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Original Research

Are radiographs overutilized in pediatric orthopaedic emergency room care?

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ABSTRACT

Background: It is estimated that $12.8 billion to $28.6 billion is wasted annually on unnecessary imaging studies and treatment in the United States. This is especially important to the pediatric population, which is unable to make decisions for themselves and vulnerable to radiation exposure. We hypothesized that a significant number of unnecessary radiographs are performed in the pediatric emergency department (ED), leading to excessive time, cost, and radiation exposure to pediatric patients.

Methods: We retrospectively reviewed 406 patients who were evaluated in a pediatric ED for possible fractures at a single institution during the 2020 calendar year. Records were reviewed for demographics, history, and physical exams, as well as the sequential order which radiographs were performed. All radiographs were evaluated by the senior author to determine if they resulted in a change in management. All data were recorded and analyzed by the senior author and our statistician using Student's t-test.

Results: 406 patient encounters were included. 2,807 radiographs were deemed unnecessary, with an average of 6.9 radiographs per patient. $454,734 was spent on radiographs that ultimately did not change management. A total of 216 hours and 43 minutes was spent in the X-ray suite alone, for an average of 32 minutes per patient. The estimated amount of radiation exposure that did not change management was potentially as high as 69 millirem per patient.

Conclusions: There is an excessive amount of monetary waste, radiation exposure, and encounter time spent with pediatric Orthopaedic patients in the ED. There are several potential strategies to alleviate this problem, which we hope can be taken into consideration to help address this widespread health care issue.

Key Concepts:

(1) There are a substantial number of unnecessary radiographs performed in the pediatric ED both during diagnosis and treatment of fractures.
(2) This unnecessarily increases the time, cost, and radiation exposure that pediatric patients experience.
(3) Several possible strategies exist to reduce this waste including obtaining films after a careful physical exam, consider which views would be most beneficial, whether the joint above and below would truly be needed, using fluoroscopy in the ED during reduction and casting and limiting post splinting or casting imaging if there was no or minimal formal reduction.

Level of Evidence: III

Introduction

It is estimated that $760 to 935 billion is wasted annually on unnecessary health care in the United States (US) [1]. $17.2 to 27.9 billion of this waste is spent on low-value screening, testing, and procedures [1]. This waste accounts for more than a third of US health care spending and contributes to the US spending more money on health care per capita than any other nation [2].

It is estimated that 1 in 33 children has undergone at least one low-value diagnostic test [3]. Pediatric patients are more radiosensitive than adults due to the higher water content in their tissues leading to more absorption and dispersion of radiation throughout the body [4].

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Children are also at increased risk of malignant transformation from radiation exposure due to 35% of the hematopoietic bone marrow being in their extremities compared to only 9% in adults [4,5].

To examine the current state of waste in our institution, we studied the use of radiographs in Orthopaedic patients evaluated in our pediatric emergency department (ED). We hypothesized that a significant number of unnecessary radiographs are performed in the pediatric ED, leading to unnecessary time, cost, and radiation exposure in pediatric patients. We used the information regarding monetary waste, increased radiographs, increased radiation exposure, and wait times to suggest a pathway to improve the quality of care and decrease unnecessary testing for our pediatric Orthopaedic population.

Materials and methods

This study was exempted by our Institutional Review Board due to being a retrospective chart review focused on quality improvement. A retrospective chart review was conducted of 406 patients who were evaluated for possible fractures in the pediatric ED at a single institution, and subsequently seen in the pediatric Orthopaedic outpatient office with one of our fellowship-trained pediatric Orthopaedic surgeons during the 2020 calendar year. Patients seen in the ED who did not follow-up in the outpatient clinic were excluded as we did not have access to these patients. This also provided a check with pediatric fellowship-trained attendings confirming the exam and that no additional injuries were missed. Medical records were reviewed for patient age, mechanism of injury, history, physical exam, treatment, and if the Orthopaedic surgery resident was consulted by the ED. Age ranges were determined based on Piaget's theory of development to account for the ability of the child to accurately describe history and symptoms [6]. We evaluated if any child was unable to cooperate with an accurate exam due to developmental delay and/or altered mental status.

The minimum necessary radiographs were determined as the isolated anatomic location of the patient's presenting symptoms and documented physical exam. For patients who presented to the ED with more than one anatomical distribution of symptoms, all radiographs involving the affected area were included. If the anatomic distribution of a patient's injury was unclear, the medical record was reviewed by a fellowship-trained pediatric Orthopaedic surgeon. Radiographs were then evaluated in the order that they were obtained to see if the initial set of radiographs identified the injury. Radiographs obtained in an anatomical location not corresponding to the patient's symptoms were considered unnecessary. Additionally, any radiograph that was repeated without a change in the patient's clinical condition was considered unnecessary in which case the initial inadequate X-ray was considered waste. Radiographs involving the treatment of a fracture, such as postreduction radiographs, were categorized as treatment radiographs. For all radiographs, we determined the cost and radiation exposure associated with each image. We also recorded the minimum time that each radiograph took to obtain.

For example, if a patient that presented to the ED with isolated acute distal radius pain after a fall, we considered 2 views of the wrist to be the necessary radiographs. Radiographs of the hand, forearm, elbow, humerus, shoulder, clavicle, or more than 2 views of the wrist were considered unnecessary. If the patient had a distal radius fracture, the patient underwent closed reduction and casting with a short arm cast in the ED. Necessary postreduction X-rays would be 2 views of the wrist, with the X-ray encompassing the entire cast. Any additional X-rays were considered unnecessary.

SPSS version 28 (International Business Machines Corporation) was used for data analysis. Intergroup comparisons of continuous variables were assessed via independent-samples t-tests and Pearson's correlation coefficient. The significance level was set at $P < .05$.

Table 1
Injury data and ultimate management.

	Number of patients $n = 406$
Exam correlated with ultimate injury, *n* (%)	371 (91.4)
Isolated injury, *n* (%)	389 (95.9)
Underwent reduction in ED, *n* (%)	253 (62.3)
Seen by Orthopaedic resident in ED, *n* (%)	289 (71.2)
Ultimately required surgery, *n* (%)	109 (26.8)

ED, emergency department.

Results

Of the 406 patients included in this study, 61.3% were male and 38.7% female. The average age was 8.8 years with a range of newborn to 18 years. 29.3% of the patients were unable to cooperate with the physical exam due to age or cognitive impairment. The most common injuries were supracondylar humerus fractures (17%) followed by distal radius and both bone forearm fractures. The most common mechanism of injury was falling from standing height, often while running or playing. 7% of the injuries were sustained from a high-energy mechanism (ie, automobile collisions, falls out of trees, all-terrain vehicle/dirt bike accidents).

91.4% (371/406) of patients had an exam that correlated with their ultimate injury. 95.9% (389/406) had an isolated injury. 71.2% (289/406) of patients were seen by Orthopaedics in the ED. 62.3% (253/406) of patients underwent a reduction in the ED and 26.8% (109/406) were ultimately taken to the operating room for definitive treatment (Table 1). 209 patients had postreduction or casting films with 47 repeated for inadequate films, inadequate cast or repeat reduction. Of these 209 post casting films, 146 underwent a formal reduction.

A total of 4,117 radiographs were performed on 406 patients, for an average of 10.1 radiographs per patient (range 2-52; SD 5.4). The child with the largest image total (52) was an 8-year-old struck by a motor vehicle. There were several other high totals in patients with a history of all-terrain vehicle accidents, motor vehicle accidents, or other polytrauma. The average—excluding polytrauma or high-energy mechanism of injury patients (382)—was 9.8 radiographs (range 2-30; SD 4.6). In 33% (134/406) of cases, the initial set of radiographs ordered did not capture the fracture, even when the physical exam was consistent with the ultimate location of the fracture. However, correct films were usually ordered after the initial radiographs did not find a fracture. The total number of excessive films that did not change management was 2,807, with an average of 6.9 per patient. 9.4% (38/406) of patients had radiographs repeated due to inadequate imaging after assessment by the Orthopaedic resident. The most commonly repeated radiograph was the lateral view of the elbow.

An oblique view was obtained in 83.5% (339/406) of patients. It was found to be useful in 75 of the 339 patients (22.1%) who completed an oblique view; most commonly a mortise view for an ankle fracture (24/75), oblique view of the elbow (18/75), or an oblique view of the hand (12/75). Most fractures were sufficiently evaluated with an anteroposterior (AP) and lateral view including wrist, forearm, humerus, femur, and tibia. Ankles, elbows, and hand fractures most often benefited from an oblique view.

During the 2020 calendar year, there was $666,954 in hospital charges from radiographs, with $454,734 in charges representing 2,807 radiographs determined to be unnecessary. Each child received an average of 0.69 millisievert (mSv) excessive radiation, with a total of 280.7 mSv in excessive radiation received by children during 2020. Each patient spent an average of 32 minutes in the X-ray suite, with a total of 216 hours, 43 minutes spent by pediatric patients in the X-ray suite (Table 2).

Table 2
Emergency department X-ray data including cost, time, and radiation.

Total radiographs, n (mean per patient)	4,117 (10.1)
Fractures identified on an initial radiograph, *n* (%)	268 (66.0)
Oblique view beneficial, *n* (%)	75 (22.1)
Radiographs that did not change management, *n* (mean per patient)	2807 (6.9)
Films repeat due to inadequacy, *n* (%)	387 (9.4)
Time spent in X-ray suite, total (mean per patient)	216 h 43 min (32 min)
Cost of radiographs, total (mean per patient)	$666954.00 ($1642.74)
Cost of radiographs that did not change management, total (mean per patient)	$454734.00 ($1120.03)
Radiation that did not change management (mSv), total (mean per patient)	280.7 (0.69)

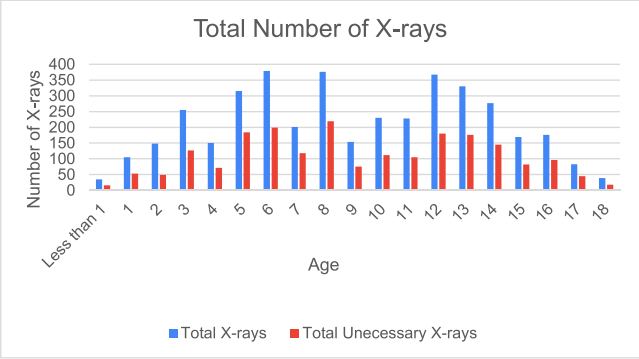

Figure 1. Total number of X-rays and number of X-rays with no change in management compared to age.

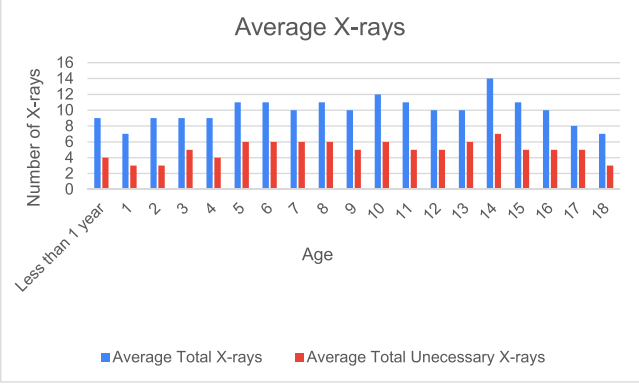

Figure 2. Average total number and average number of X-rays with no change in management compared to age.

A subgroup analysis showed no difference in the total number of radiographs obtained between patients with a focal exam (10.2 radiographs per patient) compared to patients with a nonfocal exam (9.3 radiographs per patient, $P = .14$). There were no differences in the number of unnecessary radiographs obtained for patients with a focal exam (9.3 radiographs per patient) compared to patients with a nonfocal exam (6.7 radiographs per patient, $P = .35$). There was no difference between sexes with respect to the total number of radiographs (10.2 radiographs per male vs 10.0 radiographs per female, $P = .35$) or the number of unnecessary radiographs (6.9 radiographs per male versus 7.0 radiographs per female, $P = .37$). Patients who were unable to cooperate with the physical exam had significantly fewer total radiographs (9.4 radiographs per patient unable to cooperate with physical exam versus 10.5 radiographs per patient able to cooperate with physical exam, $P = .03$) and no significant difference in unnecessary radiographs performed (6.3 radiographs per uncooperative patient versus 7.2 radiographs per cooperative patient, $P = .05$). There was no correlation between age and the total number of radiographs or the number of unnecessary radiographs. However, we did find a trend of a higher number of X-rays between 10 and 15 years old (Figs. 1 and 2).

Discussion

Our study found that on average, there were 6.9 unnecessary radiographs performed per patient, resulting in 0.69 mSv of excess radiation per patient, $454,734 ($1120.03 per patient) spent on unnecessary radiographs, and contributing to an extra 216 hours and 43 minutes (32 minutes per patient) spent in the X-ray suite during 2020. Given that these values are only from a single institution, this likely contributes to the estimated $760 to 935 billion wasted annually on health care in the US [1].

One of the main concerns in performing radiographs in children is excess radiation. We found that the average excess was 0.69 mSv. For reference, a single AP chest XR is 0.01 mSv with an average of 0.1 mSv for multiple views, and a chest CT ranges from 2 to 20.4 mSv with an average of 5.5 mSv [7]. While the amount is certainly less than a CT, it is important to limit radiation in children as exposure is cumulative. One paper looking at cardiac imaging in children estimated the lifetime attributable risk of cancer in their patients to be 0.04% versus 0.02% per 1-mSv [8]. Based on this, any attempt to decrease radiation exposure in children should be pursued.

Our study found that 95.9% (389/406) of patients had an isolated injury and 91.4% (371/406) had an exam that ultimately correlated with their injury. Despite this, only 66% (272/406) of patients had their fractures captured on the initial set of radiographs. We believe that physicians should carefully perform a physical exam to isolate the location of the injury, especially since most patients (70.7%) are able to cooperate with a physical exam. The importance of a thorough physical examination cannot be overstated. In the ED, it is a common occurrence for providers to order images based on triage sheets prior to examination. While this may seem efficient, it may ultimately lead to waste and may result in inadequate imaging. An examination prior to imaging would limit waste and potentially save time by ordering the correct imaging first. At our institution, we have been working on implementing this change as a follow-up project with the ED and Orthopaedic staff. Radiographs should then be performed only at the suspected injury site. If no fracture is visualized on an X-ray and there is still a high index of suspicion, physicians may consider performing additional radiographs or consulting with an Orthopaedic surgeon. We believe this would greatly reduce the number of unnecessary radiographs, therefore, reducing the time, cost, and radiation exposure spent obtaining them. This would also help reduce the time the patient spends in the ED, the cost to the patient and their family, and radiation exposure. While it may seem like the hospital would benefit from obtaining more imaging and the potential charges, we are inclined to believe this is not intentional. Aside from contributing to waste, obtaining additional imaging slows the ED down, resulting in less efficiency and the ability to treat less patients in a given time.

387/4117 (9.4%) radiographs had to be repeated in 38/406 patients (9.4%) due to inadequate film quality. While we recognize that it can be difficult to obtain high-quality radiographs in a pediatric patient, our

results demonstrate that obtaining adequate radiographs initially would significantly reduce the amount of time, cost, and radiation exposure that pediatric patients require for the management of fractures. In our institution, it is important to maintain the training of X-ray technicians regarding expectations in standard views as well as providing feedback when a view is suboptimal. In addition, it is important for residents to be involved with obtaining imaging when it is likely that the view will be challenging and require additional assistance.

Similarly, an oblique view was beneficial for evaluating fractures in only 75/406 (18.5%) of patients. Therefore, we recommend that physicians consider obtaining oblique views only after evaluating the initial radiographs in the wrist, forearm, humerus, femur, and tibia, where the oblique view rarely changed management in this study. We recommend obtaining oblique views routinely for the ankles, elbows, and hands where the additional image may provide beneficial information.

Some of the trends in imaging in the different populations were surprising. Children who could not cooperate in an examination and history would be expected to undergo more imaging compared to a child who could demonstrate the location of their symptoms; however, our data demonstrate the opposite. This may be due to parents and physicians limiting imaging in a population seen as more vulnerable. In addition, one would expect younger children to receive significantly more imaging than adolescents who would presumably be better and describing pain and symptoms. One possibility is that younger, smaller children were able to have a larger anatomical region imaged on a single plate due to their size. It is also possible that providers felt more comfortable ordering more imaging in older children as opposed to younger children who would be more susceptible to radiation.

No prior studies have evaluated the number of radiographs performed to accurately diagnose fractures in the pediatric population. While we consider several possible strategies to reduce the number of unnecessary radiographs, thereby reducing the amount of time, cost, and radiation exposure experienced by patients, ultimately, further research is needed to establish clear guidelines for which radiographs are indicated. A quality improvement project that we are planning on initiating as a follow-up to the current study is to establish an orthopaedist-determined X-ray protocol in place in the ED for fracture care. This could be similar to the widely used Ottawa ankle criteria used by ED providers to determine when ankle X-rays are indicated [9]. A future project could propose a similar algorithm for all potential fractures and then prospectively evaluate whether waste is reduced, and any fractures are missed.

One potential area to help reduce the amount of imaging is to critically evaluate the need for a formal postreduction X-ray in simple fractures. Schuld et al. demonstrated that postreduction radiographs did not change management in 265 patients discharged from the ED for fracture [10]. Similarly, Chaudhry et al. showed that postreduction radiographs did not significantly change management but did significantly increase the time spent in the ED in 204 patients [11]. We believe that eliminating some formal postreduction radiographs, unless there is clinical concern, could significantly reduce the number of unnecessary radiographs performed in the ED, therefore, reducing the time, cost, and radiation exposure associated with these unnecessary radiographs. However, this would require a careful decision based on individual fractures. Unstable fractures that may not have been maintained during casting should be confirmed. One option would be to examine the reduction with fluoroscopy using a mini C-arm [12]. In our department, we do not bill for fluoroscopic exams, so it does not add to the cost.

Another potential method for reducing radiation exposure would be to use MRI or ultrasound imaging instead. While MRI provides minimal radiation risk, increased cost, wait times, and the need to sedate young children make it impractical in the ED. Bahl et al. demonstrated that fractures can be visualized as reliably on ultrasound as on X-ray [13]. However, ultrasound may be limited by the availability and training of providers and may not reduce the cost or time spent in the ED. Ultrasound also is limited in its ability to characterize fractures and determine angulation so it may only be useful as a screening tool.

Limitations of our study include the requirement to follow-up in the pediatric Orthopaedic outpatient office. While this inevitably excludes patients who were seen in the pediatric ED and chose to follow up with an outside provider, it was necessary to perform the study. We also were unable to evaluate the exact cost to each patient based on the patient's insurance, since that information was unavailable for review. The values reported in the current study were based solely on the hospital charge for those images. Additionally, the decision of which radiographs to perform was at the discretion of the ED provider and therefore was not uniform across all patients.

Conclusion

There are a significant number of unnecessary radiographs performed in the pediatric ED to evaluate for fractures, leading to unnecessary increases in the amount of time, cost, and radiation exposure that pediatric patients are experiencing. While several possible strategies exist to reduce this waste, further research is needed to evaluate their efficacy.

Additional links

- POSNAcademy: Evaluation of the Limping Child
- POSNAcademy: Elbow Pain in Pediatric Athletes: Diagnosis, Management and Return to Play

Author contributions

Daniel Botros: Data curation, Investigation. **David Komatsu:** Formal analysis, Investigation, Writing – review & editing. **Wesley Carrion:** Conceptualization, Supervision, Validation. **Brian Lynch:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Stephen Bowen:** Data curation, Investigation. **Gloria Coden:** Data curation, Formal analysis, Investigation, Writing – review & editing.

Declarations of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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