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ORIGINAL ARTICLE

In-person radiologist to review the trauma panscan: a high-fidelity simulation training program for radiology trainees at an academic level 1 trauma center

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Abstract

Background Radiology trainees were uncomfortable going to the CT scanner to review trauma panscans and interacting with trauma surgeons.

Objective This study aims to determine if radiology residents can be trained to accurately identify injuries requiring immediate surgical attention at the CT scanner.

Methods A high-fidelity simulation model was created to provide an immersive training experience. Between February 2015 and April 2017, 62 class 1 trauma panscans were read at the CT scanner by 11 PGY-3 radiology residents. Findings made at the scanner were compared to resident preliminary and attending radiology reports and correlated with clinical outcomes. Timestamps were recorded and analyzed. Surveys were administered to assess the impact of training on radiology residents' self-confidence and to assess trauma surgeons' preference for radiology at the scanner. Significance level was set at $p < 0.05$.

Results The mean time to provide results at the CT scanner was 11.1 min. Mean time for the preliminary report for CT head and cervical spine was 24.4 ± 9.8 min, and for the CT chest, abdomen, and pelvis was 16.3 ± 6.9 min. 53 traumatic findings on 62 panscans were identified at the scanner and confirmed at preliminary and final reports, for a concordance rate of 85%, compared to 72% for the control group. Radiology residents agreed or strongly agreed the training prepared them for trauma panscan reporting. Trauma surgeons shifted in favor of radiology presence at the scanner.

Conclusion Radiology residents can be trained to accurately and rapidly identify injuries requiring immediate surgical attention at the CT scanner.

Clinical impact These findings support the value-added of an in-person radiologist at the CT scanner for whole-body trauma panscans to facilitate timely detection of life-threatening injuries and improve professional relations between radiologists and trauma surgeons.

Keywords Emergency radiology · Trauma · Acute care imaging

Introduction

Trauma results in 41 million emergency department visits and 2.3 million hospital admissions in the USA annually and is the third leading cause of death overall [1]. Rapid diagnosis and management of injuries are key to best possible patient outcomes. Computed tomography (CT) plays an integral role in trauma management. Whole body trauma CT panscans are used to detect traumatic injuries and results in earlier treatment, fewer missed injuries, reduced hospital length of stay, and can reduce mortality by 25% compared to selective body CT [2, 3]. At our institution, we observed untenable time delays between image transfer from the CT scanner to the PACS and radiologist. Furthermore, we observed that radiology trainees were not only uncomfortable with the idea of going to the CT scanner to review trauma panscans but also hesitant about interacting with trauma surgeons.

In this study, we hypothesized that junior radiology residents could be trained with a high-fidelity simulation program to review trauma panscans at the scanner to identify

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injuries that require immediate surgical attention with high diagnostic accuracy and at a time savings. We also sought to assess the effect of the program on the radiology trainees' perceived self-confidence and the surgeons' preferences for radiologist presence at the scanner for trauma panscans.

Methods/materials

This study was approved by the Institutional Review Board and compliant with HIPAA.

Trauma panscans

All original trauma panscans were acquired on a 64-slice CT scanner (Lightspeed VCT, General Electric Healthcare, Milwaukee, Wisconsin). Four simulation trauma panscans were created consisting of CT studies of the head and cervical spine without intravenous contrast and CT studies of the chest, abdomen, and pelvis with intravenous contrast. These simulation panscans were created from different original trauma panscans in order to depict multi-system traumatic injuries. For example, a CT study of the head with acute intracranial hemorrhage and a CT study of the abdomen and pelvis with solid organ injuries from two different patients could be combined in the same simulation panscan. Critical injuries that would require immediate surgical attention were included, including intracranial hemorrhage, cervical spine fracture, solid organ and bowel injuries, active bleeding, and pelvic fractures. As only axial images are available at the CT scanner, only axial images were shown in the simulation panscans, using the same slice thickness as would be viewed at the CT scanner. The images were provided with the window/levels and reconstruction algorithms in the order they would be viewed at the scanner: head in soft tissue and bone; cervical spine in bone and soft tissue; chest in soft tissue, lung, and bone; abdomen/pelvis in liver, soft tissue, and bone. Images were captured from the original CT studies and directly inserted into Powerpoint (RadPix Capture, Weadock Software, LLC., Ann Arbor, MI), with each CT image on a separate slide in order to create a scrollable file simulating scrolling at the CT console.

High-fidelity simulation sessions

Individual training sessions

Second year radiology residents (PGY-3) were trained individually early in their second year, prior to the start of their overnight on-call duties. Training took place in a conference room, and images were viewed by the resident on a desktop computer monitor. This was done intentionally to simulate the poorer image quality of the CT scanner monitor and to reassure the residents that critical findings could be successfully identified without using a diagnostic quality PACS monitor. A senior radiology resident and one or two radiology attendings were present for the entire training session. An acute care surgery fellow and one or two acute care surgery attendings were present for the final simulation case and discussion that followed. The training session began with an introduction to set expectations. The resident was advised to be efficient, concise, decisive, assertive, and timely. A reasonable and appropriate history was given for all cases. Relevant physical exam findings, including vital signs and obvious, visible injuries were provided.

Case 1: The resident was given 12 min to review the images and make findings; then, the cases were reviewed with the senior resident and attending to give feedback and provide teaching as would be done during radiology rotations.

Case 2: The resident was given 10 min to review the images; the senior resident assumed the role of a calm surgery resident and increased pressure by asking questions, at times interrupting the resident.

Case 3: The resident was given 7 min to review the images; the senior resident assumed the role of a belligerent and pressured surgery resident, the radiology attending assumed the role of a calm surgical attending, the questions and interruptions continued, additional clinical history was provided then updated during image review to include impending hemodynamic instability, and an audio recording of hospital noise was played to intensify the experience.

Case 4: The surgical fellows and attending(s) joined and provided loud, vigorous, and authentic clinical simulation of a severely traumatic patient who was on the verge of hemodynamic instability while the resident reviewed the images; this case was ended with the surgeons rushing the patient from the CT scanner to the operating room.

At the end of the first three cases, the cases were reviewed with the radiology resident by the radiology attending and senior resident and feedback was given regarding CT findings and communication of findings. This included advice on how to describe CT abnormalities more concisely and pointing out which CT findings were not important to mention at the CT scanner. After the fourth case and to conclude the training session, radiology and acute care surgery held a group discussion with the radiology resident that included radiology and surgical teaching points, CT findings that were most important to the trauma surgeons, and differences in communication styles between surgery and radiology.

Group training session

Approximately 2 months after the conclusion of the individual training sessions, a group training session was held for all radiology residents. Trauma CT studies were shown to 2nd and 3rd year radiology residents in a 1.5-h session while aggressively questioned by senior radiology residents according to the radiology Socratic method, also known as the "hot seat" format. The group training session concluded with a discussion led by an attending emergency radiology, trauma surgeon, and neurosurgeon regarding the clinical impact of radiology findings, answering clinical management questions posed by the radiology residents, addressing cultural differences between radiology and surgical specialties, and improving effectiveness of radiology communication of findings to surgery services.

Survey questionnaires

Radiology residents

The radiology residents were surveyed immediately prior to and after the individual training sessions to gauge the impact of the simulation training on their perceived confidence in providing in-person review of CT images at the scanner for trauma patients (Table 1). Responses were assessed using a 5-point Likert Scale.

Surgery

The surgery residents, fellows, and acute care surgery attendings were surveyed regarding their preferences for radiology presence at the CT scanner to review trauma panscans (Table 1). Responses were assessed using a 5-point Likert scale. Surveys were administered electronically (Qualtrics). The surgeons were surveyed prior to radiology residents reporting to the CT scanner and surveyed again a year later with the same survey questions.

Trauma panscan checklist

A paper checklist was created jointly by radiology and acute care surgery to determine the pertinent, emergent imaging findings that would require immediate surgical intervention (Fig. 1). This paper checklist was completed at the CT scanner by the radiology and surgery residents in consensus to ensure mutual agreement of the identified abnormalities and represented documentation of the radiology verbal report made at the scanner. This checklist allowed for time stamps to be manually documented by the radiology resident and included a free text area to write comments about unexpected delays and complications. The resident recorded the time upon leaving the reading room for the CT scanner as the start time. The amount of time to reach the CT scanner was negligible, less

Table 1 Sample questions from the radiology trainee and trauma surgeon surveys

Radiology trainee, regarding trauma panscans
- I am comfortable providing quality control on trauma CTs
- I am comfortable providing a preliminary report on a trauma panscan reviewed on the PACS in the reading room
- I believe that radiologists should be involved in trauma resuscitation by reviewing images at the CT scanner with the trauma team to identify findings that require immediate surgical attention
- I am confident in my ability to provide a "wet read" at the scanner as long as the trauma surgery team understands that the "wet reads" are designed to identify findings that require immediate surgical attention and that a full preliminary report will follow that is based on reviewing the CT study in the PACS
- I believe that the presence of radiology at the scanner to help identify findings that necessitate immediate surgical attention represents an improvement in trauma imaging (for patient care, assisting our trauma colleagues, supporting our CT techs)

Radiology trainee, after training sessions
- I believe the training prepared adequately to provide "wet reads" at the ED scanner
- I am confident in my ability to provide a "wet read" at the scanner in the ED on trauma patients to identify findings that require immediate surgical attention
- Do you think radiology should be present at the scanner during trauma patient imaging? Why or why not?
- Please comment on the training experience — did you like it and why or why not? How would you improve it?

Trauma surgery, regarding radiology trainee preliminary reports on trauma studies
- Findings are usually communicated in a timely fashion
- Findings are usually communicated to the correct person
- I feel comfortable asking follow-up questions to the radiology trainee
- I feel comfortable acting on radiology trainee preliminary report
- Radiology trainee preliminary reports are usually accurate
- Radiology trainee preliminary reports are suitable for making patient care decisions
- I would like to have Radiology present at the scanner during trauma CT scans

Fig. 1 Panscan checklist jointly created by radiology and trauma surgery. A paper version was used for the "wet read" at the CT scanner but was not included in the electronic medical record. Patient names, medical record numbers, relevant times, and imaging findings were recorded on the checklist

Anatomy	Positive Findings	No Findings	Comments
Head	▫ Hemorrhage (where): ▫ Midline shift: R L ____mm ▫ Displaced or depressed fracture (where): ▫ Obvious Herniation		
Cervical Spine**	▫ Obvious fracture (where): ▫ Malalignment on lateral scout: ▫ Canal narrowing:		** Axial fractures may be occult
Thorax	▫ Aortic injury (where): ▫ Pneumothorax: R L Tension? Y N ▫ Pleural Effusion ▫ Obvious displaced rib fracture/flail chest		
Abdomen	▫ Obvious solid organ injury (which): ▫ Obvious bowel or mesenteric injury ▫ Obvious active bleeding or PSA/AVF ▫ Hemoperitoneum ▫ Gross pneumoperitoneum		▫ Need delayed renal images
Pelvis	▫ Displaced/depressed fracture ▫ Obvious active bleeding		▫ Recommend CT cystogram
Scout	▫ Extremity fracture		

* These findings were reviewed in conjunction with trauma surgery to identify obvious, severe injuries necessitating immediate surgical management. Comprehensive written preliminary report to follow.

than 15 s. The end time was recorded after the radiology resident had completed their review of the images at the scanner, reviewed the significant findings with the surgical resident, and completed the paper checklist. The start and end times were recorded manually on the trauma checklist. After returning to the reading room from the CT scanner, the radiology resident reviewed the trauma panscan at the PACS workstation and issued a resident preliminary report which was time-stamped by and stored as part of the electronic medical record. Any major changes or additions from the radiology report made at the scanner were communicated to the trauma team via direct pager and phone call. The paper checklist, resident preliminary report, final report, and electronic medical records were analyzed to determine concordance and assess clinical outcomes.

Clinical implementation

The study period was February 2015 to April 2017. Upon completion of their individual training session, radiology residents were instructed to report to the CT scanner for class 1 trauma patients and review images, while surgery was present and complete trauma panscan checklists. The emergency department CT scanner was located three hallways away from the radiology reading room and could be reached in approximately 30 s if one walked briskly. All trauma panscans consisted of unenhanced CT studies of the head and cervical spine, and contrast-enhanced CT studies of the chest, abdomen, and pelvis. All CT studies were performed on a 64-slice CT scanner (Lightspeed VCT, General Electric, Milwaukee, Wisconsin). The departure time from the reading room to the CT scanner, the start and completion times of the panscan checklist, return time from the scanner to the reading room, CT findings on the panscan checklist, free text notes, written preliminary report, final attending radiology report, clinical management and outcomes, and the trauma panscan CT images were reviewed and recorded. Additional imaging recommendations made at the scanner that expedited patient imaging, such as CT cystogram for suspected bladder injury, were recorded. Concordance was defined as the successful identification of CT findings that necessitated immediate surgical attention on the panscan checklist when compared to the resident preliminary report and/or final attending report. Concordance rates, therefore, were calculated by taking the number of concordant CT findings divided by the total number of study group cases. Conversely, discordance was defined as CT findings that were not identified at the CT scanner but were reported on resident preliminary and/or final attending report. Discordance rates were calculated as the number of discordant findings divided by the total number of study group cases.

A control comparison group was created comprising all class 1 trauma CT panscans from May to September 2014. The preliminary report and final attending reports were reviewed. The start of the CT scan time, time of verbal communication, and time stamp of issuance of the preliminary report were obtained from the radiology information system (RIS) and electronic medical record. The resident preliminary report, attending final report, clinical management and outcomes, and trauma panscan CT images were reviewed and recorded.

Statistical analysis

All data were entered and analyzed in Microsoft Excel, with significance set at $p=0.05$ (Microsoft Corporation, Redmond, Washington).

Results

Trauma CT panscans

The panscan checklists for 62 Level 1 trauma panscan CT studies were completed, representing the study group. There were 18 trauma panscan CT studies in the control comparison group. Prior to implementation of radiology presence at the scanner for class 1 trauma patients, the mean time from start of scan to time issuance of preliminary report for the head and cervical spine CT studies was 50.7 ± 15.6 min and for chest, abdomen, and pelvis CT studies was 45.9 ± 15.8 min. The mean time to provide results at the scanner using the panscan checklist was 11.1 min (range 3–56 min). The mean time from completion of the panscan checklist to issuance of the preliminary report for the CT head and cervical spine studies was reduced to 24.4 ± 9.8 min and for the CT chest, abdomen, and pelvis decreased to 16.3 ± 6.9 min. The total time to issuance of preliminary report, from scan start to time stamp in the RIS, which included the time needed to report to and return from the CT scanner, increased to 60.6 ± 26.8 min ($p=0.06$, 19% increase) for the CT head and cervical spine, and to 58.1 ± 28.4 min ($p=0.023$, 26% increase). Graphical depiction of time savings for result communication at the CT scanner compared to the preliminary report is illustrated in Fig. 2.

Of the 62 panscans, the residents identified 53 acute traumatic findings which were confirmed at preliminary resident report and final attending report, for a concordance rate of 85%. The post-simulation study group had a concordance 13% higher than the control group, in which there was 72% concordance, with 13 of 18 cases found to require surgical attention. The discordant cases consisted of three cases: (1) a renal laceration that was upgraded from grade 2 to 3 on the final attending report; (2) an axially oriented, nondisplaced cervical spine fracture; and (3) pneumopericardium mistaken for pneumomediastinum. All three of these findings were made on image review at the PACS workstation, communicated to the surgical team, and documented in the resident preliminary report. 19% of the trauma CT panscans (12/62) in the study group were negative.

The residents recommended 12 additional studies while at the scanner for 11 of 62 patients (18%). Of these additional studies, seven (58%) were CT angiograms of the head and neck, four (33%) were CT cystograms, and one (8%) was for CT angiogram of the lower extremities. All recommended studies were performed immediately at the scanner. This increased the average time at the scanner to complete the panscan checklist to 21.3 ± 16.8 min.

Of the 62 panscans, 47 were performed without delays (76%). Delays were recorded in the "Comments" section of the panscan checklist and classified as related to the CT technologist (8/62, 13%), patient care (7/62, 11%), surgical team (2/62, 3%), and information systems (1/62, 2%). Excluding the studies in which delays were noted, the mean time to review the panscan and complete the checklist was 7.9 ± 4.0 min (range 3–20 min).

Surveys

Perceived self-confidence increased substantially after the training program, with 73% of residents being neutral,

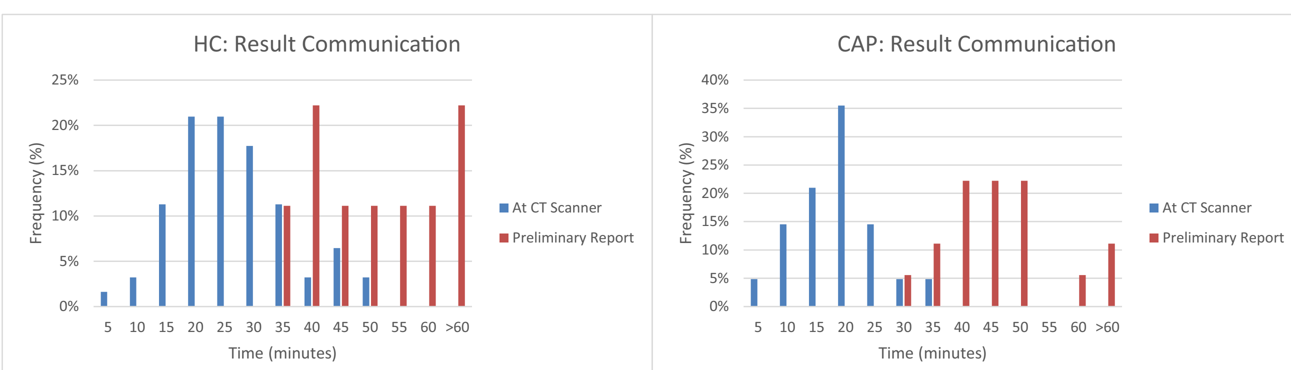

Fig. 2 Graphical depiction in the time difference between result communication at the CT scanner compared to the preliminary report for head and cervical spine (HC) and chest, abdomen, and pelvis (CAP) CT studies

Fig. 3 Graph demonstrating increase in confidence amongst radiology trainees before and after dedicated training sessions

disagreeing, or strongly disagreeing that they were comfortable providing a "wet read" at the scanner prior to training, and 91% agreeing or strongly agreeing to the same statement following training (Fig. 3). All residents agreed or strongly agreed that the training was efficacious in preparing them for reporting to the scanner to review trauma panscans. Thirty-seven surgeons responded to the survey (25 residents, 5 fellows, and 7 attendings), and no significant change was noted in most of the questions. However, a year after implementation, all subsets, from trainee to attending, notably shifted in favor of radiology presence at the scanner (Fig. 4).

Discussion

In trauma imaging, timely diagnosis and intervention are crucial to patient survival and improved outcomes [4]. Despite the transformative power of PACS workstations on radiology workflow efficiencies, technical limitations nonetheless still exist which can delay image transfer from the CT scanner to the PACS. The radiologist waiting in the reading room for images to arrive at the workstation may soon be perceived as irrelevant as a member of the patient care team to the trauma surgeons who are able to view images as soon as they have been acquired at the CT scanner. The erosion of the perceived value of radiologists has been cited as a cause for professional dissatisfaction and burnout [5]. The integration of radiologists to interact with patient care teams can change clinical management decisions and may decrease unnecessary or repeat imaging [6]. As radiologists work increasingly off-site due to the COVID-19 pandemic, radiology practice leaders need to juggle radiologist preference with the value provided by on-site radiology presence to ordering providers and patient care [7, 8].

Our study demonstrated that a high-fidelity simulation program can train junior radiology residents to identify injuries necessitating surgical intervention on the trauma panscans of class 1 trauma patients at the CT scanner with high diagnostic accuracy, increased perceived self-confidence, and with significant time savings. Since preliminary reports could only be generated and published to the electronic medical record after all images including reformats were completed by the technologist and in the PACS, radiology residents identified and communicated critical findings much faster to the trauma surgeons than it was possible to generate a preliminary report. Of the three missed CT findings, the spine fracture was quickly identified on the reformats at the PACS workstation, while the renal laceration upgrade and pneumopericardium mistaken as pneumomediastinum did not change clinical management. No patients required surgery for these missed findings. Having radiology presence at the scanner also allowed for additional imaging studies to be recommended and obtained while the patient was still in the CT scanner, which allowed for earlier diagnoses of cerebrovascular injuries and bladder injuries, thereby facilitating clinical management. In one patient, a displaced lower extremity fracture was noted on the scout image and a CTA was added, which revealed a vascular injury and allowed for prompt intervention for this critical injury. Significant time inefficiencies from patients being brought back to the scanner for additional imaging studies were thus avoided.

Radiologist presence at the scanner also allowed for insight into quality improvement opportunities. Delays related to surgical teams or CT technologists could be specifically addressed, with the understanding that patient care issues, especially when the patients are injured and very ill, are inevitable. Delays related to information technology could be analyzed for potential process modification and improvement. The radiology residents could identify system constraints in real-time and adapt. For example, at the beginning of the study period, several significant patient care

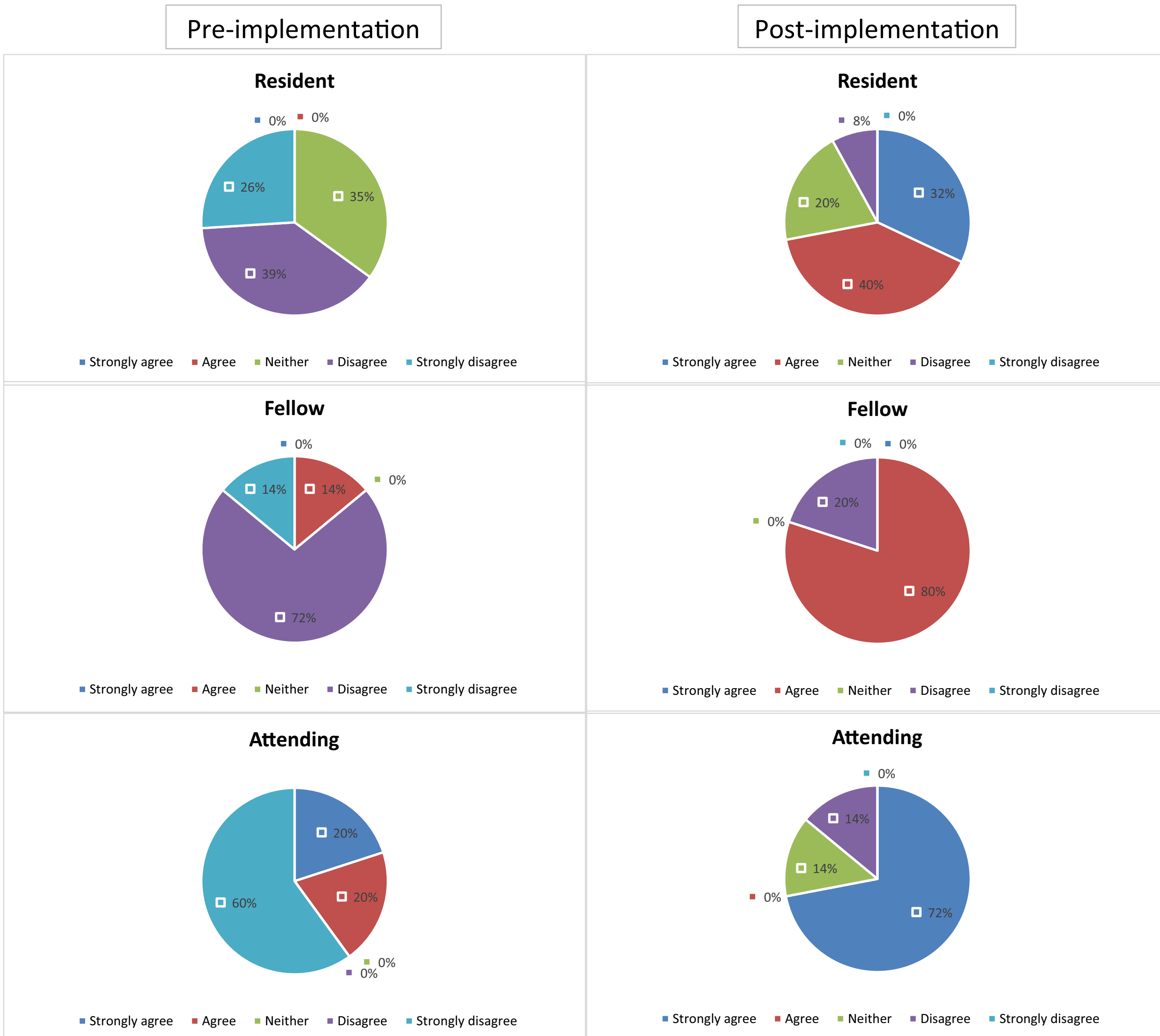

Fig. 4 Graph depicting trauma surgery survey responses to the statement, "We would like to have Radiology present at the CT scanner during trauma CT scans," prior to and 1 year after implementation of training sessions

delays resulted in a large time gap between performance of the head and cervical CT and subsequent chest, abdomen and pelvis CT. Therefore, the recommendation was made for residents to review the head and cervical spine CTs in the reading room and report to the CT control room once the technologist informed the resident that the patient was being scanned. Not all residents followed this recommendation, but the ones who did reduced the panscan review time at the scanner to under 5 min. This simulation and workflow are also potentially valuable for IT downtimes and provides support for preliminary on-scanner interpretation for medical decision-making in the event that the PACS, RIS, HER, or hospital network are down.

Our study also showed that the training program substantially increased the trauma surgeons' preferences towards favoring radiology presence at the CT scanner for trauma patients, suggesting that they recognized the value added of the radiology trainees' skills in the patient care team. The radiology residents shared anecdotes of surgeons expressing their appreciation towards their efforts at the CT scanner, and it was noted that relationships improved and became friendly and collegial between the radiology residents and trauma surgeons because of the study. These shared experiences, though difficult to measure, attest to the importance of radiologist presence and their perceived value by the patient care team.

There were several study limitations. First, the sample sizes were small, consisting of one class of eleven radiology residents and 62 trauma panscans. Secondly, the times for arrival at the scanner and time of panscan checklist completion were self-reported which carries some degree of imprecision. The residents were not rated on individual turnaround times nor had any incentive to skew their time results. Third, changes in the electronic reporting system halfway through the study may have impacted the accuracies of the time stamps, but there was no significant difference in the reported times between the first and second halves, and any variability due to these differing methods of preliminary reporting was not felt to be significant. Fourth, the determination of concordance was made assuming the final attending report was correct and by a single radiologist reviewer. It is possible that some resident reports were correct while the final report was incorrect or that significant findings were missed on both the preliminary and final reports. However, follow-up on patients was performed via chart review and no indication was made that any of the patients had significant traumatic findings that were missed by the reporting radiologists. Fifth, we did not include injury severity scores which would help to convey the severity of injuries and allow for the generalizability of the results outside of our institution. Finally, this was a study performed at a single site suburban Level 1 trauma hospital, and the results may not generalize to differently sized hospitals or larger healthcare systems serving different patient populations.

Conclusion

Using a high-fidelity simulation program, radiology residents can be trained to identify traumatic injuries successfully, quickly, and confidently on trauma panscans at the CT scanner that necessitate immediate surgical attention.

Declarations

Conflict of interest The authors declare no conflict of interest.

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