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Original Contribution

Ultrasound-guided pediatric forearm fracture reductions in a resource-limited ED☆

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ABSTRACT

Background: Pediatric forearm fractures are a common presentation in emergency departments in Papua New Guinea. Often these children undergo "blind" closed reduction with reduction adequacy assessed by standard radiographs. This study aims to demonstrate the safety and efficacy of ultrasound (US) in guiding closed reduction of pediatric forearm fractures in a resource-limited setting.

Methods: We recruited consecutive children with closed forearm fractures requiring reduction. A US scanner was used to visualize and aid fracture reductions. The outcome measures were the rate of successful reductions (ie, adequate alignment without the need for a second procedure or further surgical intervention), length of stay in hospital, and adverse events during each procedure and at follow-up after 6 weeks.

Results: Of 47 children recruited, there were 44 (94%) successful reductions, whereas 3 (6%) required repeated reduction. The mean (SD) length of stay in hospital of the successful cases was 8.77 (3.66) hours. Two patients had tight plaster casts during early follow-up which were immediately addressed. Of the 44 successful cases, only 38 were retrieved for the final review. No further adverse events were observed in the latter.

Conclusions: This small-scale study has demonstrated the safe and efficacious use of US-guided close reduction of pediatric forearm fractures in a low-resource setting. Using US, real-time visualization of reduction efforts can reassure the clinician in decision making, thus reducing the rate of repeated reductions and allowing shorter hospital stay.

1. Introduction

Forearm fractures are common pediatric injuries presenting to emergency departments (EDs) worldwide [1–4]. In most hospitals in Papua New Guinea (PNG), the diagnosis and management of forearm fractures is guided by radiography. Patients with fractures requiring reductions are often admitted to the surgical ward and booked for a blind closed reduction (CR) with casting done under general anesthesia in the operating theater (OT). The adequacy of fracture reduction and alignment is then assessed with a postreduction x-ray. If reduction adequacy is unacceptable and a repeat reduction is required, these children endure a longer period of stay in hospital leading to increased cost of care. This can also be cumbersome to the patient and family. More importantly, repeated reductions carry potential risks during resedation [5–8].

In well-resourced hospitals, an image intensifier is used to assess reduction adequacy prior to plaster cast application `[9]. This allows for assessment of reduction when the patient is still in the OT. However, most hospitals in PNG lack this expensive modality. The risk of prolonged exposure of children to radiation is also an issue during fluoroscopy guidance [9,10]. Furthermore, many hospitals in PNG lack consistently functional radiology services due to constraints in the logistics of maintenance and acquisition of consumables.

An emerging imaging alternative for the assessment of musculoskeletal injury is ultrasound (US) scan [11–13]. Its use in screening of pediatric bone fractures and evaluation of CR is also well documented and described both adults [11–13] and children [14–26]. In particular, US applied in high-resource settings has been illustrated as a cost-effective and useful alternative bedside imaging modality for the diagnosis and management of forearm fractures [14,15]. Several studies have reported a successful use of US-guided reductions of pediatric forearm fractures [27–30]. In these studies, radiography was reserved for final postreduction analysis after cast application. It has been shown that not only fracture reductions can be performed safely and effectively under procedural sedation using ketamine, benzodiazepines, and opioids [5,6,8,27], but also managing fractures in ED reduces length of hospital (LOS) stay and thus is cost-effective [28].

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In PNG, only 2 studies have mentioned briefly the role of US in the assessment and ongoing management of trauma patients in the surgical hospital units [29]. However, the authors are not aware of studies on the use of US in diagnosis and guidance of fracture reductions in the developing world setting. This study aims to investigate the safety and efficacy of US in guiding close reduction of pediatric forearm fractures in a resource-limited setting.

2. Methodology

2.1. Study design

This is a prospective case-series study of consecutive children with closed forearm fractures conducted at a teaching hospital in PNG over a 1-year period from November 2011 to October 2012. The study received ethical clearance from the institutional ethics board. The parents or guardians of participating children gave informed written consent prior to the enrollment of each child.

2.2. Inclusion and exclusion criteria

We enrolled children aged between 2 and 17 years with a closed forearm fracture confirmed by an initial x-ray illustrating a need for reduction. We used the criteria originally described by Noonan and Price [30] to determine a need for reduction in these injuries. These criteria included angulation in the sagittal plane and coronal plane of >20° and/or >15°, respectively, for children younger than 9 years, >10 to 15° and >5° for children 9 to 13 years old, and >5° to 10° and >5° in patients older than 13 years, and any degree of shortening [30]. Furthermore, we included fractures with bayonet apposition in for CR. Patients with multiple injuries, compound fractures, fractures extending intra-articular, and distal neurovascular compromise were all excluded. Patients with hemoglobin levels less than 8 g/dL were also excluded. Children with forearm fractures presenting 7 days or more after the injury were referred to the orthopedic surgeon.

2.3. Study protocol

In this study, US guidance for all the cases was done by the investigating emergency registrar after a short tutorial including a demonstration by the orthopedic surgeon. Additional learning was gained from an online instructional video.

Prior to undergoing CR, the children were thoroughly examined and weighed, had hemoglobin levels checked, and were fasted for at least 4 hours. A routine procedural sedation included ketamine 1 to 2 mg/kg intravenous (IV) along with diazepam 0.1 to 0.2 mg/kg IV. A nurse observed the sedated children at the head-end of the bed throughout the procedure. Mandatory pulse oximetry monitoring along with supplemental oxygen, via a nasal prong or facemask, was administered as required. There was access to medical oxygen, a suction machine, and a resuscitation trolley with airway adjuncts and drugs.

All CRs were performed under guidance of US using a single 3.5-MHz curvilinear probe (Model SSA-220A; Toshiba Corporation, Tokyo, Japan). The affected forearms were scanned on the *dorsal*, *lateral*, and *ventral* aspects in the longitudinal plane before and after the CR.

Depending on the degree of swelling, a full plaster cast or splint was applied to maintain reduction. We assessed the radial pulse and digital capillary refill time after CR completion and again after cast application. All patients received rectal paracetamol (20-30 mg/kg) at the end of the procedure. The patients were observed in the resuscitation room resting in the lateral position until recovery. Once the patients were fully conscious, they were sent for a postreduction x-ray to assess reduction.

2.4. Outcomes and surveillance

The primary outcome measures were the rate of adequate fracture reduction, rate of repeated reductions, the LOS stay, and early and late complication rate. Postreduction assessments were done by reviewing plain x-rays and judging as acceptable or unacceptable reduction outcomes. We predefined "acceptable reductions" as per recommendations described by Noonan and Price [30]. However, in addition, a 50% or more bony opposition without malrotation was accepted. The orthopedic surgeon reviewed the postreduction x-rays. Children with unacceptable reductions were admitted to the surgical ward for further management.

We also recorded the duration of the procedure measured in minutes as the time of initiation of sedation with ketamine IV administration, to completion of cast application. *Length of stay* was defined as the time between the initial evaluation by the author and discharge from the ED. Cast-related complications were observed and documented. The participants were followed up at 2 days and at 2 and 6 weeks for the clinical and radiologic assessment of the fracture union. Information with instructions was given to parents or guardians on elevation of the affected forearm, prescribed oral analgesia, and signs and symptoms of a "tight cast."

2.5. Data collection and analysis

A standard research form was used for recording the following data: the demographic characteristics, weight, hemoglobin, the date and mechanism of the injury, the total amount IV ketamine and diazepam, and clinical and radiologic findings during assessment. All statistical analyses were done using SPSS Version 12, for Windows Operating Systems (SPSS, Chicago, IL). Continuous data were presented as means

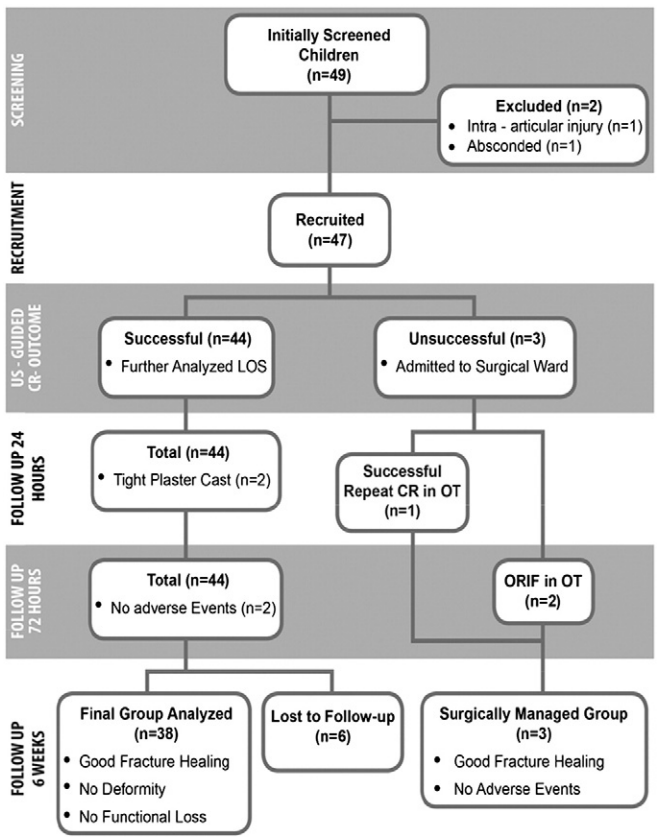

Fig. 1. Flow diagram of the study illustrating screening, recruitment, reduction outcomes, and follow-up of the participants. n is the number of participants.