Acute Injury Patterns and Complications of Open Distal Radius Fractures: A Preliminary Report

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INTRODUCTION

High energy trauma in young patients and the low density bone in elderly patients contribute to the high frequency of distal radius fractures (DRFs)[1]. Open injuries are uncommon, and the incidence is unknown. To date, there is limited evidence characterizing open DRFs to guide surgeons with operative management. Based on our literature review, there are only two case series consisting of 10 and 18 patients that evaluated the clinical outcomes of open DRFs[2, 3]. Both studies suggest a high incidence of complication in open DRFs.

Associated fractures are important in orthopaedic injuries. Given the high energy mechanism, there is an increased risk of fracture elsewhere in the same upper extremity. Recognition may be difficult in a setting of an open wound, which can sometimes distract clinicians and patients. Repetitive patterns of associated fractures with open DRF can guide the initial trauma assessment, and mandatory radiographs may be necessary in avoiding unrecognized fractures.

The close proximity to neurovascular structures and high concentration of tendons constrained by the retinaculum may increase the incidence of lacerations to these structures. Acute soft tissue injuries in open DRFs are not well characterized. Multiple factors including swelling, pain, weakness and loss of consciousness can lead to unreliable exam. Incidence of injured structures around the distal radius may provide valuable information to surgeons for operative planning. This is particularly relevant in higher Gustilo and Anderson type fractures, which do not incorporate tendon lacerations into the classification scheme.

There are three main factors that require open fractures to undergo urgent surgery. These conditions include: gross contamination and the threat of infection, concurrent vascular or neurological compromise, and impending compartment syndrome. Currently, there is no literature evidence assessing complications in open DRF, and most clinicians adapt the practice published from open lower extremity fractures. However, the complications of DRFs differ from other long bone fractures in that they are generally thought to have a lower incidence of infection but more likely to have compressive neuropathy. There may be a predictive relationship between infection, acute carpal tunnel syndrome (ACTS) and compartment syndrome based on injury patterns. Understanding risks and incidences may eliminate unnecessary return to the OR and improve outcome. In certain cases, prophylactic operative interventions (*i.e.* acute carpal tunnel release) may be suggested. The purpose of this study is to characterize fracture patterns, associated injuries, and acute complications in a trauma setting to guide surgeons with the operative management of open DRFs and the treatment of its complications.

MATERIALS AND METHODS

This is a retrospective case-control study of 88 consecutive patients enrolled in the prospectively collected database of two level I trauma centers in Boston (Massachusetts General Hospital and Brigham and Women's Hospital) beginning in 2004 to 2009. With our database search engine, medical records of patients with open DRFs were retrieved, and electronic records were reviewed. Similarly, patients with closed DRFs were also obtained during the same time period.

All adult patients (>18 years old) with open and closed DRFs who underwent an index procedure at our two trauma centers served as the basis of this study. Patients with closed DRFs must have had operative fixation within 48 hours of ED admission to be included. Admitted patients for closed DRFs were thought to have sustained a polytrauma, or have more severe fracture pattern, higher likelihood of nonoperative treatment failure, and question of neurovascular compromise. Patients referred to outpatient clinics for definitive management after debridement or external fixation of open DRF from

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	CLOSED	OPEN			
DEMOGRAPHICS		I+II+III	I	II	III
# patients	30	60	20	28	12
Age	53	55	62	59	46
% male	43%	50%	45%	46%	67%
AO CLASSIFICATION					
A	-	0.20	0.23	0.18	0.17
B	-	0.21	0.20	0.18	0.33
C	-	0.59	0.57	0.64	0.50
MECHANISM					
Fall	0.82	0.52	0.80	0.46	0.17
MVC	0.09	0.22	0.15	0.18	0.42
MCC	0.09	0.17	0.05	0.29	0.08
GSW	0.00	0.03	0.00	0.04	0.08
Others	0.00	0.07	0.00	0.04	0.25

Table 1: Demographics and mechanism of injury of closed and open distal radius fractures.

	CLOSED	OPEN			
ASSOCIATED FRACTURES		I+II+III	I	II	III
Distal ulna (excluding styloid)	10.0%	18.3%	20.0%	21.4%	8.3%
Carpal (excluding scaphoid)	0.0	3.0	0.0	0.0	16.7
Scaphoid	0.0	5.0	0.0	3.6	16.7
Metacarpal	0.0	7.0	0.0	7.1	16.7
Phalangeal	0.0	5.0	0.0	3.6	16.7
Elbow	0.0	3.0	0.0	3.6	8.3
Others	0.0	12.0	0.0	7.1	8.3
SOFT TISSUE INJURIES					
Radial/ulnar arteries	0.0%	3.0%	0.0%	0.0%	16.7%
Nerves	0.0	3.0	0.0	3.6	8.3
Tendons	0.0	8.3	0.0	0.0	41.7
ACUTE COMPLICATIONS					
Carpal tunnel syndrome	7.0%	25.0%	10.0%	21.4%	58.3%
Compartment syndrome	0.0	1.6	0.0	0.0	8.3
Infection	0.0	3.3	5.0	0.0	0.0

Table 2: Associated injuries and acute complications of closed and open DRFs.

outside institutions are excluded. Other exclusion criteria included: a follow-up period of less than 30 days, and open fractures involving only the distal ulna. In addition, patients with gun-shot wound and table saw injuries were excluded.

History and physical exam, imaging studies, and operative notes were reviewed to identify additional fractures. All fractures were documented but the emphasis was placed on the fractures of ipsilateral upper extremity. Fractures located elsewhere, such as lower extremity, spine, and contralateral upper extremity, were grouped under "polytrauma." Each anatomic equivalent was given the value of one associated injury, even if it involved multiple fractures. For example, three metacarpal fractures and one lunate fracture were considered to have 2 associated injuries. An exception was made to scaphoid fractures, which constituted a separate anatomical segment due to higher preference towards operative fixation than other carpal fractures. Associated fractures comprised of different anatomic segments include distal ulna (excluding styloid), carpal bones (excluding scaphoid), scaphoid, metacarpal bones, phalangeal bones, elbow (radial head, olecranon, distal humerus), shoulder (proximal humerus), and humeral shaft. The results were grouped based on closed and open fractures, and further divided based on open injury type.

Lacerations of the neurovascular structures and tendons were identified based on exam and operative report. Emphasis was placed on visible lacerations during the initial trauma exam or in the operating room. Multiple tendon lacerations in the region of distal radius fractures were grouped as one associated injury, and were divided into flexors and extensors.

The mechanism of injury was divided into: fall, motor vehicle collision (MVC), motorcycle collision (MCC), assault, direct blow, and sports-related. The bone injury patterns of open DRFs were characterized by AO/OTA fracture classification[4]. The classification of open fracture was based on Gustilo and Anderson[5] which was collected prospectively in our database. If any differences of open fracture classifications were noted during surgery, the operative report took precedence over the initial trauma assessment.

Acute complications of closed and open distal radius fractures were documented based on the necessity of surgical intervention or early return to the OR, defined as less than 30 days. The main complications of interest were infection, acute carpal tunnel syndrome, and compartment syndrome. Other complications such as nonunion, malunion, and post-traumatic arthritis were documented as well, but mainly constituted late sequelae of injury; therefore, these complications were not the primary focus of this study. The wound was considered infected when deep culture shows bacterial growth or when high clinical suspicion elicited operative debridement. Many open injuries required multiple operations with routine irrigation & debridement (I&D) as a part of the staged reconstructive procedure. In these circumstances, the wound was not considered infected. The time of arrival to the emergency department was determined by the documentation in the physician's note or the time of the blood draw, which was an initial part of the trauma assessment. Our operative log was reviewed for the time when patient entered into the operating room.

Carpal tunnel release was typically performed due to high clinical suspicion for ACTS or for prophylactic measure. Incidence of operative carpal tunnel release is compared between closed and open DRFs. Risk factors including Gustilo and Anderson type, AO fracture classification, associated fractures (*i.e.* carpal fractures), and tendon lacerations are analyzed to identify predictors for ACTS. Compartment syndromes defined as clinical suspicion requiring emergent fasciotomy. The incidence of compartment syndrome will be compared between open and closed DRFs.

RESULTS

Demographics and Mechanism of Injury. The average age among patients who sustained closed DRF was 53 years, and open DRF was 55 years. There was a trend towards younger patients with increasing Gustilo and Anderson grade (table I). The most common type of fracture pattern was AO type C (59%) with approximately equal distribution between type A (20%) and B (21%). Twenty patients with grade I, 28 patients with grade II and 12 patients with grade III will be presented here. Analysis of thirty patients with closed DRFs was completed for comparison. The vast majority of the DRFs were sustained by three mechanisms: fall, MVC, and MCC. Eighty-two percent of closed DRFs were the result of falls, but there was an increasing incidence of MVC and MCC with higher grade open DRFs (table 1).

Associated Injuries. The pattern of associated fractures of nearby bones and joints were different among open and closed DRFs. Ten percent of closed DRFs and 18% of open DRFs had concomitant distal ulnar fractures (excluding the styloid). As suspected, hand fractures and carpal fractures were rare in closed DRFs. Based on our preliminary result, none of the patients with closed DRFs were found to have any associated hand fractures. Interestingly, grade I open DRFs demonstrated similar trend, and all patients had isolated DRF (± distal ulnar fracture). There was higher incidence of associated fractures with grade II and III open DRFs. In grade II, 18% of patients had concomitant fractures in the carpal bones, small long bones, and more proximal fractures around the elbow. Approximately forty percent of patients with grade III fractures had similar findings (table 2).

There were no injuries involving the soft tissues in closed and grade I open DRFs. We identified median nerve laceration in one patient (out of 28) with grade II fracture. There was a sharp increase in tendon and neurovascular injuries in grade III fractures. Forty-two percent of patients sustained injuries to adjacent tendons, equally divided among extensors and flexors. Vascular injuries (17%) and nerve injuries (8%) were also identified.

Acute Complications. Acute complications that required additional procedures or unexpected return to the OR mainly include carpal tunnel syndrome, compartment syndrome, and infection. Among closed DRFs, 7.0% of patients required carpal tunnel release. No patients had infections or compartment syndromes. Grade I fractures had 10% incidence of

	CLOSED	OPEN			
TIMING		I+II+III	I	II	III
ED → OR (hrs)	17.8	10.0	10.5	9.4	8.8
PROCEDURES					
I&D	0 / 30	84 / 60	24 / 20	37 / 28	23 / 12
Volar plate	30 / 30	55 / 60	19 / 20	26 / 28	10 / 12
External fixation	0 / 30	12 / 60	1 / 20	8 / 28	3 / 12
Other fracture fixation	0 / 30	9 / 60	2 / 20	4 / 28	3 / 12
Carpal Tunnel Release	2 / 30	16 / 60	4 / 20	6 / 28	6 / 12
Tendon repair	0 / 30	8 / 60	0 / 20	0 / 28	8 / 12
Graft closure	0 / 30	6 / 60	0 / 20	2 / 28	4 / 12
RETURN TO OR					
# OR within 30 days	1.0 (1-2)	1.6	1.5 (1-8)	1.4 (1-4)	2.1 (1-4)
# OR total	1.0 (1-3)	1.8	1.7 (1-8)	1.6 (1-4)	2.8 (1-5)
# procedures within 30 days	1.2 (1-3)	3.7	3.0 (1-17)	3.4 (1-9)	5.4 (1-10)
# procedures total	1.2 (1-3)	4.3	3.2 (1-17)	3.6 (1-9)	8.0 (1-14)
Range shown in parentheses.					

Table 3: Operative management, number of procedures and return to the OR of open distal radius fractures.

carpal tunnel syndrome requiring a release, and one patient (5.0%) required multiple I&D for a deep infection. There was increasing incidence of carpal tunnel syndrome with higher grade fractures. Twenty-one percent of patients with grade II factures and 50% of patients with grade III fractures required carpal tunnel release (table 2 and 3). Interestingly, the overall infection rate of all open DRFs remained relatively low at 3%, which was the result of one patient with a grade I fracture. No patients with grade II or III required unexpected return to the OR for I&D. The average number of surgeries needed for closed DRFs and grade I open DRFs were 1.0 and 1.5, respectively. This difference was main due to one patient with grade I DRF who required over eight I&Ds secondary to scheduling conflict with a microsurgeon for a flap closure. The average number of return to the OR required for grade II and III fractures were 1.4 (range 1-4) and 2.1 (range 1-4), respectively. Seventy-one percent of grade II and 41.6% of grade III patients received only one I&D during the index procedure without evidence of subsequent acute infection. The rest of the patients, 29% in grade II and 58.4% in grade III, returned to the OR multiple times (range 1-5) for planned, staged reconstructive procedures (*i.e.* tendon repair, soft tissue closure, conversion from external fixation to internal fixation) (table 3). The duration between the emergency department arrival to the OR was 17.8 hrs for closed DRFs, 10.4 hrs for grade I, 9.4 hrs for grade II, and 8.8 hrs for grade III open DRFs (table 3). Due to low incidences of infection in general, no risks were identified to increase infection rates.

DISCUSSION

Based on our preliminary result, grade I open DRFs were comparable to closed fractures in regards to associated injuries and acute complications. There was a sharp increase in the fractures of carpal bones and small long bones in grade II open fractures but not necessarily in the surrounding soft tissues. With grade III fractures, even higher incidences of adjacent fractures were noted and associated soft tissue injuries required multiple reconstructive procedures. Hand fractures were commonly observed with equal distribution of carpal fractures, scaphoid fractures, metacarpal fractures, and phalangeal fractures, each at 17%. The overall injury to the hand was approximately 14% in grade II and 25% in grade III open DRFs. Acute injuries to the nearby neurovascular structures and tendons remained relatively uncommon in both grade I and II fractures. A considerably higher incidence of vascular injuries (17%) and tendon lacerations (42%) were observed in grade III DRFs. Interestingly, acute compressive neuropathy was more prevalent, and it appears to influence operative management more so than compartment syndrome or infection. We found a distinct trend of increasing incidence of acute carpal tunnel syndrome with higher Gustilo and Anderson grade. Grade I had 10% of patients requiring surgical release, followed by 21.4% of grade II and 58.3% of grade III undergoing carpal tunnel release. Except for one patient in grade I fracture, no additional return to the OR was necessary specifically for irrigation of deep infection, regardless of the severity of open DRFs.

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