Reprinted from PEDIATRIC EMERGENCY CARE
Vol. 15 No. 4 August 1999

Can portable bedside fluoroscopy replace standard, postreduction radiographs in the management of pediatric fractures?

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Objective: **To determine the accuracy of portable bedside fluoroscopy in documenting postreduction fracture alignment in the pediatric emergency department (ED).**

Design/Setting: **Prospective trial in an urban pediatric ED.**

Participants: **Convenience sample of 80 pediatric patients requiring ED reduction of isolated long bone fractures.**

Methods: **Patients who underwent closed fracture reduction using portable fluoroscopic guidance (FluoroScan) in the ED were enrolled in the study. Postreduction images were obtained using both bedside fluoroscopy and conventional radiographs. A pediatric orthopedic subspecialist, blinded to clinical outcome, reviewed the fluoroscopic and radiographic images for adequacy of alignment and rated the utility of conventional radiography for fracture management.**

Results: **The patients were 2.5 to 16 years of age (mean 8.3). Distal radial and radioulnar fractures comprised 96% (76/80) of cases. Sixty-three percent of the fractures were displaced, and the mean angulation of the primary fracture site was 24°. Fluoroscopy was found to be 100% sensitive (75/75 cases) and 100% specific (5/5 cases) in predicting postreduction fracture position when compared to conventional radiographs. Intrarater observer agreement on the necessity of conventional postreduction radiographs was 0.92 (95% CI 0.82–1.00) using the kappa coefficient. In no case did postreduction radiographs alter acute fracture management.**

Conclusions: **Bedside fluoroscopy with printed fluoroscopic images are highly reliable in evaluating fracture reduction and can replace conventional radiography in documenting adequate distal forearm fracture reduction when there is no intraarticular involvement.**

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Presented at the Western Ambulatory Pediatric Association. Region IV and X. Annual Meeting. Carmel, California, February 1997.

Presented at the Society for Academic Emergency Medicine 1997 Annual Meeting, May 1997, Washington, DC.

Key Words: Fluoroscopy, fractures

INTRODUCTION

As patient volume and financial constraints increase in the emergency department, innovative ways to improve efficiency and reduce costs are desirable. Fluoroscopy has been used extensively in the operating room for orthopedic procedures such as intramedullary rodding. In addition, it has been of use for central line and pacemaker placement, as well as for assistance with difficult lumbar punctures. Previous studies suggest that fluoroscopy can be incorporated into daily ED practice for procedures such as foreign body detection (1). Although insufficiently sensitive as a screening device for simple extremity fractures (2), Lee et al., in a retrospective study (3), found that known fractures that were managed with closed reduction and evaluated using fluoroscopy required 31% fewer radiographic procedures. In the same study, it was determined that, for a comparable view, radiation exposure with fluoroscopy was approximately 50% less than with conventional radiographs.

The Emergency Care Center of Children's Hospital and Health Center of San Diego currently triages 35,000 patients annually. Of these, approximately 1500 present with acute bony injuries. Current practice is to perform closed reductions of isolated upper extremity long bone fractures with fluoroscopic confirmation of alignment. All patients then undergo postreduction radiography. It was our hypothesis that portable bedside fluoroscopy with printed fluoroscopic images could accurately predict and serve as permanent documentation of postreduction fracture alignment. Therefore, a prospective study was conducted on the efficacy of bedside fluoroscopy in the management of closed reduction of pediatric long bone fractures.

METHODS

A convenience sample of 80 patients who presented to our ED between May 1996 and January 1997 for closed fracture reduction was prospectively enrolled. Sample size was calculated using a P value of 0.05 and power of 0.80 to detect a 10% difference between fluoroscopy and conventional radiography. Patients were included if they were less than 18 years of age, and had radiographically proven isolated long bone fractures that were to be reduced in the emergency department. Exclusion criteria included open fractures, supracondylar or other elbow fractures, and patients who were critically ill or required emergent CT scanning. The study protocol was approved by the institution's investigational review board.

Patients underwent closed reduction with fluoroscopic confirmation. Intravenous sedation using midazolam and fentanyl was used according to published monitoring guidelines (4). All fluoroscopic

studies were performed by the managing orthopedic surgeon using a miniature surgical C-arm (FluoroScan Imaging Systems, Northbrook, IL.). Postreduction fluoroscopic images were obtained in the anteroposterior and lateral projections before and after cast immobilization. The images were reviewed by the managing orthopedic surgeon. Adequate fracture alignment was defined as fracture alignment adequate for patient discharge without further attempts at reduction. After cast immobilization, all patients underwent standard postreduction radiography. Prior to reviewing the radiographs, the managing orthopedist judged the adequacy of fracture alignment based on the fluoroscopic image. He then recorded whether the postreduction plain radiographs altered acute fracture management. Additional data recorded included the level of training of the managing orthopedist, fracture location, degree of angulation, displacement, and number of reduction attempts.

All fluoroscopic images and radiographs were reviewed by a single subspecialty-trained pediatric orthopedic surgeon who was blinded to patient identity and clinical outcome. Postreduction fracture alignment based on fluoroscopic and radiographic images was assessed. The pediatric orthopedic specialist also determined the additional usefulness of routine radiographs and whether the obtained formal postreduction radiographs would have altered acute fracture management. To rate intra-rater reliability, the fluoroscopic images were reviewed for alignment and necessity of additional radiographs by the same pediatric orthopedic specialist on two separate occasions.

Statistical analysis was performed using the SPSS program (5). Calculated values included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of fluoroscopy in predicting postreduction fracture alignment. We defined sensitivity as the ability of the fluoroscopic image to identify correctly anatomic alignment when compared to the gold standard of conventional radiography. Intra-rater reliability was calculated using the kappa statistic. Based on two separate reviews of the fluoroscopic images by the orthopedic specialist, kappa statistic was calculated on the use of postreduction radiographs. Agreement on fracture alignment based on fluoroscopic image review on two separate occasions and agreement on fracture alignment between standard radiographs and fluoroscopic images were also evaluated.

RESULTS

The 80 study patients ranged in age from 2.5 to 16 years (mean 8.3 years, SD 3.33). Forty-eight (60%) were male. Distal forearm fractures accounted for 96% of the fractures, with radioulnar fractures comprising 62% (50) of our fracture population (Fig. 1). Mean fracture angulation was 24°, and 63% of the fractures were displaced. The majority of fractures 65% (52) were metaphyseal; 28% (22) were diaphyseal; and 8% (6) were non–intra-articular epiphyseal/physeal fractures. In no case was operative intervention necessary.

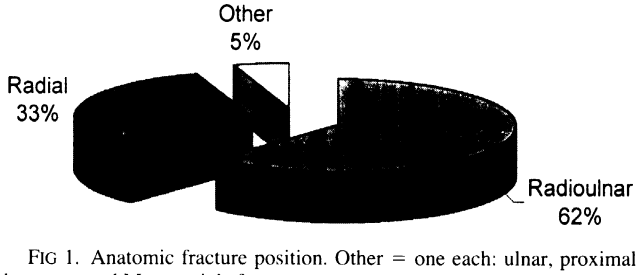

FIG 1. Anatomic fracture position. Other = one each: ulnar, proximal humerus, and Monteggia's fracture.

TABLE 1
Predictive indices of fluoroscopy results

Predictive indices	Results % (No. of Patients)	95% CI
Sensitivity	100 (75/75)	94–100%
Specificity	100 (5/5)	46–100%
PPV	100 (75/75)	94–100%
NPV	100 (5/5)	46–100%
Accuracy	100 (80/80)	94–100%

Fractures were reduced by senior orthopedic residents in 70/80 cases (88%), with a mean number of reduction attempts of 1.8 (range 1 to 5, SD 1.02, median 1.0). The managing orthopedist felt that postreduction and postimmobilization fluoroscopic fracture alignment were adequate for patient discharge in all 80 cases, and in no case did postreduction radiography alter acute fracture management. The sensitivity, specificity, PPV, NPV of fluoroscopy when read by our orthopedic subspecialist were all 100% (Table 1). All fluoroscopic images were felt to be of satisfactory image quality for this review. The need for postreduction radiographs, after review of the fluoroscopic images, was rated by our pediatric specialist on two separate occasions, with a kappa statistic of 0.92 (95% CI 0.82–1.0) Disagreement occurred in two cases in which radiographs were, on second review, not felt to be necessary. Formal radiographs were felt to be warranted on second review in 15 cases (19%) for diaphyseal fractures, to visualize the proximal or distal joint (eight cases); complex fractures for follow-up purposes (1); proximal humerus fractures due to increased soft tissue density (1); and for fractures that had incomplete anatomic alignment on the fluoroscopic image (5). Intra-rater agreement on fluoroscopic fracture alignment on repeated fluoroscopic image review, and agreement between fluoroscopic alignment and radiographic fracture alignment was 100%.

DISCUSSION

This study prospectively compared bedside fluoroscopy and conventional radiography in the management of pediatric extremity fractures. Formal radiographs did not alter bedside orthopedic management of fractures. In addition, there was 100% agreement on adequacy of fracture alignment when printed fluoroscopic images were compared to the postreduction radiographs during blinded review by a staff pediatric orthopedist. Routine postreduction radiographs were felt to be warranted in cases of diaphyseal fractures, complex fractures, and proximal humerus fractures.

The advantages of using bedside fluoroscopy are numerous and include: no time delay to obtain formal radiographs between reduction attempts, no nurse transport time or transport monitoring, possible decrease in number of operating room reductions since fluoroscopy can be done in real time, fluoroscopic images need not be reviewed by the radiologists the next day after patient management has already occurred, and there is less radiation exposure with fluoroscopy than with standard radiographs. The scattered radiation from the FluoroScan is minimal and therefore the "choice to wear protective aprons is an individual one" (6). Pregnant females and nonpatient minors should, however, avoid direct unnecessary exposure. Another advantage of fluoroscopy is that this technique allows the study of fracture alignment in several different planes to dynamically assess fracture stability.

Despite the impressive performance of fluoroscopy in our study, possible limitations include convenience sampling and small sample size. Factors limiting study enrollment included: reliance on the attending on duty to enroll patients, the availability of film in the FluoroScan, and the reliance on the managing orthopedist to save and print the fluoroscopic images. In addition, because each patient served as his own control, it is not possible to know to what extent the use of fluoroscopy skewed outcome. The availability of bedside fluoroscopy may have influenced the managing orthopedist to achieve perfect, rather than adequate, reduction. This phenomenon may account for the wide confidence intervals for specificity and negative predictive value, owing to the small number of patients that had adequate but nonanatomic postreduction fracture alignment and the absence of patients with failed reductions. Future studies are needed to specifically address time and cost savings associated with the use of fluoroscopy for fracture management. Cost savings may be estimated in terms of decreases in the number of actual radiographs obtained between reduction attempts, radiologist interpretation costs, and decreased duration of emergency department monitoring costs. The use of fluoroscopy in lieu of radiographs is desirable in the pediatric population that is often deeply sedated for closed reductions, and therefore would not require monitored transport to the radiology department.

Based on the results of our study, we conclude that portable bedside fluoroscopy can accurately predict postreduction fracture alignment and replace routine postreduction radiographs for distal forearm fractures. Routine postreduction radiographs did not alter acute fracture management, and the pediatric orthopedic specialist would not have required routine postreduction radiographs in simple distal forearm fractures. In addition, there is a high degree of intra-rater reliability when fluoroscopy is used to predict postreduction fracture position.

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