Classification and management of shoulder and elbow trauma
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Link to publication

Citation for published version (APA):

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Chapter 1

General Introduction and Outline of the Thesis
GENERAL INTRODUCTION

Shoulder Trauma

Epidemiology and mechanism of injury

Proximal humerus fractures account for up to ten percent of all fractures and are the third most common fracture in elderly patients after the hip and distal radius(4). The incidence of proximal humerus fractures in the United States is 11-25 per 10,000 per year(6, 51). In elderly individuals, falls are the most common cause of proximal humerus fractures; approximately 87 to 93 percent of fractures occur after a fall from standing height(17, 51). Anterior shoulder dislocations are the most prevalent dislocations with an incidence of 0.8-2.4 per 10,000 persons per year(33). The prevalence, expressed in cumulative incidence, is 0.7% for men, and 0.3% for women up to 70 years of age(24). The highest incidence of anterior shoulder dislocations has been reported in men age 21-30 years and women age 61-80 years(33). An anterior shoulder dislocation is caused by (forced) external rotation and abduction of the arm. In elderly people, it is again mainly caused by a fall on an outstretched hand (FOOSH)(33). In the young, these dislocations are mainly caused by sport injuries.

Classification Systems

Codman defined four anatomic parts (greater tuberosity, lesser tuberosity, articular segment, and diaphysis) of proximal humerus fractures in 1934 and proposed that fracture lines follow the epiphyseal plates(14). Since Codman, other classifications have been proposed(21, 31, 48, 49, 55), such as the one by Hertel. Hertel classified fractures using a binary description system combining the four fragments described by Codman, as well as five basic fracture planes, rendering twelve basic fracture patterns and two additional split head fracture types(31). Though, this classification system is frequently used in Europe, the two most used systems are that of the Arbeitsgemeinschaft fur Osteosynthesefragen (AO)(40) (Fig. 1) and that of Neer(49) (Fig. 2).

The Neer system groups each fracture by the number of fracture segments and describes the fractured anatomic segment as a part, rendering 1-part, 2-part, 3-part, or 4-part fractures. There are 16 different potential types of fracture (Fig. 2). The Neer classification classifies proximal humerus fractures as 2-, 3- or 4-part fractures when the fragment is >1 cm displaced or angulated more than ≥45°. These fractures belong to groups II to VI. Group I includes all proximal humerus fractures with minimal displacement.

The AO classification divides proximal humeral fractures into three groups, A, B and C. Type A are extra-articular unifocal fractures; type B are extra-articular bifocal fractures; and type C fractures are articular fractures. These three groups are subdivided into three subsequent groups according to the degree of fragmentation (Fig. 1).
The Neer and AO-classifications have limited intra- and interobserver reliability (no higher than moderate)\(^7\). Neer indicated that his classification was meant to be applied after operative exposure and felt that radiographs alone would be unreliable\(^50\); however, treatment protocols and scientific experiments rely on accurate and reliable fracture characterization prior to surgery. The addition of two-dimensional (2-D) computed tomography (CT) scans does not seem to improve interobserver reproducibility of these classification systems\(^57\). Foroohar et al. added 3D CT scans in an interobserver study, but found only slight agreement on the Neer classification, as indicated by the kappa measure \((k = 0.069 \text{ to } 0.14)\), and fair agreement on treatment \((k = 0.28 \text{ to } 0.33)\) across all three modalities\(^22\). This agreement is counterintuitive and more research is required to validate these results in a larger interobserver study; preferably one in which observer agreement on other fracture characteristics is also analyzed.

\textit{Figure 1.} The AO-classification of proximal humerus fractures (with credits to the AO Foundation)
These counterintuitive results may be caused by statistical pitfalls such as the kappa paradox; an underappreciated phenomenon of the kappa statistic, causing a lower kappa than one might expect based on absolute percentages of agreement. This paradox is caused by an imbalance in case distribution of a study. An explanation of the kappa paradox to the orthopedic readership is necessary, ensuring proper interpretation of study results. Also it may serve as a guide in designing interobserver studies.
Management of proximal humerus fractures

Most patients with proximal humeral fractures can be treated nonoperatively\(^{(17, 49)}\). Especially in older, less active or infirm patients\(^{(3, 8-11, 23, 25-28, 39)}\). Good functional outcome has been described for (AO, Hertel, Neer) 2, 3 and 4-part fractures that still have cortical contact with the shaft and are not severely angulated\(^{(16, 18)}\).

When nonoperative treatment is elected, exercises to regain functional range of motion are part of the rehabilitation trajectory. Some data suggests that better function is obtained with immediate initiation of shoulder exercises\(^{(28, 29, 40, 41)}\). However, this might be unnecessary and even contribute to nonunion of the fracture. Others have shown similar functional outcomes when rehabilitation begins approximately a month after injury, or when radiographs show signs of bone healing, and this delay is associated with lower rates of nonunion and malunion occurrence. Level 1 evidence is lacking in support of either of the options.

Management of anterior shoulder dislocations

The current Dutch guideline for treatment of anterior shoulder dislocations aims towards nonoperative treatment by short-term immobilization of the shoulder. The CBO-guideline advises immobilization during 2-4 weeks in a sling, after which exercises should commence. However; active young adults are known to have up to a 90% increased risk of recurrent dislocation after the nonoperative treatment of a primary shoulder dislocation. Evidence from the literature suggests that shoulder stabilization surgery--either open or arthroscopic--reduces the risk of recurrence and improves the functional outcome over the long term in young active first time dislocaters. A recently published randomized trial reported a significantly higher recurrence rate after arthroscopic stabilization surgery, but no difference in functional outcome between an arthroscopic or open approach\(^{(63)}\). The choice of operative technique should therefore be dependent on the preference of the patient and the experience of the surgeon. It is our impression that orthopaedic and trauma surgeons in the Netherlands do not follow evidence-based practice and adhere to the CBO guideline, which was published in 2005. A Dutch overview of the current evidence is needed to give an incentive to change the current guideline.

Elbow Trauma

Epidemiology and mechanism of injury

Radial head fractures account for 1.7–5.4% of all fractures in adults and account for one-third of all fractures around the elbow\(^{(43, 46)}\). The incidence in the general population is 2.5-3.9 per 10,000 persons per year\(^{(20, 36, 37)}\). The most common mechanism of injury leading to radial head fractures is an axial load of the radius on the capitellum, most frequently caused by a fall onto an outstretched hand. Sport injuries, fall from heights and other high-energy traumas often cause more severe fracture patterns, in which case radial head fractures may also be part of a more complex injury due to its intricate relation with other structures in the elbow; such as an Essex-Lopresti fracture (fracture of the radial head with concomitant dislocation of the distal radio-ulnar joint with disruption of the
interosseous membrane) or as part of an elbow dislocation. However, even a fall from standing height can cause a fracture-dislocation or complex proximal ulna fracture.

Elbow dislocations constitute 10-25% of all injuries to the elbow and are second to dislocations of the shoulder among injuries to the upper extremity\(^{43}\). The incidence is 5.2% per 100,000\(^{58}\). Elbow dislocations occur more often in males and adults with a mean age of 30.

Patients diagnosed with a posterior elbow dislocation often state having fallen on their outstretched hand, in which the radius and ulna are both dislocated in a posterolateral direction. These forces therefore may contribute to associated fractures such as coronoid and radial head fractures as well as ligamentous injury. The coronoid process acts as an important elbow stabilizer; it counteracts axial, varus and posterior rotatory forces by acting as a buttress\(^{44}\). The radial head acts as a stabilizer in resisting valgus stress and posterolateral forces targeting the elbow\(^{47, 54}\). Dislocation of the elbow may result in the combination of a radial head fracture and a coronoid fracture in a combination termed the “the terrible triad” due to a high rate of complications. In a case series, Ring et al.\(^{52}\) reported unsatisfactory results of treatment in seven of eleven patients with these injury patterns due to repeat dislocation, subluxation, and arthrosis.

**Classification**

In 1907, T. Turner Thomas reported that it was Berard who discovered the first reported case of a radial head fracture at an autopsy in 1834\(^{61}\). Since then we have gradually developed a better understanding of radial head fractures and have attempted to classify them to our best abilities.

The first known classification system was that of Cutler in 1926, who divided radial head fractures into three classes\(^{19}\). In Cutler's classification system, Class 1 fractures consisted of a simple crack in the head of the radius; in Class 2 fractures there was separation of one fragment of the radial head; and Class 3 were fractures with two or more pieces (table 1). A fourth class also existed in Cutler’s classification, describing radial neck fractures. Nowadays, fractures of the radial head are commonly classified according to the classification by Mason\(^{43}\) as modified by Broberg and Morrey\(^{13}\). Nondisplaced or minimally displaced fractures are classified as type 1 fracture. Fractures with an articular step-off of more than 2 mm that comprise more than 1/3 of the articular surface are defined as type 2 fractures. Type 3 fractures are displaced whole head fractures (Table 1). Johnston wrote about a fourth type to denote a fracture of the radial head with associated dislocation in 1962\(^{34}\), which Broberg and Morrey use as a fourth type in their modification of Mason’s classification scheme. In another attempt to link treatment of radial head fractures to classification, Hotchkiss\(^{32}\) modified the Mason classification (Table 1), by suggesting that the presence of a mechanical block preventing movement qualifies a radial head fracture as type 2.
Table 1. Classification schemes for radial head fractures and their fracture characteristics

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fracture characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutler *1926</td>
<td></td>
</tr>
<tr>
<td>Class I</td>
<td>Crack in the radial head</td>
</tr>
<tr>
<td>Class II</td>
<td>Separation of one fragment</td>
</tr>
<tr>
<td>Class III</td>
<td>Fragmentation</td>
</tr>
<tr>
<td>Mason *1954</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Non-displaced fracture</td>
</tr>
<tr>
<td>II</td>
<td>Displaced partial head fracture</td>
</tr>
<tr>
<td>III</td>
<td>Displaced entire head fracture</td>
</tr>
<tr>
<td>Johnston *1962</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Non-displaced fracture</td>
</tr>
<tr>
<td>II</td>
<td>Displaced partial head fracture</td>
</tr>
<tr>
<td>III</td>
<td>Displaced entire head fracture</td>
</tr>
<tr>
<td>IV</td>
<td>Fracture as part of an elbow dislocation</td>
</tr>
<tr>
<td>Broberg and Morrey *1987</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>&lt; 2mm displaced fracture</td>
</tr>
<tr>
<td>II</td>
<td>≥ 2mm displaced fracture and ≥30% of the articular surface</td>
</tr>
<tr>
<td>III</td>
<td>Comminuted Fracture</td>
</tr>
<tr>
<td>IV</td>
<td>Fracture-dislocations about the elbow that are associated with radial head fractures</td>
</tr>
<tr>
<td>Hotchkiss *1997</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Non or marginally displaced fracture without block to forearm motion</td>
</tr>
<tr>
<td>II</td>
<td>Displaced fracture suited for open reduction and internal fixation</td>
</tr>
<tr>
<td>III</td>
<td>Displaced fracture not suited for open reduction and internal fixation</td>
</tr>
</tbody>
</table>

Management

Up until recently, the Mason classification has guided treatment (15, 59, 60). Mason type 1 fractures are usually treated nonoperatively with good or excellent results in most patients. Residual stiffness is a problem in a few, and early mobilization (<48 hours) is encouraged to minimize elbow stiffness. For Mason type 2 fractures, the choice of treatment is subject to discussion, partially due to the absence of level 1 evidence. Previously, these fractures were treated nonoperatively; if treatment failed, radial head excision would be performed. Nowadays, the tendency lies towards open reduction and internal fixation of isolated displaced partial articular radial head fractures because this treatment leads to less pain and better range of motion ROM and functional outcome scores. (62). Mason type 3 fractures are displaced whole radial head fractures (43) and are most commonly treated operatively. There is an ongoing debate about when the radial head should be partially or fully excised, should be repaired with plate and screws, or replaced with a prosthesis (1, 12, 30).
Management is influenced more by the displacement and instability of fracture fragments than by involvement of part or all of the head. Radiocapitellar contact is an important element of forearm and elbow stability and unstable displaced fractures of the radial head do not provide the needed support. Radiographic signs associated with radial head fracture instability, such as loss of contact, should be tested for interobserver agreement, as these unstable fractures are associated with concomitant fracture or dislocation. If this finding has adequate interobserver reliability, it could help examiners identify and treat associated ligament injuries and fractures, because when ligamentous injuries are present, restoration of radiocapitellar contact is essential[2, 5, 13, 38]. Elbows that are unstable after injury or reconstructive surgery as seen on radiographs often are stabilized using external fixation or cross-pinning of the joint supplemented by cast immobilization. The superiority of one approach or the other remains a matter of debate.

OUTLINE OF THE THESIS

This thesis addresses several issues in the classification and management of shoulder and elbow trauma, which have been described in the introduction. It is subdivided into three parts:

**Part one** consists of this introduction (Chapter 1) on the classification and management of shoulder and elbow trauma. Chapter 2 aims to answer the question why interobserver studies in the orthopedic literature have relatively low kappas but high interobserver agreement. This chapter sheds a light on an important statistical pitfall associated with other interobserver studies later on in this thesis.

**Part two** focuses on shoulder trauma classification and management, particularly of proximal humerus fractures and anterior shoulder dislocations. Chapter 3 aims to test the interobserver variability of the AO and Neer classification, but also of proximal humerus fracture characteristics, such as displacement of the greater tuberosity and anterior primary shoulder dislocations, in a large interobserver study. Chapter 4 discusses different treatment options for primary shoulder dislocations, primarily focusing on the role of operative treatment; comparing open with arthroscopic techniques. Chapter 5 describes a randomized controlled trial comparing functional outcome in early versus late exercises in patients with a nonoperatively treated proximal humerus fractures.

**Part three** of this thesis focuses on the elbow, particularly radial head fractures and elbow instability. Chapter 6 compares external fixation with cross-pinning in terms of adverse events and Broberg and Morrey Scores in elbows that are unstable after injury or reconstructive surgery. Both patients with simple elbow dislocations as well as fracture dislocations were included in this study. Chapter 7 and 8 discuss management of radial head fractures. Chapter 7 is a variability study analyzing the characteristics of radial head fractures, aiming to isolate one that would define stability. Chapter 8 is a protocol of a randomized controlled multicenter international trial comparing two known treatment methods for stable, partial articular radial head fractures; nonoperative treatment versus open reduction and internal fixation.

Finally, Chapter 9 provides an overall summary and conclusions based on the results of the data presented in the studies in this thesis.
REFERENCE LIST


