Repeat radiographic imaging in patients with long bone fractures transferred to a pediatric trauma center

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ABSTRACT

This study sought to determine the proportion of children with long bone fractures who undergo duplicate radiographic imaging after transfer to a pediatric trauma center (PTC) for further management. The secondary objective was to explore provider rationale and diagnostic yield of repeat X-rays. This was a single-site, retrospective cohort study conducted at a PTC. All patients, aged 0–21 years, who were transferred to the PTC for management of a long bone fracture were included. Electronic medical records were reviewed to determine the proportion of children who had repeat radiographic imaging and the provider rationale for obtaining this. T-test and X^2 analyses were used to compare patients who had repeat X-rays with those who did not. During the study period, 309 patients (63% male, mean age 7.2±4.3 years) were transferred from 30 referring hospitals. Of these, 43% (n=133) underwent repeat radiographs. Patient age (p=0.9), gender (p=0.7), fracture location (p=0.19), and type of referring emergency department (pediatric vs general, p=0.3) were not significantly associated with repeat imaging. Rationale for repeat imaging could be ascertained in 31% of cases (n=41); the most common reasons were request by orthopedist (17%, n=23) and suboptimal original imaging (10%, n=13). Repeat imaging at the PTC did not reveal new or additional diagnoses in any case. Nearly half of the children in our study population undergo repeat and likely unnecessary imaging. Strategies to reduce repeat radiographs should be developed, as redundant imaging exposes patients to additional radiation and increases medical expense.

INTRODUCTION

The majority of children seeking emergency medical care are evaluated in community emergency departments (ED), though some require transfer to a tertiary care center for further evaluation and management.[1] Orthopedic injuries, specifically fractures, are among the most common conditions requiring transfer to a pediatric trauma center (PTC).[2] Transferred trauma patients are at risk for increased radiation exposure due to repeat diagnostic imaging.[3 4] Additionally, duplicate tests result in increased medical costs for transferred patients.[5]

The pediatric population is especially vulnerable to the effects of radiation for multiple reasons. Developing organs and tissues are more sensitive to radiation than adult tissues. Further, radiation exposure has a cumulative effect, and children have a long life expectancy during which the oncogenic effects of radiation can manifest as malignancy.[6] For these reasons, children necessitate special consideration and effort to reduce diagnostic radiation exposure.[7]

Previous work has assessed the incidence of repeat CT scans in pediatric trauma patients,[8 9] and general efforts have been directed at CT radiation reduction[8 10]; however, repeat radiographic imaging in the pediatric trauma population has not yet been described. This pilot study aims to determine the incidence of repeat X-rays in transferred pediatric patients with long bone fractures while also identifying factors associated with repeat imaging and provider rationale for obtaining repeat X-rays.

MATERIALS AND METHODS

This was a retrospective cohort study at a single institution, an American College of Surgeons accredited level 1 PTC at an academic children's hospital. Data were collected from July 1, 2016 until June 30, 2017. All patients aged 0–21 years who were transferred to the PTC for management of a long bone fracture were included.

Patients were identified through the Pediatric Transport database, and each patient's electronic medical record (EMR) was reviewed. Review of the EMR included examination of plain films obtained at the referring hospital and those uploaded and/or repeated at the PTC ED. Repeat X-ray was defined as a duplicate view of the same site. The following clinical data were abstracted from the chart and recorded in a database: age, gender, fracture type, and presence of pediatric expertise at the referring facility, as these have been associated with provider decision-making, clinical management, and/or likelihood of optimal initial imaging.[11–13] We defined pediatric expertise as the presence of a dedicated pediatric ED as opposed to a combined general ED.

Radiologist interpretation was reviewed for every image available in the EMR related to that clinical encounter. Provider documentation (ED attending, ED resident, and orthopedist) was reviewed in an attempt to determine rationale for repeat imaging.

Descriptive statistics were used to describe the patient population. Age was analyzed as both a continuous variable and dichotomous variable (children ≤5 years and children ≥6 years) to reflect age groups in which children may differ by ability to cooperate, which may influence the need for repeat imaging.[14] T-test and X^2 analyses were performed to compare patients who underwent repeat X-rays with those who did not.

Data were entered in Microsoft Excel (2016, Microsoft, Redmond, WA) and analyzed by using SPSS Statistics V.23.0 (SPSS).

RESULTS

In total, 309 patients presented for further management of long bone fractures. Males comprised 63% of the cohort. The mean age was 7.2±4.3 years (range: 13 days to 18 years). Patients were referred from 30 different hospitals, 77% of which had a dedicated pediatric ED as opposed to a combined pediatric and adult ED. In 14/25 of the cases involving children less than 2 years of age, skeletal surveys were obtained suggesting that there was clinical suspicion for non-accidental trauma.

The majority of patients presented with an upper extremity fracture: 45% with elbow/humerus fractures and 23% with forearm/wrist fractures (which includes Monteggia fractures). Lower extremity fractures comprised nearly one-third of the total: 19% with femur fractures and 13% with tibia/fibula/ankle fractures.

A total of 133 (43%) patients underwent repeat imaging on arrival at the PTC. The group of patients who underwent repeat imaging was compared with the group who did not have repeat imaging (table 1). There were no significant differences between the two groups with regard to gender, age, location of fracture, or type of initial ED (pediatric vs general).

Table 2 Provider rationale for obtaining repeat radiographic imaging

Rationale	% (n=133)
Disk malfunction	4 (5)
Suboptimal imaging	10 (13)
Orthopedist request	17 (23)
Could not determine: original imaging uploaded	43 (57)
Could not determine: no original imaging uploaded	26 (35)

Provider rationale for obtaining repeat radiographic imaging could be ascertained in 31% of cases (table 2). Reasons fell into three broad categories: (1) request by orthopedist (17%); (2) suboptimal imaging (10%); and (3) disk malfunction (4%). Rationale could not be determined in the remaining 69%. In 26% of cases, original imaging was not uploaded into the patient's EMR. After review of radiologist interpretation and provider documentation, it could be ascertained that in none of these 133 cases did repeat X-rays reveal a new or additional diagnosis.

DISCUSSION

Our study is among the first to highlight the incidence of repeat radiographs in transported pediatric patients. Previous work has characterized repeat cross-sectional imaging in transferred pediatric trauma patients, and the reported incidence varies widely from 9% to 91%.[3 4 9 15 16] In our study population, 43% of patients underwent repeat radiographic imaging. Notably, the diagnostic yield of repeat radiographs was very low—in no case did repeat X-rays reveal a new or additional diagnosis. Interestingly, there were no differences between the group that underwent repeated imaging and the group that did not with respect to age, gender, fracture type, and type of initial ED.

Table 1 Characteristics of pediatric patients with and without repeat radiographic imaging

Variable	Total n=309	Repeat imaging n=133 (43%)	No repeat imaging n=176 (57%)	p Values
Gender				
Male	63% (196)	62% (82)	65% (114)	0.7
Female	37% (113)	38% (51)	35% (62)	
Age				
Mean age (y)	7.2±4.3	7.2±3.9	7.3±4.5	0.9
Age ≤5 y	40% (124)	41% (55)	39% (69)	0.8
Age ≥6 y	60% (185)	59% (78)	61% (107)	
Fracture type				
Humerus/elbow	45% (140)	52% (69)	40% (71)	0.19
Forearm/wrist	23% (70)	18% (24)	26% (46)	
Femur	19% (60)	19% (25)	20% (35)	
Tibia/fibula/ankle	13% (39)	11% (15)	14% (24)	
Initial ED*				
Pediatric	77% (235)	74% (97)	80% (138)	0.3
Combined/general	23% (69)	26% (34)	20% (35)	

*Missing data, n=304, 131, 173 for total, repeat imaging, and no repeat imaging, respectively.
ED, emergency department.

The occurrence of duplicate radiographic imaging is problematic for several reasons. Most importantly, unnecessary radiographic imaging exposes the patient to additional radiation. The medical community has already placed a strong and necessary emphasis on reducing CT radiation,[7–10] yet plain radiographs remain an underused radiation source to target for reduction in pediatric patients. While the radiation exposure from radiographic imaging is significantly less than that from CT,[6] the lifetime exposure from all such imaging is cumulative. Therefore, it is important to reduce any unnecessary exposures and irradiate only when medically necessary.

Additionally, repeated imaging contributes to increased cost, which is well documented in the literature.[5 9 17 18] For example, at our institution the fee for a standard 2-view elbow radiograph is currently $197.85 and a 2-view of the tibia/fibula totals $239.62. This fee includes the radiologist's interpretation, the technologist's time and effort, as well as all materials. Given the high prevalence of pediatric fractures[19] and the likelihood of similar institutional practices, this could represent a substantial burden of cost to the medical system. Thus, eliminating medically unnecessary imaging may be one effective way to decrease overall cost.

In addition to contributing to increased radiation exposure and cost, obtaining duplicate imaging may prolong length of stay and negatively impact the patient experience. For instance, previous work has demonstrated that patients who require diagnostic imaging have significantly longer lengths of stay in the ED.[20 21] This is important with respect to ED overcrowding and patient throughput, and because length of stay has been identified as an important component of patient satisfaction.[22] After evaluation at the initial hospital, transfer to the PTC, and subsequent assessment in the tertiary care ED, transferred patients experience a protracted evaluation process. During this time frame, they are often kept nothing by mouth and remain in some degree of discomfort due to their injury. Reducing unnecessary imaging and decreasing time to definitive management may promote patient-centered care and improve the clinical experience.

Our study is also novel in that it explores reasons and provider rationale for obtaining repeat imaging. In our cohort, disk malfunction accounted for 4% of repeat imaging and suboptimal initial imaging accounted for 10%. In 43% of cases, original imaging was uploaded and repeated; however, provider documentation did not indicate rationale for obtaining repeat radiographs. We suspect that in at least some of the cases repeat X-rays were obtained to further characterize or better visualize degree of angulation or extent of fracture displacement based on textbook recommendations,[23 24] though this could not be corroborated in review of the orthopedist documentation. To reduce instances where initial imaging is suboptimal, facilities should implement strategies to promote strict adherence to standard pediatric imaging protocols.

In 26% of cases, the original imaging was not uploaded and lack of documentation limits our ability to determine why. We suspect some of these instances likely represent cases in which the image disk was not transferred with the patient or was misplaced en route/on arrival at the PTC. Alternatively, this could also represent disk malfunction, disk incompatibility or a provider-level decision. In the digital age, the vast majority of images are transported with the patient on a disk that can be uploaded and viewed at the receiving institution. While this readily facilitates image sharing, if the disk is not sent with the patient, is misplaced en route, or is incompatible with the recipient's operating system, then imaging will invariably be repeated.

Others have also highlighted the issue of transferred patients arriving to a PTC without imaging (either disks or films) performed at the initial hospital. Cook *et al* noted that over half (53%) of pediatric patients transferred for further evaluation of abdominal trauma were transferred without their initial imaging and subsequently required duplicate imaging.[9] This problem is entirely preventable, and future work should explore whether implementation of a checklist or another intervention may help to ensure that all records and imaging are transferred with the patient.

There are limitations to this study, including the small sample size. Additionally, it was performed at a single PTC, which limits generalizability to the pediatric trauma population as a whole. The retrospective nature of the chart review impaired attempts to fully explore provider rationale for obtaining repeat radiographs. Nevertheless, we demonstrate here that nearly half of the patients in this population undergo repeat and likely unnecessary radiographic imaging. Although no new diagnoses were revealed in the duplicate imaging, it is possible that the additional radiographs aided clinical management by providing superior images demonstrating fracture angulation or displacement. However, the available provider rationale data showed that this was likely in a minority of cases, as suboptimal imaging was reported as the rationale in only 10% of cases.

Finally, another limitation is that only a small minority of our patients had injuries suspicious for abuse, so our findings may not be relevant for the evaluation of children with suspected non-accidental trauma. This is a special population of patients that often requires more extensive clinical evaluation and imaging.[25]

Despite these limitations, this pilot study is the first to report prevalence of repeat X-rays in transferred pediatric patients. Because duplicating X-rays results in excessive radiation exposure as well as increased medical expense, opportunities to reduce redundant imaging should be explored. Other institutions should consider collecting similar baseline data so the scope of this problem may be better understood. Additionally, future study may involve quality improvement efforts to reduce duplicate imaging, including the development of protocols to standardize medical decision-making related to obtaining repeat X-rays. Collaboration among radiologists, orthopedists, and emergency medicine providers may achieve the goal of obtaining optimal imaging for appropriate diagnosis and treatment while minimizing unnecessary radiation exposure.

Contributors LMR and MM conceived and designed the study. LMR supervised the conduct of the study and data collection. CWM, BLK and DS undertook recruitment of participating centers and patients and managed the data, including quality control. LMR and CWM provided statistical advice on study design and analyzed the data. CWM drafted the manuscript, and all authors contributed substantially to its revision. LMR and CWM take responsibility for the paper as a whole.

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