Severe Consequences of the Misclassification and Subsequent Undertreatment of 'Type 1' Open Fractures

Julie B. Samora, MD, PhD, MPH[1]; Carley Vuillermin, MBBS, MPH, FRACS[2]; Peter M. Waters, MD, MSSc(Ed)[2]

[1] Department of Orthopedics, Nationwide Children's Hospital, Columbus, OH; [2]Department of Orthopaedic Surgery, Boston Children's Hospital, Boston, MA

Abstract: Operative treatment with formal irrigation and debridement has classically been considered the standard of care for open forearm fractures. Considerable debate exists regarding the management of type 1 open forearm fractures in the pediatric population. Several recent studies have demonstrated that nonoperative management consisting of local wound irrigation and debridement in the emergency department, followed by closed reduction and casting with a course of antibiotics may be an appropriate treatment option for these fractures. The purpose of the current case study is to present two cases of open forearm fractures, which were designated as type 1 fractures in young children that resulted in devastating outcomes following emergency department wound management and fracture care.

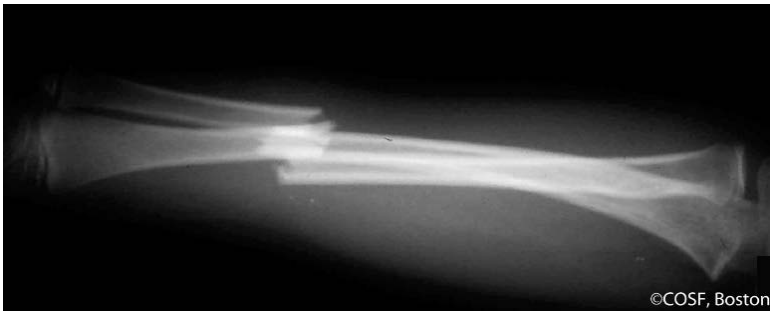

Figure 1. *Representative radiographs of the initial both bone forearm fracture of Case #1. (Figures courtesy of Children's Orthopaedic Surgery Foundation)*

Introduction

Operative treatment with formal irrigation and debridement with parenteral antibiotic coverage has classically been considered the standard of care for open fractures[1–3]. Gustilo and Anderson (1976) developed a classification system to define open fractures, in which type 1 fractures are described as an open fracture with a laceration ≤1cm, minimal soft tissue damage, and no evidence of contamination[1]. An immediate difficulty arises when assessing an open fracture with a small laceration in the emergency department: does the size of the skin laceration directly correlate with the degree and type of contamination and/or underlying soft tissue disruption? Unfortunately, the reliability of the classification has been estimated at only ~60%[4,5], which is less than ideal.

Considerable ongoing debate exists regarding the management of type 1 open fractures in the pediatric population. In the present age of expedient and limited in-hospital care, it has become common for many pediatric problems to be treated in the ambulatory setting. Several recent studies have demonstrated that nonoperative management consisting of local wound irrigation and debridement (I&D) in the emergency department, followed by closed reduction and casting with a course of antibiotics, may be an appropriate treatment option for type 1 open fractures[6–10].

We present 2 cases of open fractures of the forearm in young children, which were initially judged as type 1

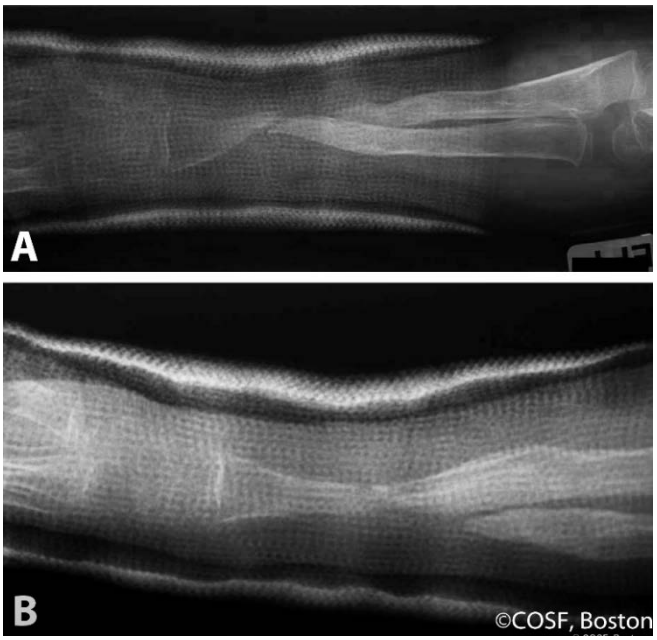

Figure 2. *AP A and lateral B radiographs demonstrating a radius nonunion and substantial bony loss of the ulna upon presentation to referral center.*

fractures that resulted in devastating outcomes following emergency department wound management and fracture care.

Case Report 1

A 5½-year-old right hand dominant healthy female sustained a ground-level fall that resulted in a type 1 open diaphyseal both bone forearm fracture (Figure 1). Initial treatment included emergency department irrigation and debridement (I&D) with closed reduction at an outside facility. Eight days later, she returned to the same facility with a wound infection, and she underwent a formal I&D. Cultures grew *Escherichia vulneris* and *Clostridium*, for which she was started on Unasyn. Five days later she underwent a repeat formal I&D, with ulnar plating, radial external fixation, and tendon repair. The external fixator was removed at 2 months. Persistent infection required removal of the ulna plate and resection of the midportion of the ulna 6 weeks thereafter, and then another I&D 1 month later. IV and oral antibiotics, including Meropenem, Flagyl, and Rifampicin, were continued. Throughout this time frame, she had 20 hyperbaric oxygen treatments.

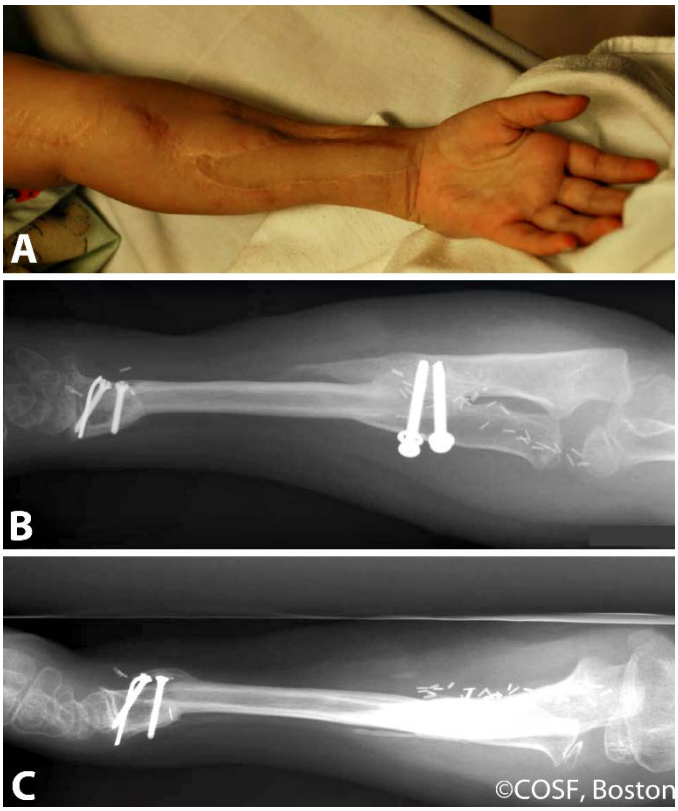

Figure 3. *Healed vascularized graft (A) and internal fixation B, C.*

Although radial union was achieved, the patient soon after sustained a refracture and was placed in a short arm cast. Antibiotics were discontinued at 7 months, with no evidence of infection; however, a persistently unstable forearm (Figure 2) with loss of hand sensibility and intrinsic motor function in the ulna nerve distribution. Forearm level amputation had been recommended through the non-union sites by 2 external orthopedic surgeons. The patient was referred for discussion of reconstruction.

At referral, the patient's left forearm was unstable with minimal active range of motion in her hand and wrist and decreased sensation in the radial and ulnar nerve distributions. After extensive consultation regarding options, a decision was made for staged reconstruction with creation of a single bone forearm (SBF) with a vascularized free fibular graft and secondary neuromuscular animation.

Figure 4. *Intraoperative photograph after the free gracilis.*

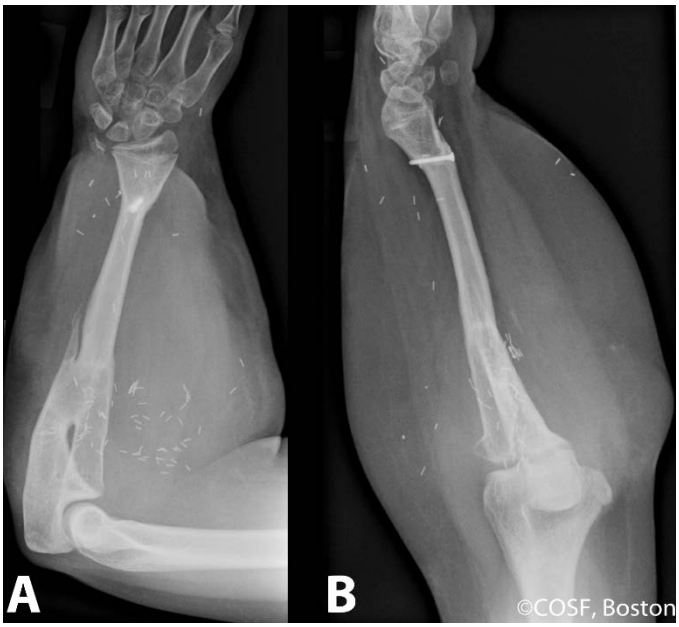

Figure 5. *Anteroposterior (A) and lateral (B) radiographs of the healed single bone forearm.*

At the initial reconstructive surgery, the radius and ulna were dysvascular with evidence of chronic osteomyelitis requiring debridement back to healthy bone. Intra-operative gram stains and cultures were negative. A vascularized free fibular graft was performed with reconstruction of a 5-centimeter ulnar nerve defect using sural cable grafts. She achieved union of the SBF 4 months post-operatively without complication (Figure 3). Ulna nerve sensibility and intrinsic motor function returned over the next 6 to 12 months.

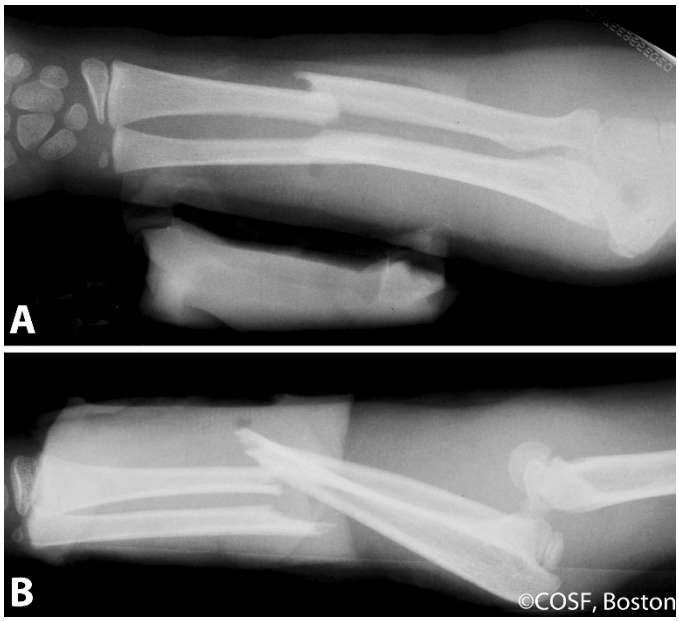

Figure 6. *Anteroposterior (A) and lateral (B) images of displaced both bone forearm fracture dislocation of Case #2.*

Further reconstruction then proceeded over four surgical encounters across more than 5 years including a vascularized free functional gracilis transfer to restore active digital flexion (Figure 4), tenolysis and tendon transfers for restoration of dorsal wrist and hand extensor function, a second vascularized free functional gracilis transfer to the EDC and EPL for augmenting wrist and thumb extension, and lastly a brachioradialis and ECRL tendon transfer to ECRB was performed to improve wrist extension. She improved her strength and active range of motion, and her wrist and hand became more balanced.

Finally, 3 years later, she underwent debulking of her 3, forearm free flap skin paddles combined with a retinacular reconstruction to centralize her wrist extension (Figure 5). She is doing well enough to participate in competitive scholastic athletics at this time and has a functionally assistive, sensate hand that grew into skeletal maturity. To quote her father at the end of her care, “when you told me the first time we met it would take a lot of work and time to get a functional, but not normal hand, I underestimated what ‘a lot’ meant but

Figure 7. *AP radiograph demonstrating closed reduction of the elbow dislocation and improved alignment of the both bone forearm fracture.*

it was worth it as she is better off than she would have been with an amputation."

Case Report 2

The second case report is that of a healthy 5-year-old female who sustained a ground-level fall resulting in an open midshaft both bone forearm fracture with an elbow dislocation (Figure 6). Initial treatment was with emergency department irrigation of wound and closed reduction of the forearm fracture and elbow dislocation with casting at an outside facility (Figure 7). She was provided with Keflex for the open wound and Tylenol #3 for pain. Due to poorly controlled pain, she was transferred to another hospital two days after her injury. She was found to be febrile and in increasing pain. Upon removal of her cast, there was purulent discharge along with evidence of advancing fasciitis. She was taken emergently to the operating room, where an extensive irrigation and debridement was performed, including the bulk of her volar forearm musculature removed. Cultures were positive for multiple aerobic and anaerobic species, including *Clostridium bifermentens, Enterobacter cloacae, Enterococcus faecium,* other *Enterococcus species,* and *Klebsiella oxytoca*. She was started on IV Zosyn. On repeat I&D the following day showed progressive infection, with intraoperative request for tertiary transfer.

Upon presentation to our facility, she was febrile to 38.2 C with elevated inflammatory markers, a dysvascular distal limb with poor sensibility, and persistent purulent drainage (Figure 8). She was taken emergently to the operating room for I&D. Antimicrobial coverage was broadened, adding Gentamicin and Vancomycin. Intraoperatively, there was extensive necrosis of the entire volar forearm musculature, necrotic bone in the diaphyseal region of both the ulna and radius and purulence from the cubital fossa through the hand in both flexor and extensor compartments. The brachial artery was viable; however, the radial and ulnar arteries were thrombosed from the mid-forearm through the carpal arch. There was limited collateral blood flow to the hand. Extensive debridement of all non-viable infected muscle, soft tissues, and bone was performed.

Figure 8. *Clinical presentation on arrival to our institution, with a dysvascular limb, necrosis, and gross purulence.*

The patient was hemodynamically stable. An intraoperative decision with Orthopaedic Surgery, Plastic Surgery, and Infectious Diseases was made rather than immediate amputation; the plan was made to return to the operating room in 6 hours to reassess the viability of the extremity (Figure 9).

Discussion with the family and patient occurred regarding probable need for amputation. At the second look surgery, there was more extensive necrosis

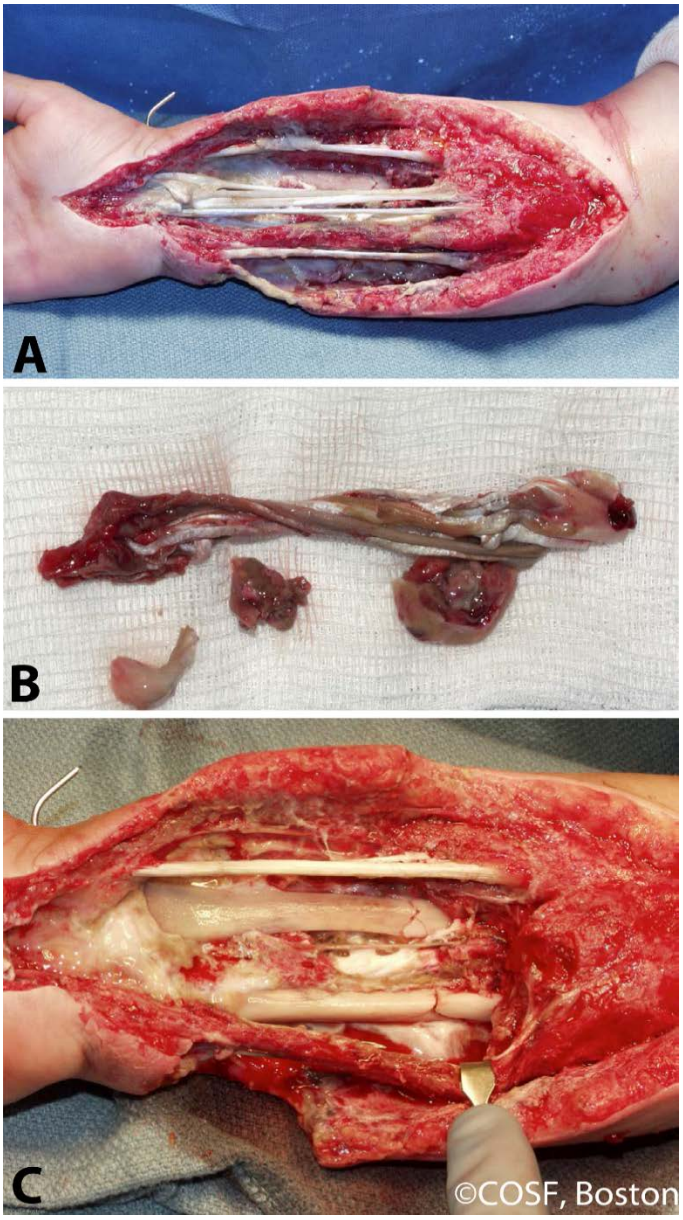

Figure 9. *Upon 6-hour return to the operating room, further necrosis of the tendons and soft tissue were encountered and removed A, B. There was more extensive necrosis with discoloration of the bone and all nonviable tissue was removed, leaving minimal volar soft tissue C.*

extending the length of the radius and ulna. The hand was not viable. The bone of the proximal radius and ulna and the proximal musculature flexor pronator origin and extensor supinator origin was viable. The biceps, brachialis, and triceps regions were not infected. A below-elbow amputation of the limb was performed to preserve the elbow joint and the extent of the proximal forearm that was viable.

Figure 10. *Final radiograph demonstrating amputated extremity.*

After 4 subsequent irrigations and debridements with vacuum-assisted dressing changes, she underwent delayed primary closure of the amputation 13 days after her initial injury. The patient was continued on intravenous Meropenem with a PICC line for 8 weeks. She was fitted with a prosthesis for assistive functional use (Figure 10).

The patient is now 14 years post-amputation. Although she initially used a prosthesis, she stopped using one after four years. She remains an avid athlete.

Discussion

The management of open fractures has been a major concern for as long as medical care has been recorded[1]. There is decreased morbidity and mortality with aggressive, early surgical debridement of open fractures and devitalizing soft tissue wounds[11]. Thorough and immediate surgical irrigation and debridement has been shown to lead to much lower rates of infection[12,13].

However, the incidence of infection cited for type 1 open fractures is low, ranging between 0 and 3%[1,7,10,14,15], and the vast majority of outcomes of type 1 open pediatric fractures are good. Several recent authors have reported their experiences with treating type 1 pediatric open fractures with closed reduction and nonoperative treatment[6,7,9]. While nonoperative management of

pediatric type 1 open fractures has been deemed as both safe and effective[6,7,9], many case series are not powered to capture rare outcomes.

Both case examples were initially assessed as type 1 injuries and managed nonoperatively with devastating results, indicating that there can be rare but potentially severe complications from a less-aggressive approach. The authors cannot conclusively state that these severe infections would not have occurred with operative irrigation and debridement, and parenteral antibiotics. Although it is reasonable to speculate that the nonoperative care given to these children was a significant factor in their profound morbidity from their type 1 open fractures.

We should all remain vigilant in the treatment of open forearm injuries in pediatric patients and ensure we are assessing the entire injury including the mechanism, environmental contamination and associated skeletal injuries, and not just the size of the wound.

References

1. Gustilo R, Anderson J. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Jt Surg Am Volume*. 1976;58(4):453-458. doi:10.2106/00004623-197658040-00004.
2. Sanders R, Swiontkowski M, Nunley J, Spiegel P. The management of fractures with soft-tissue disruptions. *J Bone Jt Surg*. 1993;75(5):778-789. doi:10.2106/00004623-199305000-00020.
3. Anglen JO. Wound Irrigation in Musculoskeletal Injury. *J Am Acad Orthop Sur*. 2001;9(4):219-226. doi:10.5435/00124635-200107000-00001
4. Brumback R, Jones A. Interobserver agreement in the classification of open fractures of the tibia. The results of a survey of two hundred and forty-five orthopaedic surgeons. *J Bone Jt Surg*. 1994;76(8):1162-1166. doi:10.2106/00004623-199408000-00006.
5. III WW, Swiontkowski MF. Treatment principles in the management of open fractures. *Indian J Orthop*. 2008;42(4):377-386. doi:10.4103/0019-5413.43373.
6. Doak J, Ferrick M. Nonoperative Management of Pediatric Grade 1 Open Fractures With Less Than a 24-Hour Admission. *J Pediatr Orthoped*. 2009;29(1):49-51. doi:10.1097/bpo.0b013e3181901c66
7. Iobst CA, Tidwell MA, King WF. Nonoperative Management of Pediatric Type I Open Fractures. *J Pediatr Orthoped*. 2005;25(4):513-517. doi:10.1097/01.bpo.0000158779.45226.74
8. Yang EC, Eisler J. Treatment of Isolated Type I Open Fractures. *Clin Orthop Relat R*. 2003;410(NA;):289-294. doi:10.1097/01.blo.0000063795.32430.4c.
9. Bazzi AA, Brooks JT, Jain A, Ain MC, Tis JE, Sponseller PD. Is nonoperative treatment of pediatric type I open fractures safe and effective? *J Child Orthop*. 2014;8(6):467-471. doi:10.1007/s11832-014-0616-x.
10. Godfrey J, Choi PD, Shabtai L, et al. Management of Pediatric Type I Open Fractures in the Emergency Department or Operating Room: A Multicenter Perspective. *J Pediatr Orthoped*. 2019;39(7):372-376. doi:10.1097/bpo.0000000000000972.
11. Skaggs DL, Friend L, Alman B, et al. The effect of surgical delay on acute infection following 554 open fractures in children. . *J Bone Jt Surgery-american Volume*. 2005;87(1):8-12. doi:10.2106/00004623-200501000-00003.
12. Luhmann SJ, Schootman M, Schoenecker PL, Dobbs MB, Gordon EJ. Complications and Outcomes of Open Pediatric Forearm Fractures. *J Pediatr Orthoped*. 2004;24(1):1. doi:10.1097/01241398-200401000-00001.
13. Werner CM, Pierpont Y, Pollak AN. The urgency of surgical débridement in the management of open fractures. *J Am Acad Orthop Surg*. 2008;16(7):369-375. doi:10.5435/00124635-200807000-00002
14. Dellinger PE, Caplan ES, Weaver LD, et al. Duration of Preventive Antibiotic Administration for Open Extremity Fractures. *Arch Surg-chicago*. 1988;123(3):333-339. doi:10.1001/archsurg.1988.01400270067010
15. Dellinger PE, Miller SD, Wertz MJ, Grypma M, Droppert B, Anderson PA. Risk of Infection After Open Fracture of the Arm or Leg. *Arch Surg-chicago*. 1988;123(11):1320-1327. doi:10.1001/archsurg.1988.01400350034004