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Review, monitor, educate: A quality improvement initiative for sustained chest radiation reduction in pediatric trauma patients

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Background: We hypothesize that in pediatric trauma patients, CT scans after normal chest x-rays do not add information that alters clinical decision making.
Methods: A retrospective review of trauma patients < 15 years with chest imaging evaluated at a pediatric trauma center between 1/2013 and 6/2019 was performed. Imaging was reviewed for significant findings that could affect care. A guideline was established in January 2017 which emphasized x-rays prior to CTs and no CTs after normal x-rays. A prospective review was performed from 1/2017-6/2019. Pre and post guideline groups were compared.
Results: From 2013 to 2016, 246 patients met inclusion. 29.5% had a chest CT after a normal x-ray, only 1.8% (1/57) had a significant result. From 2017 to 2019, 188 patients were reviewed post guideline; only 9.4% received a CT after normal x-ray, of which 6.3% (1/16) were significant. Neither changed clinical management.
Conclusions: Chest CT following normal chest x-ray does not change clinical management in pediatric trauma patients. Monitoring and education following guideline implementation improves long term outcomes.

Introduction

National attention has been drawn to decreasing pediatric radiation exposure with a push to "image gently", however there are currently no national pediatric chest computed tomography (CT) guidelines.[1] While CT scans undeniably aid in the evaluation and treatment of pediatric patients, they do confer a considerable amount of radiation exposure to the child.[1] This creates a challenge for physicians, especially those caring for the acute pediatric trauma patient. There is debate as to the actual risk of using radiation with children, but the concern is certainly warranted, and attempts have been made to limit unnecessary radiation, including reducing unnecessary scans.

Pediatric chest trauma is relatively uncommon but results in considerable morbidity and mortality.[2] Thoracic injury accounts for 5–12% of pediatric trauma admissions.[3] Patients with isolated chest trauma have a 5% mortality rate, which increases to a 25% mortality rate with a concurrent head or abdominal injury and a 40% mortality rate with injuries to all three areas.[3] Chest CT scans are commonly used in adult blunt trauma evaluation. However, due to the flexibility of the pediatric chest wall, thoracic injury due to blunt trauma presents differently in children and adults.[4] Most of these injuries can be identified with plain chest x-ray and be further investigated with CT if necessary. Although there are no guidelines regarding pediatric chest CT usage, prior clinical studies have established that chest CTs offer little benefit over chest x-rays in regard to changing management in pediatric trauma patients.[5–8]

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However, the current body of work on this topic has largely occurred at academic medical centers and it is important to ensure that the same is true in community hospitals.

Our institution is a level 1 Adult and Level 2 Pediatric community trauma center. In a previous trauma accreditation survey, CT overutilization was seen as an opportunity for improvement. This prompted an evaluation of CT usage, with the hope of reducing patients' radiation exposure. Literature supports that evidence-based guidelines minimize care variation and most importantly improve outcomes.[9] In an effort to best establish a radiation reduction guideline, our institution's radiation usage was reviewed and areas were identified where there was an opportunity to decrease radiation exposure in pediatric trauma patients. We hypothesized that chest CT scans after a normal chest x-ray would not add clinically relevant information to justify the use of the imaging and that the addition of a radiation reduction guideline would reduce overutilization of chest CT scans.

Materials and methods

A retrospective chart review of all trauma alert patients <15 years evaluated at our pediatric trauma center between January 2013 and June 2019 was performed. This study was approved by the Institutional Review Board of Lehigh Valley Health Network. Patients were excluded if their radiological evaluations were from an outside facility; the chest CT was to evaluate a pre-trauma comorbidity or spinal injury; no radiological chest evaluation was performed; or the mechanism of injury was burn or drowning. This was evaluated by reviewing the history and physical and all imaging in detail. At our institution, a chest CT scan can be used to evaluate spine and chest pathology. If there was no mention of chest pain and the patient endorsed spine pain, it was determined as spine imaging and it was excluded. If spine pain was not clearly stated, we determined it as a CT to evaluate for chest pathology. Patients were reviewed for demographics, mechanism of injury, and radiological results. A pediatric surgery attending physician reviewed the CT scans and x-rays to determine if there were significant findings. Both the radiology report and the actual images were reviewed by the pediatric surgery attending physician. For chest x-rays, a significant result was one that could affect clinical care or warranted further evaluation to determine the clinical plan, such as a pneumothorax >10%, hemothorax, first rib fracture, multiple rib fractures, or lung contusion. For chest CTs, a significant result was one that would change the clinical plan, such as requiring chest tube placement or angiography.

Based on the retrospective review, a radiologic reduction guideline was established in January 2017. At our institution, during the time of this study, the attending adult trauma surgeons were the primary decision makers during the initial assessment of the pediatric trauma patient. Accordingly, a multidisciplinary team with representation from pediatric trauma, adult trauma, and radiology was formed to develop a guideline with input from relevant parties. The guideline emphasized not using chest CTs after normal chest x-rays in pediatric trauma patients and encouraged providers to obtain a chest x-ray before a chest CT, in an effort to decrease overutilization. The individuals involved in guideline development disseminated the information to their respective specialties. There were opportunities for questions to ensure that all participants were fully informed and in agreement. Chest CT utilization was monitored, and guideline education was provided at monthly multidisciplinary trauma quality meetings, which included representation from pediatric trauma, adult trauma, and radiology. The meetings were an opportunity to review compliance with the guideline and reinforce the principles behind the guideline. Inappropriate chest CT scans (a chest CT without a prior x-ray or a chest CT following a normal x-ray) were reviewed to understand the rationale for ordering and provide feedback in order to promote future compliance with the guideline. A prospective review was performed from January 2017 to June 2019 to assess efficacy of the guideline.

Descriptive statistics were generated for the entire sample. Study variables were compared before and after guideline implementation. The Chi-Square test was used to assess if there was an association between categorical variables. If >20% of expected cell counts were less than 5, the Fisher's Exact test was used instead. The Mann-Whitney *U* Test was used when the associations were skewed or the expected cell counts were less than five. Analyses were two-tailed with alpha set at 0.05. SPSS (IBM, USA) was used to conduct the analysis.

Results

There was a total of 434 patients included in the analysis, 246 (56.8%) in the pre-guideline group and 188 (43.3%) in the post-guideline group. Descriptive statistics are shown in Table 1. The majority of patients were male (58.6%) and white (70.4%), and most experienced blunt-type trauma (96.5%). The most frequent cause of injury was from a motor vehicle accident (157 [36.2%]). Most patients were not transferred (92.4%) and had a median initial Glasgow Coma Scale of 15.0 (IQR 14.0–15.0). Majority of patients survived their injuries (97.0%) and the median length of stay was 2 (IQR 1–3) days, while the median injury severity score was 5 (IQR 2–11). Patients primarily went into the pediatric unit after the Emergency Department (52.3%). Of the 31.8% of patients who received a chest CT, 62.3% resulted in no injury. 90.6% of patients received a chest x-ray prior to CT scan, with the primary result of the x-ray being no injury (88.0%).

A comparison of study variables between study period was done (Table 1). There was a statistically significant association between gender and study period ($p = 0.0470$). There were slightly more males in the post-guideline group compared to in the pre-guideline group (64.0% vs. 54.5%, respectively). There was no significant association between either age or race and study period ($p = 0.8398$ and $p = 0.0829$). There was a statistically significant association between cause of injury and study period ($p = 0.0007$). The post-guideline group had a higher percentage of falls on the same level (10.1% vs 1.6%, respectively), bicycle vs auto injuries (5.9% vs 4.5%, respectively), and other injury types (16.0% vs 11.8%, respectively). The pre-guideline group saw higher percentages of all other injury types. There was a statistically significant difference in injury severity score between study periods with pre-guideline group had a higher median injury severity score compared to the post-guideline group (6.0 [IQR 2.0–14.0] vs 5.0 [IQR 1.0–10.0], respectively) ($p = 0.0001$).

During the pre-guideline period, 246 patients met the inclusion criteria. Out of the 193 patients whose chest x-ray was not significant, 29.5% (57/193) received a subsequent chest CT, of which only 1.8% (1/57) had a significant result (Fig. 1). After the implementation of the chest CT radiologic reduction guideline, 188 patients met the inclusion criteria. Out of the 170 patients whose chest x-ray was not significant, only 9.4% (16/170) received a chest CT, of which only 6.3% (1/16) had a significant result (Fig. 2). Of the two patients in the total study group who had significant results found on their CT following a normal x-ray, both patients were severely injured and their chest CTs did not change their clinical management or outcome.

There was a statistically significant association between patients receiving a chest CT and study period. A higher percentage of patients received a chest CT pre-guideline compared to post-guideline (43.9% vs 16.0%, respectively, $p<.0001$) (Table 1).

Table 1
Descriptive statistics for the study sample and comparison of study variables between study groups.

	Total (n = 434)	Pre-guideline (n = 246)	Post-guideline (n = 188)	p-value
Age, years *median (IQR)*	9.0 (3.0–12.0)	8.0 (3.0–12.0)	9.0 (3.0–12.0)	0.8398[c]
Gender (n = 432)				0.0470[a]
Male	253 (58.6)	134 (54.5)	119 (64.0)	
Female	179 (41.4)	112 (45.5)	67 (36.0)	
Race (n = 425)				0.0829[b]
White	299 (70.4)	183 (74.4)	116 (64.8)	
Black	33 (7.8)	19 (7.7)	14 (7.8)	
Asian/Pacific Islander	4 (0.9)	1 (0.4)	3 (1.7)	
Other	89 (20.9)	43 (17.5)	46 (25.7)	
Injury type				0.4270[a]
Blunt	419 (96.5)	236 (95.9)	183 (97.3)	
Penetrating	15 (3.5)	10 (4.1)	5 (2.7)	
Cause of injury				0.0007[a]
Motor vehicle accident	157 (36.2)	91 (37.0)	66 (35.1)	
Motor vehicle accident versus pedestrian	84 (19.4)	50 (20.3)	34 (18.1)	
Fall on same level	23 (5.3)	4 (1.6)	19 (10.1)	
Multi-level fall	64 (14.8)	40 (16.3)	24 (12.8)	
Bicycle injury	9 (2.1)	7 (2.9)	2 (1.1)	
Bicycle versus auto	22 (5.1)	11 (4.5)	11 (5.9)	
Contact sports	16 (3.7)	14 (5.7)	2 (1.1)	
Other	59 (13.6)	29 (11.8)	30 (16.0)	
Glasgow coma scale – initial (n = 432) *median (IQR)*	15.0 (14.0–15.0)	15.0 (14.0–15.0)	15.0 (14.0–15.0)	0.6030[c]
Length of stay, days *median (IQR)*	2.0 (1.0–3.0)	2.0 (1.0–3.0)	1.0 (1.0–3.0)	0.0577[c]
Injury severity score *median (IQR)*	5.0 (2.0–11.0)	6.0 (2.0–14.0)	5.0 (1.0–10.0)	0.0001[c]
Destination after emergency department				–[d]
ICU/Critical care unit	146 (33.6)	93 (37.8)	53 (28.2)	
Home	21 (4.8)	0	21 (11.2)	
Med/Surg pediatric unit	227 (52.3)	135 (54.9)	92 (48.9)	
OR (including pre-op area)	34 (7.8)	18 (7.3)	16 (8.5)	
Step down unit	4 (0.9)	0	4 (2.1)	
Transferred to another facility	1 (0.2)	0	1 (0.5)	
Morgue	1 (0.2)	0	1 (0.5)	
Was a chest CT done?				<.0001[a]
Yes	138 (31.8)	108 (43.9)	30 (16.0)	
No	296 (68.2)	138 (56.1)	158 (84.0)	
Was a chest x-ray done?				<.0001[a]
Yes	393 (90.6)	205 (83.3)	188 (100)	
No	41 (9.5)	41 (16.7)	0	
Results of chest CT (n = 138)				0.5159[b]
Pneumothorax	13 (9.4)	10 (9.3)	3 (10.0)	
Hemothorax	0	–	–	
Rib fracture	2 (1.5)	2 (1.9)	0	
Pulmonary contusion	13 (9.4)	9 (8.3)	4 (13.3)	
Mediastinal injury	1 (0.7)	1 (0.9)	0	
No injury	86 (62.3)	70 (64.8)	16 (53.3)	
Other	8 (5.8)	7 (6.5)	1 (3.3)	
Multiple injuries	15 (10.9)	9 (8.3)	6 (20.0)	
Results of chest x-ray (n = 393)				0.0001[b]
Pneumothorax	3 (0.8)	2 (1.0)	1 (0.5)	
Hemothorax	1 (0.3)	0	1 (0.5)	
Rib fracture	1 (0.3)	0	1 (0.5)	
Pulmonary contusion	19 (4.8)	4 (2.0)	15 (8.0)	
Mediastinal injury	2 (0.5)	1 (0.5)	1 (0.5)	
No injury	346 (88.0)	179 (87.3)	167 (88.8)	
Other	15 (3.8)	14 (6.8)	1 (0.5)	
Multiple injuries	6 (1.5)	5 (2.4)	1 (0.5)	

Data are n(%) unless otherwise stated. Percentages might not add to 100% due to rounding. IQR = interquartile range.
[a] Chi-Square test was used to calculate p-value.
[b] Fisher's Exact test was used to calculate p-value.
[c] Mann Whitney *U* test was used to calculate p-value.
[d] p-value unable to be calculated.

Additionally, no patients had a CT before an x-ray following guideline implementation compared to 26.7% of patients before implementation (Table 2).

Among the 154 patients that had an insignificant chest x-ray and did not have a chest CT, as per our protocol, there were no readmissions, emergency department visits, office visits related to cardiopulmonary injury within 90 days. There were also no deaths related to missed injuries.

Discussion

While CT scans provide additional information about pediatric trauma patients, the utility of this information must be considered and the risks of radiation exposure should be weighed as well. At our institution, we observed that chest CTs following normal x-rays did not change patient management. In the two patients who had clinically significant chest CTs following a normal x-ray, the chest

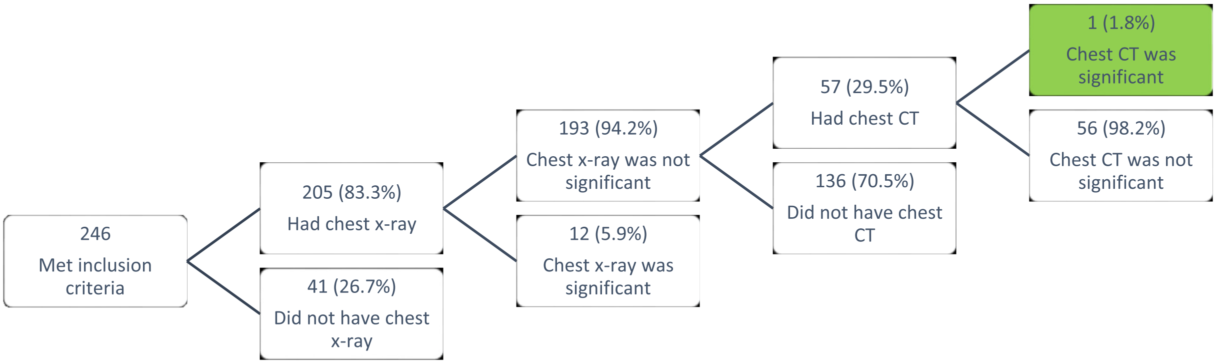

Fig. 1. January 2013 to June 2016.

CT did not result in additional interventions. Additionally, we found that implementation of a guideline effectively reduced the amount of inappropriate CT scans obtained.

The development and implementation of our radiation reduction guideline required multidisciplinary input. It was essential to obtain buy-in from radiology, pediatric and adult trauma teams in order to ensure successful implementation. This was part of a larger culture change at our institution and a shift to reduce unnecessary radiation. While this drive initially began with the pediatric trauma population, we have noted a subsequent reduction in adult trauma CT scans as well. In this way, quality improvement projects can inspire larger scale change.

The outcomes of the two patients who had a significant chest CT following a non-significant chest x-ray are of note. One was an 8-year-old female status post motor vehicle accident with a prolonged extrication who presented with severe intracranial hemorrhage and herniation. The chest x-ray did not identify any abnormalities, but the chest CT revealed airspace disease consistent with aspiration or contusion. Unfortunately, her injuries were extensive, and she did not survive. If she had survived, she would have been intubated in the intensive care unit and her respiratory function would have been closely monitored regardless of if the chest CT was obtained or not. While her chest CT did have information not found on her x-ray, it ultimately did not change her clinical outcome. The other had a significant CT scan of the cervical spine in conjunction with multiple injuries and a severe mechanism of injury (head on motor vehicle accident in which the patient was inappropriately restrained in the car seat and was ejected to the front of the vehicle), based on which the radiologist recommended a chest CT scan. The chest CT demonstrated fractures at the T3 vertebra, moderate hemorrhage in the mediastinum, and pleural effusions suggestive of hemothorax. Due to his severe injuries, he remained intubated and was taken to the pediatric intensive care unit. No direct actions were taken as a result of his chest CT. Regarding the T3 fracture, he was already under full spinal precautions as he was exhibiting signs of neurogenic shock. A lumbar fracture had been identified prior to the chest CT and neurosurgery was involved throughout his care. No intervention was needed for his mediastinal hemorrhage. A chest tube was not needed until the next day, when he developed unilateral decreased breath sounds leading his care team to suspect tension pneumothorax. In both cases, the significant chest CT scan did not change their management or outcome.

Chest CTs do not come without risk. For the pediatric patient, there is the possibility of ill effects due to radiation. Children have more years of life to accumulate radiation and see its possible adverse effects.[1] One recent study of note is Meulepas et al.'s retrospective review from the Netherlands of 168,394 children who had CT scans. Children exposed to CT radiation had an excess relative risk of brain tumors.[10] Pearce et al. had also found that CT scans increased the risk of brain cancer. Additionally, they found that CT scans caused an increased risk of leukemia.[11] It is difficult to know the true cancer risks of childhood radiation and existing data both supports and refutes this risk.[1] Regardless, due to the severity of the potential risks, care should be taken when considering the use of radiation in pediatric patients. A guideline to support decision making in imaging will aid in reduction of imaging for these patients.

Another risk to excessive imaging is the possibility of incidental findings that do not affect the patient's health but result in further workup. This can involve further radiation exposure and have both financial and psychological effects on the patient and their family. For example, pulmonary incidentalomas are found in pediatric chest CTs. These nodules have a low risk of malignancy.[12] It has

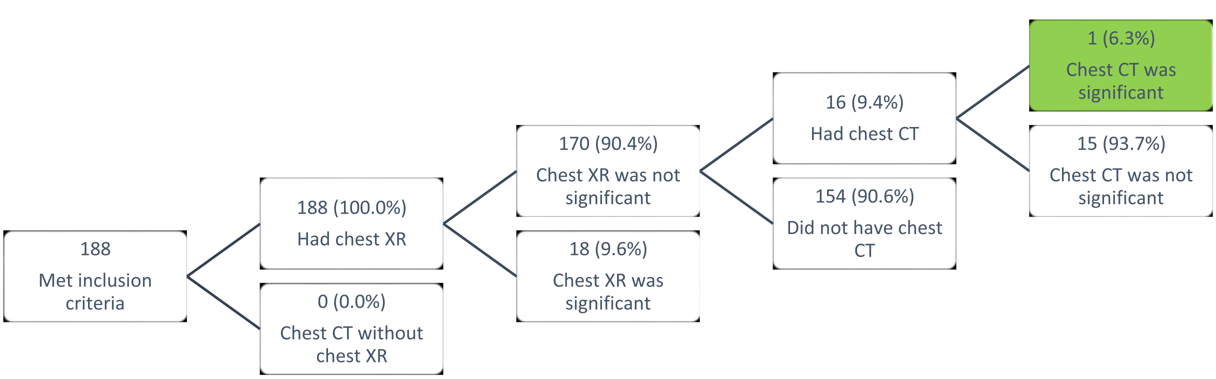

Fig. 2. January 2017 to June 2019.

Table 2
Imaging pre and post guideline.

	1/13 to 6/16	1/17 to 6/19
Had chest x-ray	83.3% (205/246)	100% (188/188)
Had chest CT	43.9% (108/246)	16.0% (30/188)
Had chest CT without prior x-ray	26.7% (41/246)	0% (0/188)
Had chest CT with normal x-ray	23.2% (57/246)	8.5% (16/188)

been suggested that there should be a reduction in pediatric chest CTs to lessen the finding (and subsequent workup) of these pediatric incidentalomas.[13,14]

Imaging that does not add clinical value increases healthcare costs without improving quality of care. As of 2018, Medicare reimbursement for a chest CT without contrast was $156.28 while reimbursement for a 1 view chest x-ray was less than an eighth of the chest CT at $19.79.[15] This is an opportunity for cost savings without compromising patient care.

This work is especially relevant given that the use of CT scans in children visiting the emergency department has increased fivefold from 1995 to 2008.[16] With improvements in CT technology and speed, it is no longer necessary to anesthetize children for CT scans, which has contributed to the rise in pediatric CT scans.[16] Notably, pediatric CT usage vary depending on hospital characteristics. Pediatric CT usage is higher in non-pediatric facilities.[17] Strait et al. performed a review of patients 14 years and younger in the National Trauma Databank which revealed that 3% of patients with no chest injury received a chest CT scan, as did 13% of patients with minimal chest injury. They found that level 1 pediatric trauma centers were least likely to scan children with no or minimal injury.[18] Additionally, academic hospitals appear to have lower pediatric CT rates than community hospitals.[19,20] Our results demonstrate however that a pediatric community trauma center with adult trauma surgeon involvement can achieve best practices of reduced radiation utilization with the establishment of an evidence based protocol, education and review.

Finally, another theory that has been suggested to explain unnecessary imaging is the idea of defensive medicine, where health care providers' actions are driven by fear of litigation.[21–23] In the case of pediatric trauma patients increased radiologic evaluations are at times performed in order to address parent's concerns or due to social factors, such as the family living far away. However, literature supports that defensive CT scans do not change management. Chen et al. performed a prospective observational study at a level I trauma center. They found that 38% of CT scans were ordered defensively yet only 2.2% of these scans changed patient management.[24]

It is worth noting that there was a high proportion of inappropriate CT scans performed prior to guideline implementation at our institution. We suspect that the reason for this high volume was that during the pre-implementation phase, there was limited involvement of the pediatric surgeons in the primary assessment of the pediatric trauma patients. Without a standardized protocol or guideline in place, chest CTs were often obtained for severe mechanism of injury or as part of whole body "pan-scans" of severely injured patients. During this time, it appears that CT scans were often performed in lieu of x-ray. As shown in Table 2 and 26.7% of patients who had chest imaging had a chest CT without a prior x-ray. The pediatric surgeon attendings were involved with the development and implementation of the guideline. Though the adult trauma surgeons were still the primary decision makers during the post-implementation phase, the pediatric surgeons were more involved in the patient care and helped with the implementation and education of the best practice guideline.

Limitations to this study include the retrospective aspect of the pre-guideline data collection and the differences between the pre and post guideline groups. The post-guideline group had slightly more males, differences in cause of injury, longer length of stay, and a lower median injury severity score (ISS) as compared to the pre-guideline group. The lower ISS in the post guideline group may have contributed to the decreased CT scans if providers perceived a decreased risk of significant injury and were therefore less likely to order further imaging. However, since ISS is not calculated till after the patient is fully evaluated and cared for, it is unclear if this may have affected our outcomes. Though the length of stay trended towards significantly different between the pre and post groups, this may also be a result of the increased involvement of the pediatric surgeons in the care of the trauma patient, leading to increased comfort with earlier discharge.

Golden et al. called for further research to verify their findings at other sites.[5] After viewing our data, we felt strongly enough to implement a guideline at our hospital that chest CT scans should not be done following a normal chest x-ray in pediatric trauma patients. After guideline implementation, we saw a decrease in overall CT scans, CT scans following a normal x-ray, and CT scans without an initial x-ray. We would be interested to see additional institutions examine their pediatric trauma patients and implement similar guidelines.

Conclusion

Chest CTs following a normal chest x-ray do not change clinical management in pediatric trauma patients. Chest CTs should be considered unnecessary when the chest x-ray is normal. Judicious use of chest CTs reduces exposure to radiation, incidental findings, and unnecessary costs. Implementation of a guideline can reduce the number of inappropriate CTs. Continued monitoring and education following guideline implementation improves outcomes.

Summary

We hypothesize that in pediatric trauma patients, CT after normal chest x-ray does not add information that alters clinical decision making. A retrospective review of pediatric trauma patients was performed, based on which a radiation reduction guideline was implemented. In this patient population, CT following normal x-ray did not change clinical management and implementation of a radiation reduction guideline was effective in reducing CT scans.

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