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How to deal with a glenoid fracture

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- The glenoid fossa is involved in approximately 10% of all scapular fractures.
- Glenoid fossa incongruity is surprisingly well tolerated.
- Surgery is recommended when 20% or more of the anterior glenoid fossa is involved.
- Glenoid rim fractures often lead to chronic shoulder instability.
- Unstable glenoid neck fractures need surgical treatment and stable fractures can be treated conservatively.
- CT examination with 3D reformations of the glenoid fossa has improved insight into fracture morphology and fracture patterns and is very helpful for clinical decision makers.

Keywords: glenoid; fossa fracture; neck fracture; instability; 3D CT reformations; classification

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Introduction

Glenoid fractures are rare[1] and relatively little is known about their mechanism, fracture pattern and optimal treatment strategies. Fractures that involve the glenoid fossa may occur as a result of dislocation and, when present, bony avulsions and rim fractures are strongly associated with anterior shoulder dislocations.[2,3] More classical fractures of the glenoid can be extra- or intra-articular and the degree of displacement is pivotal in the decision on operative or non-operative treatment. This is reflected in fracture classification systems that have been designed mainly based on location and severity of fracture pattern. If untreated, displaced glenoid fractures may lead to persistent pain, mal-union, development of early glenohumeral (GH) osteoarthritis and chronic shoulder instability. It is therefore of utmost importance to properly diagnose, analyse and treat these fractures.

Over the past few decades there has been controversy about the management of displaced glenoid fractures, involving a significant part of the articulating glenoid. There is little evidence supporting operative treatment of fractures of the glenoid fossa and glenoid neck and there are no randomised studies to support such treatment. Exact data are difficult to find in the published literature, due to heterogeneity and co-morbidities in different studies.[4] In spite of that, many authors advocate surgical treatment for the large displaced intra-articular fractures,[5-9] whereas the more frequent anterior glenoid rim fractures,[2] which may accompany dislocation of the shoulder, have good outcomes with non-operative treatment. Current treatment options for treatment of glenoid fractures include non-operative as well operative treatment. This review summarises the available evidence for a treatment algorithm applicable to different types of glenoid fractures.

Anatomy and biomechanics of the glenoid

The scapula is well protected by an envelope of the rotator cuff tendons and muscles that also provides stability to the GH joint. The GH joint is inherently unstable due to a relative small glenoid joint surface. In a study of the GH relationship, Iannotti et al[10] found that the anteroposterior dimension of the glenoid fossa was pear-shaped or oval, the lower half being larger than the upper half. It was also demonstrated that the radius of curvature of the glenoid, measured in the coronal plane, was on average 2.3 mm greater than that of the humeral head, indicating incongruity in the normal GH joint. This lack of concavity is partially compensated for by articular cartilage. In an anatomical study, Soslowsky et al[11] found that the mean thickness of the articular cartilage of the glenoid was 3.8 mm covering the bony subchondral plate and that congruity was reinforced by a fibrous labrum around the glenoid cavity.

In a biomechanical study, Frich et al[12] proved that the glenoid fossa comprised a relatively thick subchondral bone plate conveying load onto a relatively small amount of cancellous bone. It was also shown that the glenoid was composed of a stronger posterior vault compared with a thinner and steeper anterior vault.

Altogether, the bony architecture of the glenoid provides low conformity and renders the GH prone to dislocation, a tendency that is not fully compensated by cartilage thickness and labrum.

Fig. 1 Fracture involving a significant portion of the anterior glenoid fossa. The fracture type fits several classifications: a) Ideberg type 1b fracture; b) Bigliani type IIIb fracture; or c) AO type 1a fracture.

Epidemiology and aetiology

Glenoid fractures are rare and relatively little is known about their mechanism, fracture pattern and optimal treatment strategies. Scapular fractures account for 1% of all fractures[13] and, according to the literature, the glenoid is involved in up to 20% of all scapular fractures.[5,14,15]

Fractures of the scapula usually occur following high-energy trauma. The fracture mechanism is not always clear but fossa fractures are mostly observed after a direct impact of the humeral head onto the glenoid fossa. The avulsions and rim fractures are strongly associated with anterior shoulder dislocations.

Hovelius et al[16] reported a percentage of approximately 8% of associated anterior glenoid rim fractures, following shoulder dislocation. This injury is also associated with recurrent dislocations, persistent pain, mal-union and early onset osteoarthritis.

A fracture of the scapular neck is the second most common fracture type, which typically occurs due to a direct trauma such as a fall onto the shoulder, or a fall on the outstretched arm.[17] Depending on the severity of the trauma, medial displacement and/or angulation of the entire glenoid body may be seen. In some cases, parts of the glenoid may be displaced leading to extreme incongruity of the glenoid fossa.

Forequarter injuries may lead to severe deformity of the entire shoulder girdle. Ganz and Noesberger were the first to describe the concept of a 'floating shoulder'.[18] In this entity of fractures, the neck fragment is unstable because the suspensory and stabilising functions of the clavicle are lost.[19]

Diagnosis and classification

Authors have attempted to classify glenoid fractures for both prognostic and treatment purposes.[20] It has, however, been claimed that the existing classification systems are purely descriptive with no therapeutic implications. In addition, none of them provides prognostic information on the fractures except that the location and the extent of the glenoid fossa involved in a glenoid fracture are prognostic for GH instability.[21]

Until recently, the most frequently used classification system for this kind of fracture was that of Ideberg, published in 1995.[20] Ideberg's classification system of intra-articular fracture patterns was only developed on the basis of standard radiographs and later modified by other authors, such as Goss[14] and Mayo.[22]

Classifications based on radiographic examination are not very helpful in typing the fracture and in estimating the degree of glenoid fossa displacement. CT scanning has fundamentally changed the assessment of glenoid fractures and has proven to be very useful in diagnosing the extent of injury and the relationship of the humeral head with the main fragment of the glenoid.[1,4]

Additional CT reformations are also useful in evaluating fracture morphology and fracture patterns. Quantitative three-dimensional (3D) analysis is, in particular, useful to evaluate precisely fractures involving the glenoid and the glenoid fossa.

Isolated glenoid fossa fractures were first classified by Bigliani et al in 1998.[23] The authors identified four types, depending on attachment to the capsule and on fragment size. A Bigliani type IIIB fracture involves more than 25% of the glenoid detached from the labrum (Fig. 1). Typical of glenoid rim fractures was separation of the anterior and sometimes part of the inferior glenoid rim. Several modifications of the glenoid fossa fracture classifications, introducing several sub-types, have been proposed over the years. Lately, Bartoníček et al[24] suggested their modified version based on the size of the avulsed fragment, the course of the fracture line and the location of the fragment.

In 2012, the AO Foundation developed a comprehensive classification of scapular fractures with three main groups described based on anatomical parts.[25] The glenoid is one of these parts and includes both extra- and intra-articular fractures. This classification system has been validated by Harvey et al[26] and has been found reliable for plain radiographs and even more reliable when CT is used. The classification has two levels, with the first level

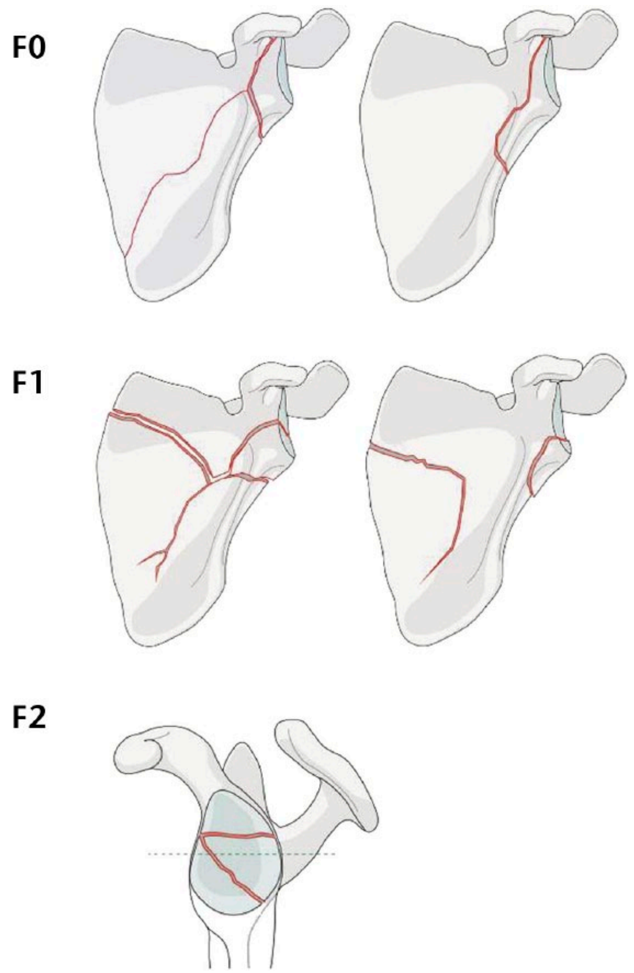

Fig. 2 The AO classification of glenoid fractures is widely used. Three fracture types that involve the glenoid articular segment and fossa are identified. F0 = fracture of the articular segment, not involving the glenoid fossa; F1 = simple glenoid fossa fractures; and F2 = multi-fragmentary glenoid fossa fractures.

describing the basic features of the fracture, which may be extra- or intra-articular, and whether the intra-articular fracture is simple or multi-fragmentary. The classification can be extended to a second level where the intra-articular facture is described according to its location within four quadrants of the glenoid fossa (Fig. 2). This system has also been validated and found reliable, at least for experienced shoulder surgeons.[25]

Typically for the neck fracture,[27] the fracture pattern extends from the suprascapular notch area across the neck to the lateral border of the scapula. Hardegger et al[28] have sub-classified scapular neck fractures into two groups: anatomical and surgical neck fractures. The surgical neck of the scapula is on the medial base of the coracoid process, while the anatomical scapular neck is lateral to the base of the coracoid.

Most classifications of scapular neck factures have focused on the displacement of the glenoid fragment in relationship to the scapular body. The obliquity of the glenoid articular surface in relationship to the scapular body is claimed to influence the prognosis of neck fractures. Medialisation[29] and rotational mal-alignment of the entire glenoid block therefore need special attention.[30]

For the extra-articular fractures, the gleno-polar angle (GPA) is commonly used as a criterion for operative treatment.[31] The GPA is in the range of 36° and 43°[32] and the most common recommendation for operative treatment is a GPA $< 20°$ (Fig. 3),[30] although some controversy still exists on this point. It is, however, evident that GPA measured on 3D reconstruction CT scans is the most accurate and reproducible method to assess these fractures.[33]

The concept of medialisation as movement of the glenoid fragment relative to the scapular body has been disputed by Zuckerman et al.[29] Our own observations on this issue gave reasons to believe that the predominant pattern of fracture displacement also involves lateralisation of the scapular body leading to some degree of scapular shortening (Frich and Larsen, unpublished observations), a theory also supported by Obremskey et al.[34]

Fractures of the glenoid fossa or glenoid neck may be combined or are often the result of complex trauma that affects the shoulder girdle. Therefore, fracture pattern diagnosis is just as important as fracture classification. Complex fracture patterns cannot easily be classified and overlapping definitions of the unstable shoulder girdle will not fit into any classification (Fig. 4). The concept of a 'floating shoulder' always involves scapular neck fractures and attention should be paid to associated fractures of the glenoid, clavicle or disrupted coraco-clavicular and coraco-acromial ligaments.[17,18]

Treatment options

Treatment of glenoid fossa fractures depends on instability, the degree of displacement and the articular surface fragment size. In contrast to fractures of the scapular body, which are mostly treated conservatively, surgery is more often indicated for fractures involving the glenoid fossa.[35-37]

Significant displacement of the glenoid fragments may result in nonunion and poor outcome but the identification and classification of this injury can be difficult, despite modern imaging (CT) techniques. The treatment strategy for the osseous defects that need to be treated is also not clear and most studies assessing shoulder instability concentrate on bone deficits of the glenoid seen in isolation.[38]

Except for anterior fractures, there is little evidence supporting operative treatment for glenoid fractures and late

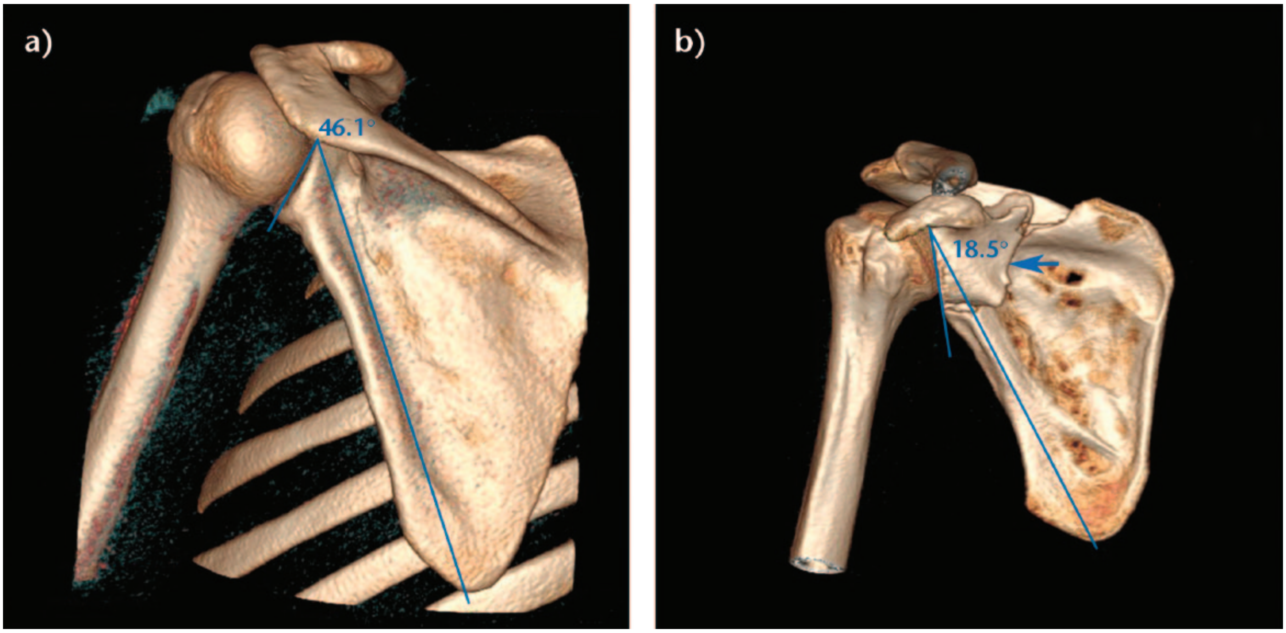

Fig. 3 a) The gleno polar angle (GPA) is normally > 40°, b) GPA is reduced to < 20° due to medialisation and rotation of the glenoid articular segment. The blue arrow marks the fracture through the neck of the glenoid.

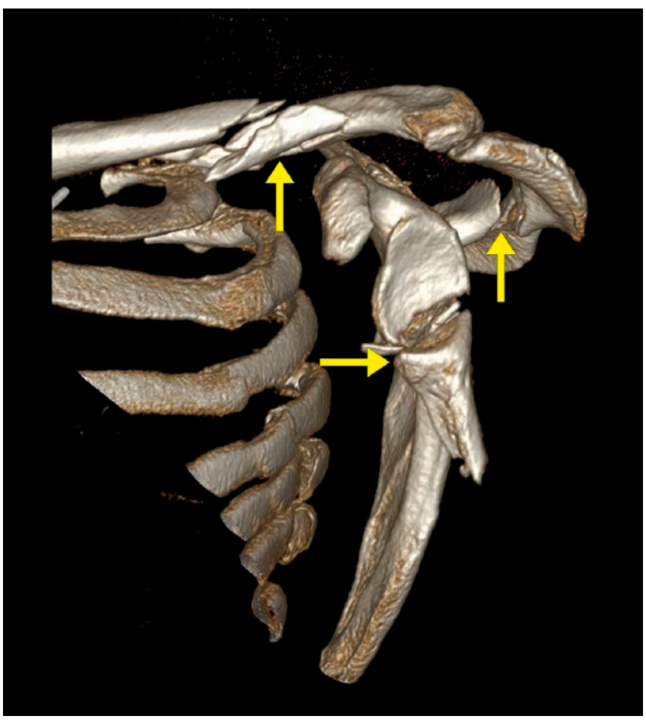

Fig. 4 Complex fracture pattern involving a comminuted and displaced inferior glenoid fracture. Note also fractures of the clavicle and scapular spine (yellow arrows).

instability of the shoulder does not appear to be a significant complication of non-operative treatment of fossa fractures.[2]

Fractures of the glenoid fossa may cause instability depending on the size of the osseous defect. Yamamoto and Itoi[38] identified a critical point for GH stability, at a glenoid defect greater than 21%, in a biomechanical cadaver study.

Traditionally, an anatomical and concentric joint restoration should be the goal of surgical treatment and a prerequisite for the best functional outcome.[39] Maquieira et al,[2] on the other hand, reported that incongruity of the glenoid joint surface was well tolerated. In a paper by Königshausen,[5] a relative indication for surgery was proposed when exposure of the subchondral bone of 5 mm of intra-articular displacement was observed.[22] The authors also suggested that intra-articular displacement of > 10 mm was an absolute indication for surgery. A displacement of 4 mm or 5 mm has subsequently been used as an indication for surgery in several publications.[5]

Definitions for operative indications by millimetres of displacement are neither clearly defined nor validated. This level of indications for surgery has, however, been justified on the basis of the thickness of cartilage being reported to be 3.8 mm on average.[11]

The surgical approach to large fractures of the glenoid fossa is highly influenced by the fracture pattern. The first internal fixation of the glenoid fossa was performed in 1939 and until recently open reduction and internal fixation (ORIF) was the ‘gold standard’ for large glenoid fractures. However, not all glenoid fractures can be sufficiently reduced and stabilised by an open (anterior) approach.[40] The superior approach through the rotator cuff interval or acromial approach may be suitable for treatment of transverse glenoid fractures,[41] whereas neck fractures are often managed through a posterior approach. The modified Judet approach gives access to the entire posterior aspect of the scapular body and can be used for most fractures, but requires a large skin incision and extensive muscular disruption. Many fractures can be sufficiently exposed, reduced and fixed through less invasive incisions indicated by the individual fracture.[42] The introduction of arthroscopically assisted treatment for glenoid fractures has been described for an Ideberg type I pattern, or a fracture of the antero-inferior glenoid.[20] For glenoid fractures involving less than 21% of the articulating area, several arthroscopic procedures using suture anchors or transcutaneous screws have been established in recent years.[3,6,7,43,44] Operative treatment of glenoid fractures may increase in the future due to the increase of assisting arthroscopic fixation possibilities, and subsequent reports have been published on arthroscopic treatment of several Ideberg type fractures. Type III and IV patterns, characterised by a transverse fracture line that separates the upper one-third to one-half of the glenoid fossa and the coracoid from the rest of the scapula, with superior-to-inferior screw fixation, are now routinely treated using this technique.[43] In chronic cases or late sequelae, autologous bone grafting or coracoid transfers are described as viable treatment options to repair large glenoid rim fractures.[45]

The basic treatment principles of scapular neck fractures are that unstable fractures need surgical treatment and stable fractures can be treated conservatively.[5)] The results are generally good or excellent but non-operative treatment of scapular neck fractures with displacement is to some extent connected with subacromial pain and abduction dysfunction.[46]

Authors' preferred technique

If surgical treatment of large glenoid fossa fractures is required, arthroscopic-assisted internal fixation provides the surgeon with an excellent overview of the entire glenoid and the fracture can be set manually under direct visual control. Our preferred techniques for glenoid rim fractures, involving less than 20% of the joint surface, are arthroscopic-assisted re-fixation techniques using suture anchor repair and screws. Large antero-inferior glenoid fragments are stabilised using combined arthroscopic and open techniques. Very displaced extra-articular glenoid neck fractures are treated operatively. We often use an oblique posterior approach, directed by location and pattern of the fracture, using anatomical plates or custom-made plates stabilising the glenoid to the lateral border of the scapular blade.

Surgery is always preceded by meticulous planning using CT. We recommend the use of 3D CT reformations to diagnose correctly the fracture pattern and to quantify displacement and angulation of neck fractures.

The timing of surgery is an important step, which is influenced by concurrent bony lesions or soft tissue lesions. Post-operative rehabilitation starts two weeks after discharge from the hospital with guided passive and active range-of-motion exercises. Strengthening exercises start six weeks post injury. The rehabilitation protocol may vary depending on the length of hospital admission and owing to associated injuries and pathology.

Complications

Complications of operative management of glenoid fractures include infection,[15,28] heterotopic ossification,[47] and infraspinatus nerve palsy or plexus palsy.[22] In a review of 15 studies evaluating surgical treatment of glenoid fossa fractures, Lantry et al[48] found that metalware was often the cause of the complication and had to be removed in 7% of patients. Scheibel et al[8] reported on ten patients who underwent ORIF after traumatic anterior glenoid fractures involving more than 25% of the articulating area. They found a high early complication rate, including one patient with metal loosening and three patients suffering constant pain due to screw impingement. Intra-articular screws always cause damage to the cartilage and necessitate revision surgery.[7]

Non-operative treatment is also connected with complications. In cases of inferior or superior fragments, displacement as well as angulation should be considered for operative treatment to minimise the risk of early post-traumatic osteoarthritis.[14,20,49]

Conclusions

In this review, we have summarised the available evidence on treatment algorithms for different types of glenoid fractures.

The ideal treatment for displaced glenoid fractures is debatable. Based on the literature, the outcome following a glenoid fracture is generally good in non-operative cases as well as after surgery. Glenoid fossa fractures should be carefully evaluated using CT scans and indications for surgery should follow strict guidelines based on meticulous classification and the degree of displacement. Non-operative treatment should always be considered and we believe that a greater intra-articular displacement can be well tolerated, especially in older patients due to their lower functional requirements.

It is also expected that operative treatment may increase in the future due to the increase of arthroscopic fixation possibilities.[14] There are reports of good clinical and radiological outcomes after arthroscopic repair for large fragment and displaced fractures of the glenoid fossa and displaced fractures of the glenoid neck. There is, however, a paucity of evidence relating to outcomes and the reported data are difficult to appreciate, due to heterogeneity and co-morbidities in different studies.

Authors' experience

The authors' experience is based on patients presented to our Level-I trauma centre. Undisplaced or minimally displaced fractures of the glenoid fossa can be treated non-operatively and with good results. Intra-articular displacement of ⩾ 5 mm should be a relative indication for internal fixation. The combination of intra-articular displacement with a fracture gap of ⩾ 5 mm and/or angulation of the fragments within the glenoid fossa should be an indication for surgery due to the increased risk of non-union, mal-union and post-traumatic osteoarthritis. In cases of large displaced fractures and independent of fracture type, arthroscopic-assisted ORIF is recommended. It is, however, clear to us that in addition to the technical equipment, a surgeon requires extensive experience to perform these procedures.

Extra-articular fractures and stable anatomical neck fractures can be treated non-operatively. Operative treatment is used if medialisation is greater than 20 mm or if the GPA is $< 20°$. Gross angular deformity can also indicate surgery.

Fracture pattern diagnosis is just as important as fracture classification. Intra-articular fractures and neck fractures of the glenoid are often part of a larger fracture complex. In particular, high-energy trauma to the shoulder girdle or poly-trauma may inflict a high percentage of associated injuries to the ipsilateral lung, chest wall or thoracic cage, which need attention. One should not focus on the fracture alone and the decision to recommend surgical treatment must also take into account these associated injuries. The treatment of the 'floating shoulder' therefore requires specialist treatment.

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CONFLICT OF INTEREST

None

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