Humeral shaft fractures. Current concept review

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Abstract

Humeral fractures account for 3-5% of all fractures, with an incidence of about 14.5/100,000 people per year. Nearly 60% of these fractures are found in the bone shaft, 30% in the proximal area, and the rest are in the distal humerus. The majority of the shaft fractures (90%) consolidate with orthopedic management using a humeral brace. Consolidation signs in humeral shaft fractures are observed between 16 and 18 weeks. These fractures cause temporal disability in patients. Surgical options for this fracture are compression plates, intramedullary devices, or external fixation. A delay in the consolidation, known as pseudoarthrosis may appear in 2-10% of these fractures. Another known complication is the radial nerve injury that appears in about 4-22% of cases.

Key words: Humeral shaft. Fracture. Compression plate.

Anatomy

The humerus is the longest bone of the upper limb; it articulates with the scapula through the humeral-scapular joint at its proximal end, as well as the radius and ulna at the elbow joint. The humeral upper extremity consists of a head, neck, the greater tubercle (trochiter), and the lesser tubercle (trochin). The sphere-shaped head is articulated with the glenoid fossa of the scapula. The anatomical neck of the humerus has the groove, which separates the head of the tubercles. The union between the head, neck, and body or diaphysis of the humerus is marked by the same tubercles, which have muscular insertions. Between the two tubercles is the inter-tubular groove, also called the bicipital groove, which separates them and functions as a path or track for the tendon of the bicep in its major division^{1,2}.

The humeral diaphysis extends from the surgical neck to the distal form humeral condyles. This has a cylindrical shape in its most proximal end, and as it goes toward the distal, it becomes cone-shaped, to finish in its most distal end with a flute-like shape. It is characterized by the deltoid tuberosity, which is lateral for the insertion of the deltoid muscle, as well as the oblique groove of the radial nerve located in the posterior face, which as its name suggests is where the radial nerve is located, as well as the deep brachial artery^{1,2}.

The distal third widens to form the medial and lateral supracondylar ridges, ending in extensions called epicondyles that are places of muscular insertion. It is made up of the epicondyles, the trochlea, the humeral condyle, and the olecranon, coronoid, and radial fossae. It has two articular faces: the lateral humeral condyle, which articulates with the head of the radius, and the

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medial trochlea, who articulates with the proximal portion of the ulna. Above and in front of the trochlea is the coronoid fossa, it receives the coronoid process of the ulna during complete flexion of the elbow. Behind it is the olecranon fossa, which accommodates the olecranon of the ulna during the full extension of the elbow. Above and in front of the humeral condyle is the radial fossa, which is responsible for housing the edge of the head of the radius when the forearm is fully flexed^{1,2}.

Epidemiology

In North America, diaphyseal fractures of the humerus occur about 70,000 times a year, representing between 3 and 5% of all treated fractures in a 1-year period. It has a bimodal distribution, occurring in young patients between 21 and 30 years of age and in elderly adults between 60 and 80 years of age. The injury in young people is usually a result of high energy, while in elder adults, it is usually a fall. From all humerus injuries, it is established that around 5% are associated with bone exposure, and over 60% are fractures with simple traces²⁻⁶.

Regarding the fracture's traces, transverse fractures of the humerus are often a consequence of direct trauma to the arm. The traction of the deltoid muscle pulls the proximal fragment of the fractured humerus. The indirect injury caused by a fall with the extended extremity can cause a spiral fracture of the body. The superposition of the oblique ends of the bones, with a spiral fracture, explains the shortening. Since the humerus is surrounded by muscles and has a well-developed periosteum, bone fragments usually consolidate with ease²⁻⁶.

The humerus is in contact with the following nerves in the corresponding zones:

- Surgical neck – Axillary nerve
- Radial groove – Radial nerve
- Distal part of the humerus – Median nerve
- Medial epicondyle – Cubital nerve.

A fracture in the corresponding zone where the nerves are located could affect them, causing neuropraxia, axonotmesis or neurotmesis, the first two having a positive prognosis for recovery, while neurotmesis usually occurs with full affection and its regeneration is difficult. These have an incidence of 4-22%²⁻⁷.

Physical examination

The basic principles for a physical examination are employed, mainly using inspection and palpation.

Inspection ought to be performed to evaluate possible visible deformity at plain sight, and especially evaluate the quality of soft tissue to define whether or not the fracture can be considered as compound or closed. Moreover, determine the neurovascular status of the distal limb to the fracture site for possible affection of vessels or nerves.

During palpation, possible crepitation can be found, as well as pain to superficial and deep palpation of the affected site. Elbow and wrist articulations ought to be palpated, assessing mobility and pain ranges, which indicate associated injuries.

Special tests such as sensitivity and muscle strength should be assessed to register a possible neurologic affection^{2,7}.

Imaging tests

The imaging tests used as a gold standard are anteroposterior X-ray and lateral X-ray of the arm. In case of a comminuted fracture, a computerized axial tomography would be requested to assess risks of intra-articular traces⁷.

Treatment

Since it is an extremity with a wide range of movements brought by the shoulder and elbow, it is possible to have marked degrees of reduction and angulation without significant limitation of the patient. For that reason, conservative management is considered an excellent management option⁴⁻⁹.

Historically, the Egyptians have described the use of different methods of conservative management for over 3500 years, such as skeletal traction, casting or splinting with abduction, Velpeau dressing and a hanging cast, all of them with advantages and disadvantages. Today, the brace has replaced all the aforementioned conservative methods; it has become the gold standard in non-surgical treatment in management. It facilitates mobility of the shoulder and elbow joints while keeping support over the humerus fracture⁴⁻⁹.

The brace for a humerus fracture was first used in the 1970s, when Dr. Sarmiento popularized this technique, explaining its hydraulic principles with active muscular contraction and the effect of gravity. Estimations suggest high binding rates of 90-100%⁴⁻⁹. Initial treatment consists of using a U-shaped splint to provide immobilization and reduce pain for 7-10 days. Subsequently, a change to a brace is performed, avoiding the use of a sling to avoid consolidation in the internal

Table 1. Indications for the management of a fracture of the diaphyseal humerus

Humerus fractures			
To evaluate	Conservative management	Surgical management	
		Relative	Absolute
Fracture type Simple/In contact/Aligned/Extra-articular/Closed or Compound Simple/No contact/Unaligned/Extra-articular/Closed or Compound Fragmented/In contact/Aligned/Extra-articular/Closed or Exposed Fragmented/No contact/Unaligned/Closed or Compound Fragmented/No contact unaligned/Articular/Closed or Compound Pathological fracture	X (B) X (B) X (B) X (B)	X (P, IMN, EF) X (P, IMN, EF) X (P, IMN, EF)	X (P) X (IMN)
Associated injuries Poly-trauma Bilateral fracture Severe soft tissue injury Neurovascular lesion Infection in fracture area		X (EF) X (EF) X (EF)	 X (EF) X (EF)
Type of patient Patient requiring limb as a support Patient in combat/war area Patient with high physical/sports demand	 X (B)	 X (P)	 X (IMN) X (EF)

B: brace; P: compression plates; IMN: intramedullary nail; EF: external fixator. The relative and absolute indications are shown.

rotation. The patient is allowed to make swinging movements, as well as passive and active flexing and extending, avoiding abduction movements. Some of the possible risks are skin maceration and poor binding of the fracture, which can be avoided through proper care and radiological follow-up in consultation⁴⁻⁹.

The values to consider for an acceptable alignment and subsequent conservative management are up to 3 cm of shortening, an angulation of under 20 degrees and rotation under 30 degrees²⁻⁹.

Several factors need to be account, like conformation of the fracture, separation (in millimeters) of bone fragments, smoking patients and being female with a greater risk of failure in the consolidation of a fracture using a brace. These factors ought to be taken into consideration when using conservative management¹⁰.

The surgical treatment brings a quicker stabilization, with an earlier consolidation of up to 90%; however, it is not exempt from complications such as a risk of iatrogenic injury of the radial nerve (5%), and loss of fixation and infection²⁻¹⁰.

Indications for early surgical treatment are divided into three categories:

- Indications by fracture type (exposed or closed)
- Indications by associated injuries
- Indications by the type of patient.

These indications can be absolute or relative, and all factors should be analyzed, such as failed conservative treatment, the presence of a pathological fracture, a trace with intra-articular extension, vascular injury, and obesity, among others. **Table 1** summarizes the indications for conservative and surgical management²⁻¹⁰.

The objective of surgical treatment is to reestablish length, alignment, and rotation, giving it a stable fixation and bringing early mobility. Implant options are plates, intramedullary nails, and an external fixator, which is reserved for high energy mechanisms with soft tissue injury¹⁻¹⁰.

Osteosynthesis with 4.5 plates

The material of choice for performing general fixation of fractures is metal since it is rigid and resistant; moreover, it is well tolerated biologically.

The most utilized materials in the manufacturing of implants are stainless steel and titanium. The material must have the abilities to produce the minimum local effects and provide rigidity, which is defined as the relationship between the applied load and the produced deformity, and grant adequate resistance to tolerate the applied effort to the implant during the load, hence avoiding rupture by the weariness of the unit²⁻¹².

Other aspects to consider are as follows:

- Ductility, defined as tolerance before plastic deformities
- Corrosion, which determines how much metal is released into the surrounding tissue
- Surface structure, which is the part of the implant that comes in contact with the bone and soft tissue
- Biocompatibility, which is the effectiveness of the implant to resist infection, allergic reactions (nickel), and not induce tumors due to a neoplastic reaction.

Plates were introduced to the market in 1969, with designs which allowed for axial compression through eccentric screws¹³.

They come in different modalities, among which are compression, neutralization, support, and brace. These 4.5 plates are designed to support a weight of up to 90 kg before presenting a failure^{4,13}.

They are considered the gold standard for humerus fracture fixation. They provide early stability to begin early rehabilitation. Unlike intramedullary nails, the plate does not promote sub-acromial clamping. The plate provides a rigid fixation and is used in different types of bone fractures, which are not support bones or in articular fractures, where a formation of abundant calluses is not desired. Plates are considered suitable for traces of transversal diaphysary fractures or short oblique fractures of long bones. The presence of abundant calluses after the plate placement means the presence of a fixation with a certain degree of instability, which could lead to rupture due to weariness of the implant¹³.

Limited contact or blocked dynamic compression plates (DCP) are preferred to the old DCP since they better preserve circulation of bone tissue. These plates are made in stainless steel or titanium, which has great tissue tolerance; contact with bone tissue is reduced due to its conformation. Therefore, the capillary network of the periosteum is less compromised, and porotic alterations of the bone under the plate are reduced¹³.

There are new percutaneous techniques, which have proven positive clinical results with few risks and complications, thus further reinforcing their use for fractures with simple traces¹¹⁻¹³.

Intramedullary rod (nail)

Indications for fracture fixation using intramedullary nails are the presence of pathological fractures, high comminution where anatomy cannot be restituted using

a plate, and when the patient utilizes said extremity as support. Its entry is through the supraspinatus tendon of the rotator cuff. Thus, it can be accompanied by a functional limitation of the shoulder following its colocation with alterations of mobility ranges.

Among its complications are rotational instability, iatrogenic fracture caused when placing the implant and damage to the supraspinatus tendon. Hence, it is only used in specific cases^{14,15}.

External fixator

The external fixator brings a therapeutic role in cases of fractures linked to multiple traumas or in cases of medicine practiced in combat for a temporal stabilization where another organ/system requires primary care.

Additional indications considered as absolute by several authors are the presence of severe soft tissue injuries and neural/vascular injuries, which require acute stabilization for their repair. Relative indications are the presence of fractures in the distal third of the humerus, the presence of bilateral humerus fractures, and the presence of infection.

Some of the benefits include the fact that the hematoma is preserved, the risk of pseudoarthrosis is reduced, and it is less invasive. On the other hand, its risks are the possibility of presenting an injury of the radial nerve, as well as a risk of infection due to bacterial migration if the proper hygienic measures are not taken.

Fixator placement is based on specific anatomical points to reduce the risk of injury: neurovascular, ease of manipulation by the physician, and adaptability of its location with everyday activities. The needles of the external fixator in the proximal third ought to be placed in the anterolateral region, trying to avoid the axillary nerve and the path of the tendon of the large head of the bicep; there should be at least two needles for more stable fixation in this region. In the distal third, at least two needles are placed in the lateral region. The distal needles ought to be placed 1 cm over the olecranon fossa to avoid injury of the radial nerve, which is approximately 4 cm above the lateral epicondyle^{16,17}.

Post-operative care

Immediately after the surgery, the patient is placed in a sling, monitoring his/her neurovascular state acutely. After 7 days, passive and active exercises

are recommended to recover mobility ranges, in addition to avoiding bursa adhesions, which limit shoulder mobility. Lifting can begin if sufficient stability is obtained, otherwise lifting exercises are not recommended until there is a formation of bone callous, which can usually be seen through an X-ray after 4 weeks, before this, physical therapy may begin with an anti-inflammatory focus and increase in the range of mobility²⁻¹⁷.

Surgical and non-surgical complications

The most common complications reported are mainly neurovascular lesions/contusions, wound infection, and pseudoarthrosis.

Neurovascular affection

Radial nerve paralysis is mainly reported in extensive posterior approaches, or when placing the implant, when it is being placed laterally to the humerus, and in a distal position where it could be close to the nerve path, damaging it. Reports of incidences of post-operative injuries of the radial nerve are between 6 and 11% no matter the type of fixation, and from this, around 71% recover with non-surgical management²⁻¹⁸.

Wound or surgical site infection

Infection occurs in up to 1-2% of fracture that was initially unexposed and 5% of exposed fractures. Post-surgical infection occurs in 0.8-4%, varying its percentage depending on the type of implant, type of surgical wound and the status of the patient²⁻¹⁸.

Pseudoarthrosis

Pseudoarthrosis is an entity characterized by a lack of union after 4 months from the onset of the fracture. Its symptomatology usually manifests with pain and a loss of function of the affected extremity, in addition to radiological data showing a lack of consolidation in the trace of the fracture¹⁹⁻²⁶.

Osteosynthesis

This manifestation is divided into two types:

- Hypertrophic – shows data of bad quality bone tissue; it is a result of improper stability of the fracture

- Atrophic – occurs when there is a lack of biological stimulation for the proper development of bone callous.

Pseudoarthrosis rate at 24 weeks in patients treated non-surgically is 2-23%, compared to 10-15% in those patients who have surgery for fixation¹⁹⁻²⁶.

There are different factors that promote the onset of pseudoarthrosis. A combination of several of these factors increases risk. These are as follows¹⁹⁻²⁶:

- Compound fractures
- High-impact injuries
- Major bone loss
- Soft tissue interposition
- Infection
- Unstable patterns of fractures (transverse, short oblique, and comminute) and bone tissue distraction
- Segmental fractures
- Nutritional status (smoking, drinking, osteoporosis, malnutrition, and obesity)
- Unstable/inadequate immobilization.

Surgical indications in patients with data of pseudoarthrosis are the presence of pain and mobility of fractures, considering the time of evolution¹⁹⁻²⁶. Risk of re-fracture can occur in up to 1% of patients¹⁹⁻²⁶.

Conclusions

Diaphyseal fractures of the humerus have a high rate of success under conservative management using a brace, even though there are different instances where surgical treatment is necessary to bring greater stability and a better prognosis using plates or an intramedullary rod, with or without a bone autograft.

Conflicts of interest

All authors declares no conflicts of interest for the publication of these manuscript.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments were performed on humans or animals for this research.

Data confidentiality. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Privacy and informed consent. The authors declare that no patient data appear in this article.

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