Treatment of a High-Velocity Ballistic Humerus Fracture With Circular External Fixation and Polyaxial Locking Struts: A Case Report

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Summary: Ballistic fractures of the extremities pose many challenges for orthopaedic surgeons because they can be associated with soft-tissue and neurovascular injuries. Fractures of the humerus comprise approximately 25% of ballistic upper extremity injuries. The fracture pattern tends to be diaphyseal, multifragmentary, and have a large zone of injury. This is a case of a 22-year-old man with a diaphyseal, multifragmentary, ballistic humeral shaft fracture with associated ballistic both bones forearm fracture, arm and forearm compartment syndrome, and antecubital fossa soft-tissue loss. The humerus fracture was treated in a closed manner with application of a circular external fixator and novel polyaxial locking struts. The patient demonstrated union of the fracture after 10 weeks of treatment, at which time, the frame was removed. On completion of treatment, the patient had full shoulder range of motion with a united and stable humerus.

Key Words: ballistic fracture, gunshot, external fixation, circular frame, polyaxial locking struts

INTRODUCTION

Ballistic humeral shaft fractures are difficult injuries to treat and are often associated with neurovascular injury to the extremity and concomitant ballistic injuries to the neck, chest, abdomen, and pelvis. Treatment options include nonoperative management, both open and minimally invasive plate osteosynthesis, intramedullary nailing, and external fixation, with no gold standard for management of these complex injuries. The associated neurovascular injury and soft-tissue loss associated with ballistic humeral shaft fractures creates a challenging scenario for the orthopaedic surgeon because stabilization of the fracture has to be considered with vascular procedures to the extremity, soft-tissue reconstruction procedures, and management of nonextremity ballistic injuries. This case report describes the treatment of a comminuted, high-velocity ballistic humeral shaft fracture with a circular external fixation and novel polyaxial locking struts.

PATIENT INFORMATION

The patient is a 22-year-old man who sustained multiple high-velocity gunshot wounds to the right upper extremity, chest, and abdomen. The patient sustained a comminuted humerus fracture which extended from the proximal metaphysis of the humeral head down to the supracondylar region with minimal bone stock proximally and distally. The patient also sustained a comminuted radius and ulna fracture (Fig. 1). In addition to the fractures, the patient had an associated 10 × 8-cm soft-tissue defect to the antecubital fossa and a high radial nerve palsy. The patient was brought urgently to the operating room for an emergency thoracotomy and laparotomy for hemodynamic instability. During this initial operation, there were concerns for compartment syndrome to the right upper extremity, and anterior fasciotomies of the brachium and forearm were performed. The fractures and soft-tissue defects were irrigated and debrided and placed into a posterior splint. Given the highly comminuted nature of the humerus fracture with very little...
intact bone stock proximally and distally, the ipsilateral both bone forearm fracture with floating elbow, in addition to the soft-tissue defect and fasciotomies, the decision was made to definitively treat the fracture with circular external fixation and polyaxial locking struts.

SURGICAL TECHNIQUE

The humerus fracture was definitively treated with circular external fixation 4 days after the initial presentation once the patient was hemodynamically stable, and the chest and abdomen had been closed. The patient was placed in the supine position on a radiolucent table and prepped and draped in the usual fashion. The soft-tissue envelope had improved substantially, and the anterior fasciotomies over the brachium and forearm were closed. The proximal humeral fracture fragment was stabilized with three 4-mm Schantz pins placed in a multiplanar orientation. A 150-mm 5/8 circular external fixation ring was fixated to the 4-mm Schantz pins. A 150-mm full ring was placed around the supracondylar region of the distal humerus fracture and was fixated with 2 transcondylar 1.8-mm wires and a 4 mm Schantz pin (Fig. 2). The wires were tensioned to 100 Kg and were used to stabilize the distal fragment. The rings were then connected with 3 polyaxial locking struts (Fig. 3). The polyaxial locking struts were installed loosely to each circular ring in an unlocked to permit closed manipulation of the fracture. Using intraoperative fluoroscopy, the fracture was reduced in a closed manner by directly manipulating the rings to re-establish appropriate length, alignment, and rotation. The polyaxial struts were then locked into position once the fracture was reduced, and the humeral shaft fracture was rigidly stabilized by completely tightening nuts on either end of the strut to the circular frame.

POSTOPERATIVE COURSE

The patient was limited to 5 lb of weightbearing through the right upper extremity and began immediate active and passive range of motion exercises of the shoulder, elbow, hand, and wrist. Pin site care was performed as needed. At 8 weeks postoperatively, radiographs and computed tomography scan demonstrated healing along the entire length of the humerus. The frame was removed at 10 weeks postoperative. At 20 weeks postoperative, the patient demonstrated 0–90 degrees of elbow flexion, 170 degrees of shoulder abduction and forward elevation, 50 degrees external rotation and internal rotation to the lumbar spine (Fig. 4), and complete union of the fracture (Fig. 5). The patient’s elbow flexion was limited by the anterior soft-tissue injury. The patient had a persistent radial nerve palsy secondary to the ballistic injury.

DISCUSSION

Ballistic humeral shaft fractures are difficult to manage when compared with nonpenetrating humerus fractures because of the wide zone of injury, associated neurovascular damage, and soft-tissue loss. There is minimal published data on ballistic humerus fractures to guide treatment. Treatment with plate osteosynthesis, intramedullary nailing, external fixation, and nonoperative management with splinting have all been demonstrated to be viable options with many cases successfully treated nonoperatively.2 In this specific case, circular external fixation was chosen as the treatment method of choice because of the minimal intact bone stock, wide zone of injury ipsilateral forearm fracture and floating elbow, compartment syndrome requiring fasciotomy, and antecubital soft-tissue loss necessitating soft-tissue reconstruction.

A recent review of upper extremity ballistic fractures found that ballistic humerus fractures are often multifragmentary with a long fracture length.1 This creates technical challenges in stabilizing the humerus because extensile approaches with plate fixation require a large surgical exposure with soft-tissue disruption to gain adequate fixation across the fracture. Several treatment methods have been

FIGURE 1. Multilevel ballistic upper extremity fractures in a 22-year-old patient. Plain radiograph of a high-velocity humeral shaft fracture performed status postfasciotomy for compartment syndrome (A). Computed tomography reconstruction of the humerus fracture demonstrating a multifragment pattern extending from the proximal metaphysis to the supracondylar region of the elbow with an unacceptable alignment (B). Ipsilateral comminuted ballistic both bone forearm fracture (C).

FIGURE 2. Intraoperative radiographs of a ballistic humerus fracture demonstrating the 3 pin, multiplanar configuration of the fixation in the proximal fragment (A) and the 1.8-mm wire and Schantz pin fixation in the supracondylar elbow region in the distal fragment (B).
Finally, external fixation of the pins could not be achieved due to minimal bone stock and the need for pin placement into the subchondral bone of the humeral articular surface.

FIGURE 3. Intraoperative clinical photographs of the final circular frame construct stabilized with polyaxial locking struts. These intraoperative photographs demonstrate the final configuration of the circular frame from both the lateral (A) and anterior (B) aspects of the upper extremity.

The reduction and stabilization of this humerus fracture was aided by the use of novel polyaxial locking struts. Before the development of these struts, circular frames were constructed using threaded rods or through a hexapod configuration of nonlocking polyaxial struts. Although both static frames and hexapod frames are highly effective in treating challenging fractures, polyaxial locking struts offer several advantages. Fracture reduction with static frames can be challenging and either requires applying the frame to a fracture that has been reduced by some other means or using complex techniques with olive wires to reduce the fracture. Using polyaxial locking struts, the frame can be applied to an unreduced fracture and then manipulated using closed, open, or a combination of reduction maneuvers and immediately locked into place once acceptable length, alignment, and rotation has been re-established. The struts are quickly and easily locked by tightening the nuts on either end of the strut and engaging the locking collar (Fig. 6). The polyaxial struts are equipped with polyaxial locking hinges on either end that offer 45 degrees of angulation with the circular ring in any direction. This wide arc of angulation permits a substantial amount of manipulation of fractures in space. In addition, unlike a hexapod frame which relies on 6 struts for stability, the polyaxial locking struts become a fixed angle construct when locked into place that reduces the number of struts required to stabilize a frame from 6 struts to 3. The polyaxial locking struts do not need to be placed in a specific orientation such as a hexapod frame but can be placed in any orientation around the rings. The ability to create a stable circular frame with less polyaxial struts results in reduced frame cost, shorter operative times, and less clutter on the circular rings for ease of placing fixation into the extremity.

FIGURE 4. Clinical photographs of elbow and shoulder range of motion 10 weeks after the completion of treatment of a ballistic humeral shaft fracture treated with circular external fixation and polyaxial locking struts. The patient demonstrates full elbow extension (A) and 90 degrees of elbow flexion (B). The patient demonstrates 170 degrees of forward elevation of the shoulder (C) and internal rotation to the lower lumbar spine (D) which is comparable with the contralateral uninjured shoulder.
Finally, the circular external fixator stabilized the fracture with minimal additional soft-tissue disruption and permitted unfettered access to the arm because the patient required multiple soft-tissue procedures to reconstruct the antecubital fossa wound. The frame was also rigid enough to permit immediate range of motion of both the elbow and shoulder with joint motion comparable with the contralateral uninjured shoulder (Fig. 4). Complications associated with circular external fixation include pin site infections, osteitis, malunion, and joint contractures. The circular external fixator requires ongoing pin site care because these devices are often applied for weeks to months. These complications are well-documented in the treatment of lower extremity fractures and can approach 30%; however, the rate in upper extremity fractures is not currently known due to a paucity of literature.

CONCLUSIONS

This case report describes successful treatment of a highly comminuted ballistic fracture spanning the entire diaphysis of the humerus using circular external fixation and locking polyaxial struts. Treatment should be individualized based on the fracture pattern, associated neurovascular injury, associated injuries, and soft-tissue status of the upper extremity. Whichever treatment method is used, close follow-up of these patients is necessary because ballistic fractures in the upper extremity can lead to malunion, pseudarthrosis, stiffness, and significant functional limitation.

REFERENCES


FIGURE 5. Final anteroposterior (A) and lateral (B) radiographs of a ballistic humeral shaft fracture treated with circular external fixation and polyaxial locking struts.

FIGURE 6. Novel polyaxial locking strut. The polyaxial hinges with a 45-degree motion arc are demonstrated by the asterisks. These hinges become locked into a position when the strut is tightened to the circular ring with a nut. The quick adjustment locking collar that sets the length of the strut is indicated by the arrow.