Peripheral Nerve Injuries Following Gunshot Fracture of the Humerus

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Abstract

Current best evidence supports observation for peripheral nerve palsies following a fracture of the humerus unless associated with an open fracture. However, the indications for nerve exploration with humerus gunshot fractures are unclear.

All patients aged 18 to 89 years who were treated for a gunshot fracture of the humerus at an academic trauma center between 2004 and 2008 were retrospectively reviewed. Patient demographics, fracture characteristics, fracture healing, nerve injury, and intraoperative findings were examined. Twelve patients were identified, of which 6 had nerve palsies at presentation. Three patients had an isolated single nerve palsy, and all recovered spontaneously within 90 days with observation. The other 3 patients had a concomitant brachial artery laceration, and all required a secondary nerve procedure, including 1 primary nerve repair for a near complete transection and 2 re-explorations with neurolysis due to lack of spontaneous recovery by 90 days. Nerve palsies are common after gunshot fractures of the humerus, but nerve transections are uncommon. We observed 1 nerve transection in 12 cases. However, in all 3 cases with a brachial artery injury, a nerve injury required surgical intervention. Subsequently, we recommend continued observation of isolated nerve palsies associated with gunshot fractures of the humerus. However, consider early nerve exploration of palsies when associated with a concomitant vascular injury.

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This study was performed at Temple University Hospital, Philadelphia, Pennsylvania.

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Figure: Diagram of the initial treatment algorithm for gunshot fractures of the humerus. Abbreviations: ExFix, external fixation; IMN, intramedullary nailing; ORIF, open reduction and internal fixation.
Peripheral nerve injury is a well-known complication of fractures of the humerus, occurring in 1% to 18% of cases. Although the majority of reported nerve injuries involve the radial nerve, deficit may occur in the ulnar nerve and median nerves as well. Arguably, the standard of care for the management of peripheral nerve injury following humerus fractures is observation; several studies have shown spontaneous recovery of nerve function with nonoperative treatment. In open fractures of the humerus, primary exploration of radial nerve palsies may be indicated. However, the management of nerve injury following penetrating injuries remains unclear.

Gunshot injuries create intrinsically different fracture patterns than do other mechanisms of injury. Although not an indication for surgery in and of themselves, gunshot fractures are high-energy injuries that may cause substantial comminution and soft tissue injury necessitating surgical repair. Peripheral nerve palsies, including radial, median, and ulnar nerves, commonly occur with gunshot fractures of the humeral shaft. In many cases, these palsies are transient, neuropraxic conditions warranting observation without intervention. However, in some cases, failure to explore and repair a lacerated or incarcerated nerve in a timely manner can result in compromised outcomes. Subsequently, some report that all humerus gunshot fractures undergoing surgical stabilization should have concomitant nerve exploration when a preoperative palsy is present. However, early exploration is not without risks; iatrogenic injury to peripheral nerves occurs in 4.2% to 20% of patients. A higher rate of false negative findings also exists in early exploration.

The current study investigated (1) whether peripheral nerve palsies in the setting of gunshot fractures of the humerus were indications for nerve exploration and (2) if nerve palsies associated with gunshot fractures were the result of contusions or transections.

**Materials and Methods**

After appropriate Institutional Review Board approval was obtained, a retrospective review was performed on all patients aged 18 years and older who presented to our institution with a gunshot fracture of the humerus between July 1, 2007, and June 30, 2010. Inclusion criteria for this study were a gunshot fracture of the humerus treated operatively. Exclusion criteria were articular fractures (ie, intra-articular distal humerus or proximal humerus) and a medical history of peripheral nerve damage. A total of 12 patients met the inclusion criteria. Demographics, fracture characteristics, initial neurovascular status, treatment, intraoperative findings, and outcomes at last follow-up were examined.

Surgical management included intramedullary nailing, open reduction and internal fixation (ORIF) with plate and screw fixation, and external fixation. A simple algorithm had been used to determine the type of fixation (Figure 1): If any nerve injury existed, ORIF with nerve exploration or external fixation with delayed nerve exploration was performed. If no preoperative nerve deficit existed, the fixation type was the surgeon’s choice and also included intramedullary nailing. Late complications and secondary procedures were also recorded. At final follow-up, patients were examined for motor function of the radial, median, and ulnar nerves and graded on a scale of 0 to 5:

- 0/5: No muscle contraction
- 1/5: Muscle flickers, but no movement
- 2/5: Movement possible, but not against gravity
- 3/5: Movement possible against gravity, but not against resistance
- 4/5: Movement possible, including against some resistance
- 5/5: Normal strength

**Results**

Among the 12 patients meeting the inclusion criteria, 10 were men and 2 were women. Average age was 25.5 years (range, 18-42 years) (Table). The fractures were classified using the AO classification system and included 9 C3 fractures, 2 C1 fractures, and 1 A2 fracture. Seven patients underwent ORIF; 3 patients underwent intramedullary nailing, and 2 patients underwent external fixation with delayed ORIF.

On initial evaluation, 6 patients had a motor and sensory palsy of ≥1 nerve; 2 patients had an isolated radial nerve palsy, 2 patients had an isolated ulnar nerve palsy, and 2 patients had a combined radial and ulnar palsy or a radial and median nerve palsy. Among the 6 patients with a nerve palsy, 3 had a concomitant brachial artery laceration requiring emergent repair. This subset of concomitant vascular injury included patients with a combined nerve palsy and a lacerated ulnar nerve.

Both patients with an isolated radial nerve deficit underwent ORIF with nerve exploration, which demonstrated a nerve in continuity. Both patients ultimately experienced a nerve recovery of at least 4/5 within 90 days of injury.

The first patient with an ulnar nerve palsy without vascular injury underwent ORIF with nerve exploration, ultimately recovering complete nerve recovery of 5/5 within 90 days of injury. The second patient with an ulnar nerve palsy had an associated vascular injury requiring emergent intervention.

![Figure 1: Diagram of the initial treatment algorithm for gunshot fractures of the humerus.](image)
brachial artery repair initially temporized with external fixation. At the time of exploration, approximately 80% of the ulnar nerve was found to be lacerated at the level of the fracture (Figure 2). The nerve underwent primary repair; however, the patient was ultimately lost to follow-up.

Both patients with a combined neurological deficit also had a brachial artery injury requiring emergent repair. The patient with a combined radial and median nerve deficit received ORIF and nerve exploration, which revealed extensively contused but otherwise intact nerves. Ultimately, due to no evidence of nerve recovery by examination to either nerve by 90 days and electrodiagnostic studies that identified a conduction block and distal denervation, the patient was re-explored, revealing extensive scarring and a neuroma-in-continuity. The patient who presented with a combined radial and ulnar nerve deficit underwent external fixation with delayed wound exploration. Similar to the other combined palsy case, extensive radial and ulnar nerve contusion were initially noted. Following 90 days of observation without nerve recovery by examination or electrodiagnostic study, the patient was re-explored with identification of a neuroma-in-continuity for both nerves.

The remaining 6 patients underwent ORIF or intramedullary nailing. All patients had an intact neurovascular examination preoperatively without iatrogenic palsies postoperatively. The patient with preoperative ulnar nerve weakness went on to a full recovery of ulnar nerve strength.

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### Table

<table>
<thead>
<tr>
<th>Patient No./ Sex/Age, y</th>
<th>AO/OTA Class</th>
<th>Initial Neurovascular Exam</th>
<th>Fixation</th>
<th>Treatment of Nerve (Findings)</th>
<th>Follow-up, d</th>
<th>Nerve Exam by 90 d</th>
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</thead>
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<tr>
<td>1/M/19</td>
<td>C1</td>
<td>Intact</td>
<td>IMN</td>
<td>Not explored</td>
<td>77</td>
<td>Intact/unchanged</td>
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<td>2/M/23</td>
<td>C3</td>
<td>Radial palsy</td>
<td>ORIF</td>
<td>Explored (intact)</td>
<td>90</td>
<td>4/5</td>
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<td>3/M/24</td>
<td>C1</td>
<td>Radial palsy</td>
<td>ORIF</td>
<td>Explored (intact)</td>
<td>164</td>
<td>4/5</td>
</tr>
<tr>
<td>4/M/18</td>
<td>C3</td>
<td>Radial &amp; ulnar palsy</td>
<td>ExFix</td>
<td>Explored (contused)</td>
<td>108</td>
<td>0/5, radial &amp; ulnar (underwent delayed neurolysis)</td>
</tr>
<tr>
<td>5/M/25</td>
<td>C3</td>
<td>Radial &amp; median palsy</td>
<td>ORIF</td>
<td>Explored (contused)</td>
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<td>0/5, radial &amp; median (underwent delayed neurolysis)</td>
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<td>Intact</td>
<td>IMN</td>
<td>Not explored</td>
<td>80</td>
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</tr>
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<td>Intact</td>
<td>ORIF</td>
<td>Explored (intact)</td>
<td>109</td>
<td>Intact/unchanged</td>
</tr>
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<td>8/M/22</td>
<td>C3</td>
<td>Intact</td>
<td>IM rod</td>
<td>Not explored</td>
<td>Lost</td>
<td>Intact/unchanged</td>
</tr>
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<td>C3</td>
<td>Ulnar palsy</td>
<td>ORIF</td>
<td>Explored (intact)</td>
<td>159</td>
<td>5/5</td>
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<tr>
<td>10/M/31</td>
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<td>Ulnar palsy</td>
<td>ExFix</td>
<td>Explored (lacerated)</td>
<td>NA</td>
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<td>ORIF</td>
<td>Explored (intact)</td>
<td>941</td>
<td>Intact/unchanged</td>
</tr>
</tbody>
</table>

**Abbreviations:** AO, Arbeitsgemeinschaft für Osteosynthesefragen; Exam, examination; ExFix, external fixation; IM, intramedullary; IMN, intramedullary nailing; NA, not available; Neuro, neurovascular; ORIF, open reduction and internal fixation; OTA, Orthopaedic Trauma Association.

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**Figure 2:** Diagram of the revised treatment algorithm for gunshot fractures of the humerus. Abbreviations: ExFix, external fixation; IMN, intramedullary fixation; ORIF, open reduction and internal fixation.
**Discussion**

Common indications for surgical treatment of humeral shaft fractures include open fractures; polytrauma; bilateral fractures; segmental fractures; ipsilateral fracture of both bones of the forearm (ie, a floating elbow); extensive local associated injury involving the joint, brachial plexus, muscle, or tendon; lower-extremity injury; pathologic fracture; body habitus that distracts the fracture site; and those that have failed closed treatment. However, few reports in the literature pertain specifically to gunshot fractures of the humerus. Gunshot fractures are, by definition, open fractures, yet the current treatment for most gunshot fractures is local wound debridement and closed fracture management. The presence of peripheral nerve injuries should not change the treatment plan (ie, operative vs nonoperative) for these fractures because nerve deficits have been shown to resolve spontaneously, even in these situations. However, when surgical fixation is being planned, the nerve is often explored when deficit is present. Whether this is necessary is still open to debate.

The current study had several limitations. The patient sample size was small (12 patients). Also, the follow-up time was variable and limited. In our experience, studies focusing on gunshot patients are routinely plagued by poor follow-up due to patient circumstances. However, since we were focusing on initial findings of nerve injury, the lack of consistent follow-up should not compromise the ultimate findings and conclusions.

The reported incidence of nerve injury associated with humeral gunshot fractures is 0% to 58%, whereas vascular injury may occur in 0% to 15% of cases. In our population, 25% of gunshot fractures of the humerus were associated with a vascular insult, whereas 50% of fractures caused by gunshot had associated nerve palsy. Although our incidence of nerve injury is consistent with the literature, we report a higher rate of vascular injury than previously noted. One in 12 had a nerve laceration and 2 in 12 had a contusion of multiple nerves that would ultimately require re-exploration and neurolysis. All of the patients in our series who had neurologic deficit without vascular injury were found not to have a direct nerve injury and ultimately experienced spontaneous return of function. However, multiple nerve palsies and nerve lacerations were more common with concomitant vascular injuries. In cases of vascular insult, early nerve exploration should be considered (Figure 2). Isolated nerve palsies following gunshot fractures can continue to be treated with observation because they often resolve with time.

A bullet causes direct injury as it passes through tissue (causing crush injury) as well as indirect injury due to stretch of nearby tissues. A vacuum effect develops in the cavity created in the bullet’s wake that may pull debris and foreign material into the wound. Also, a shock wave may propagate in a cone shape, affecting surrounding tissue further. Nerves are relatively mobile, and the excursion allowed by this mobility likely prevents laceration as the missile passes by the nerve. Most cases of radial nerve dysfunction involve an intact nerve, and near complete recovery is expected. Our findings support this notion and are consistent with those found in the literature. If neurologic deficit is present, expectant management is acceptable. In contrast, all patients in our series with a vascular injury had a concomitant nerve injury requiring early or late intervention. One patient had transection of the ulnar nerve requiring repair. Two other patients had combined injuries of 2 nerves that did not recover by 90 days, ultimately requiring repeat exploration that identified extensive scarring and possible neuromas-in-continuity. As such, in the setting of a nerve injury at presentation with a concomitant vascular injury, early nerve exploration should be considered.

**References**