Diplomarbeit

The prevalence of secondary complications in proximal humeral fractures after conservative and surgical management in elderly patients

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Statutory Declaration

I hereby declare that this thesis is my own original work and that I have fully acknowledged by name all of those individuals and organizations that have contributed to the research for this thesis. Due acknowledgement has been made in the text to all other material used. Throughout this thesis and in all related publications I followed the "Guidelines of the Medical University of Graz on Good Scientific Practice".

Graz, 10.04.2020 *Puja Jafarpour eh.*

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List of abbreviations

3D	Three-Dimensional
ANOVA	Analysis of Variance
AO	Arbeitsgemeinschaft für Osteosynthesefragen
AP	Anterior-Posterior
AVN	Avascular Necrosis
CI	Confidence Interval
CM	Centimeter
CRPS	Complex Regional Pain Syndrome
CT	Computed Tomography
DOI	Date of Injury
FX	Fracture
GA	General Anesthesia
HA	Hemiarthroplasty
HH	Humeral Head Height
HHD	Humeral Head Dislocation
HO	Heterotopic Ossification
IMI	Institute for Medical Informatics, Statistics and Documentation of the Medical University Graz
IMN	Intramedullary Nail
IQR	Interquartile Range
MHH	Hannover Medical School
MM	Millimeter
MRI	Magnetic Resonance Imaging
N	Number
OR	Odds Ratio
ORIF	Open Reduction Internal Fixation

OTA	Orthopaedic Trauma Association
PCC	Pearson Correlation Coefficient
PCHA	Posterior Circumflex Humeral Artery
PHF	Proximal Humeral Fracture
PP	Pressure Pain
RD	Risk Difference
ROM	Range of Motion
RR	Risk Ratio
RSA	Reverse Shoulder Arthroplasty
SD	Standard Deviation
SE	Standard Error
SICOT	International Society of Orthopaedic Surgery and Traumatology
YRS	Years

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Zusammenfassung

Einleitung

Die Inzidenz von proximalen Humerusfrakturen steigt fortlaufend. Gleichzeitig machen diese beinahe 5% aller Frakturen aus. Ungefähr 80% aller proximalen Humerusfrakturen treten bei Patient_innen über 60 Jahren auf, während Frauen zwei bis dreimal häufiger betroffen sind als Männer. Dabei sind 80% aller proximalen Humerusfrakturen entweder leicht oder nicht disloziert. Simultan steigt sowohl die Zahl der Komorbiditäten als auch die Komplikationsrate. Das Ziel dieser Studie ist es, die Prävalenz sekundärer Komplikationen, inklusive ungeplanter Operationen bei Patient_innen mit einer proximalen Humerusfraktur abhängig von der Behandlungsmethode (operativ vs. konservativ) zu untersuchen.

Material und Methoden

Eine retrospektive Kohortenstudie wurde an einem überregionalem Traumazentrum durchgeführt. Die Studie schließt insgesamt 156 ältere Patient_innen (mittleres Alter 77 ± 8.9 Jahre; 75% weiblich) innerhalb von zwei Jahren mit proximalen Humerusfrakturen [AO: A (54,5%), B (23.7%), C (21.8%)] ein, welche entweder eine operative (n = 28) oder konservative Behandlung (n = 128) erhielten. Das primäre Ziel der Studie war es die Anzahl an sekundären Komplikationen und ungeplanten Operationen zu ermitteln. Das sekundäre Ziel der Studie war es eine mögliche Assoziation mit demographischen, frakturtypischen und behandlungsspezifischen Faktoren zu ermitteln.

Ergebnisse

Insgesamt wurden 36 sekundäre Komplikationen (23.1%) und acht ungeplante Operationen (5.1%) erfasst. Es gab keinen signifikanten Unterschied in der Verteilung der Prävalenz der sekundären Komplikationen bezogen auf die erfolgte Behandlung [operativ (n = 5; 18%) vs. konservativ (n = 31; 24%); p = 0.620]. Wir stellten eine unabhängige, relative Risikoerhöhung für Komplikationen bei Patient_innen mit Osteoporose [OR 2.119; 95% KI 0.958 – 4.687; p = 0.064] sowie eine relative Risikoreduktion für ungeplante Operationen bei älteren Patient_innen [OR 0.885; 95% KI 0.788 – 0.993; p = 0.037] fest.

Fazit

Innerhalb der operativen Gruppe gab es eine nahezu gleiche Prävalenz an sekundären Komplikationen, verglichen mit der konservativen Gruppe. Eine vorbekannte Osteoporose ist tendenziell mit dem Auftreten einer sekundären Komplikation assoziiert. Vor allem jüngere Patient_innen, die eine sekundäre Komplikation erleiden, werden mittels chirurgischer Maßnahmen behandelt.

Abstract

Introduction

The incidence of proximal humeral fractures (PHF) is rising constantly; with PHF representing almost 5% of all fractures. About 80% of the PHF occur in patients with an age above 60 years and women are affected two to three times more often than men. Although 80% of the fractures are either slightly dislocated or not dislocated. Our aim was to investigate the prevalence of secondary complications and unplanned surgeries in patients with PHF with regards to the treatment method (operative vs. non-operative) and comorbidities.

Material and Methods

A retrospective cohort study was performed at level I trauma center. The study included 156 elderly patients (mean age 77 ± 8.9 years; 75% female) with PHF [AO: A (54,5%), B (23.7%), C (21.8%)] during a 2-year period, who received either surgical (n = 28) or conservative treatment (n = 128) during a 2-year period. The primary outcome was the prevalence of secondary complications and unplanned surgeries. Secondary outcome included the association with demographic-, fracture-type-associated, or treatment-specific variables.

Results

A total of 36 secondary complications (23.1%) and eight unplanned surgeries (5.1%) were accounted. There was no significant difference in the distribution of secondary complications with regard to the chosen treatment [operative (n = 5; 18%) vs. non-operative (n = 31; 24%); p = 0.620]. We noted an independent tendential risk-increase for complications in patients with osteoporosis [OR 2.119; 95% CI 0.958 – 4.687; p = 0.064] and a relative risk-reduction of unplanned surgeries in elderly patients [OR 0.885; 95% CI 0.788 – 0.993; p = 0.037].

Conclusion

The operative group yielded similar prevalence of secondary complication rates compared to the non-operative group. While osteoporosis increases the prevalence of secondary complications, complications in younger patients are more often treated by surgical procedures.

1 Introduction

Orthopedics, is derived from the Ancient Greek words *orthos* “correct, straight” and *paidion* “child” [68]. Nicolas Andry, a French physician and the inventor of the word “orthopaedics”, published his famous book “L’orthopedie” in 1741 [37]. This laid the foundation for this essential specialty within medicine. A lot has changed since then, and so orthopedic surgeons treat a wide range of conditions concerning the musculoskeletal system today; both surgical and non-surgical. Nowadays, especially elderly patients suffer from the consequences of chronic and traumatic musculoskeletal conditions, which are the leading cause of disability worldwide [69]. Common risk factors such as osteoporosis in addition to increased demographic trends towards an aging population lead more often to proximal humeral fractures (PHF). Comorbidities and advanced ages might increase further “secondary” complications after usual treatment methods as well. This thesis will investigate the prevalence of secondary complications and unplanned surgeries in fractures of the proximal humerus regarding the treatment method (operative or non-operative) and comorbidities in patients above 60 years of age.

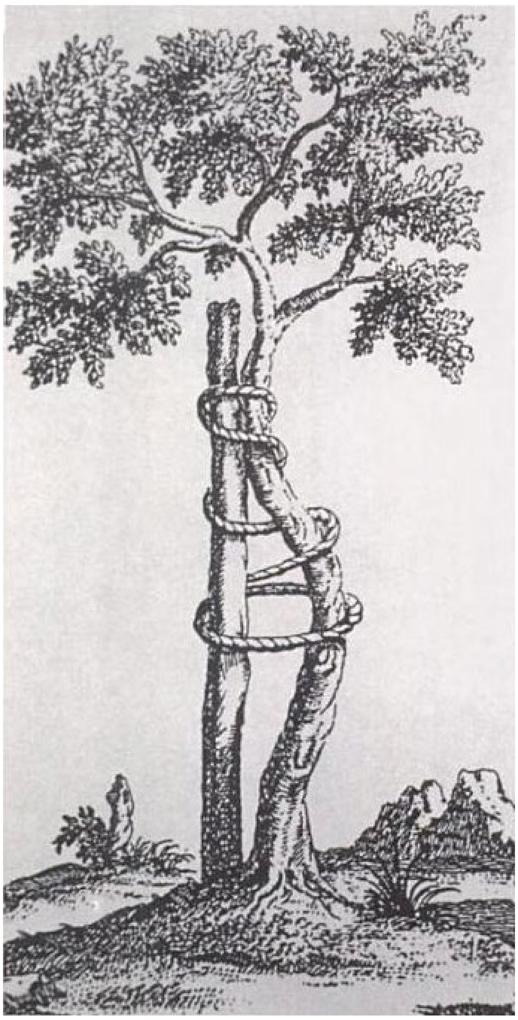

Figure 1: The crooked tree – “Orthopaedia or the art of correcting and preventing deformities in children” [68].

2 Background

2.1 Anatomy

The glenohumeral joint is a polyaxial diarthrosis composed of two bones - the humerus and the scapula. The slight articulating surface on one side and several muscles and soft tissues surrounding the shoulder joint on the other side, make the glenohumeral joint the most movable joint in the human body [58].

2.1.1 Bones and articular surfaces

The humerus is a long bone divided into three parts, the corpus humeri and the proximal and distal epiphyses. The humeral head, anatomical neck, as well as the greater tuberosity and lesser tuberosity form the proximal end of the humerus [20]. The proximal part of the humerus is twisted compared to the distal end. The humeral torsion angle in adults is 16° [55]. The humeral head articulates with the glenoid fossa of the scapula. The surface area of the glenoid concavity covers only about 1/4 of the humeral convexity. This makes the shoulder joint exceptionally mobile. For the same reason, the glenohumeral joint needs various stabilizing mechanisms like the rotator cuff muscles, various ligaments, and of course the fibrous capsule, in order to strengthen the joint [58].

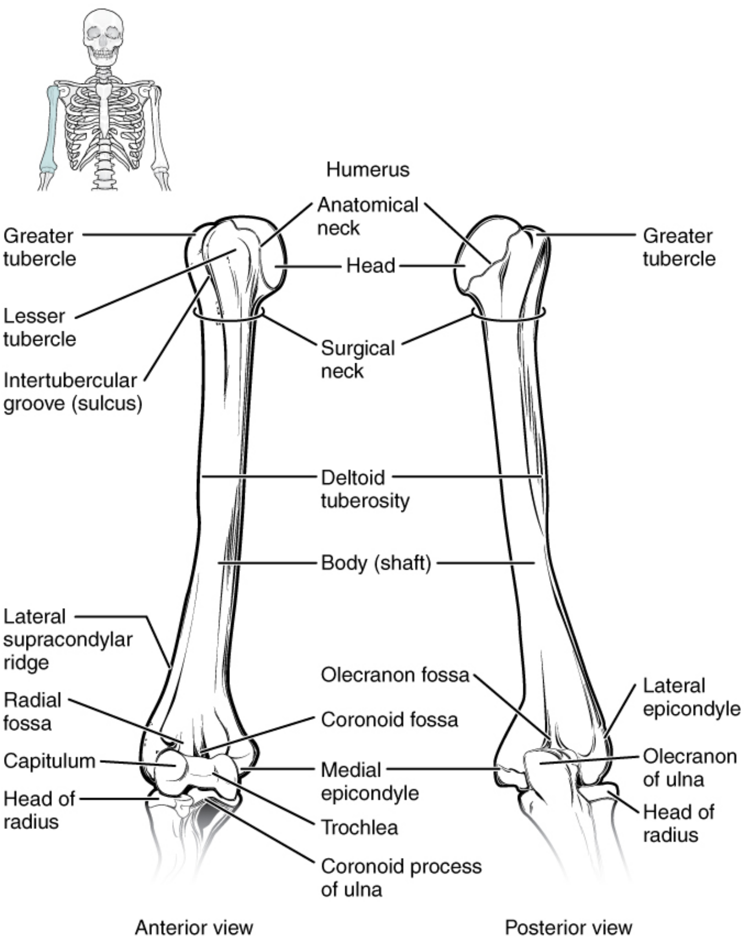

Figure 2: Right humerus: anterior and posterior aspects.
Photo by OpenStax College – Anatomy & Physiology, Connexions Web site – CC-BY-3.0

2.1.2 Ligaments, Cartilages, and Capsule

There are multiple ligaments, with different functions. The acromioclavicular ligament is divided into two parts: the superior and inferior, which strengthen the joint capsule. The coracoclavicular ligament is divided into two parts too: the conoid- and the trapezoid ligament. Both of them limit the clavicle and scapula from moving apart. The coracoacromial ligament prevents the humeral head from upward movement when the arm is outstretched. Together with the acromion and the coracoid process, it builds the fornix humeri. For having its wide range of motion (ROM), the glenohumeral joint requires a slack and spacious articular capsule. A slack and spacious joint capsule can be guaranteed with the axillary recess, which builds a one-centimeter (cm) deep pocket. The coracohumeral ligament is loose at internal rotation and anteversion. The glenohumeral ligaments (inferior, middle, and superior) prevent the capsular fibers from being stuck and stabilize the capsule-labral complex. The glenoid labrum is a triangular shaped fibrocartilage which extends the articular surface. With this, the glenoid labrum optimizes the stability of the glenohumeral joint, especially to anterior [1, 58].

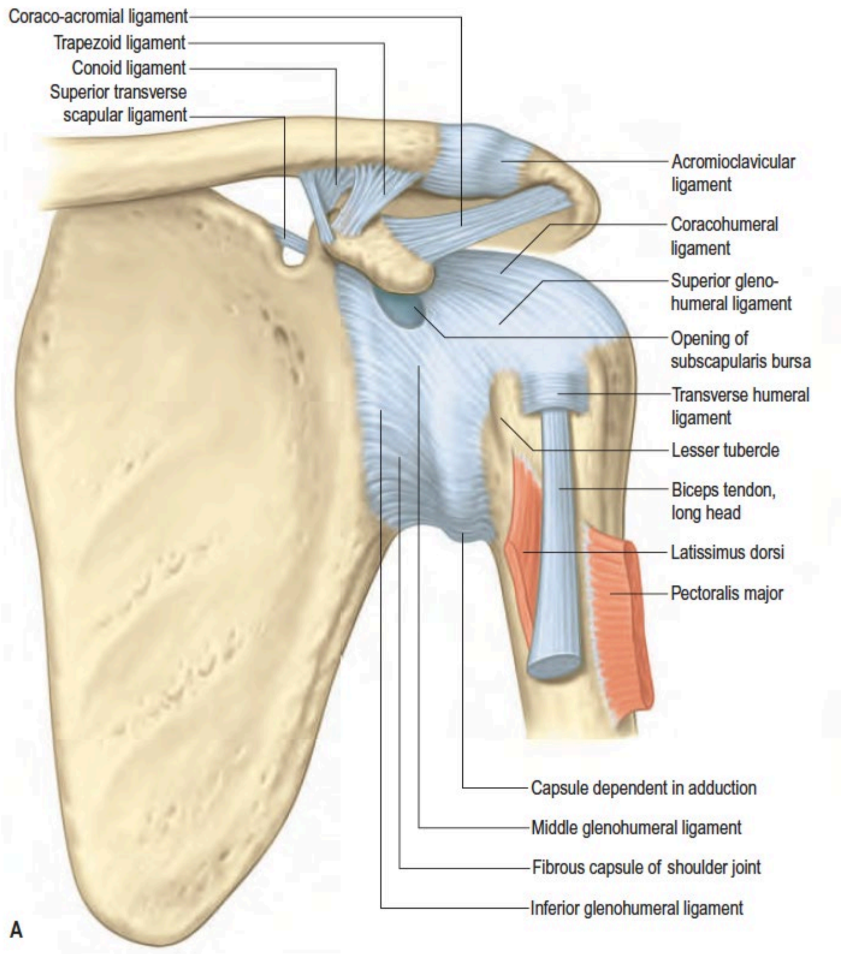

Figure 3: The ligaments associated with the left shoulder, anterior aspect [58].

2.1.3 Vascular supply and Innervation

The humeral head and the glenohumeral joint are supplied by the anterior circumflex humeral artery, coming from the axillary artery. The larger posterior circumflex humeral artery (PCHA), which is also a descending branch from the axillary artery, curves around the humeral neck. Among other things, the PCHA is responsible for the supply of the surgical neck and the shoulder joint capsule. Below the teres major muscle tendon, the axillary artery turns into the brachial artery. This artery supplies the humeral shaft and distal humeral epiphysis on the basis of profound branches, several anastomoses, and nutrient arteries [58].

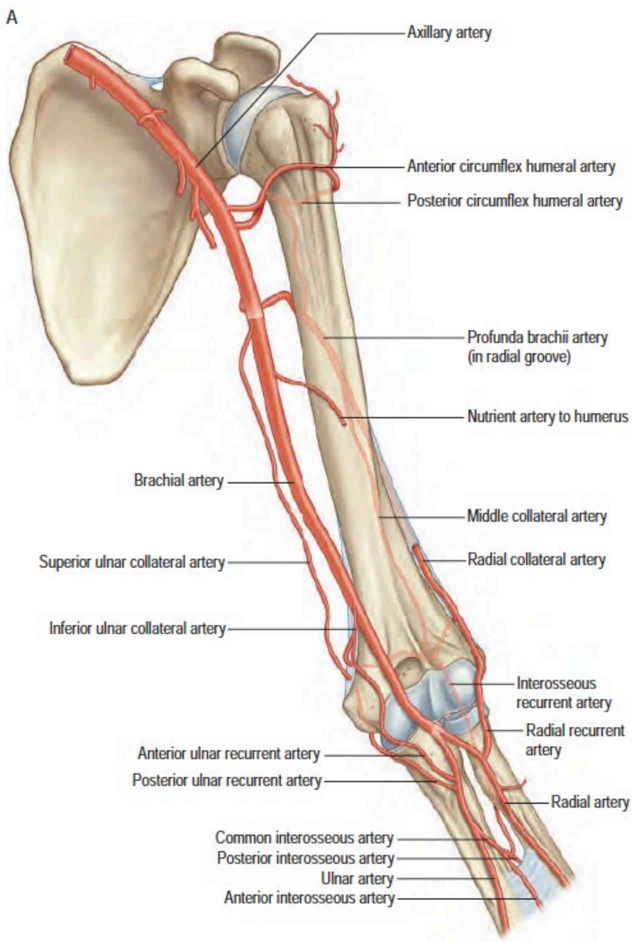

Figure 4: The vascular supply of right humerus, dorsal aspect [58].

The axillary nerve arises from the posterior cord of the brachial plexus (C5, 6), which is located dorsal of the axillary artery. With that, the nerve is deeply seated. The axillary nerve innervates the deltoid and teres minor muscles. Beyond that, it gives a branch to the shoulder joint and some small cutaneous branches, that reach until the lower skin part above the deltoid area. As a result of its deep location, it is truly difficult to detect hypoesthesia via Tinel's sign in early lesions of the axillary nerve in case of a rupture [58].

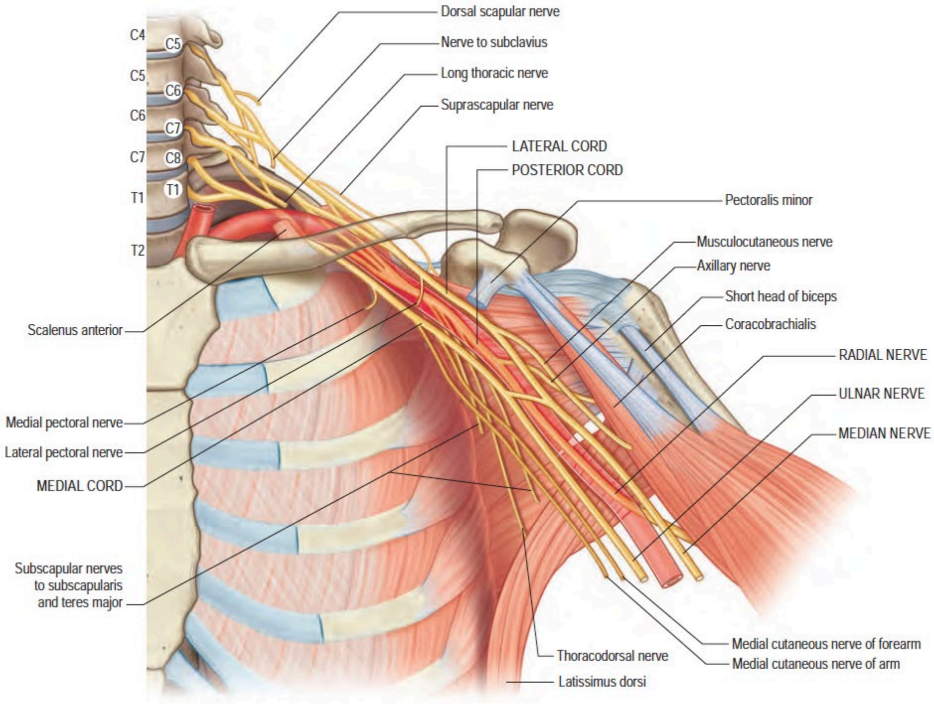

Figure 5: The innervation of the left shoulder, anterior aspect [58].

2.2 Epidemiology

The incidence of PHF is rising constantly, caused by the age shift and increased average age. Simultaneously, the comorbidity and with that, the complication rate are increasing [42]. PHF represent almost 5% of all fractures. It is the third most frequent fracture after hip fractures and distal radial fractures [14, 45]. Together with the proximal femur-, distal radius- and vertebral body fractures, PHF are one of the most common fractures in osteoporotic bones. Within the last 30 years the incidence of PHF has tripled to 105 per 100.000 persons per year. Women are two to three times more often affected than men [6]. About 80% of the PHF occur in patients with an age above 60 years. Thereby, 80% of the fractures are either slightly-dislocated or not dislocated [40]. Whereas, the other 20% of the PHF show either a displacement more than 10 millimeters (mm) or a tilting more than 45° of the head-neck complex. These 20% often require surgical treatment [31, 62].

2.3 Risk factors

Most of the PHF are induced by osteoporosis, which leads to a higher morbidity in the elderly patients. Especially women older than 70 years suffer from a significant decrease in bone mineral density. Alcohol consumption over a long period, long-time cortisol therapy, and hypogonadism facilitate PHF, even in younger patients [42, 63].

2.4 Pathomechanism

A typical reason for PHF in elderly patients is falling on the stretched arm from standing height or even lower [43, 50]. The falling direction is often oblique ahead. Elderly patients commonly do not need a considerable trauma for fractures, since osteoporosis plays a major role for them. Severe traumatic injuries, which have a huge force effect, cause PHF also in younger patients and children. This often comes with dislocation, soft tissue defects, and fractures as a part of polytrauma [42]. The fracture type is determined by bone quality, fall mechanism and energy plus absorption by the surrounding soft tissue [17]. Fractures are distinguished between compression, shear, tension, rotation and bending breaks [65]. Falling on the outstretched arm can cause a bending fracture in the area of the surgical neck. This leads to consecutive medial shaft dislocation through the acting traction of the internal rotators (pectoralis major, teres major, and latissimus dorsi muscles) [30]. If the arm is abducted, exaggerated rotation can cause humeral head fractures. This occurs especially in osteoporotic bones, when the humeral head strikes against the acromion. A direct impact on a fixed scapula leads to compression fractures, while the humeral head pushes against the glenoid [22, 30]. Avulsion fractures of humeral tuberosities occur as a result of humeral head dislocation, which are typical shear fractures. This is often seen after direct trauma, especially in younger patients e. g. after seizures. The rather rare humeral fractures of the anatomical neck are induced by acting shear forces [42].

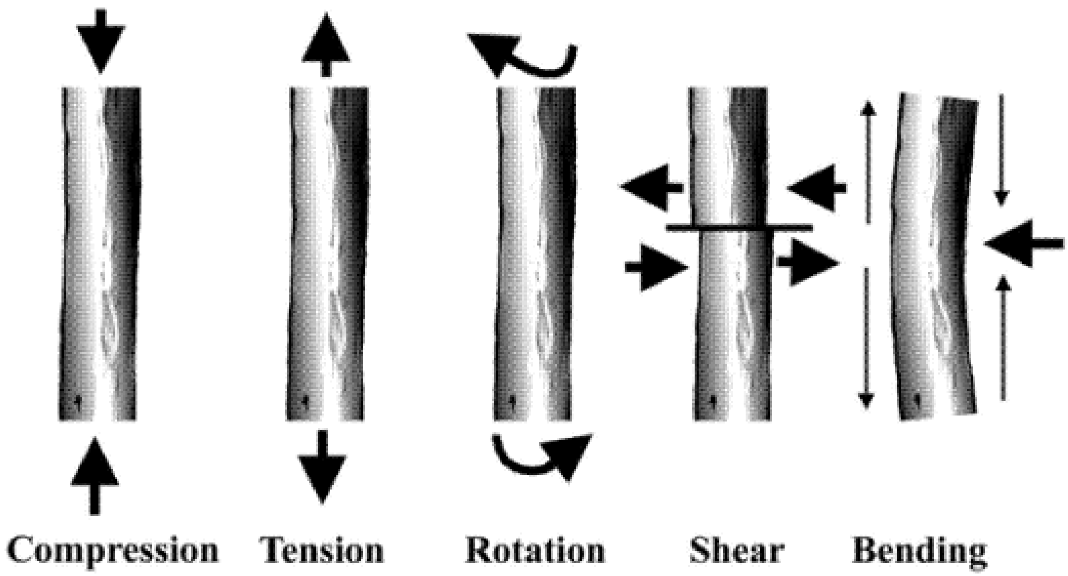

Figure 6: The types of forces acting upon bones [65].

2.5 Fracture morphology

The ideal function of the glenohumeral joint is dependent on an anatomical and correct axial alignment. As such, it is important to know the anatomy and topography of the shoulder joint, in order to treat PHF successfully. Even small displacements or few changes of the anatomical position can lead to functional deficiency [42]. For a correct axial restoration of humeral head fragments, it is inevitable to know the retroversion angle of the humeral head, which varies between 25 – 35° [16].

PHF are divided into fragments of the head, shaft, greater tuberosity, and lesser tuberosity. The differentiation between fractures of the anatomical neck and the surgical neck is prognostically significant. The anatomical neck lies proximal of the tuberosities and separates the head from the shaft. The surgical neck is located distal of the tuberosities, just at the transition to the shaft area. Although fractures of the anatomical neck are uncommon, they have a high risk for ruptures of the vascular supply. Therefore, a high risk for aseptic bone necrosis is given [42]. Whereas, fractures of the surgical neck, which account nearly half of all PHF, have still often a sufficient head perfusion and so a better prognosis [43].

Fractures of the surgical neck also lead to shaft dislocation towards anteromedial. This happens as a result of the tractive force on the crest of the greater tuberosity by the pectoralis major muscle. Avulsion fractures of the greater tuberosity cause a dislocation of the tuberosity fragment towards dorsocranial due to muscle traction. After multi-fragmentary fractures, the loss of one "muscle group" can lead to imbalanced acting forces, which affect the humeral head. This can also cause a total dislocation of all humeral head fragments. With the avulsion of the greater tuberosity and the remained lesser tuberosity, the subscapular muscle, which inserts there, causes an internal rotation position of the humeral head [42]. Head-Split fractures occur as a direct consequence of central impact with a squeezing of fragments and cartilage to anterior and posterior. This leads to a fragmentation of the articular surface into many separated pieces [10]. Fracture-dislocations are divided into anterior and posterior dislocations. The anterior fracture-dislocation represents about 95% of all dislocation of the shoulder. This is often caused by excessive forces in external rotation or abduction within the scope of sports or traffic accident. The posterior fracture-dislocation constitutes about 5% of all dislocated shoulders, which are caused by epileptic seizure (60%) and other events e. g. electrical accidents and other seizure disorders (often induced by hypoglycemia or alcohol) [42].

2.6 Fracture classification

The classification of fractures is essential not only for the diagnosis, but also for the treatment program and appraisal of the estimated prognosis [42]. Already in 1896, Kocher described a fracture classification on the basis of clinical observation. This was the first time, that a pattern for describing PHF was developed, even before the implementation of X-ray. He has distinguished between three anatomical regions: the surgical and anatomical head as well as the tuberosities. But there was no distinction of dislocated and non-dislocated fractures or multi-fragmentary fractures [36].

In 1934, Codman drafted a classification based on the four main fragments, the head, the shaft, and the greater and lesser tuberosities [12]. Simultaneously, he discerned the importance of the soft tissue surrounding for the fracture cohesion. These findings set the basis for the fracture classification described and modified by Neer in 1970 [10]. Neer's modification results in an association of the dislocation type and the treatment method plus prognosis. The classification is segmented into minimal displacement and displaced fractures or by two to four fracture segments [10, 42]. This structure is till now, the most used classification in PHF. Correct usage requires fundamental anatomical knowledge. This implicates the exact recognition of the bony fragments in the X-ray, as well as the effect of the inserting tendons in fracture-dislocation [42]. A segment is considered as dislocated, when it is displaced more than 1 cm or 45° angulation as well as tuberosity dislocation about 5 mm or more [8, 42]. According to Neer, the risk of developing an avascular necrosis (AVN) is increased by a higher number of dislocated segments and thus a worse prognosis [47].

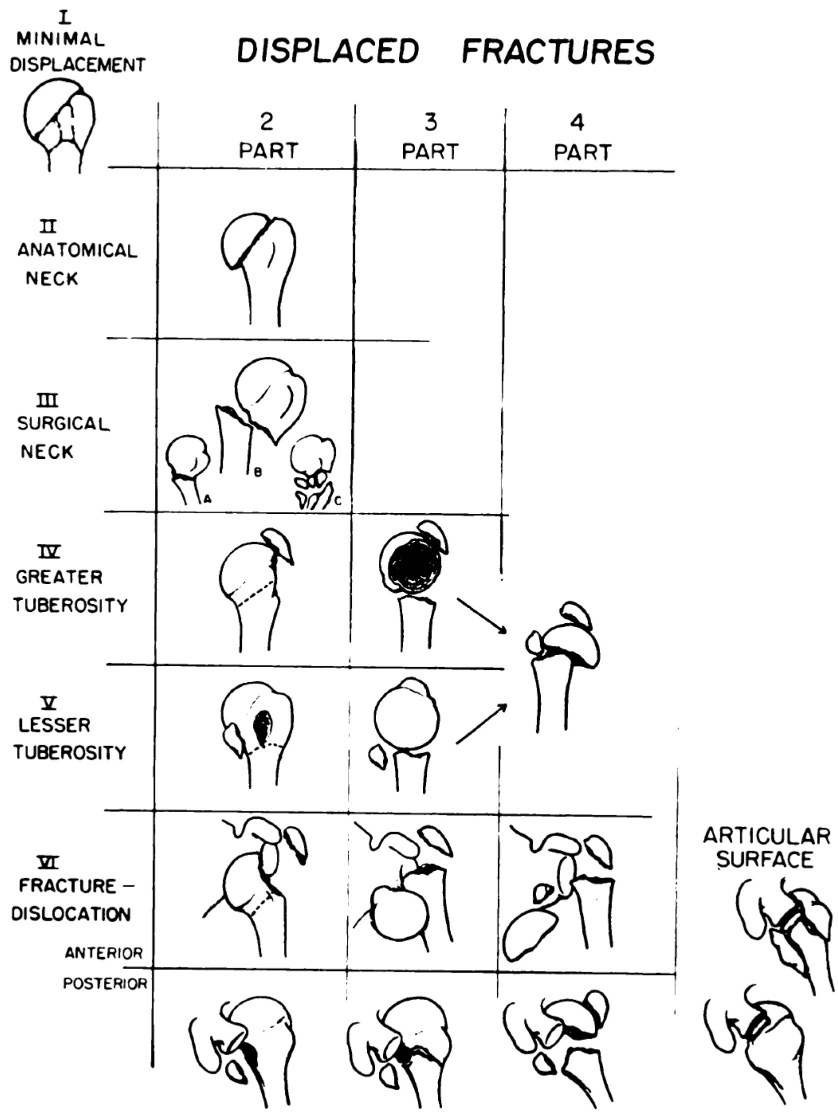

Figure 7: Displaced proximal humeral fractures - Neer classification [10].

The AO-/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/ Orthopaedic Trauma Association) classification, originally initiated by Mueller M. and later recommended by the International Society of Orthopaedic Surgery and Traumatology (SICOT) in 1984, corresponded to the ABC classification. This classification has been modified in 1990 and was widely taken up for classifying also other extremity parts [29, 57, 60, 66]. This scheme consists of three alphanumeric groups: A, B, and C. Type A fractures define two main extraarticular fragments with a low risk for AVN. Type B fractures are partly extraarticular and partly intraarticular, where often two or three segments are affected. That results in a higher risk for AVN. Type C fractures proceed typically intraarticular with two, three, and four fragments; entailing the highest risk for an impaired circulation within the humeral head. Each group can be divided into three subgroups according to the determined severity. Thereby, the scope of dislocation or varus respectively valgus can be defined [46, 60].

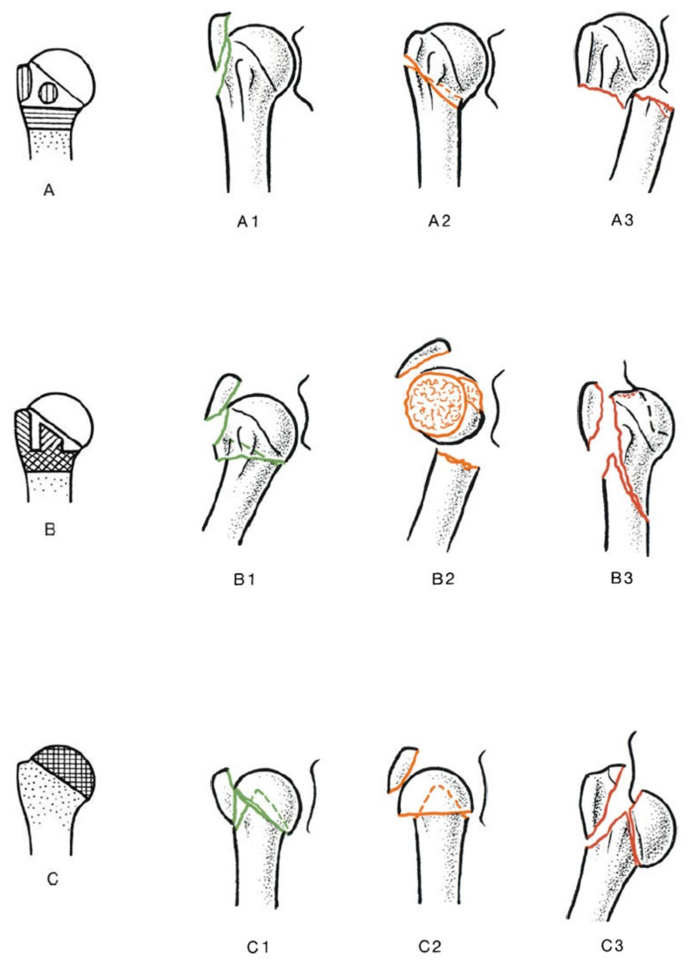

Figure 8: AO classification of proximal humeral fractures [46].

2.7 Diagnostic methods

2.7.1 Anamnesis

The direction and the impact of PHF should be considered in the analysis of an injury mechanism. Possible soft tissue injuries and indices for other associated injuries play also a relevant role. Furthermore, symptoms such as pain and (sensory or motoric) failure of the affected arm should be investigated [2].

2.7.2 Clinical examination

PHF often show diffuse swelling in the region of the humeral head and a hematoma, which can spread after four to five days to the forearm and the thoracic wall. In case of fracture-dislocation a distinctive shoulder contour is remarkable [42].

2.7.3 Imaging

Possible medical imaging modalities in this context are conventional radiography, computed tomography (CT), magnetic resonance imaging (MRI), and sonography. Conventional radiography in two planes is performed to assess shoulder and proximal humerus injuries properly. The established views are on one hand the anterior-posterior (AP) oblique shoulder radiograph, also known as “Grashey view” or “true AP”, and on the other hand the lateral Y view or the axial shoulder view. The “true AP” is a 30° upper body rotation angle radiograph in contrast to the regular AP glenoid view. As a result, the examiner has a clear view of the joint gap. The lateral Y view is advantageous for detecting fracture-dislocation, especially for detecting posterior dislocations, which are overlooked up to nearly 60% in the anterior AP plane [2, 42, 52].

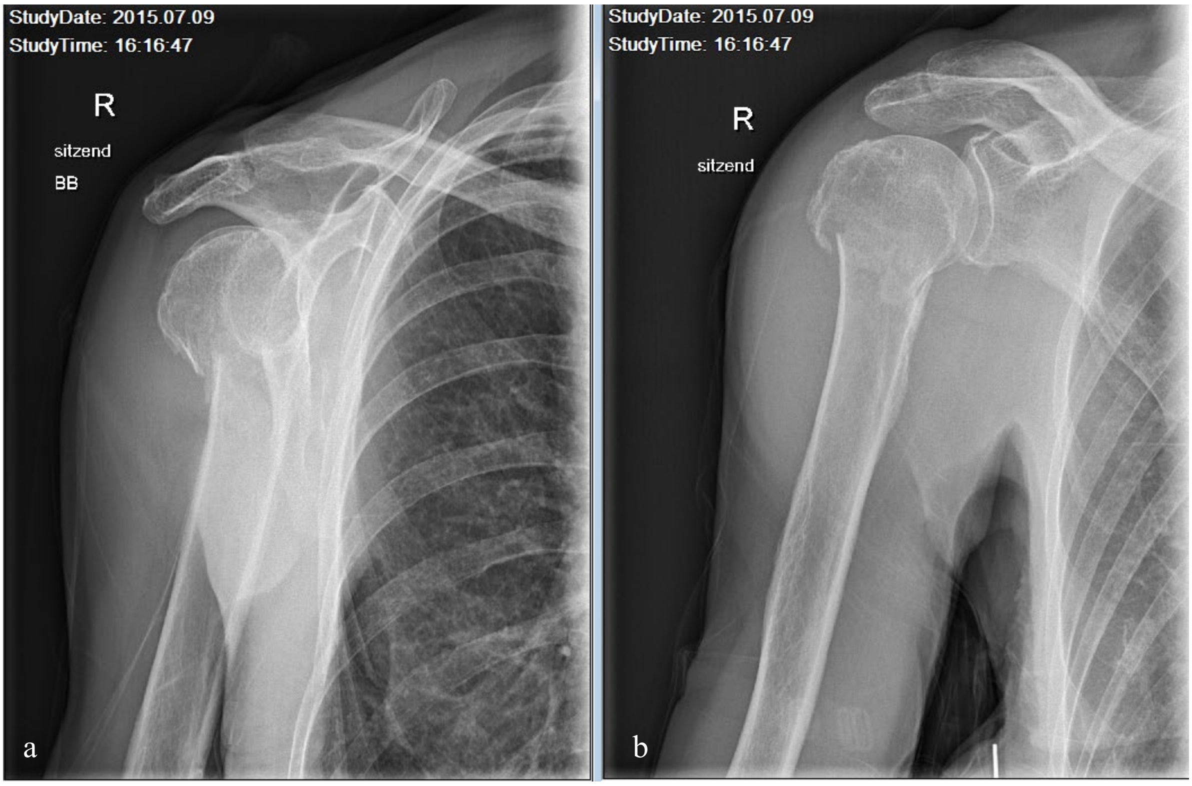

Figure 9 a+b: A two-part fracture of the right proximal humerus (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

When it comes to more complex fractures, it is recommended to perform a CT scan. By using multiplane CT-reconstructions or virtual three-dimensional (3D) rendering, it is possible to determine the exact amount, size, and shape of the fragments. Furthermore, it facilitates planning a surgery accurately. Referring to the feasibility between performing an osteosynthesis or an arthroplasty, a CT scan functions as a decision guidance [2, 42].

Figure 10: The CT scan of an extraarticular 3-part fracture with secondary glenohumeral dislocation (University Hospital Graz).

Magnetic resonance imaging (MRI) is used on suspicion of a pathological fracture or a brachial plexus injury. Moreover, it is used in addition for evaluation of the rotator cuff [2, 42].

Ultrasound imaging offers an advantage, as it is a dynamic examination method. Hence, it allows to verify rotator cuff and biceps tendon injuries, the size of hematoma, fracture segments, and soft tissue interposition. Beyond that, it is possible to detect biceps tendon pathologies and vascular injuries in the area of axillary artery by use of duplex sonography [2, 42].

Diagnostics such as osteoporosis screening should be performed, since a decreased bone mineral density leads to humeral head fractures in elderly.

In conclusion, osteoporosis prevention is crucial to save costs and also to avoid tragic consequences like dangerous femoral neck fractures [42].

2.8 Therapy

Court-Brown et. al. [15] have shown that, in the group of elderly patients, the age, the rate of dislocation, and the fracture type are essential predictors for a good functional treatment result in PHF. The way of the treatment (osteosynthesis or non-surgical treatment) had no influence on the treatment result [40]. Fractures should be distinguished in stable- and unstable fractures. Dynamic examination, like the stability test or image-converter X-ray, build basic diagnostic tools of the shoulder, when it comes to steadiness [42].

2.8.1 Non-surgical treatment

Medical primary care, such as immobilization through bandage, correct positioning, and well-dosed analgesia should be guaranteed, in order to treat PHF. Non-dislocated or slightly-dislocated humeral head fractures are defined as displacements smaller than 1 cm or 45° angulation. That applies to tuberosity dislocation smaller than 5 mm (Neer I), too [2, 10, 42]. These fractures are kept together by the periosteum, joint capsule, and rotator cuff muscles. These fractures are usually treated conservatively. Dislocated 2-part fractures (Neer III) also benefit from non-surgical treatment. This leads to good clinical results mostly after completing reposition manoeuvres [42, 53].

The conservative treatment is normally performed in an outpatient setting. If there is a medial shaft dislocation > 50%, so a closed reduction is performed under analgesia or in general anaesthesia (GA) [25, 41]. A Gilchrist's bandage is applied around the shoulder, while the elbow is left out. Within the first and the third week, the shoulder is basically immobilised. After the first week, analgesia is not required routinely. From the third until the sixth week, pain-adapted pendular movement and led-movement exercises up to 90° should be performed. The shoulder bandage can be applied, depending on the patients' request. From the sixth until the twelfth week, the Gilchrist's bandage is omitted. Pain-adapted stretching exercises, supported by physiotherapy, should be performed by the patients themselves [41]. Meanwhile, follow-up exams should be performed constantly, in order to check the stability of the fracture. The fracture should be also followed up by radiographs. Initially, this is done weekly and later on every two weeks [30]. Following the non-operative treatment pattern, a good or excellent outcome is measured in 77-88% of the patients according to retrospective studies [26, 34, 39]. In a 10-year follow up, Zyto K. [70] showed a functional outcome (mean abduction of 100°; mean forward flexion of 120°; mean Constant score of 59) in nine patients with 3-part fractures, which had been treated conservatively [49].

Figure 11: An applied Gilchrist's bandage on a right shoulder [67].

2.8.2 Surgical treatment

There are several factors, that make operative treatment in PHF inevitable. This includes dislocated fractures (> 1 cm, > 45°), fracture-dislocations, head-split fractures, open fractures, pathological fractures, fractures with associated (nerval or vascular) injuries, and secondary dislocations after initial conservative treatment [2, 30]. An early surgical treatment is especially beneficial for younger patients, who suffer from dislocated or displaced multi-fragmentary fractures. If correct medical care is delayed, the rate of AVN could increase [30].

The goals of treating PHF by surgery are on one hand the anatomical reduction and on the other hand a stable retention. Thereby, two forms of surgical treatment are given: osteosynthesis and arthroplasty. Aside from the general condition, compliance, and the claim of the patient, other key elements for decision-making include fracture morphology, patient age, extent of osteoporosis, and also experience of the surgeon [42].

The patient’s upper body should be set upright with a 30° angle in a semi-recumbent position with an overhanging shoulder, for an optimal position during surgery [42]. The surgical access is achieved, either over a deltopectoral or anterolateral deltoid splitting approach. Cutting through muscles implies a higher risk of devascularisation of the humeral head, although it is a necessary procedure. The benefit of open reduction and internal fixation (ORIF) in patients is undoubted, if they have a good pre-injury shoulder function and a dislocated 2-part fracture (Neer II). On the contrary, performing ORIF in particularly elderly patients with 3- and 4-part fractures (Neer III/ IV) is unsafe. If the bone quality is proper and the fracture is reducible, plate fixation can be realised in 3- or 4-part fractures. However, arthroplasty should be preferred, especially in old patients with a poor bone quality, damaged articular surfaces, limited arterial supply, or a minor functional claim [34].

Krettek et al. [41] have developed an evidence-based indication algorithm, which shows the recommended non-operative or operative treatment method in PHF. The orthopaedic department of Hannover Medical School (MHH) created a treatment pattern considering the age and fracture-related factors of its patients, in order to give ideal therapeutic decisions for PHF.

	not dislocated	slightly dislocated (< 1cm, < 45°)	dislocated (> 1cm, > 45°)	fracture-dislocation head-split fracture open soft tissue injury pathological fracture non-reducible shaft dislocation > 50%
< 60 years	conservative	conservative/ surgery	surgery	surgery
> 60 years	conservative	conservative	conservative	surgery

Table 1: The MHH treatment algorithm for proximal humeral fractures (table translated by the author) [41].

Besides the operative treatment by locking plates, intramedullary nailing (IMN) is another well-established for fixing humeral shaft fractures. After the development of proximal humeral nails with polyaxial locking screws and additional cement augmentation, this implant with improved proximal stability has become a viable option for PHF. With this technique, the risk for AVN of the humeral head and fracture-fragments can be reduced, due to the slight soft tissue recess [34].

Two prosthetic treatment options are the Hemiarthroplasty (HA) and the Reverse Shoulder Arthroplasty (RSA). The HA grants stability and gives decent pain relief to patients after a successful surgery. Its capacity in bringing back the shoulder movement and function has been well investigated [34, 38]. Fracture-dislocations and humeral head-splitting fractures are considered indications for HA [13, 28]. Three main principles of operative procedures that enhance the HA outcome were illustrated to be humeral head height (HH), tubercle reduction/ restoration, and retroversion [7]. If the HH is not restored correctly, the shoulder function will be defective, and extension can lead to tuberosity detachment, impingement, and rotator cuff deficiency. However, shortening the HH, reduces the tension and the length of the deltoid muscle by compromising its ability [3].

Appropriate functional results depend on a decent rehabilitation measure [18, 19]. Commonly, the rehabilitation program includes four to six weeks of shoulder support with passive- and pendular movement [34].

Originally, the RSA was developed in order to find a remedy for degenerative rotator cuff arthropathy [32]. Indications for RSA include head-split fractures, dorsal-locked fracture-dislocation with massive articular surface damage (> 50%), non-reconstructable fractures, and fracture-dislocation in elderly patients [42]. This functions by declining and medializing the center of rotation of the shoulder joint. RSA often results in an enhanced deltoid torque with a better shoulder elevation without dependence on the rotator cuff [5, 34, 56]. Thereby, an intact axillary nerve plays a major role. The functional outcome would be limited, if the deltoid muscle got denervated during surgery [34]. In a retrospective study, Klein et al. [35] have shown that after RSA (Delta III) a mean anterior elevation of 123°, abduction of 113°, and a Constant Score of 68 points were measured. This points out the comparability of the RSA to other surgical techniques.

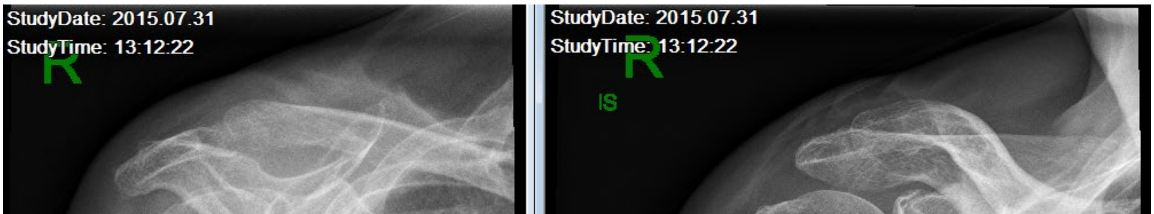

Figure 12 a+b: An operative treatment with locking plate in proximal humerus fracture (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

It is important to differentiate between complication after surgical and non-surgical treatments, which occur when treating PHF.

If non-operative treatment did not proceed properly, restriction regarding the ROM and the shoulder stiffness may appear, just as nonunion (~ 6%), healing in malposition (~ 28%), secondary dislocations (~ 33%), and secondary osteoarthritis (~ 33%) [2, 54]. Zyto K. [70] described in his retrospective study, that humeral head necrosis occurs in 14.3% of all patient groups. In those cases, surgical treatment should be performed afterwards, especially in younger patients (< 60 years) or in patients with a high functional demand.

The complication type, which emerges after operative treatment is often different. Operative treatment cause restrictions related to ROM, implant dislocation (1.3-2.5%), implant breaks (0.7-6.5%), subacromial impingement (1-33%), secondary osteoarthritis (65%), heterotopic ossification (HO), complex regional pain syndrome (CRPS), and late onset infections [2, 4, 9, 10, 23, 59, 61, 64].

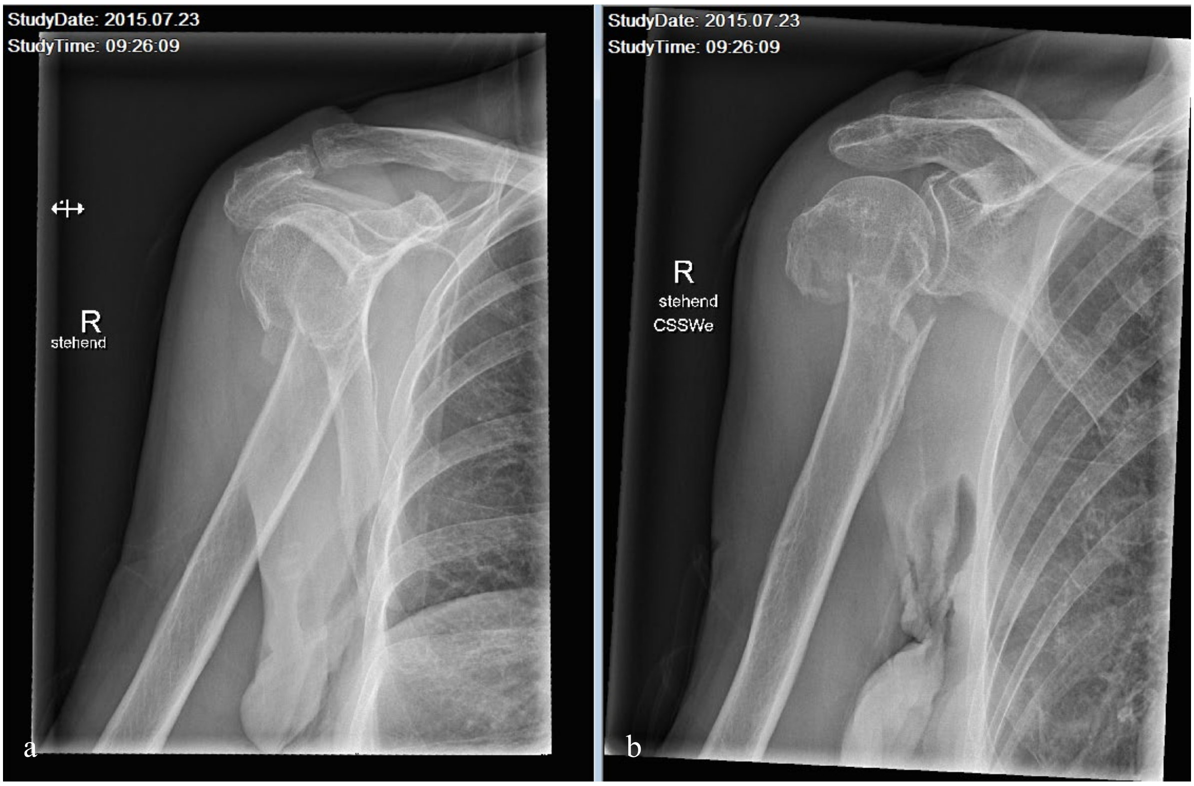

Figure 13 a+b: A secondary dislocation in proximal humerus fracture after conservative treatment (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

3 Material and Methods

3.1 Hypotheses of the study

This study investigates two hypotheses:

The first hypothesis is that the classification (AO), numbers of fragments (Neer) or demographic factors are associated with long-term complications (secondary dislocation, nonunion, malunion, avascular necrosis or posttraumatic osteoarthritis) in PHF.

The second hypothesis of this study is that unplanned surgeries are not significantly associated with the treatment styles of PHF (non-operative vs. operative), when fracture types (Neer respectively AO fracture classification) and demographic variables are controlled.

As such, we formulate the study objectives to answer in the following questions:

1. Are there any differences between the prevalence of secondary complication respectively unplanned surgeries regarding conservative vs. operative treatment in PHF, if fracture types and demographic factors are considered?
2. Are there any demographic, fracture-typical or treatment-specific variables, which show an independent association to secondary complications respectively unplanned surgeries?

3.2 Study design and procedures

3.2.1 General Information

This study was designed as a retrospective cohort study. After receiving the authorization of the ethic review committee of the Medical University Graz (project number: 31-093 ex 18/19) on the 25th February 2019, the data collection was started. All patients (n = 293) were presented or treated because of PHF at the Department of Orthopaedics and Trauma of the Medical University Graz (Austria) in 2015 and 2016. These patients were searched by the Institute for Medical Informatics, Statistics, and Documentation of the Medical University Graz (IMI) via keyword search.

3.2.2 Data protection

For the data evaluation of this study, sensitive medical information was needed: e. g. patient ID-numbers, dates of birth, surgery dates, therapeutic processes, and other personal information. This data is accessible in the hospital information system openMEDOCS from the Styrian Hospitals Limited Liability Company (KAGes) and PACS (Picture Archiving and Communication System). All of the collected data were anonymized, registered in a Microsoft Excel datasheet, and later used for statistical analysis.

3.3 Study population

3.3.1 Inclusion criteria

Patients, who matched following criteria, were included in the study:

i. With AO fracture classification (A1-C3)
ii. With Neer fracture classification (2-4 part)

3.3.2 Exclusion criteria

Patients who matched following criteria were excluded from the study:

i. Age < 60 years
ii. With non-isolated proximal humerus fracture
iii. With pathological fracture
iv. Without pre-treatment radiographs
v. Without follow-up assessments
vi. Unable to give informed consent

3.3.3 Demographic information

The demographic information included age, gender, risk factors (osteoporosis, smoking, and diabetes mellitus), the side of the injury (left or right), open fracture, fracture type Neer (2-, 3-, and 4-part), fracture type AO (A1-C3), treatment methods like surgical (locking plate, intramedullary nail, and arthroplasty) and conservative treatment, and follow-up time.

3.4 Statistical analysis

For this study, descriptive and inferential statistics were performed. Descriptive statistics only deals with properties of the observed data and does not require a large data set.

Inferential statistics, on the other hand, tries to deduce the underlying probability distribution and is more accurate for larger data sets.

The following tests were performed to quantify the bivariate association: Fisher's exact test or Chi-squared test amongst discrete and dichotomous variables, Wilcoxon rank-sum test for non-parametric distributions, Student's t-test, and analysis of variance (ANOVA) amongst discrete and metric variables with parametric distributions.

In order to answer the study questions, relevant data with a significance factor of $p < 0.10$ in bivariate analysis was populated in a logistic regression analysis. P-values < 0.05 were considered as statistically significant.

3.5 Software Tools

All of the statistical analyses were performed with the software Stata/MP™ (Stata®, v13.0, 2015). The main data collection was done with the spreadsheet software Microsoft Excel (Microsoft®, v16.34, 2019). For drawing up the text document, the program Microsoft Word (Microsoft®, v16.34, 2019) was used. Citations were made by the reference management software EndNote™ (Clarivate Analytics, X9.3.2, 2019). Literature search was done with PubMed® (National Center for Biotechnology Information) and Google Scholar (Google LLC). Furthermore, books and scholarly journals were used, which were accessible in the library of the Medical University Graz.

4 Results

4.1 Patient demographics

We found a total of 293 patients with proximal humeral fractures between 2015 and 2016 in our research patient-data registry. Of these, 137 patients met the exclusion criteria and were set apart (Table 2).

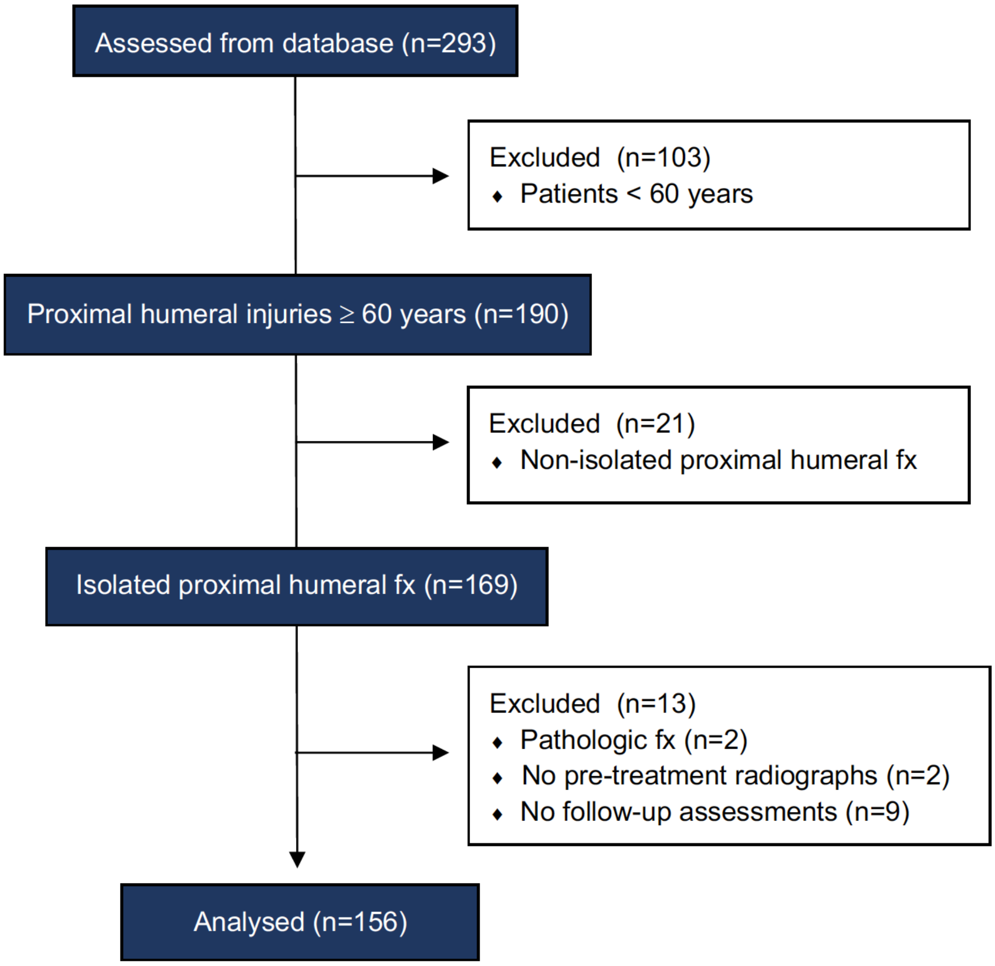

Table 2: The flow diagram of proximal humeral fractures of the studied population (n = 156); n = number; fx = fracture

Table 3 shows the demographic characteristics of the final population under study (n = 156) and their relation to the secondary complication of PHF. The ages of these 156 patients (75% female) had a mean and a standard deviation (SD) of 77 ± 8.9 at the day of injury (DOI). Regarding the risk factors, 53.2 % of the patients suffered from osteoporosis, 17.3% suffered from diabetes mellitus, and 12.2% had a history of smoking. Comparing the injuries of the left and the right arm, both were affected to the same extent (50%). An open fracture was seen in one patient. According to Neer classification, 54.5% 2-part fractures, 23.7% 3-part fractures, and 21.8% 4-part fractures were found. According to AO classification, 13.5%, 28.2%, and 12.8% of the fractures were classified as type A1, A2, and A3. Further, 13.5%, 7.7%, and 2.6% of the fractures were classified as type B1, B2, and B3. Additionally, 8.3%, 10.9%, and 2.6% of the fractures were classified as type C1, C2, and C3. According to the treatment methods, 82% were treated conservatively and 18% were treated surgically.

Table 3: Characteristics of the study population and their relation to secondary complication of proximal humeral fractures				
Variable	Total (n = 156)	Non-complication (n = 120)	Complication (n = 36)	*p*-value
Patient characteristics				
Age (years)				*0.88*[1]
Mean (± SD)	77 (± 8.9)	77 (± 8.9)	77 (± 8.8)	
Median (IQR)	75 (70-84)	75 (70-84)	77 (71-84)	
Gender, n (%)				*0.12*[2]
Female	117 (75)	86 (71.7)	31 (86.1)	
Male	39 (25)	34 (28.3)	5 (13.9)	
Risk factor, n (%)				
Osteoporosis	83 (53.2)	59 (49.2)	24 (66.7)	*0.07*[3]
Smoking	19 (12.2)	13 (10.8)	6 (16.7)	*0.39*[3]
Diabetes Mellitus	27 (17.3)	22 (18.3)	5 (13.9)	*0.62*[3]
Injury characteristics				
Side of injury, n (%)				*0.7*[3]
Left	78 (50)	59 (49.2)	19 (52.8)	
Right	78 (50)	61 (50.8)	17 (47.2)	
Fracture characteristics				
Open fracture, n (%)	1 (100)	1 (100)	0 (0)	*> 0.99*[2]
Fracture type Neer, n (%)				*0.61*[3]
2-part	85 (54.5)	67 (55.8)	18 (50)	
3-part	37 (23.7)	29 (24.2)	8 (22.2)	
4-part	34 (21.8)	24 (20)	10 (27.8)	
Fracture type AO, n (%)				*0.02*[2]
A1	21 (13.5)	16 (13.3)	5 (13.9)	
A2	44 (28.2)	39 (32.5)	5 (13.9)	
A3	20 (12.8)	12 (10)	8 (22.2)	
B1	21 (13.5)	19 (15.8)	2 (5.6)	
B2	12 (7.7)	8 (6.7)	4 (11.1)	
B3	4 (2.6)	2 (1.7)	2 (5.6)	
C1	13 (8.3)	11 (9.17)	2 (5.6)	
C2	17 (10.9)	9 (7.5)	8 (22.2)	
C3	4 (2.6)	4 (3.3)	0 (0)	
Treatment characteristics				
Treatment method				*0.62*[3]
Conservative	128 (82)	97 (80.8)	31 (86.1)	
Surgery	28 (18)	23 (19.2)	5 (13.9)	
Locking Plate	25 (100)	20 (80)	5 (20)	
Intramedullary Nail	1 (100)	1 (100)	0 (0)	
Arthroplasty	2 (100)	2 (100)	0 (0)	
Follow-up time (days)				*> 0.99*[1]
Mean (± SD)	112 (± 121)	89 (± 95)	190 (± 161)	
Median (IQR)	69 (42-127)	58 (37-100)	137 (71-268)	

[1]Wilcoxon rank-sum test; [2]Fisher's exact test; [3]Pearson Chi-square test

Table 3: Characteristics of the study population and their relation to secondary complication of proximal humeral fractures.

We detected a total of 36 complications during a follow-up time of 69 days (median with an interquartile range (IQR) of 42-127). Regarding the demographics and the risk factors, we found that there were more patients with osteoporosis (n = 24; 66.7%) in the complication group than in the non-complication group (n = 59; 49.2%). This association was statistically not significant, but it was considered as relevant data [p = 0.07]. Assessing the fracture classification (AO), some of the fracture types e. g. A2, B1, C1 and C3 show a total significance [p = 0.02], when regarding the fracture types individually.

Regarding the bivariate analysis, the risk of complications after conservative treatment (24.2%) was tendentially higher than after surgical treatment (17.9%) [risk ratio (RR) 0.737; 95% CI 0.315 – 1.728]. This association was statistically not significant [p = 0.469].

Regarding the occurrence of unplanned revisions, the risk of initial operative treatment was tendentially higher (10.7%) than after conservative treatment (3.9%) [RR 2.743; 95% CI 0.696 – 10.813], but also not statistically significant [p = 0.139].

Analyzing secondary complications and unplanned surgeries in detail, Table 4 depicts the characteristics in correspondence to different treatment methods. Regarding the prevalence of secondary complications, we figured out that patients in the non-operative group (n = 128) suffered from: malunion (n = 4), nonunion (n = 4), humeral-head dislocation (n = 12), avascular necrosis (n = 2), and greater-tuberosity dislocation (n = 9). However, patients in the operative group (n = 28) suffered from: humeral-head dislocation (n = 1), nerve lesion (n = 1), and hardware defect (n = 3). This distribution had a statistical significance between non-operative vs. operative treatments [p = 0.001].

Concerning the distribution of unplanned surgeries, we found that the indication for revision in patients of the non-operative group were nonunion (n = 2) and dislocation (n = 3). However, the indications for revision in patients of the operative group were hardware defects (n = 3), specifically secondary screw perforations (n = 2) and impingement syndrome (n = 1). This distribution had no statistical significance with the chosen treatment [p = 0.16].

Table 4: Characteristics of secondary complications and unplanned surgeries corresponding to different treatment methods				
Variable	Total (n = 156)	Non-operative (n = 128)	Operative (n = 28)	*p*-value
Secondary complication, n (%)				
Malunion	4 (2.6)	4 (3.1)	0 (0)	
Nonunion	4 (2.6)	4 (3.1)	0 (0)	
Humeral head dislocation	13 (8.3)	12 (9.4)	1 (3.6)	
Nerve lesion	1 (0.6)	0 (0)	1 (3.6)	
Avascular necrosis	2 (1.3)	2 (1.6)	0 (0)	
Greater tuberosity dislocation > 2 mm	9 (5.8)	9 (7)	0 (0)	
Hardware	3 (1.9)	0 (0)	3 (10.7)	
Total	36 (23.1)	*31 (24.2)*	*5 (17.9)*	0.001[1]
Unplanned surgery, n (%)				
Nonunion	2 (1.3)	2 (1.6)	0 (0)	
Dislocation	3 (1.9)	3 (2.3)	0 (0)	
Hardware	3 (1.9)	0 (0)	3 (10.7)	
Total	8 (5.1)	5 (3.9)	3 (10.7)	0.16[1]

[1]Fisher's exact test

Table 4: Characteristics of secondary complications and unplanned surgeries corresponding to different treatment methods.

Adding relevant variables into the multivariate regression analysis, we found that independent from cofactors like osteoporosis and AO-classification the risk for complications after surgical treatment was not significantly lower than after conservative treatment [Odds Ratio (OR) 0.440; 95% CI 0.129 – 1.505; p = 0.191]. However, we observed that the risk for complications in patients with osteoporosis was tendentially higher than in non-osteoporotic patients [OR 2.119; 95% CI 0.958 – 4.687; p = 0.064] (effect values are presented in Table 5).

Table 5: Logistic regression analysis of variables related to complication					
Variable	b	SE	z-score	*p-value*	95% Conf. Interval
Osteoporosis	0.8	0.4	1.9	*0.064*	[– 0.04; 1.5]
AO-Classification (reference: AO A)					
AO B	-0.02	0.5	-0.04	0.965	[– 1; 0.9]
AO C	0.8	0.5	1.5	*0.132*	[– 0.3; 1.9]
Surgery	-0.8	0.6	-1.3	*0.191*	[– 2; 0.4]
constant	-1.7	0.4	-4.6	*< 0.001*	[– 2.4; – 1]

b = unstandardized coefficient; SE = standard error

Table 5: Logistic regression analysis of variables related to complication

Furthermore, we noticed no significant difference in the risk of unplanned revision after surgical treatment than after conservative treatment [OR 1.605; 95% CI 0.249 – 10.352; p = 0.619] when controlled for age and AO-classification.

Furthermore, we recognized a significant association between the risk for unplanned surgeries and patients age [OR 0.885; 95% CI 0.788 – 0.993; p = 0.037] (effect values are presented in Table 6).

Table 6: Logistic regression analysis of variables related to unplanned surgery					
Variable	b	SE	z-score	*p-value*	95% Conf. Interval
Age	- 0.1	0.06	- 2.1	***0.037***	[– 0.2; – 0.007]
AO-Classification (reference: AO A)					
AO B*	-	-	-	-	-
AO C	0.5	0.9	0.5	*0.609*	[– 1.3; 2.3]
Surgery	0.5	1	0.5	*0.619*	[– 1.4; 2.3]
constant	6	4.2	1.44	*0.150*	[– 2.2; 14.1]

*Variable B is not assigned, since there is no revision; b = unstandardized coefficient; SE = standard error
Table 6: Logistic regression analysis of variables related to unplanned surgery.

4.2 Case series of unplanned surgeries

Table 7 depicts the detailed description and analysis of the cases of unplanned surgeries after secondary complications. We have presented the cases of eight patients with unplanned surgeries (mean age 69 ± 4.5 years; 87.5% female) in our final analysis. Regarding the comorbidities, one patient was a smoker; five patients suffered from osteoporosis; one patient was smoking and suffered from osteoporosis; and one patient had no comorbidity. Concerning the AO-classification, two patients were classified as A2; two other patients as A3; one patient as C1; and three patients as C2. Regarding the treatment characteristics, five patients were treated conservatively and three patients by locking plate. Referring to the complication, three patients sustained a dislocation; two patients a nonunion; and three patients a hardware defect. Regarding the unplanned revision, five patients received a locking plate and three patients received a metal removal.

Table 7: Detailed description of patients with unplanned surgeries after secondary complication

Case	Age (yrs)	Sex	Comorbidity	Neer	AO	Treatment characteristics	Complication	Unplanned surgery	Time[1] (d)
1	77	F	smoking	2-part	A3	conservative	dislocation	locking plate	20
2	62	F	both[2]	2-part	A2	conservative	nonunion	locking plate	172
3	67	M	osteoporosis	4-part	C2	locking plate	hardware	metal removal	116
4	72	F	osteoporosis	4-part	C2	locking plate	hardware	metal removal	654
5	69	F	osteoporosis	2-part	A3	conservative	nonunion	locking plate	317
6	71	F	osteoporosis	4-part	C1	conservative	dislocation	locking plate	23
7	71	F	osteoporosis	2-part	A2	conservative	dislocation	locking plate	28
8	64	F	none	4-part	C2	locking plate	hardware	metal removal	217

[1]Timepoint of unplanned surgery; [2]smoking and osteoporosis; yrs = years; d = days; F = female; M = male
Table 7: Detailed description of patients with unplanned surgeries after secondary complication.

4.3 Case presentation

A 62-year old female patient self-presented at the Orthopaedics and Trauma Department of University Hospital Graz on 5th December 2015 after she fell on her right shoulder. She had a distinct pressure pain (PP) in the area of the right proximal upper arm and a pain-related shoulder mobility-impairment. The peripheral blood supply and (motoric or sensory) functions were unimpeded. There was no sign of a hematoma. After performing radiography of the right shoulder, we saw an impacted proximal humerus fracture with a medial tilting of 5 mm.

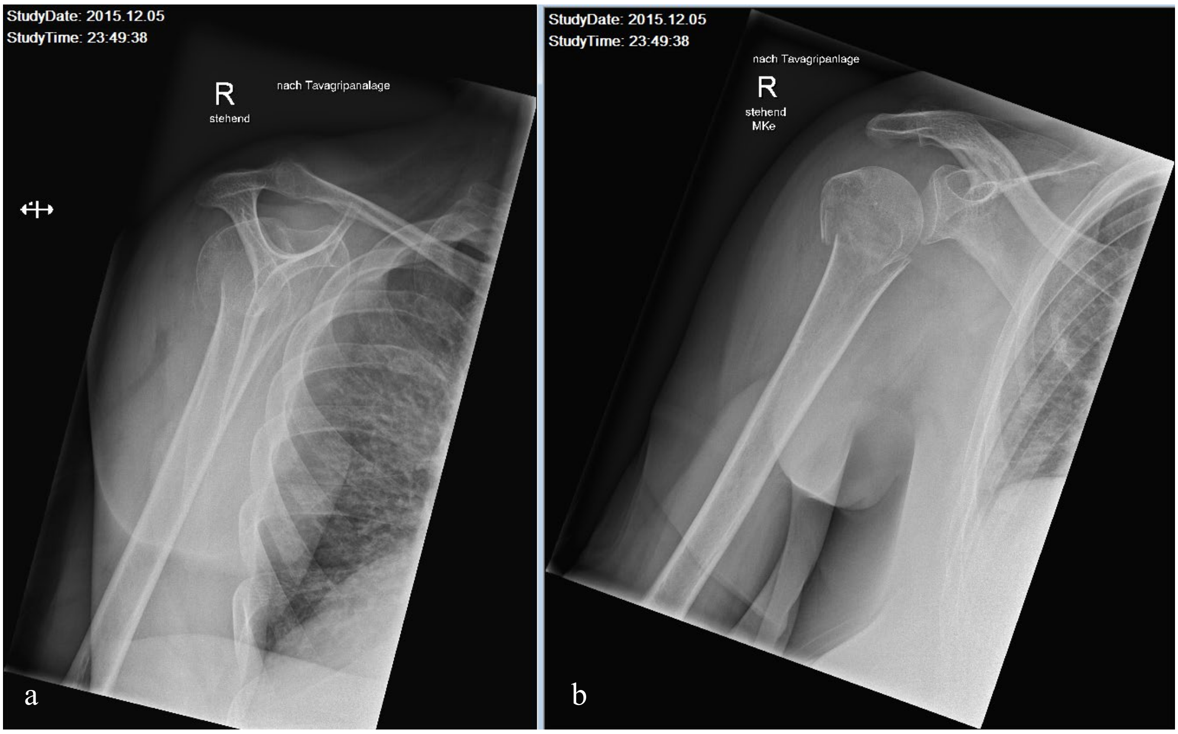

Figure 14: a+b: A two-part fracture of the right proximal humerus (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

The patient was released with a conservative treatment pattern together with some detailed information about the risk of secondary humeral-head dislocation. The patient was examined on a regular basis, initially weekly and later every month. She reported remarkable pain and mobility impairment. After nearly five months, an X-ray of the right shoulder showed a decent shaft medialization with a half-shaft width. There were no signs of bony consolidation, but there were multiple sclerosed fracture-borders. Therefore, a surgical appointment was set for the 25th May 2016.

The nonunion of the proximal humerus was treated surgically. A pseudarthrosis revision with decortication, autologous spongiosa graft, and plate osteosynthesis were performed complication-free. In the following examinations, the patients' progress was visible, and no (pain or mobility) impairment was reported. The radiographs showed a congruent joint situation and a stable metal implant location at all times.

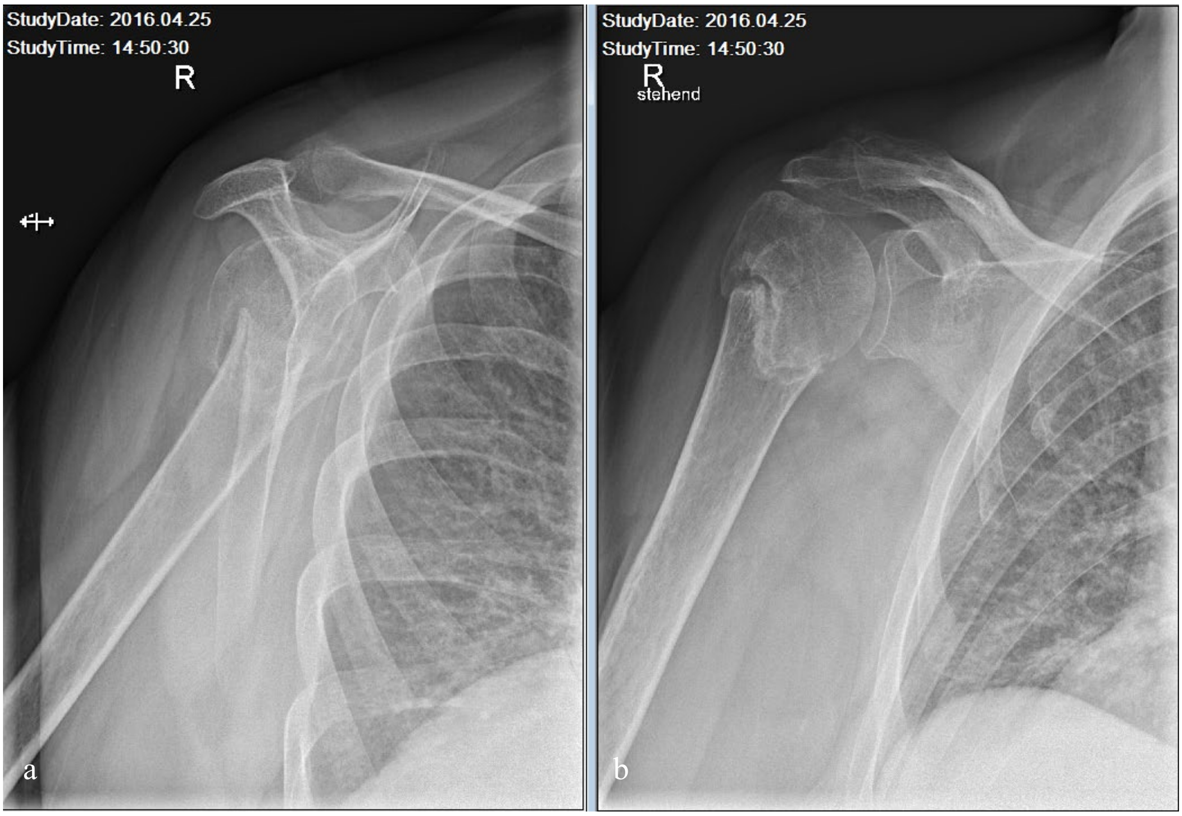

Figure 15: a+b: A nonunion of the right proximal humerus after treated conservatively for 5 months (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

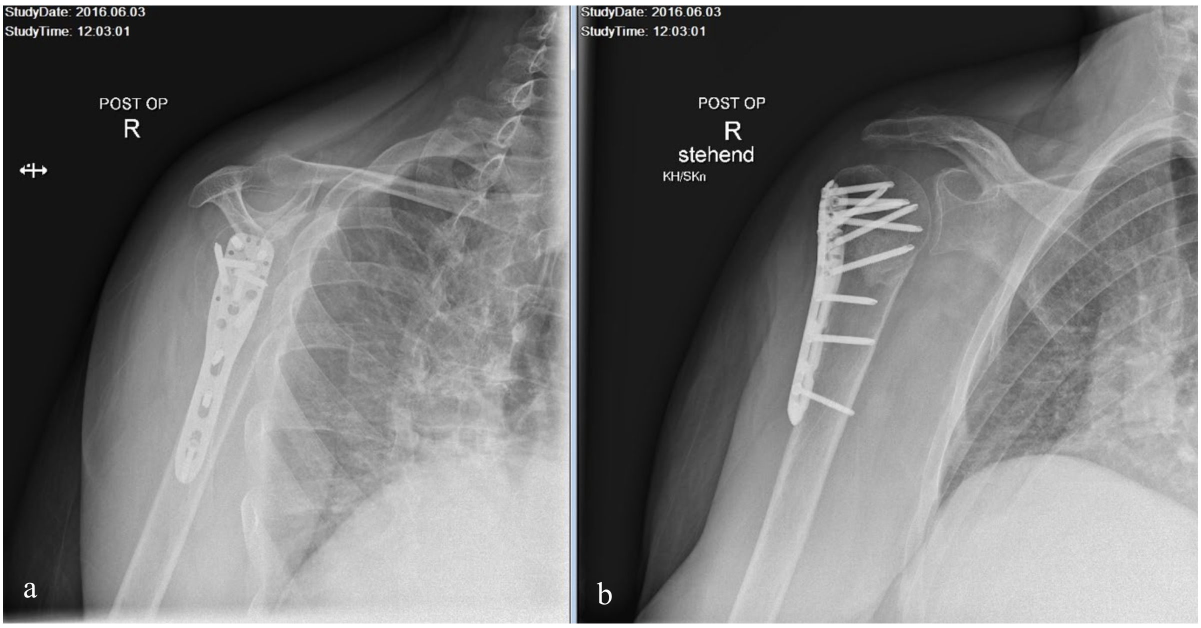

Figure 16: a+b: The surgical treatment after nonunion of the right proximal humerus (University Hospital Graz)
a Lateral Y view,
b AP glenoid view.

5 Discussion[1]

5.1 Statement of principal findings

With our retrospective cohort study, we wanted to investigate the comparative prevalence of secondary complication and unplanned surgeries and their dependence on treatment methods. To achieve this goal, it was important to consider specific variables. Statistically, these variables required a relatively large data set.

We were able to include 156 elderly patients (mean age 77 ± 8.9 years; 75% female) with different PHF types (AO-/ Neer classification) in our final analysis. All of these patients were treated at the University Hospital Graz between 2015 and 2016. We found a total of 36 complications (23.1%) and eight unplanned surgeries (5.1%) during the 2-year period. We found a statistical significance regarding the distribution of secondary complications modalities between the treatment groups (operative vs. non-operative), whereas the overall rate of complications and unplanned surgeries differed not significantly. Furthermore, we recognized a significant association between age and unplanned surgeries. Our data suggest that the younger patients are, the more likely are complications treated with operative procedures. Moreover, we observed that the risk for complications in patients with osteoporosis was tendentially higher than in non-osteoporotic patients [$p = 0.064$].

5.2 Strengths and weaknesses of the study methods

We used conventional fracture-classification assessment (AO/ Neer), in order to categorize our group of patients having PHF. By using multivariable regression analysis, we have tried to reduce confounding in our data analysis.

When choosing our study population, we included only patients with PHF, who were above an age of 60 years, similar to the study population of Ge et al. [27], Howard et al. [33], Okike et al. [48], and Plath et al. [51], but in contrast to Brunner et al [4], Clavert et al. [11], and Erasmo et al. [24] (patients age ≥ 18 years). Therefore, no predictions can be made to patients < 60 years of age.

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A potential strength of our study includes the use of a relatively large sample size (n = 156) of patients with displaced PHF, which is relatively comparable to the sample sizes of Brunner et al. (n = 158) [4], Ge et al. (n = 198) [27], Howard et al. (n = 160) [33], and Okike et al. (n = 207) [48]. However, Brunner et al. [4], Ge et al. [27], and Howard et al. [33] used prospective study designs according to a predefined protocol. Hence, the retrospective style of our study cannot assure the absence of selection bias.

A possible limitation of the present study may be the lack of conducted standardized radiographic evaluations. Performing follow-up X-rays at a determined time point could lead to more comparable results related to the fracture-healing process. Besides, the fracture-classification system was dependent on the radiographic analysis, which was performed by the author and supervised by two orthopedic consultants. This can result in an increased inter-rater reliability, and hence the accuracy can benefit from additional standardized radiographic evaluation by radiologists. Another limitation of the study may be the fact that no functional outcomes were measured directly. It was not possible to assess all contact details and summon the patients into the hospital for measuring the strength and the ROM of the shoulder joint. This limitation originated from the enormous effort for the data collection, which exceeded the capacity for the extent of a diploma thesis.

5.3 The study results in light of previous studies

Regarding the study population (n = 156), the prevalence of secondary complications accounted for 36 patients (23.1%), which led to eight unplanned surgeries (5.1%) during the two-year period (2015-2016). Secondary complications were found in 31 patients (24.2%) in the non-operative group (n = 128) and five patients (17.9%) in the operative group (n = 28). Furthermore, this led to unplanned surgeries in five patients (3.9%) in the non-operative group and three patients (10.7%) in the operative group.

The study group of Brunner et al. [4] detected 53 patients (33.5%) with at least one complication, coming to an amount of 39 unplanned surgeries (24.6%) between September 2002 and January 2005. The prevalence of nonoperative-related complication was 35%, whereas the prevalence of acquiring a surgery-related complication was 9%, which is tendentially higher compared to our results. They found out that elderly patients (> 60 years) experienced a significantly ($p = 0.02$) higher incidence for complication than younger patients. So, they suggest that through anatomic reduction of the tuberosities and recreation of the medial support, the incidence of secondary screw perforation can be reduced, even in osteoporotic bones. Clavert et al. [11] found secondary complication in 13.7% (consisting of 8.2% secondary displacement and 5.5% nonunion) of patients (n = 73) between 2004 and 2005. Another two patients suffered from symptomatic plate breakage after eight months, which needed a second surgery. The prevalence of patients which needed a revision accounted a total of 11, which is higher than in our study population, if counted up to our sample size. As a result, Clavert et al. recommended to use locking plates for providing more secure fracture-fixation. In order to assess the real prevalence of complications, Erasmo et al. [24] suggested in 2014 that it is necessary to follow patients for more than a year after operative treatment. They recorded 23 patients (28%) with secondary complication in their study population (n = 82) during a four-year time-period, which led to a revision in 12 patients (14.6%). However, seven secondary complications were implant-related (3 secondary screw perforations, 3 impingement syndromes, and 1 infection). In contrast to this study, we recorded three implant-related secondary complications (2 secondary screw perforations and 1 impingement syndrome). Ge et al. [27] claim that similar agreeable functional outcomes can be achieved with operative or non-operative treatment for 2-part PHF in the elderly patients. However, benefits in functional outcomes prefer an operative management of 3-part PHF. This prospective study recorded a total of 35 secondary complications (17.7%), 31 in the operative group and four in the conservative group between February 2010 and December 2014, which is similar to our results. Regarding the secondary complications, there was no specification about the amount of unplanned surgeries.

It is noted that none of the described studies investigated direct association between demographic factors and fracture-classification systems (AO/ Neer). This circumstance makes it difficult to compare the results properly.

5.4 Conclusion

The results of our study allowed us to have a better understanding of the epidemics of secondary complications and unplanned surgeries in PHF. The operative group yielded similar prevalence of secondary complication compared to the non-operative group. We found no clear evidence whether the presence of diabetes mellitus, or smoking, or an advanced age were associated with the prevalence of secondary complications. However, we recorded a relevant association between the presence of osteoporosis and the prevalence of secondary complication. The younger patients are, the more likely are complications treated by surgical procedures. In order to obtain a statistically significant result, it is important to acquire a larger data set. Future studies should also include a prospective aspect, where functional outcomes regarding the shoulder joint are objectified via current clinical scores. The possibility for realizing standardized radiological evaluations in order to get a more precise fracture-classification system, should be discussed. Although an adequate therapy is essential, the priority should include fracture prevention through the reduction of orthostatic hypotension, neurovascular instability, cardiac dysrhythmia, vestibular insufficiency, and low bone density [44].

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