

Current Concepts Review – Fractures of the Shaft of the Humerus

Souborný referát. Zlomeniny diafýzy humeru

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SUMMARY

Fractures of the shaft of the humerus are common injuries. Historically, the treatment of choice has been functional bracing. Recent technical advances such as angular stable plate and nail constructs lead to a shift in the treatment algorithm for this type of fracture. Surgical treatment is recommended in high grade open fractures, multilevel injury, polytrauma patients, nerve and serious vascular injuries, pathological fractures, and delayed or nonunions. This article aims to describe the published scientific data and current treatment modalities most suitable for each type of fracture.

EPIDEMIOLOGY

Fractures of the shaft of the humerus account for 1% to 3% of all fractures in adults (11). Large epidemiologic studies report a bimodal distribution with a minor peak in the third decade consisting mainly of men sustaining high-energy trauma and a second major peak in the eighth decade, mostly women with osteoporotic fractures resulting from simple falls (13, 31).

CLASSIFICATION

Fractures are often classified by their location: proximal third, midshaft and distal third. The widely used and accepted AO classification scheme classifies fractures by type and severity (22). Type A fractures are simple spiral, oblique and transverse fractures. Spiral, bending and fragmented wedge fractures are classified as B1, 2 and 3 and Type C fractures are complex fractures (Fig. 1).

CLINICAL ASSESSMENT AND RADIOGRAPHY

The clinical evaluation of a patient with a humeral shaft fracture should comprise complete physical examination and a detailed neurovascular examination. Conventional radiographs in two planes are the standard diagnostic procedure.

NONOPERATIVE TREATMENT

Nonoperative treatment remains the treatment of choice for most closed, isolated diaphyseal fractures of the humerus. However, spiral or oblique fractures that involve the mid- or proximal-third of the diaphysis seem more susceptible to nonunion when treated with functional bracing and surgery should be considered (26).

OPERATIVE TREATMENT

Good indications for surgical treatment are high grade open fractures (Gustilo type II and III), ipsilateral forearm fractures (floating elbow), nerve and serious vascular injuries, pathological fractures, and delayed or nonunions. Relative indications include bilateral injuries, segmental fractures, fractures with axial distraction, and multiple trauma. Several operative techniques have been advocated including external fixation, (locking) plate fixation, and antegrade and retrograde intramedullary devices.

Transverse to short oblique fractures

Nonoperative treatment remains the treatment of choice for most closed, isolated diaphyseal fractures of the humerus. Functional bracing such as the Sarmiento brace where the elbow and shoulder joints are not immobilised is associated with a low rate of nonunion and good functional results (15, 27, 28).

At the author's institution, the injured arm is immobilized in a sling or splint immediately after trauma. Once the soft tissue swelling subsides, after 10 to 14 days, the initial splint is exchanged for a functional brace. Bracing is continued until clinical and radiographic examination confirms adequate healing (Fig. 2).

Comminuted and/or segmental fractures of the humeral diaphysis

Comminuted and/or segmental fractures of the humeral diaphysis are the result of a higher energy force and commonly have associated soft tissue and neurovascular injuries. Along with appropriate wound care, these injuries are often amenable to intramedullary fixation especially in polytraumatized patients (Fig. 3). Advantages of intramedullary nailing include less soft tissue compromise, lower risk of iatrogenic radial nerve damage, shorter

procedure times and load-sharing mechanical properties (7, 8, 21). Antegrade nailing shows significantly more initial stability and higher bending and torsional stiffness for proximal fractures, whereas retrograde nailing is best suited for distal fractures (19) (Fig. 4).

Surgical approach

Antegrade nailing

The patient is placed in the beach chair position. The anterolateral approach is the most commonly used and is a continuation of the deltopectoral approach. The deltoid is split in line with its fibers to avoid injury to the axillary nerve.

Traditional approaches that involve incising the rotator cuff, may lead to shoulder pain or limited range of motion. An alternative approach through the rotator interval has been described by Park et al. (24).

Once inserted, nails should be countersunk below the articular surface of the humeral head to avoid subacromial impingement (10).

Retrograde nailing

The patient is positioned prone with the fractured arm in 90 degrees of abduction on a radiolucent side table. A longitudinal incision is made starting at the tip of the olecranon. The triceps tendon is split, exposing the dorsal surface of the humerus. The entry point is located 1.5 to 2 cm proximal to the olecranon fossa. Special care is taken to avoid damage to the elbow capsule. Reaming must be done carefully to avoid iatrogenic fracture at the entry point.

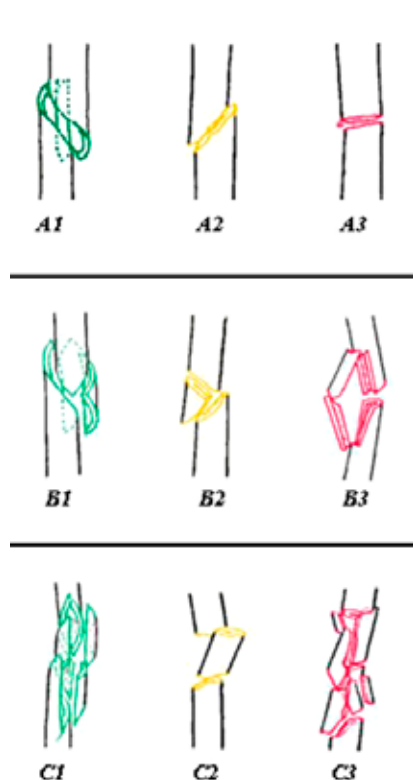


Fig. 1. AO Classification System.

Clinical results of intramedullary nailing

In a direct comparison of antegrade and retrograde insertion of an unreamed humeral nail, Blum et al. found a nonunion rate of 8.8% in the retrograde group. Fissures or fractures at the insertion site were noted in 5% of cases. The authors concluded that retrograde nailing is technically more demanding than antegrade nailing (3).

Lin et al., in a retrospective study of 161 humeral shaft fractures (98 acute fractures and 63 delayed unions or nonunions) treated with both retrograde and antegrade humeral locked nails reported an overall nonunion rate of 5.6%. There was no statistically significant difference between treatment types (20).

One retrospective study of 48 patients treated with antegrade nailing, reported a 96% union rate and 91% good or excellent results with respect to function (30).

Closed segmental fractures

Closed segmental fractures are ideal situations for less invasive plate fixation passed through small windows proximal and distal to the fracture (Fig. 5).

Advantages include the limited amount of dissection needed compared to conventional plating. Concerns regarding iatrogenic nerve palsy could be resolved in several clinical studies (1, 16, 34).

Oblique and spiral fractures

In displaced spiral and oblique fracture patterns, plate fixation has proven to be beneficial (Fig. 6). Advantages of open reduction and plate fixation include direct visualization, removal of interposed muscle, anatomic reduction and identification,

exploration, and protection of the radial nerve. Disadvantages of plate fixation are soft-tissue stripping and the risk for additional iatrogenic injury to the radial nerve.

Surgical approach

The choice of approach ultimately depends on the individual surgeon's training and level of experience. However, the key to a successful reduction and stabilization is an extensive exposure of the fracture.

A posterior approach provides excellent access to the posterior aspect of the humeral shaft and is best suited for distal fractures. The anterolateral approach is useful for exposure of fractures involving the proximal and middle thirds of the humeral



Fig. 2. A – Transverse midshaft fracture of the humerus in a 35 year-old female patient sustained after a simple fall. B – Functional bracing with a Sarmiento brace. C – Radiographs at three months show adequate alignment and callus formation at the fracture site. (Courtesy of David Ring, MD, PhD, Boston, US).



Fig. 3. A – Displaced comminuted spiral humerus shaft fracture in a 42-year-old polytraumatized patient. B – Postoperative images after antegrade intramedullary nailing.

shaft. The benefits of this approach include its extensile nature and its avoidance of the radial nerve. The antero-medial approach offers direct access to the neurovascular bundle in case of suspected neurovascular injury.

The radial nerve must be identified and protected throughout the procedure, regardless of the approach.

In comminuted, oblique or spiral fracture patterns, lag screw fixation can provide additional stability. In high-energy trauma or in the presence of severe comminution bridge plating techniques to maintain alignment may be more appropriate than anatomic reduction.

Locking plates provide significantly higher fixation stability in osteoporotic bone and may reduce the risks of fixation failure and nonunion.

One biomechanical study comparing locking plates with non-locking plates for a comminuted midshaft fracture model did not show an advantage of locking screws under axial loading (23)

We believe that standard compression plates achieve sufficient stability in normal-quality bone and simple fracture patterns.

Clinical results of plate fixation

One randomized prospective study on intramedullary nailing (n = 38) versus compression plating (n = 46) of diaphyseal fractures of the humerus reported no statistically significant differences between groups with respect to union. IM nailing was associated with a statistically significant higher incidence of shoulder pain and stiffness whereas plating was associated with a higher incidence of elbow pain and stiffness (6).

A recent retrospective study evaluated ninety-six patients with high-energy fractures of the humeral shaft that were treated with plate fixation. The union rate was 97.5%. At the final follow up, no significant differences



Fig. 4. Retrograde nail for an oblique midshaft fracture of the humerus.



Fig. 5. A – Closed comminuted fracture of the distal shaft of the humerus in a 24-year-old male patient sustained after falling off his motorcycle. B – Six months after less invasive plate fixation. C – The patient reported no pain and discomfort and active ROM is unrestricted.

between the injured and uninjured extremities were seen in range of motion at the shoulder and elbow with the exception of shoulder flexion and loss of upper extremity strength was modest. The mean Disabilities of the Arm, Shoulder and Hand score was 25.9 (range, 0–79) (14).

Denard et al. (12) directly compared functional bracing versus compression plating of humeral shaft fractures in a retrospective study of 213 patients. The occurrence of nonunion (20.6% vs 8.7%; $p = 0.0128$) and malunion (12.7% vs 1.3%; $p = 0.0011$) was significantly more common in the nonoperative group. They demonstrated no significant difference between groups with respect to time to union, infection, radial nerve palsy or ultimate range of motion.

Diaphyseal fractures adjacent to proximal or distal articulations

The goal of these injuries is to incorporate the metaphyseal segment including the articulation in order to permit a more active joint mobility. The advent of angular stable fixation has permitted a greater degree of stability with these complex injuries even in the face of underlying osteoporosis (Fig. 7).

Pathologic and impending pathologic fractures

Metastatic fractures of the humerus account for about 20% of all pathological fractures. Although, life expectancy has improved due to advanced oncological treatment, it is still limited. The goal in treating these fractures is to achieve pain relief and attain rigid and durable

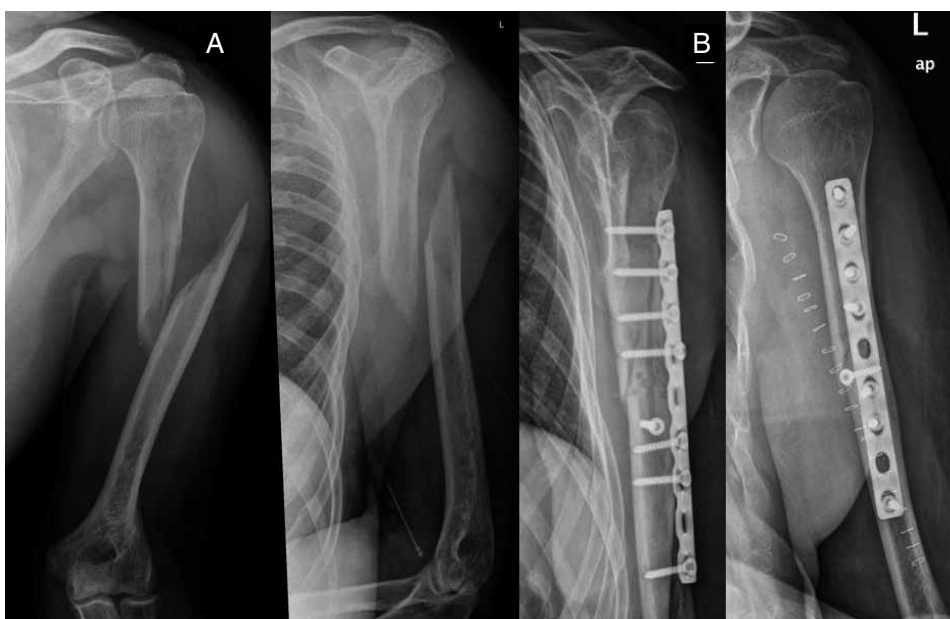


Fig. 6. A – Displaced oblique fracture of the humeral shaft. B – Good alignment after plate and additional lag screw fixation.

internal fixation to allow for immediate postoperative use of the upper extremity.

Closed intramedullary nailing, with or without cement augmentation, offers several advantages. It is less invasive than plate fixation, can protect a long segment of the bone, has a shorter procedure time and allows immediate delivery of radiotherapy without the risk of wound compromise (Fig. 8)

Periprosthetic fractures

The prevalence of these fractures has been reported to be 0.6% to 2.8% (9, 18).

Indications for open reduction and internal fixation are unstable displaced fractures or failed nonoperative treatment in patients with a well-fixed prosthesis.

The challenge is to achieve fracture union and pain relief while maintaining glenohumeral motion. Selection of the surgical approach and the fixation technique is dependent on fracture site location and type of prosthesis.

Locking compression plates or cerclage wires and allograft struts have been used with successful outcomes (2, 17) (Fig. 9).

Pediatric fractures

Humeral shaft fractures comprise approximately 2.5% of all fractures in children (33). Indications for surgery include improved mobilization in polytrauma, wound care in open injuries and persistent malalignment of $>30^\circ$ for proximal third, $>20^\circ$ for middle third, and $>15^\circ$ for distal third shaft fractures (5). The authors' preferred method of treatment is closed reduction and retrograde flexible nailing. A small incision is made over the lateral epicondyle. The cortex is opened with a 3.2- or 4.5-mm drill bit, depending on implant size (40% of the diameter of the canal) and the drill is advanced under image intensification into the medullary canal. Two equally sized prebent nails are then inserted and driven proximally to



Fig. 7. A – Comminuted dia- and metaphyseal humeral fracture in a 30 year-old male patient, sustained after a fall while playing soccer. B – Implant failure and redisplacement four weeks after locking plate and lag screw fixation. C – Additional medial plate fixation achieved sufficient stability. However, the patient returned with progressive radial and ulnar nerve neuropathy three weeks after the revision surgery and neurolysis and decompression was performed.



Fig. 8. A – Metastatic fracture of the humeral shaft in a patient with epithelioid sarcoma of the thigh. B – Unreamed locked intramedullary nailing was performed due to systemic chemotherapy and a large soft tissue tumor adjacent to the fracture site. (Courtesy of Heide Delbrück, MD, Aachen, Germany)

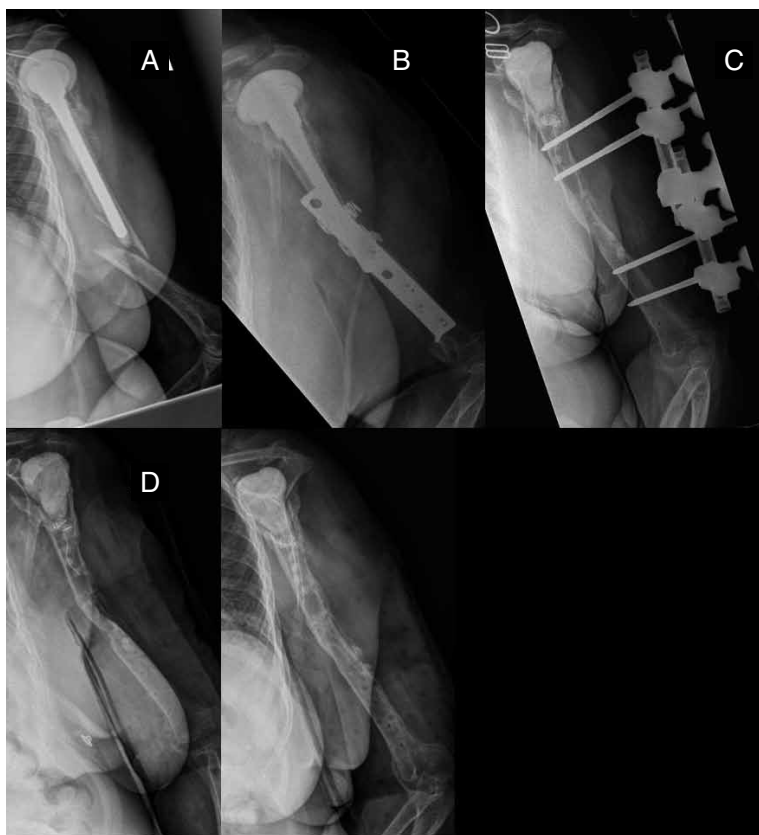


Fig. 9. A – Periprosthetic fracture of the humerus shaft in a 74-year-old patient two months after shoulder arthroplasty for a headsplint fracture. B – Adequate realignment after plate and cerclage fixation. C – Three months later the patient presented with signs of chronic infection and received debridement, implant removal, temporary placement of an external fixator and antibiotic spacer. D – Final follow up: The patient reported minimal pain and discomfort and refused reimplantation. Active ROM: abduction 40°, elevation 30°.



Fig. 10. A – Displaced oblique distal humerus shaft fracture in a 7-year-old girl, sustained after a fall from a swing. B – Three months after retrograde elastic nailing. Active ROM is unrestricted. C – Displaced oblique proximal humerus shaft fracture in a 9-year-old girl, sustained after a fall from a bunk bed. D – nails are impacted proximally to within 1–2 cm of the proximal humeral physis.

within 1–2 cm of the proximal humeral physis in proximal fractures of the shaft. A shorter length of nails can be chosen in midshaft or distal fractures (Fig. 10). Implant removal is performed once radiographs confirm adequate fracture healing.

COMPLICATIONS

Complications may occur as an inevitable consequence of a more severe injury or as a result of treatment, which may be to the result of errors in either procedure selection or in the surgery provided.

Malunion and nonunion

Nonoperative management as well as operative techniques can result in nonunion (27, 32). Smoking, medical comorbidities such as metabolic abnormalities, non-compliance of the patient and extensive comminution are risk factors for malunion and nonunion (4). Careful patient selection and a meticulous operative technique might help reduce these complications.

Neurologic injury

Radial nerve palsy is reported to occur in 11% of fractures and its incidence is higher in distal fractures of the humerus and transverse and spiral fracture patterns than in proximal fractures or comminuted or oblique patterns (29).

Transection of the radial nerve is usually associated with open fractures, near amputations and extensive upper-extremity injuries. In closed injuries, nerve entrapment, contusion, crush or stretch injuries can cause radial nerve palsy. Intact radial nerves nearly always recover (29) and we only recommend exploring the radial nerve when the fracture of the humerus is open and laceration is expected (25).

POSTOPERATIVE REHABILITATION

Patients are advised to wear a sling with the upper limb in the so-called safe position (the shoulder in internal rotation, neutral flexion, and neutral abduction and the elbow flexed 90°) for two to three weeks after the surgery.

Active pendulum and gentle passive range-of-motion exercises with up to 80° of elevation begin immediately after the operation.

Active-assisted range-of-motion exercises are introduced when sling removal is appropriate.

Isometric rotator cuff exercises and graduated active range-of-motion exercises under the supervision of a physiotherapist are continued for up to six months after the operation, dependent on recovery of function.

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