Current Trends in the Management of Ballistic Fractures of the Hand and Wrist: Experiences of a High-Volume Level I Trauma Center

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Paul A. Ghareeb¹, Charles Daly¹, Albert Liao¹, and Diane Payne¹

Abstract

Background: Ballistic fractures of the carpus and hand are routinely treated in large urban centers. These injuries can be challenging due to many factors. Various treatment options exist for these complicated injuries, but there are limited data available. This report analyzes patient demographics, treatments, and outcomes at a large urban trauma center. **Methods:** All ballistic fractures of the hand and wrist of the patients who presented to a single center from 2011 to 2014 were retrospectively reviewed. Patient demographics, injury mechanism, treatment modalities, and outcomes were analyzed. **Results:** Seventy-seven patients were identified; 70 were male, and 7 were female. Average age of the patients was 29.6 years. Seventy-five injuries were low velocity, whereas 2 were high velocity. Sixty-seven patients had fractures of a metacarpal or phalanx, whereas 4 had isolated carpal injuries. Six had combined carpal and metacarpal or phalanx fractures. Thirty-six patients had concomitant tendon, nerve, or vascular injuries requiring repair. Sixty-three patients underwent operative intervention, with the most common intervention being percutaneous fixation. Sixteen patients required secondary surgery. Eighteen complications were reported. **Conclusions:** The majority of patients in this report underwent early operative intervention with percutaneous fixation. Antibiotics were administered in almost all cases and can usually be discontinued within 24 hours after surgery. It is important to consider concomitant nerve, vascular, or tendon injuries requiring repair. We recommend early treatment of these injuries with debridement and stabilization. Due to lack of follow-up and patient noncompliance, early definitive treatment with primary bone grafting should be considered.

Keywords: ballistic, fracture, hand, wrist, gunshot wound

Introduction

Ballistic fractures of the hand and wrist are commonly treated at large urban medical centers and in military settings. The high density of intricate tissues within the hand and wrist leads to complex and often debilitating injuries. Most of these cases necessitate surgical intervention, but the best method of reconstruction is currently unknown. The surgeon must take into account multiple variables when deciding the best course of action, including the energy level of the weapon, the type of tissues that are damaged, and the location of the injury.

There have been previous reports of treating these injuries with closed reduction and percutaneous pinning, open reduction and internal fixation, intramedullary fixation, and external fixation.^{1,3,5-7,12,13,17,18} Furthermore, primary or secondary bone grafting has become an important adjunct in these fractures due to the common finding of bone loss.^{4,9,14,15}

In the past, these injuries were frequently treated with multiple operative debridements, intravenous antibiotics,

and close monitoring prior to fixation to ensure the viability of the soft tissue envelope.¹³ However, there has been a recent shift toward early definitive fixation, minimizing the usage of antibiotics, and early bone grafting.^{1-4,6,7,9,12-15,17,18} Finally, successful recovery from complex ballistic fractures requires an early and regimented therapy program, which is often difficult to obtain in this population.

There are limited reports available regarding the treatment of ballistic fractures in large civilian trauma centers. The purpose of this report was to examine this patient population to determine the effectiveness of our current treatment modalities, and to identify whether differences exist between different surgical strategies.

¹Emory University, Atlanta, GA, USA

Corresponding Author:

Paul A. Ghareeb, 737 Brookridge Drive, Atlanta, GA 30306, USA.
Email: pgharee@emory.edu

Methods

After institutional review board approval, a retrospective review of a prospectively collected trauma registry was performed to identify all patients who presented with a ballistic fracture to the hand or wrist at a single large urban level I trauma center from 2011 to 2014. Wounds were managed using the following algorithm. All patients arriving with a ballistic fracture were evaluated by the hand surgical team after the primary trauma survey. All wounds were irrigated and debrided at the bedside, and a dose of intravenous antibiotics (either first-generation cephalosporin or clindamycin if an allergy existed) was administered. Tuft fractures of the distal phalanx or stable fractures were treated nonoperatively with splinting. All other fractures were treated operatively, typically within the first 48 hours. Unstable or displaced fractures were reduced by either the closed or open method; internal/external fixation was applied for severe bony defects. Bone grafting was considered for bony gaps and for malunion/nonunion. If fractures resulted in irreparable tissue and vascular injury, then amputation was completed.

Demographic data were collected, and treatment types and outcomes were analyzed. Length of time in the emergency department, administration of antibiotics, and operative intervention choice and timing were recorded. Velocity data were documented by history and injury pattern. All patients were given follow-up appointments on discharge. Follow-up information was gained if patients returned to the clinic.

Results

Seventy-seven patients were identified who presented to our level I trauma center with a ballistic fracture to the hand or wrist over the 4-year study period. Demographic data are demonstrated in Table 1. The average injury severity score (ISS) was 7.82 in our population. Thirty-two patients had fractures of a single metacarpal or phalanx, 35 had fractures of multiple metacarpals or phalanges, and 4 had isolated carpal injuries. Six had combined carpal and metacarpal or phalanx fractures. Thirty-three patients had other associated injuries. Sixty-three patients (81.8%) underwent early operative intervention. Thirty-six (46.8%) patients were found to have concomitant tendon, nerve, or vascular injuries requiring operative repair.

The most common treatment was placement of Kirschner wires (K wires), followed by splinting, external fixation, plating, and a combination of the techniques (Table 2). Sixteen patients (20.8%) required secondary surgical intervention, which included 9 secondary bone grafting procedures, 1 delayed amputation, 2 additional hardware placements, 2 washouts, a planned external fixator removal, and a skin graft for wound closure. Eighteen (23.4%) complications were reported (Table 3).

Table 1. Patient Demographics and Injury Mechanism.

Total patients	77
Male	70
Female	7
Average age (years)	29.6
Left hand	45
Right hand	29
Bilateral	3
Race	
African American	66
Caucasian	6
Hispanic	3
Other	2
Injury mechanism	
Assault	46
Self-inflicted	18
Unknown	12

Table 2. Methods of Operative Fracture Fixation.

Fixation type	Kirschner wires	Splinting	External fixation	Plating	Combined
Number of patients (%)	32 (41.2)	16 (20.8)	15 (19.5)	2 (2.6)	12 (15.6)

Table 3. Complication Rates.

Total number of complications (%)	18 (23.4)
Wound healing	9 (11.6)
Nonunion	4 (5.2)
Pin dislodgement	2 (2.6)
External fixator removal	2 (2.6)
Osteomyelitis	1 (1.3)

The average length of stay for all patients was 8.67 days, whereas the average stay for isolated hand and upper extremity injuries was 4.86 days. Follow-up data were available for 66 patients (85.7%). The average length of follow-up for these patients was 111.18 days. The average number of follow-up appointments was 2.64. Only 13 (16.9%) patients were followed long enough to document bony union. The rest were lost to follow-up prior to this period. At the last follow-up visit, 37 (48.1%) patients were found to have some range of motion deficit and 21 (27.3%) were found to have a full range of motion, and in 19 (24.7%) cases, this information was unknown.

Antibiotics were administered in all except 3 cases. Intravenous antibiotics were initially administered in the emergency department in 51 cases, in the operating room in 15 cases, on the ward in 7 cases, and at an outside facility in 1 case. Antibiotics were discontinued within 24 hours in 56 cases and were continued for an extended period of time in 21 cases.

Figure 1. Radiograph demonstrating comminuted intra-articular fractures of the thumb proximal and distal phalanges and a comminuted fracture of the small finger middle phalanx. The patient underwent early operative intervention with fusion of the thumb interphalangeal joint and external fixator placement to the small finger.

Figure 2. Postoperative radiograph.

Discussion

Ballistic fractures pose a challenge to the hand surgeon. Many factors must be considered, including injury mechanism, involvement of surrounding structures, and patient compliance. Our center treats a high volume of these injuries, as demonstrated by the sample size obtained over a 4-year period. In assessing ballistic fractures, one must identify the type of fracture, degree of comminution and bone loss, joint involvement, and the viability of the soft tissue envelope. Figures 1 and 2 demonstrate a common patient presentation and examination, as well as a combination of treatment strategies including K wire fixation and external fixator placement.

In all, 81.8% of patients in this series underwent early operative intervention with limited irrigation and

debridement. The most common method of stabilization was K wire fixation (41.2%). The benefits of K wire fixation include technical ease and speed, and when performed in a closed fashion, one can avoid exposing and devascularizing bone fragments in a comminuted fracture. It is useful in cases where there is a high degree of comminution and bone loss. Length can be preserved, and it may serve as a bridge to secondary bone grafting. The second most common treatment included conservative management with debridement and splinting, followed by external fixation. Two external fixator devices were removed by the patients prior to union, which likely compromised their overall outcome. Kiehn et al concluded in their report that early internal fixation may have an advantage over external fixation in certain situations.⁶ Counseling must be performed to ensure patient compliance, and we agree that an alternative

technique should be considered in patients who are at risk for poor compliance. In all, 18.2% of patients underwent conservative management with irrigation and debridement with splinting in the emergency department. This was most commonly chosen for distal phalanx tuft fractures, stable nondisplaced fractures, or in patients who were too unstable to proceed to the operating room due to other injuries.

In all, 11.7% of patients underwent secondary bone grafting. Bony loss after ballistic fracture is common, and bone grafting with autograft or allograft materials is typically utilized in these cases. Primary bone grafting has been described by several authors.^{4,9,14,15} Nguyen and Wollstein reported 12 cases where primary grafting with allomatrix was utilized to achieve union. This was a mixture of demineralized bone matrix and a calcium sulfate carrier, and has osteoinductive and osteoconductive properties.⁹ They concluded that primary bone grafting was a useful option in patients with low contamination and in noncompliant patients. Although primary grafting was not employed in our series, based upon our follow-up rate, we recommend that it should be strongly considered in cases of segmental bone loss and minimal contamination due to the risk of poor follow-up and inability to perform secondary procedures.

In all, 46.8% of patients were found to have concomitant nerve, tendon, or vascular injuries. Injuries associated with ballistic fractures have been underreported in the literature, with only a handful of reviews discussing this. Pereira et al found a similar rate of 48.4% in their review of 62 cases, whereas Stromberg found an incidence of 29.2% in the population studied.^{12,17} The surgeon should attempt to diagnose these conditions preoperatively, but this is often challenging due to pain and distracting injuries to other areas which may interfere the exam. Exploration should occur in cases where there is a clinical suspicion.

Although the rate of infectious complications after low-velocity ballistic fractures may be low, early antibiotic therapy is standard for the treatment of these injuries.^{10,11} In a meta-analysis of ballistic fractures performed by Papasoulis and colleagues, they found a trend toward lower infection rates in patients being treated nonoperatively who were administered a short course of antibiotics (1.7% with antibiotics vs 5.1% without).¹⁰ All patients undergoing operative intervention received antibiotics. They found no benefit to providing gram-negative coverage or in treating for extended periods of time. Furthermore, they determined that oral antibiotics were equivalent to intravenous therapy in this population. In a series of low-velocity injuries reported by Komurcu et al, the authors reported a minor infection rate of 10.5%.⁷

In all, 96.1% of patients received intravenous antibiotics in our series. The trend at our institution was to initiate antibiotics in the emergency department and to discontinue them within 24 hours. All patients received a first-generation

cephalosporin unless an allergy was present or if other injuries necessitated broader spectrum coverage. There were 9 reported cases of poor wound healing, and 1 case of osteomyelitis. Interestingly, the patients who received prolonged antibiotics had a higher rate of wound complications in this review. It is likely, however, that patients were continued on antibiotics due to the nature of the soft tissue envelope and clinical concern for infection.

Follow-up ranged widely between patients. Patients only participated in hand therapy twice on average, and the majority were quickly lost to follow-up. Follow-up with a physician was also found to be variable, with many patients being lost to follow-up. In a series of 72 patients, Kiehn and colleagues reported that 39% of patients were lost to follow-up after discharge from the hospital, whereas 85% were lost prior to documentation of fracture healing.⁶ In all, 26% of those patients had an external fixator in place when lost to follow-up, which supports avoiding this method of fixation if possible in high-risk patients.

The overall complication rate in our series was 23.4%, with most of those complications being related to wound healing. We found a 5.2% incidence of nonunion. However, the nonunion rates are likely higher than reported due to the lack of follow-up and appropriate imaging in this population. Only 16.9% of patients were followed long enough to demonstrate bony union, making it difficult to draw conclusions about treatment modalities and union rates. Similarly, functional outcome data that we gathered were limited. However, some range of motion deficit was found in the majority of cases. In a telephone survey of patients who were treated for ballistic fractures, Pereira et al found that 86% of patients reported good to moderate quality of life and function but that only 35% of patients ultimately returned to work.¹²

In conclusion, this study highlights the current management of ballistic hand and wrist fractures at a high-volume level I trauma center. Early limited debridement and operative stabilization, as well as limited antibiotic administration, was utilized, with results similar to previously published reports on these injuries. Furthermore, our analysis highlights several challenges that the reconstructive hand surgeon must face including patient access to care, compliance, and poor follow-up tendencies in this population. The negative impact of these factors is difficult to quantify. In particular, external fixation devices must be applied carefully in this population due to the risk of noncompliance. Hand rehabilitation, an essential part of regaining full upper limb function, is also difficult to achieve in these patients. Fortunately, current advances in reconstructive strategies may help to address the overall poor outcomes of these patients. Techniques such as extracellular matrices, dermal templates, and fat transfer may have an increasing role in tissue recovery, whereas new bone graft techniques are promising

developments in fracture treatment.^{8,16} Specifically, research on primary bone grafting and techniques to improve patient follow-up should be explored.

This study is limited by the retrospective nature of review, as well as the low overall rate of follow-up. However, our findings of low follow-up rates and poor outcomes when employing external fixation should play a significant role in the treatment algorithm of this patient population. This should include consideration of early definitive stabilization as well as primary bone grafting when applicable. Prospective trials comparing operative treatments are needed to further understand the optimal fixation strategy, and further research to improve patient compliance and access is warranted.

Ethical Approval

Institutional review board approval was obtained for this work (IRB # 00076024).

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study. Additional informed consent was obtained from all patients for whom identifying information is included in this article.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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