diagnostic quality images in an OR setting and being relied on to instruct students and newly hired technologists. OR technologists typically are not formally educated on how to teach.[1] This is another gap in C-arm instruction that could be further explored.

The COVID-19 pandemic had a notable effect on clinical education for the allied health professions, especially radiography.[19] Because of fear of spreading the virus, as well as the potential liability for students, many clinical rotation sites ceased serving students or severely limited the scope of their clinical rotations.[19] This likely included the OR because only essential surgeries were performed. All elective procedures were cancelled, thereby severely limiting potential OR cases for student technologists to learn from. Research on the effects of COVID-19 on radiologic technologists' instruction in the OR would be interesting. Recent graduates in radiologic technology might be less prepared than students who graduated before COVID-19.

Conclusion

Gaps in current C-arm education leave many radiologic technology students and trainees lacking in confidence and competence. Although access to a C-arm for practice and simulation before OR and C-arm rotations would vastly improve preparedness, most radiography programs do not have C-arms for their students' benefit. New graduates are expected to have C-arm competence to effectively and safely provide surgeons with images to guide them during procedures, and radiology departments that hire radiologic technologists expect their new hires to be ready. However, current C-arm instruction can produce stress and anxiety for many radiologic technologists who are introduced prematurely to the OR, and this stress and anxiety can prohibit learning, reduce confidence, and slow the development of competence, which consequently might result in additional radiation exposure for patients and OR staff. Radiography instruction should ensure students are prepared to keep radiation dose as low as reasonably achievable and produce quality images, but instruction also should support the well-being of their graduates by reducing stress and anxiety through hands-on instruction.

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