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PROXIMAL HUMERUS FRACTURES, ANATOMY, EPIDEMIOLOGY, MECHANISMS OF ACTION, CLASSIFICATION, CLINICAL PRESENTATION, IMAGING PRESENTATION, DIFFERENTIAL DIAGNOSIS, TREATMENT AND COMPLICATIONS

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SUMMARY

Introduction: *Proximal humerus fractures (PHF) make up 5 to 6% of all fractures presented in adults. Approximately 67 to 85% of proximal humerus fractures are managed non-surgically, however with technological advances, improved techniques and increased patient demand, the rate of surgery is increasing. The use of open reduction internal fixation (ORIF) has remained stable, hemiarthroplasty has decreased and reverse shoulder arthroplasty (RSA) has increased.*

Objective: *to detail current information related to proximal humerus fractures description, anatomy, epidemiology, mechanisms of action, classification, clinical presentation, imaging presentation, differential diagnosis, treatment and complications.*

Methodology: *a total of 35 articles were analyzed in this review, including review and original articles, as well as clinical cases, of which 24 bibliographies were used because the other articles were not relevant for this study. The sources of information were PubMed, Google Scholar and Cochrane; the terms used to search for information in Spanish, Portuguese and English were: humerus fractures, Neer, proximal humerus, osteosynthesis and humerus prosthesis.*

Results: *Fractures of the proximal humerus figure between 4 and 5 % of all fractures, 5 and 6 % in some other bibliographies; among those of the humerus they are the most common with 45 %. Fractures of the proximal humerus are more frequent in women, presenting higher rates compared to men, presenting a ratio of 2:1, possibly also due to alterations in bone density. Fractures of the proximal humerus at birth are infrequent, representing a rate of 10.1/100,000 births.*

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Conclusions: *Fractures of the proximal humerus account for 4 to 6 % of all fractures; among those of the humerus they are the most common at 45 %. Approximately 85 % of these fractures are non-displaced. Fractures of the proximal humerus have a bimodal distribution. Fractures of the proximal humerus are more frequent in women, presenting higher rates compared to men, presenting a ratio of 2:1. The most common mechanism of injury is the fall on the upper limb in extension at the same height. It is of utmost importance to know the correct anatomy in order to have a better impact on the quality of treatment. Affected individuals classically come with the upper limb held to the thorax with the contralateral hand and showing swelling, pain on palpation, pain during mobility and sometimes crepitus. A good examination should be performed for possible neurovascular involvement. All patients suspected of having a proximal humerus fracture should have radiographic imaging. There are several classifications, however the most widely used is the Neer classification. It is important to make a correct differential diagnosis. The main goal of treatment is to relieve pain and restore function. There are various types of treatment that will depend on the type of fracture and the patient's clinical condition. Among the most common complications are neurovascular injury, thoracic injury, myositis ossificans, pseudarthrosis, shoulder stiffness and osteonecrosis.*

KEY WORDS: *humerus, fractures, osteosynthesis, trauma.*

INTRODUCTION

Proximal humerus fractures (PHF) account for 5-6% of all fractures in adults. Treatment of these fractures in the setting of low-energy falls in the elderly is increasingly recognized as these events support the overall impact of the direct and indirect value of fragility fractures and osteoporosis. As the population ages, individuals with compromised bone density increase. The general operative and non-operative management of proximal humerus fractures is of paramount importance in the current literature(1).

The medical, functional and fracture-related difficulties form a real challenge in the management of these fractures. Approximately 67-85% of proximal humerus fractures are managed non-surgically, however with technological advances, improved techniques and increased patient demand, the rate of surgery is increasing. The use of open reduction internal fixation (ORIF) has remained stable, hemiarthroplasty has decreased and reverse shoulder arthroplasty (RSA) has increased(2-6).

METHODOLOGY

A total of 35 articles were analyzed in this review, including review and original articles, as well as cases and clinical trials, of which 24 bibliographies were used because the information collected was not important enough to be included in this study. The sources of information were Cochrane, PubMed and Google Scholar; the terms used to search for information in Spanish, Portuguese and English were: humerus fractures, Neer, proximal humerus, osteosynthesis and humerus prosthesis.

The choice of bibliography exposes elements related to proximal humerus fractures, anatomy, epidemiology, mechanisms of action, classification, clinical presentation, imaging presentation, differential diagnosis, treatment and complications.

DEVELOPMENT

EPIDEMIOLOGY

Fractures of the proximal humerus figure between 4 and 5 % of all fractures, 5 and 6 % in some other bibliographies; among those of the humerus they are the most common with 45 %. The incidence of these fractures varies according to the region. It is more frequent in the elderly population because it is interrelated with osteoporosis; bibliographies report up to 300,000 cases per year being more common than hip fractures. Approximately 85% of these fractures are non-displaced. Fractures of the proximal humerus present a bimodal distribution, presenting the first peak of incidence in individuals between 10 and 14 years of age, to later appear between 80 and 84 years of age. Fractures of the proximal humerus are more frequent in females, presenting higher rates compared to males, presenting a ratio of 2:1, possibly also due to alterations in bone density, and when these fractures occur in children under 18 months of age they should be thoroughly evaluated because they may be due to non-accidental trauma. Proximal humerus fractures at birth are infrequent, representing a rate of 10.1/100,000 births(7-13).

ANATOMY

The shoulder shows the greatest range of motion compared to the rest of the joints in humans, due to the structure of the glenoid cavity which is shallow and its surface is only 1/4 of the size of the humeral head; therefore the soft tissues are fundamental for the stability of the shoulder, both muscle, capsule and ligaments. The proximal humerus is between 35° to 40° of retroversion taking into account the epicondylar axis. Neer presents a division of the bony segments in 4, being in order the following:

I: humeral head.
II: lesser tubercle or trochlea.
III: greater tubercle or trochleter.
IV: humeral diaphysis.

The deforming muscular forces exerted on the bony segments are:

a. The trochleter is directed superiorly and posteriorly by the supraspinatus and external rotators.
b. The trochlea is directed medially by subscapularis traction.
c. The diaphysis of the humerus is directed medially by the pectoralis major.
d. The insertion of the deltoid generates abduction of the proximal fragment.

In the vascularization we find that the primary vascular action comes from the anterior and posterior humeral circumflex arteries; in addition the arcuate artery which is the continuation of the ascending branch of the anterior humeral circumflex artery, enters through the bicipital groove and irrigates a large part of the head of the humerus. Small branches coming from the posterior humeral circumflex artery, which arrive through the osteotendinous vascular anastomoses of the rotator cuff, also

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converge at the head of the humerus. Fractures of the anatomic neck are rare, with poor prognosis due to its poor vascularization. In the innervation we find that the circumflex nerve passes just anteroinferior to the glenohumeral joint, penetrating the quadrangular space. It may present a traction lesion due to its rigid fixation to the posterior fascicle, the deltoid and its proximity to the inferior capsule, being probable its lesion due to anterior dislocations or anterior fracture-dislocations(1,8,14,15).

MECHANISM OF INJURY

The most common mechanism of injury is the fall on the upper limb in extension at its own height, usually present in elderly individuals and in osteoporotic women. Young people show proximal humerus fractures due to high energy impact trauma, such as in motor vehicle accidents, these cases usually present as higher risk fractures and dislocations, with major soft tissue disruption and some other related injuries. Between 25% of proximal humerus fractures in children from traumatic falls are linked to sports, 33% linked to motor vehicle accidents(8,10,11). Some less common mechanisms are:

- Pathologic fractures:probably due to the presence of malignant or benign lesions in the proximal humerus.
- Excessive abduction of the shoulder in an individual with osteoporosis, where the trochlea does not allow rotation of the humerus.
- Seizures or electric shocks.
- Direct trauma, related to trochlear fractures.

CLINICAL PRESENTATION

It is always important to take a correct and complete history accompanied by an individualized physical examination. In those over 65 years of age, the clinical presentation usually follows a low energy fall with the arm outstretched due to an attempt to break the fall. Affected individuals classically come in with the upper limb held to the chest with the contralateral hand and showing swelling, pain on palpation, pain on motion and sometimes crepitus. Perilesional ecchymosis is probably not evident at the beginning; ecchymosis is usually present on the chest wall and flank, so it is important to differentiate from those generated by a thoracic alteration. It is necessary to make a good examination to evaluate the function of the circumflex nerve, which can be evaluated by the presence or absence of sensitivity in the lateral part of the proximal portion of the arm located superior to the deltoid. Because of pain, motor function tests cannot always be performed. The distal part may be displaced inferiorly due to a loss of deltoid tone and not due to a certain glenohumeral dislocation; generally, this improves 4 weeks after the fracture, however if this is maintained it may be due to a circumflex nerve injury. It is necessary to visualize in the inspection the signs of open fracture, ecchymosis that can reach up to the thorax, arm and forearm. Frequently there is crepitus and pain at the fracture site. The loss of the deltoid contour suggests a concomitant dislocation of the shoulder which is usually due to a high energy mechanism. In addition, the presence of an associated neurovascular lesion should be evaluated(1,8,15).

Figure 1. X-ray showing fracture of the left proximal humerus.

Source: The Authors.

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IMAGING PRESENTATION

All patients suspected of having a proximal humerus fracture should have radiographic imaging performed. Suggested projections include the following:

- ➢ True AP or "Grashey" projection.
- ➢ Scapular Y.
- ➢ Lateral axillary.

The Velpeau projection is often used when there is an inability of the individual to perform the axillary lateral radiographic position. It is performed with the individual's arm held in internal rotation in a sling and the film is taken up and down with the subject leaning backward into the beam field.

West Point radiograph, the subject is placed face down on the x-ray table, the altered shoulder is elevated on top of the table and the cassette is held against the top of the shoulder; the x-ray beam is focused on the axilla. It provides a tangential projection of the anteroinferior border of the glenoid rim.

CT is often used for preoperative planning, especially when the exact location of the humeral head, greater tuberosity and when there is intra-articular comminution. CT directs towards the appropriate surgical treatment by differentiating which procedure may be better, fixation or reconstruction.

Magnetic resonance imaging is rarely indicated, however it can be used to define an associated rotator cuff disorder(1,8,15).

CLASSIFICATION

Among the first classifications used for the proximal humerus was that of Ernest Codman, who in 1934 defined the fractures based on the affectation according to 4 anatomical parts: humeral diaphysis, articular surface, greater tuberosity and lesser tuberosity; this categorization did not take into account the fracture displacement, nor separated the fractures of the surgical neck and the anatomical neck(16,17).

In 1970 Neer's classification system was released, which is the most commonly used when talking about proximal humerus fractures. Neer developed Codman's classification of the four main anatomical segments, in addition to quantifying and qualifying fracture displacement. Neer conceptualized displacement as a fracture fragment displaced more than 1 cm or with an angulation greater than 45 degrees. Using the above, he defined fractures as one-, two-, three-, or four-part fractures. With this method of classification, all non-displaced fractures are grouped together while displaced fractures require more individualized groupings. Neer's classification system is described below.

The four fragments are: trochlea, trochlea, humeral diaphysis and humeral head.
The fracture types are:
Fractures in one fragment: there is no displacement of the fragments, regardless of the number of fracture lines.
Fracture in two fragments: they can be in anatomical neck, surgical neck, trochleter and trochlete.
Fracture in three fragments: it can be of the surgical neck and trochleter, as well as of the surgical neck and trochlete.
Fracture in four fragments.
Fracture-luxation.
Fracture with repercussion of the articular surface(8,14,16).

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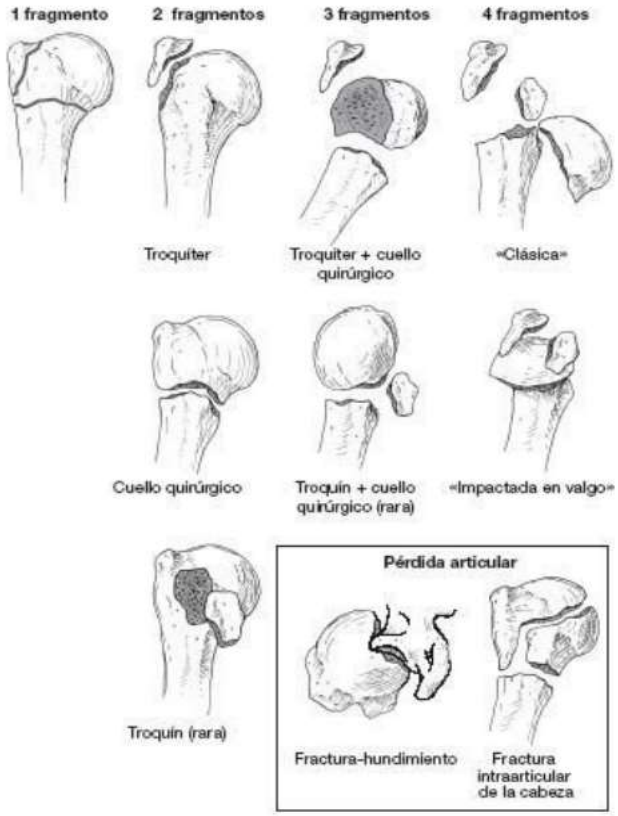
Figure 2. Neer classification.



Source: Koval KJ, Zuckerman JD. Fracturas y luxaciones. 2 ed. Madrid: Marban; 2003.

In 1980 the AO/OTA classification was made, classifying proximal humerus fractures according to the involvement of the articular surface, anatomical location and dislocation. It divides fractures into 3 major groups and complementary subgroups according to fracture location, presence or absence of dislocation and status of the surgical neck.

Type A: extra-articular unifocal fractures that include the greater tuberosity or the surgical neck.

A1: a unifocal extra-articular tuberosity.

A2: a unifocal extra-articular impacted metaphysis.

A3: a unifocal extra-articular non-impacted metaphysis.

Type B are bifocal fractures that include some unusual dislocations.

B1: extra-articular bifocal with metaphyseal impaction.

B2: extra-articular bifocal without metaphyseal impaction.

B3: extra-articular bifocal with glenohumeral dislocation.

Type C: all intra-articular anatomical fractures of the neck, including dislocation and division of the humeral head.

C1: articular with slight displacement.

C2: impacted joint with large displacement.

C3: articular with dislocation(1,8,16).

In 2004, Hertel et al. gave a form of binary classification in lay blocks. The so-called Codman-Hertel system allows the identification of predictors of humeral head ischemia generated by fractures. They showed the importance of fracture morphology, in addition to presenting medial hinge disruption and medial calcar extension less than 8 mm as notable predictors for fracture fragment and head vascularity. Resch et al. formed a similar classification system however this was based more on fractures impacted in valgus versus varus(16,18,19).

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Figure 3. X-ray showing fracture of the right proximal humerus.

Source: The Authors.

DIFFERENTIAL DIAGNOSIS

There are several differential diagnoses among which we can mention:

Acute fractures, chronic fractures, related complications, subcoracoid impingement, calcific tendonitis, SLAP lesion, glenohumeral internal rotation deficit, lesser garter shoulder, posterior labral tears, partial thickness tears, full thickness tears, glenohumeral arthritis, adhesive capsulitis, avascular necrosis, scapulothoracic crepitus, proximal biceps tendinitis and proximal biceps tendinopathy, acromioclavicular separation, distal clavicle osteolysis, acromioclavicular arthritis, dislocation, associated labral injuries or pathology, suprascapular neuropathy, scapular wing - medial or lateral, brachial neuritis, thoracic outlet syndrome, quadrilateral space syndrome, scapulothoracic dyskinesia, os acromiale, muscle tears(1,20,21).

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Figure 4. X-ray showing fracture of the left proximal humerus, after osteosynthesis.

Source: The Authors.

TREATMENT

The main objective of treatment is to relieve pain and restore function. Most of the fractures of the proximal humerus do not show any benefit with surgical techniques, however in the most complicated cases it is essential(22).

At the moment, several clinical trials recommend immobilization with a sling and consequent mild progressive rehabilitation in surgical and anatomical fractures of the neck with minimal displacement. The permissible value of displacement with respect to a solitary fracture of the greater tuberosity is still under discussion. The current literature emphasizes early surgical management in these solitary two-part injuries.

Progressive physical therapy and rehabilitation schemes consist of early and mild pendulum exercises for the shoulder starting approximately 10 to 14 days post-injury, or depending on the patient's symptomatology.

Analyses have shown a success rate of approximately 80% to 85% in non-surgical treatment when examining all types of proximal humerus fractures, however, we can state that conservative management presents a higher success rate in:
Fracture of the greater tuberosity displaced less than 3-5 mm.
Surgical neck fractures minimally displaced in one, two and three parts according to the Neer classification previously mentioned.
Individuals who are not ideally suited for surgery(15).

Fractures in 1 fragment or minimally displaced: they are the great majority with up to 85% of frequency in fractures of the proximal humerus. The use of a sling with rotation locking is recommended. Radiographic control should be performed periodically as a control for possible loss of fracture reduction. In stable or impacted fractures, it is recommended to start early shoulder mobility usually within 7 to 10 days. Exercises of pendulum can be done and later passive exercises of mobility amplitude. Active range-of-motion exercises can be performed 6 weeks after the injury, and counter-resistance exercises can be performed at 6 to 12 weeks. Full range of motion and function is not expected for 12 months.
Fractures in 2 fragments:
Fractures of the anatomic neck: infrequent and complex to manage through closed reduction, so they usually require open reduction and internal fixation especially in young people or a prosthesis such as a shoulder hemiarthroplasty. This type of fracture has been strongly associated with osteonecrosis.

Fractures of the surgical neck: in irreducible fractures and fractures in osteopenic bone, open reduction and internal fixation should be performed. If it is possible to reduce the fracture and there is good bone quality, percutaneous fixation by means of threaded wires or cannulated screws, if possible, should be chosen.

Greater tubercles fractures: when they present displacement of more than 5 mm to 10 mm, they require open reduction and internal fixation with or without repair of the rotator cuff;

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otherwise, pseudoarthrosis and subacromial entrapment may occur. When this occurs in the context of anterior dislocation, it may become reduced after reduction of the glenohumeral dislocation; if so, it should be managed conservatively. Solitary trochlear fractures should be approached through a superior incision, separating the deltoid muscle.

Lesser tubercles fractures: a posterior dislocation must be ruled out. They can be managed in a closed manner, except when the displacement of the fragment generates a blockage of internal rotation. There are clinical trials indicating that surgery is no more beneficial than non-surgical treatment in patients 60 years of age or older with 2-part proximal humerus fractures, suggesting that the current practice of surgically treating most of these fractures in older adults may not be beneficial(8,14,23).

Fractures in 3 fragments: unstable due to the action of opposing muscular forces, they also present some difficulty to reduce in a closed manner. Displaced fractures require surgical fixation, however in very fragile individuals or in those in whom surgery is contraindicated, they can be treated conservatively. Young people can undergo open reduction with internal fixation, maintaining vascularization. The deltopectoral approach is frequently used to approach the shoulder, as it can be extended to have a good field to enter the proximal humerus area. Open reduction with internal fixation and arthroplasty can be performed through this approach. In older individuals, the use of a partial prosthesis may be favorable. Locked plates improve fixation in osteoporotic bone, with good results.

Fractures in 4 fragments: related to osteonecrosis with a percentage of 4-35%. Sometimes if the head of the humerus is inside the glenoid cavity and remains with the soft parts intact, an open reduction with internal fixation can be performed. Another means of treatment is to make a fixation through locked plates, screws, sutures and/or needles. An alternative in the elderly may be hemiarthroplasty, which relieves pain, but has variable results in terms of function. Four-part fractures impacted in valgus form a pattern of injury associated with a lower rate of osteonecrosis and show optimal performance with open reduction and internal fixation(8).

In some studies, intramedullary nailing has been shown to be better to locking plate in reducing total complication, surgical blood loss, surgery time, post-surgery fracture recovery time and post-surgery humeral head necrosis rate in proximal humeral fractures(24).

Fracture-dislocations can be in:

- Two fragments: subsequent to reducing the dislocation, generally managed in a closed manner, with the exception of presenting displaced fragments.
- Three and four fragments: in young individuals, open reduction with internal fixation can be performed, and in older individuals, hemiarthroplasty.

The brachial plexus and the axillary artery are located close to the fragments of the humeral head in anterior fracture-displacements. After fracture healing, re-dislocation is rare. Hemiarthroplasty is indicated in fracture-dislocations of the anatomic neck because of the high rate of osteonecrosis. These injuries are associated with a high frequency of myositis ossificans after several attempts at closed reduction. Fractures of the articular surface or Hill-Sachs lesion, inverted Hill-Sachs lesion: they are frequently linked to posterior dislocations. Individuals with humeral head depression greater than 40 percent usually require hemiarthroplasty; in individuals around 40 years of age, open reduction with internal fixation should be suggested initially if possible(8,14).

Currently, the use of reverse shoulder arthroplasty in proximal humerus fractures is increasing due to the decrease of hemiarthroplasty, on the other hand, the rates of internal fixation and open reduction remain stable. Reverse shoulder arthroplasty is the treatment of choice in 3-part, 4-part and segmental fractures of the proximal humeral head in physiologically older individuals. This procedure shows functional results, range of motion and improved satisfaction when compared to other surgical procedures. Although the reported complication rates of RSA exceed those of ORIF or hemiarthroplasty, revision and reoperation rates are lower(2).

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Figure 5. Intraoperative image showing fracture of the left proximal humerus, after osteosynthesis with plate and screws.

Source: The Authors.

Figure 6. Intraoperative image showing fracture of the left proximal humerus, after osteosynthesis.

Source: The Authors.

COMPLICATIONS.

Complications include the following:

Vascular injury: not very common, representing approximately 5% to 6%. Mainly due to axillary artery involvement. The incidence increases in older patients due to its association with arteriosclerosis and the decrease of elasticity in the blood vessel wall. Sometimes the vascular lesion goes unnoticed due to the good collateral circulation in the shoulder.

Injury of the brachial plexus: infrequent, representing only 6%.

Injury to the circumflex nerve: mainly in anterior fracture-dislocations, because it is located on the inferior capsule, being injured by traction or laceration. When there is a complete injury

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of the circumflex nerve without improvement in about 2 to 3 months, it is necessary to perform a complementary electromyographic study and a surgical exploration.

Thoracic injury: it can be generated due to an intrathoracic dislocation when there is a fracture-luxation of the surgical neck, so it is essential to rule out possible pneumothorax or hemothorax.

Myositis ossificans: rare and related to chronic non-reduced fracture-dislocations, frequent attempts of closed reduction, as well as to approaches in which the deltoid muscle is sectioned.

Shoulder stiffness: its incidence can be reduced by good physiotherapy. Recalcitrant adhesions may require open arthrolysis.
Osteonecrosis: may occur in approximately 3-14% of three-part proximal humerus fractures, 4-34% in four-part fractures and a high percentage in anatomic neck fractures.

Pseudoarthrosis: primarily seen in displaced fractures of the surgical neck with two fragments and soft tissue interposition, it can also be due to excessive traction, inadequate fixation, large fracture displacement, poor bone quality, infection or systemic disease. This can be managed surgically with open reduction and internal fixation, which can be with or without bone grafting; another form of appropriate treatment would be through prosthetic replacement.

Consolidation in bad position: it is generated after an inappropriate closed reduction or by the failure of an open reduction with internal fixation, resulting in an entrapment of the trochleter on the acromion, with the consequent restriction of the range of mobility of the shoulder(8,14).

CONCLUSIONS

Fractures of the proximal humerus account for 4 to 6 % of all fractures; among fractures of the humerus they are the most common at 45 %. Approximately 85% of these fractures are nondisplaced. Fractures of the proximal humerus have a bimodal distribution. Fractures of the proximal humerus are more frequent in women, presenting higher rates compared to men, presenting a ratio of 2:1. The most common mechanism of injury is the fall on the upper limb in extension at the same height. It is of utmost importance to know the correct anatomy in order to have a better impact on the quality of treatment. Affected individuals classically come with the upper limb held to the thorax with the contralateral hand and showing swelling, pain on palpation, pain during mobility and sometimes crepitus. A good examination should be performed for possible neurovascular involvement. All patients suspected of having a proximal humerus fracture should have radiographic imaging. There are several classifications, however the most widely used is the Neer classification. It is important to make a correct differential diagnosis. The main goal of treatment is to relieve pain and restore function. There are various types of treatment that will depend on the type of fracture and the patient's clinical condition. Among the most common complications are neurovascular injury, thoracic injury, myositis ossificans, pseudarthrosis, shoulder stiffness, malunion and osteonecrosis.

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