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Salvage of upper extremities with humeral fracture and associated brachial artery injury

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ABSTRACT

Background: Humeral fractures with brachial artery injury present a challenge for treating surgeons. Treatment practices vary, including use of vascular shunts, multispecialty teams versus an upper-extremity surgeon, and temporizing external fixation. Our objectives were to describe our treatment approach, to define "absolute ischaemia," to determine whether to use a vascular shunt, and to identify variables that could improve limb salvage rate.

Methods: We conducted a retrospective study of 38 patients with humeral fracture and brachial artery injury from 1999 through 2012 at a level I trauma centre. Demographic and treatment characteristics were compared between blunt and penetrating injuries and between treatment by multispecialty teams and treatment by an upper-extremity surgeon. We investigated other variables of interest, including immediate internal fixation, shunt use, time to brachial artery repair, and flap coverage. This study focused on immediate limb salvage and not on eventual functional outcomes of the limb or patient satisfaction regarding the extremity. The main outcome measure was salvage versus amputation.

Results: Thirty-six upper extremities were successfully salvaged, and two underwent eventual amputation. Immediate internal fixation (33 of 38 patients) did not have an adverse effect on the rate of successful limb salvage ($p > .05$). Shunt use and treatment by an upper-extremity surgeon were not associated with improved salvage rate ($p > .05$). The need for flap coverage was significantly associated with failed salvage of the extremity ($p = .02$).

Conclusions: Salvage of the upper extremity with humeral fracture and associated brachial artery injury is not dependent on time to brachial artery repair, shunt use, or specialty of treating surgeon. Immediate internal fixation can be performed without adversely affecting the potential for successful salvage. Flap coverage, which is an indicator of severity of soft-tissue injury, correlates with amputation in these severe injuries.

Type of study/level of evidence: Therapeutic III.

Introduction

Amputation or near amputation of the upper extremity requiring vascular repair for salvage presents a challenging situation for the patient and surgeon. Although brachial artery injuries infrequently result in amputation [1,2], the at-risk limb presenting with arterial injury is almost universally treated with expedient revascularization, and relative consensus exists regarding this approach [1–9]. Although many recent reports [1–10] of successful revascularization and limb salvage after brachial artery injury have been published, the techniques and outcomes for management of major upper-extremity trauma presenting with substantial combined bony and vascular injury have not been well studied. The purposes of this study were to show a viable option of immediate limb salvage using a treatment algorithm that consists of immediate internal fixation and determination of when emergent vascular shunting is necessary.

Variations in practice include the use of temporizing vascular shunts, multispecialty team treatment as opposed to single upper-extremity surgeon management of the injury, and external versus immediate internal fixation or even intramedullary nailing. An

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upper-extremity surgeon has an orthopaedic or plastic surgery background with added qualifications and training in the discipline of hand surgery. Immediate internal fixation has become the standard for treatment of open fractures in other anatomic locations, including the forearm and tibial and femoral shafts [11–13]. By contrast, many authors still advocate external fixation of open humeral fractures and for cases of arterial repair to protect the anastomosis [14–16].

We describe our approach to treating humeral fractures with associated brachial artery injury, including closed fractures, near amputations, and amputations. We also review our experience in an attempt to identify significant predictors of limb survival versus amputation. We hypothesized that we would be able to identify specific treatment variables that would be associated with a higher salvage rate, such as decreased time to revascularization by shunt use and management by an upper extremity surgeon with the ability to address all components of the injury (osteological, vascular, and neurological) at a single setting. Our secondary hypothesis was that immediate internal fixation would be safe and effective for limb salvage.

Patients and methods

Study design

We studied a retrospective cohort of patients presenting with humeral fracture and associated brachial artery injury. After obtaining Institutional Review Board approval, we searched the database at our level I trauma centre to identify all adult patients (older than 18 years) with this injury. The study time period extended from 1999 through 2012. To qualify for study inclusion, patients had to be followed at least to the clinical end point of limb viability (discharged with limb intact) or amputation. Patency of arterial repair was verified by palpation or Doppler ultrasonography of radial and ulnar arteries at follow-up. Advanced imaging studies were not conducted because the clinical end point of interest was limb viability.

After excluding patients with surgical neck fractures and elbow dislocations with arterial injury, we screened 48 patients who met the inclusion criteria. We then excluded transferred patients whose revascularization procedures were performed at outside institutions (three patients) because we were not able to obtain data on our covariates of interest in those cases. We also excluded six patients with complete amputations and one patient with a near amputation of limbs that were deemed unsalvageable at presentation.

We organized our injuries by blunt or penetrating injury mechanisms. Blunt injuries were defined as closed or open injuries resulting from of crush mechanisms, motor vehicle collisions, or motorcycle collisions. By definition, any open distal humeral fracture with a vascular injury is defined as a Gustilo type IIIC. A closed injury is the equivalent but without an overt clinical open wound. Because of soft-tissue injury secondary to degloving injuries, these injuries were thought to be equivalent. Penetrating injuries were defined as any type of gunshot wound that resulted in a fracture and vascular injury.

Data analysis

Our initial exploratory analysis consisted of the calculation of median and interquartile ranges for continuous variables and frequencies of categorical variables. A nonparametric K-sample test on the equality of medians was conducted to determine the significant differences in continuous variables [17]. Differences in categorical variables were tested for significance by conducting Fisher's exact tests. Our primary outcome variable was extremity survival versus amputation. However, considering the low number of amputations, we have reported the pertinent findings of the analysis and have organized the tables according to different variables of interest to provide more balanced comparison groups. Overall comparisons were made between blunt and penetrating injury mechanisms (Table 1) and between treatment by a multispecialty team and treatment by an upper-extremity surgeon (Table 2). The distribution of nerve injuries is reported in Table 3. Alpha for significance was set at 0.05, and all p values were two-tailed. Statistical analysis was conducted with the use of Stata 11.2 software (College Station, TX, USA).

Treatment algorithm

At out institution, humeral fractures with vascular injury generally are approached with a standard protocol. After initial management and stabilization of the traumatized patient by the general surgery team, the near-amputated or amputated limb is evaluated by a senior in-house orthopaedic surgery resident physician. Neurological and vascular statuses are documented. In cases of suspected arterial injury (diminished pulses, pallor, and unequal blood pressures), the on-call vascular or hand surgeon is called to urgently re-establish perfusion. Computed tomographic arteriography and conventional angiography are not routinely performed because we think they are unnecessary for establishing the diagnosis. Open fractures are treated with intravenously administered cefazolin antibiotic prophylaxis for infection, in addition to standard tetanus prophylaxis.

In situations in which some distal perfusion occurs through collateral vascular supply, as determined by clinical examination of the distal extremity and back-bleeding, the sequence of surgical management consists of thorough debridement of the open wound with simultaneous identification of critical neurovascular and tendinous structures through the open wound. A shunt is indicated when "absolute ischaemia" is present. Absolute ischaemia is defined as a limb status in which no collateral flow is present for any period of time. This condition can occur with the following: (1) an amputated part; (2) a crush mechanism with which collateral flow is unlikely; (3) an injury with which the soft-tissue injury is so severe (e.g., from a shotgun or high-velocity rifle) that no collateral flow is present via the typical superior or inferior ulnar collaterals or, more proximally, via the posterior circumflex or subscapular system.

In a case in which absolute ischaemia time has or will have existed for 6 h by the time of re-establishing arterial flow via reconstruction of the brachial artery system by whatever means necessary, a shunt is indicated and is inserted emergently, second only to identifying the critical nerves (median and ulnar) during the initial exposure. In some cases, absolute ischaemia does not exist despite disruption of the brachial artery. In those cases, absolute ischaemia does not occur despite disruption of the brachial artery. In cases in which the history, timing, and mechanism of injury leave doubt, we use the visualization of reverse arterial bleeding from the distal end of the transected brachial artery. In those cases, shunting is not indicated and the time permitted for irrigation and debridement and definitive fixation is longer.

Separate anterior or posterior approaches to the humerus can be used to facilitate fixation of proximal or distal fracture patterns, respectively, unless the traumatic wound can be incorporated into the preferred surgical approach. The humeral fracture is then stabilized with immediate internal fixation with 3.5- or 4.5-mm Arbeitsgemeinschaft für Osteosynthesefragen limited contact dynamic compression plate fixation in the majority of cases. Proximal and distal fracture patterns are fixed with precontoured locking plates. The humerus can be acutely shortened to achieve stable osteosynthesis.