Controversies in Orthopedic Surgery of The Upper Limb

E. Carlos Rodríguez-Merchán
Alonso Moreno-Garcìa
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E. Carlos Rodríguez-Merchán
Department of Orthopedic Surgery
La Paz University Hospital-IdiPaz
Madrid, Spain

Alonso Moreno-García
Department of Orthopedic Surgery
La Paz University Hospital-IdiPaz
Madrid, Spain

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Preface

In this book, we have reviewed and analyzed some important controversies in orthopedic surgery of the upper extremities. Seven chapters on shoulder problems have been included: displaced proximal humeral fractures in the elderly; acromioclavicular dislocations in adults; calcific tendinopathy of the rotator cuff in adults; recurrent anterior shoulder instability in adults; controversies in shoulder arthroplasty; clavicle fractures; and massive rotator cuff tears.

Two chapters have been devoted to humerus injuries: humeral shaft fixation in adults; and controversies in the management of intra-articular distal humerus fracture in adults. We have devoted four chapters to elbow pathology: controversies in the management of radial head fractures in adults; controversies in the surgical treatment of distal biceps tendon ruptures in adults; controversies in tennis elbow in adults; and controversies in elbow arthroplasty.

Wrist problems have been analyzed in five chapters: distal radius fractures in the elderly; scapholunate dissociation; wrist arthritis; controversies in carpal tunnel syndrome in adults; and problems of the distal radioulnar joint. Finally, two chapters on hand problems have been included: controversies in the treatment of fingertip amputations in adults; and metacarpophalangeal and proximal interphalangeal joint arthroplasty.

All the chapters have been written by experts in the corresponding topic; in which they have carried out a thorough review and analysis of the recent literature and have stated their points of view on topics of great current controversy. As editors of this book, we thank all the authors for their generous participation and hope that the contents of this book may be of use to orthopedic surgeons in general and especially to those dedicated to the surgery of upper limb injuries.

Madrid, Spain

E. Carlos Rodríguez-Merchán
Alonso Moreno-García

Contents

1 Displaced Proximal Humeral Fractures in the Elderly: Conservative Treatment Versus Open Reduction and Internal Fixation Versus Hemiarthroplasty Versus Reverse Shoulder Arthroplasty

Sarah Mills and Juan C. Rubio-Suárez

1.1 Introduction

Proximal humeral fractures (PHF) in the elderly are nowadays among the most frequent fractures. Their incidence is increasing fast associated with population aging. These fractures are related to osteoporosis or poor bone quality [1].

These fractures impair quality of life as they affect patients' independence, just after the event and even in the long term, when some patients still report some degree of disability [2].

Treatment for these fractures has been a matter of discussion in the last few years as it supposes a challenge. That is why many studies evaluating different techniques have been published. Surgical treatment is complex, but it was the preferred option some years ago. Due to the moderate-high rate of complications and unpredictable outcomes, numerous studies tried to evaluate clinical results and cost-effectiveness of the different therapeutic options available.

Although surgery has not proven superior clinical results (and it is, obviously, more expensive) when compared to conservative treatment in PHF in the elderly, in this chapter we will discuss the different surgical techniques that can be chosen.

1.2 Epidemiology, Pathoanatomy, and Fracture Classification

1.2.1 Epidemiology

PHF constitute 5–6% of all fractures in adults and are more frequent in women (2:1) [1]. In the last few years, their incidence increased simultaneously with osteoporosis' prevalence due to population aging. They are usually due to ground-level falls on an outstretched arm. Very often, these fractures are the first evidence of bone fragility. When present, secondary prevention of future fractures is mandatory. Risk factors for suffering a PHF, in addition to osteoporosis, are diabetes, epilepsy, or female gender.

The most common associated lesion is axillary nerve injury. Vascular injury is uncommon (<5%) and occurs more frequently in the elderly, associated with surgical neck fractures or subcoracoid dislocation of the humeral head. PHF

S. Mills (✉) · J. C. Rubio-Suárez
Department of Orthopedic Surgery, La Paz University Hospital, Madrid, Spain
e-mail: sarah.mills@salud.madrid.org

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can present with concomitant chest wall injuries or other fractures due to the fall.

1.2.2 Pathoanatomy

Depending on fracture pattern and location, humeral head vascularization can be compromised. The principal blood supply depends on the posterior humeral circumflex artery. Vascularity of the humeral head is more likely to be intact if more than 8 mm of calcar is attached to the articular fragment.

Hertel described some criteria to predict ischemia in the humeral head (Table 1.1) [3]. It is very important to highlight that the presence of those factors does not predict avascular necrosis of the humeral head.

PHF can be displaced or not; when displaced, deforming forces are determined by:

- Pectoralis major that displaces shaft anteriorly and medially.
- Supraspinatus, infraspinatus, and teres minor that externally rotates greater tuberosity.
- Subscapularis internally rotates articular segment or lesser tuberosity.

1.2.3 Classification

AO/OTA classification can be used, but Neer classification is the most extended one. According to the later, fractures can occur at the surgical neck, anatomic neck, greater tuberosity (GT), and lesser tuberosity (LT), determining four principal fragments: GT, LT, articular fragment, and shaft. Neer classification is based on the anatomic relationship of the four parts [4].

Table 1.1 Hertel criteria for prediction of humeral head ischemia [3]

<8 mm of calcar attached to articular segment
Disrupted medial hinge
Increased fracture complexity
Displacement >10 mm
Angulation >45°

"A part" is considered only if one of the following:

- It is displaced more than 1 cm.
- It is angulated more than 45°.

Two parts surgical neck fractures are the most common. More complex fracture patterns are seen with increasing age.

1.3 Diagnosis: Clinical Presentation and Imaging

1.3.1 Clinical Presentation

Like other fractures, PHF I presents with pain, swelling, and decreased range of motion. On physical exam, we will typically find an extensive hematoma over the chest, arm, and forearm, known as Hennequin hematoma.

A comprehensive neurovascular exam must be performed, and axillary nerve examination should not be overlooked, by determining deltoid muscle function and lateral shoulder sensation. Arterial injuries are often masked by extensive collateral circulation that can preserve distal pulses, so a high grade of suspicion is needed.

1.3.2 Imaging

When a PHF is suspected, the following radiographs should be ordered:

- True AP radiograph – Grashey projection
- Scapular Y projection
- Axillary projection

CT scan is helpful in preoperative planning and when determining humeral head or GT tuberosity position when they are uncertain. It also serves to determine the presence of head-split fractures. MRI is helpful when a rotator cuff injury is suspected, but its use is not standardized.

1.4 Treatment

Treatment options for PHF in the elderly have been under debate in the last few years. Nonsurgical treatment was the preferred option before the arrival of new implants and techniques. Many recent studies investigate if this interest in surgical intervention is supported by evidence or it is only a fad due to the appearance of new techniques and implants. Shoulder arthroplasties as a therapeutic option for PHF appeared in the twenty-first century. After that, few studies investigated its effectiveness and outcomes.

Studies analyzing different techniques for PHF treatment show that there is no benefit of surgical intervention in displaced fractures in comparison to nonoperative treatment. In addition, all surgical techniques have more complications and are more expensive than conservative management [5–7]. Summarizing, published results do not support the increasing trend for surgery in elderly patients with PHF [8, 9].

1.4.1 Nonoperative Treatment

Nonoperative treatment consists of sling immobilization for 4–6 weeks, followed by progressive rehabilitation. Immediate physical therapy offers a faster recovery. The vast majority of PHF can be treated conservatively (Fig. 1.1).

- Minimally displaced surgical and anatomic neck fractures.
- GT fracture with <5 mm displacement.
- Patients who are unsuitable for surgery.
- In the last years, age was included as an indication for conservative treatment even in case of displaced and complex fractures.

1.4.2 Operative Treatment

Surgical treatment for displaced PHF in the elderly is a subject under debate. Different techniques and implants are available: angular-stable plates, nails, or arthroplasties. Their indications and characteristics are described in the following sections. However, to date, little evidence supports one technique over another. All of these techniques had been evaluated in randomized control trials (RCT) versus the nonoperative treatment, and no relevant differences were found in terms of clinical or functional outcomes [5, 8, 10].

1.4.2.1 Open Reduction and Internal Fixation (ORIF)

Angular stable plate with locking screws is a widely used treatment for PHF, and before the development of nails or arthroplasties, it was the gold-standard technique. Later studies showed a 30% rate of reinterventions due to complications [10].

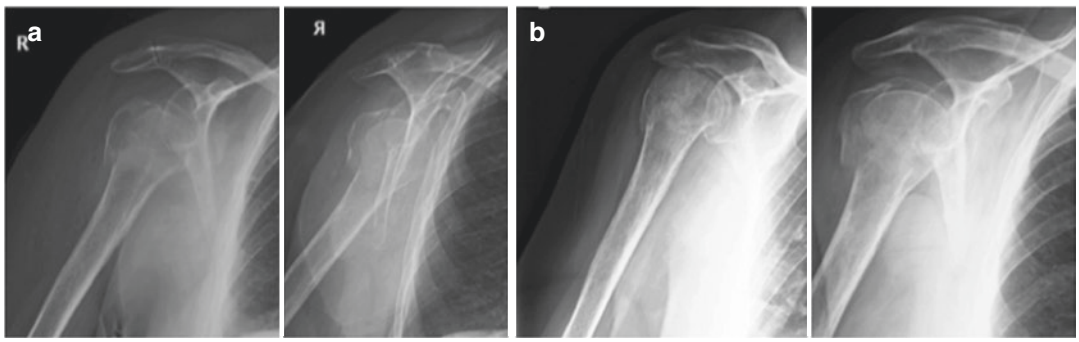

Fig. 1.1 84-year-old female with displaced proximal humeral fracture: (**a**) First X-ray evaluation after the fall. (**b**) Radiographical outcome: fracture healed after conservative treatment. Eight weeks follow-up

This technique is indicated if:

- GT is displaced >5 mm.
- Displaced 2-part fractures.
- 3- and 4-part fractures in younger patients.
- Head-splitting fractures in younger patients.

Better outcomes depend on some mechanical details, like the presence of medial support, which is necessary for fractures with posteromedial comminution, and calcar screw placement, which is critical to decreasing the risk of varus collapse of the articular fragment.

Technique

ORIF can be performed either by deltopectoral or lateral approach; this one has an increased risk for axillary nerve injury (Figs. 1.2 and 1.3).

- Nonabsorbable sutures are needed to isolate tuberosities and use them to reduce the fragments.
- The most common hardware used is a locking plate to fix the fracture once fragments are reduced.
  - The most frequent complication of this technique is screw cutout (14%). In osteoporotic bone, varus collapse is often seen, and it can be prevented with a screw placed inferomedial at calcar.
  - The plate must be placed lateral to the bicipital groove to avoid vascular injury (ascending branch of the anterior humeral circumflex artery).

Minimally invasive approaches were described to avoid soft tissue damage and healing problems due to periosteal stripping. These techniques present with two main disadvantages: a higher risk of axillary nerve injury and a more difficult fracture reduction maneuver [11].

Recent studies evaluate results for cemented augmentation locking screws. Results are promising, and hardware-related complications can be

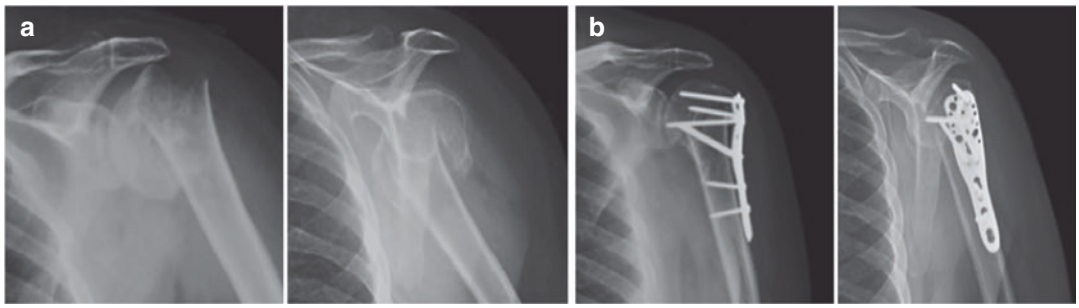

Fig. 1.2 (**a**) Displaced proximal humeral fracture in a 73-year-old female. (**b**) Radiographical outcome after treatment with open reduction and internal fixation with locking plate

Fig. 1.3 Patient from Fig. 1.2, clinical outcome with full active range of motion after 15 months of follow-up and rehabilitation program

reduced drastically if this technique is employed. Neither clinical outcomes nor the need for revision surgery is modified; only the rate of implant-related failure and the global rate of complications were diminished. This technique also appears to help reduce the rate of avascular necrosis [12]. However, further studies are needed to achieve stronger evidence.

1.4.2.2 Intramedullary Nailing (IMN)

Intramedullary nailing can be used in surgical neck fractures or 3-part GT fractures in younger patients or patterns combined with shaft fractures. IMN can be performed in shorter surgical time, and there are no differences in complication rates when compared to ORIF with plates [13]. It offers less stability in torsion compared with plates, but no differences were found in fracture healing, nor ROM recovery compared to plating [14].

- The superior deltoid-splitting approach is used to insert the nail.
- The most common complications are rod migration and shoulder pain secondary to rotator cuff injury.
- Care should be taken when placing locking screws, as radial and musculocutaneous nerves can be injured.

1.4.2.3 Arthroplasty

Complex 3-part and 4-part fractures in the elderly are frequently impossible to fix due to comminution, poor bone quality, and high risk of mechanical and biological complications. For these cases, articular replacement seems to be a good solution.

Hemiarthroplasty (HA) was first employed in treating these fractures, but this technique is highly demandant, and good results are influenced by tuberosity healing, accurate size selection of the stem, and its final position. A functional rotator cuff is also needed for the proper functioning of a HA.

As results with plates and HA were inconsistent, reverse shoulder arthroplasty (RSA) emerged as an option to treat these complex fractures. Outcomes for RSA are less dependent on tuberosity healing and rotator cuff function/integrity compared to HA.

Age is a demonstrated predictor of outcome, so when choosing arthroplasty for treating a PHF, RSA is advisable over 70-year-old patients [15].

Hemiarthroplasty (HA)

The performance of a hemiarthroplasty is indicated in 4-part fractures, 3-part fractures with osteopenia, head-splitting, and severe articular fractures. HA is used in younger patients (40–65 y.o.) with complex fracture-dislocations or head-splitting component that may fail fixation.

- Recommended use of convertible stems in case reverse shoulder arthroplasty is needed.
- The deltopectoral approach is the most extended.
- Tuberosities must be sutured and passed through the prostheses' holes to improve stability.
- The height of the prosthesis is determined with the superior border of the pectoralis major tendon.
- Head to tuberosity distance (HTD) must be maintained (GT 8 mm below the articular surface) to respect external rotation kinematics.

Individualized assessment and preoperative planning are essential to succeed. Outcomes are better for younger patients and fractures treated acutely. It is very important to accurately choose the size of the prosthesis and to ensure the reattachment of the tuberosities to the stem/shaft [16].

Risk factors for a poor postoperative result are rotator cuff injuries, tuberosities malunion or nonunion, and age. Outcomes for this technique are not always satisfactory, and complications like significant postoperative pain, tuberosities' detachment, component malposition, instability, or rotator cuff tears are not uncommon (overall rate 35%) [16]. Healing of the tuberosities determines the success of this technique, and, when healing properly, better score punctuations and better ROM (in forward elevation and external rotation) are achieved [17]. Prosthesis has a mean survival time of 6.3 years [15].

When comparing HA with plating, better functional outcomes were registered with the use of

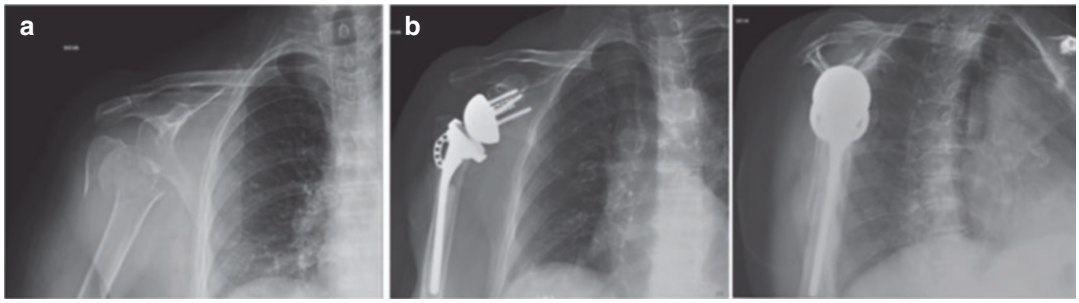

Fig. 1.4 (**a**) Female, 81-year-old, displaced proximal humeral 4-part fracture. (**b**) She was treated with reverse total shoulder arthroplasty

plates; however, HA had a lower rate of revision surgery and fewer surgical complications [18].

Due to poor results with HA, surgeons started using RSA to treat these complex fractures, which yielded better functional and patient-reported satisfaction scores when compared to HA. ROM in flexion after rehabilitation program was also better in RSA group, without differences for ROM in rotation. Both techniques have similar complication rates [17].

When analyzing the clinical and functional outcomes and comparing them with the nonoperative treatment, no differences were found, although the number of studies is scarce and evidence is low [5].

Reverse Shoulder Arthroplasty (RSA)

Reverse shoulder arthroplasty relies on deltoid muscle function instead of rotator cuff integrity or tuberosities position and healing. It is useful in low-demand elderly individuals with non-reconstructible tuberosities and poor bone stock or fracture-dislocations. Despite RSA can compensate for nonfunctioning rotator cuff, repairing tuberosities is recommended for an improved ROM.

Better outcomes if:

- Good glenoid bone stock is ensured.
- Restoration of humeral height and version. Poor results when retroversion of the humeral component is >40°.

The deltopectoral approach or the anterolateral deltoid splitting approach is the most frequently used.

Outcomes

The most reasonable options for treating PHF nowadays are RSA or nonoperative treatment. A randomized control trial (RCT) revealed that RSA has minimal benefits over conservative treatment in terms of pain perception [19]. RSA has been compared to ORIF too. Patient satisfaction and clinical outcomes resulted higher in the RSA group after two years of follow-up. Reverse total shoulder arthroplasty showed better ROM (except for internal rotation) and strength [10]. The complication rate for RSA is 8–11% [10, 17], with a 6% needing another surgery [10].

When compared to HA, RSA showed better results regarding patient satisfaction, outcome scores, and a higher range of motion (forward elevation). Healing of the tuberosities in RSA is irrelevant for score punctuation, and it is only relevant for recovery of external rotation (Fig. 1.4) [17].

1.5 Postoperative Rehabilitation

Rehabilitation is a very important part of the treatment of these fractures, and the best results are achieved when well established physical therapy protocols are followed. Stiffness is directly related to a long immobilization period.

- **Early passive range of motion.** As soon as the patient tolerates it
- **Active range of motion and progressive resistance**
- **Advance stretching and strengthening**

In minimally displaced fractures, an immediate rehabilitation program is an option, but. in displaced fractures, as is often the case in the elderly, immobilization for a small period is needed until the pain is relieved. It has been shown that stiffness related to immobilization, when it extends over 3 weeks, remains even after 2 years in the follow-up. The relevance of early rehabilitation has been widely proved, and it gains even more importance in the elderly. Adequate rehabilitation improves function and quality of life, and that is especially important in people that have poor neuromuscular status with bone fragility. Everything that compromises their independence can dramatically worsen their general health [2].

1.6 Outcomes Evaluation

Outcomes are generally evaluated with health questionnaires and functional scales, specifically conceived for upper limb affections.

1.6.1 Health Questionnaires

Scales as EQ-5D or 15D are the most frequently applied.

1.6.2 Functional Scales

Some examples are DASH score, Constant score, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), or Oxford shoulder score (OSS).

1.7 Overall Complications

- **Screw cutout:** The most frequent complication when locking plate fixation is used.
- **Avascular necrosis:** Better tolerated than in lower extremities. This complication is not related to risk factors for humeral head ischemia, nor type of fixation.
- **Nerve injury:**
  - **Axillary nerve:** Most common nerve injury (up to 60%)
    Deltoid-splitting approach
  - **Suprascapular nerve**
  - **Musculocutaneous nerve**
- **Malunion.**
- **Nonunion:** Risk increased with age and smoking. Nonunion of the tuberosities results in misfunctioning rotator cuff.
- **Rotator cuff injuries and dysfunction. Long head of biceps (LHB) tendon injuries.**
- **Missed posterior dislocation.** Maintain high suspicion in lesser tuberosity fractures.
- **Adhesive capsulitis.**
- **Posttraumatic arthritis.**
- **Infection.**

1.8 Mortality

Increased mortality has been related to different types of fractures: hip or periprosthetic fractures, vertebral fractures, distal femoral fracture, etc. [20]. All of them are often related somehow to a variable degree of frailness or comorbidities. Proximal humeral fractures are frequently associated with factors related to poor general health and morbidity, and also an increased mortality rate during the first year after the fracture has been described, especially in males and in those fractures treated surgically [21].

Registered one-year mortality rate after a PHF in people aged over 80 years old is 19.8%; the relative risk of dying after suffering a proximal humeral fracture was higher during the first 30 days after the incident (5 times higher) compared to the general population. Independent factors related to death were increased age, male sex (7 times higher), low bone mineral density, or concomitant fractures [21].

It is proposed that multidisciplinary teams (like in hip fractures in the elderly) may be advisable to treat these frail patients in order to reduce morbidity and mortality.

1.9 Conclusions

- Proximal humeral fractures represent 5% of all adult fractures and the second in frequency at the upper limb. They are related to osteoporosis, and almost 75% appear in people over 60 years of age. Its overall incidence is 40 in 100,000 patients, and, because of population aging and the increase of life expectancy, its incidence is predicted to triple in the next 10 years [19].
- These fractures impair quality of life and decrease patients' independence, so they have become a public health concern. Many studies have tried to establish protocols to improve their management.
- All therapeutic options available achieve pain relief (except in case of complications), but results are less predictable in terms of functional outcomes and range of motion. New implants and techniques were approved trying to fill this gap. Nevertheless, the gold-standard technique for treating PHF is still under debate. The implementation of different techniques and implants made necessary the development of studies, trying to determine whether to choose one over another, but the evidence is still scarce, and high-quality studies are still needed to establish more solid conclusions.
- Based on the evidence available, the trend is nonoperative treatment for PHF in the elderly, supported by moderate to high evidence. Current evidence shows that surgical treatment of displaced PHF in the elderly has no benefit compared to nonsurgical treatment. On these bases, surgical treatment must be very restrictive, and every case has to be individualized [9].
- In those cases in which surgery is needed, RSA seems to be the most adequate option. Elderly patients present with poor bone quality: it produces complex fracture patterns and also increases the risk of complications with ORIF. RSA showed better outcomes over the other surgical techniques (plates, nails, or hemiarthroplasty) in the elderly. All of them relieve pain, but RSA offers better results in terms of ROM and strength.
- RSA could be recommended in those cases of complex fractures with head split, head dislocation, or associated complex rotator cuff tears.
- The question now is "What do I choose? RSA or nonoperative treatment?" It is very important to individualize and study each patient's comorbidities and functional status. If surgery is chosen, we should remember that RSA offers a minimal advantage over conservative treatment and only in pain perception [19].

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2 Surgical Versus Conservative Interventions for Treating Acromioclavicular Dislocation of the Shoulder in Adults

Jorge de las Heras-Sotos, Alonso Moreno-García, and E. Carlos Rodríguez-Merchán

2.1 Introduction

Acromioclavicular joint (ACJ) dislocation is a frequent lesion, especially in young active patients. The main restrictors of the clavicle to avoid dislocation are the conoid and trapezoid ligaments that attach the clavicle to the coracoid (CC ligaments). In addition, the acromioclavicular joint has its own ligaments (AC ligaments: anterior, posterior, superior, and inferior) that contribute both to the vertical and the anteroposterior stability. Traditionally, minimal significance was given to the AC ligaments in relation to the pathoanatomy of these injury; however, recently, Kurata et al. found that the AC ligaments contribute significantly to AC joint stability, and superior displacement >50% of the AC joint can occur with AC ligament tears alone [1]. The trapezius and deltoid muscles, along with the deltotrapezoid fascia, contribute as well to the stabilization of the AC joint, in what Pastor et al. defined as a dynamic stabilization mechanism [2]. The AC joint serves as the link between the scapulothoracic, glenohumeral, and sternoclavicular joints and allows both gliding and rotational motion. It is usually injured after a lateral blow that drives the clavicle medially and superiorly, injuring the aforementioned ligaments and creating instability into the joint. In this chapter, we are going to review the best evidence available for the management of these injuries.

2.2 Epidemiology and Classification

Shoulder injuries are common, and the increased risk is mainly attributable to sport-related injuries. ACJ injury has been reported as the most common upper extremity injury in sports. In a recent study, the overall incidence was 2 per 10,000 person-years, being more common in young adults and males, although the risk for high-grade injuries was greater in older patients. ACJ injuries were related to sport activities and road traffic accidents [3]. In a study aimed to evaluate the incidence of ACJ injuries in a general population, Skjaker et al. reported that ACJ injuries constituted 11% of all shoulder injuries. Sports injuries accounted for 53%, compared to 27% in other shoulder injuries, and the most common sport associated with ACJ injuries was football [4].

The first classification of acute ACJ injuries was introduced by Tossy et al. They classified the injuries from grade I to III based on radiological examination and the degree of rupture of the supporting ligaments. Rockwood et al. established a more detailed classification that graded injuries from type I to VI [5]:

J. de las Heras-Sotos · A. Moreno-García
E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery, La Paz University Hospital-IdiPaz, Madrid, Spain

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Type I: Incomplete injuries of the AC ligaments and no injury of the CC ligaments. There is pain at the AC joint but no displacement.

Type II: Complete injury of the AC ligaments with incomplete injury of the CC ligaments. There is upward displacement of the clavicle but not above the acromion (50% displacement) (Fig. 2.1).

Type III: Complete injury of both the AC and the CC ligaments. The clavicle is displaced upwards, with the lower cortex of the clavicle at the level of the superior cortex of the acromion (100% displacement) (Fig. 2.2).

Type IV: Complete injury of both AC and CC ligaments with posterior displacement of the clavicle, penetrating the trapezius muscle.

Fig. 2.1 Rockwood type II

Fig. 2.2 Rockwood type III

Fig. 2.3 Rockwood type V

Type V: Complete injury of both AC and CC ligaments with displacement of the clavicle above the acromion, significantly more than in type III, with disruption of the attachments of the deltoid and trapezius muscles (Fig. 2.3).

Type VI: Complete injury of both AC and CC ligaments with inferior displacement of the clavicle underneath the acromion and the coracoid process. This is a very rare entity.

2.3 Diagnosis

The clinical picture depends on the severity of the injury and the type of lesion. For **type I,** there is minimal to moderate local tenderness to palpation, mild swelling over the AC joint, and minimal pain with arm movements. In **type II**, the distal end of the clavicle may be slightly superior to the acromion, and there is usually a local ecchymosis. On clinical examination, anterior–posterior motion of the clavicle in the horizontal plane can present, but there should not be instability in the vertical plane. In **type III,** injuries and due to the severe ligamentous involvement, there is an inferior translation of the limb which produces the characteristic shoulder droop sign, the clavicle being prominent laterally. In this type of lesion, the AC joint can be reduced with

upward pressure under the elbow or by having the patient actively shrug: the "shrug test." For **type IV**, we will find the same symptoms and findings as in type III, and in addition the examination of the injured shoulder from above reveals that the outline of the displaced clavicle is translated posteriorly compared with the uninjured shoulder. **Type V** is an exaggeration of the type III injury, and the distal end of the clavicle appears to be clearly displaced and tenting the skin. **Type VI** injuries are rare and frequently associated to severe concomitant injuries that the disruption of the AC joint may not be recognized initially. Characteristically, the superior aspect of the shoulder has a flat appearance, the acromion is prominent, and there is a step to the superior surface of the coracoid process.

Diagnostic imaging is essential for assessing the severity of ACJ separation. The AP view of the ACJ on radiographs with the patient in the sitting or standing position allows to assess the vertical translation of the clavicle with respect to the acromion. A projection-directed cephalad 10–15° (Zanca view) shows a clearer view and is preferred by some surgeons [6]. For the assessment of the horizontal translation, there is not a unanimous accepted method. Axial images, scapular Y views, or CT are used for that purpose [7]. Magnetic resonance imaging (MRI) is of special relevance when evaluating healed or reconstructed CC ligaments, through the evaluation of the signal intensities of the graft, tendon-bone interface, and neighboring bone [8].

2.4 Treatment and Results

Conservative treatment is the rule for ACJ injuries with no displacement or upward displacement of less than 50%. Regarding surgical treatment for ACJ dislocation, a recent review published by the Cochrane Library concludes that there is low-quality evidence that surgical treatment has no additional benefits in terms of function, return to former activities, and quality of life at 1 year compared with conservative treatment [9]. However, this review was based on low-quality evidence studies and outdated techniques, for what de Sa et al. "would caution readers against placing too much stock in the key findings of this Cochrane review" [10]. Nowadays, it is generally accepted that injuries grade IV to VI should be managed operatively, and controversy remains about optimal treatment of type III injuries.

In general, it is accepted that Rockwood **type I and II** injuries should be treated conservatively. Treatment of these injuries typically consists of analgesics, cryotherapy, and the use of a sling during 1–2 weeks. Early range of motion activities are permitted, and weaning of the sling as pain permits is advised [11].

Management of **type III** injuries is today a source of controversy. While many authors report excellent results with surgical treatment, although the evidence of many of these works is low, others like Schlegel et al., in a prospective study, report good results of conservative management [12]. A metanalysis published by Smith et al. concluded that there is a lack of well-designed studies to justify the optimum mode of treatment of grade III acromioclavicular dislocations [13]. In this situation, it is wise to recommend conservative management initially in type III injuries and only resorting to surgery when the trial of nonoperative management fails. An exception could be high-demand patients, athletes, and laborers in whom surgical treatment may be indicated firstly due to poor tolerance to ACJ instability.

Regarding **type IV, V, and VI** injuries, surgeons generally agree that active and fit-for-surgery patients may benefit from operative treatment. Again, there is a lack of well-designed controlled trials addressing this issue.

2.5 Surgical Treatment

The goal of surgical treatment is to restore bidirectional acromioclavicular joint stability by repairing or reconstructing the injured structures, either with or without use of arthroscopy, and respecting the local anatomy.

The timing to surgery is an important issue in surgical treatment of ACJ injuries. We know that

the AC joint ligaments lose their potential to heal after 3 weeks following injury. In fact, after the studies of Maier et al., it is recommended to perform operative treatment as early as possible within a timeframe of 1 week after trauma to exploit the utmost biological healing potential of the injured ligaments. After their histological study, the authors' findings indicate that the human acromioclavicular ligament complex exhibits early and highly dynamic intrinsic responses to traumatic rupture [14]. When comparing the clinical and radiographic results and the complication rate between early and delayed surgical treatment of ACJ dislocation, Song et al. in a metanalysis showed that better functional outcomes and more satisfied reduction was achieved with early treatment. However, the authors acknowledged the need for high-quality evidence studies to support this assertion [15]. In agreement with basic science results and for clinical purposes, the separation line between acute and chronic cases is normally set at 3 weeks [6].

Fig. 2.4 Hook plate fixation

2.6 Acute Injuries

For the treatment of *acute cases*, less than 3 weeks from injury, several techniques have been published with the objective to achieve ACJ stabilization that will allow the healing of the injured ligaments. Historically, metal implants were used like the **Bosworth screw** from the clavicle to the coracoid process, introduced in 1941. It showed to be effective for the stabilization of the ACJ in injuries grade III, IV, and V. The need for a second surgery to remove the implant and higher patient satisfaction with newer suspensory devices has relegated the use of this technique. The **hook plate** was introduced later as an alternative implant, showing higher Constant scores and patient satisfaction when compared to the Bosworth screw (Fig. 2.4). It is a simple surgical technique, with minimally invasive access, allowing early resumption of normal activity. The hook plate fixation allows time for the native AC and CC ligaments to heal in place by reducing the AC joint and maintaining the reduction. Good clinical and radiological results have been published with its use. Kienast et al. reported 89% excellent and good results but with a complication rate of 10.6% [16]. Some authors have postulated the combination of hook plate fixation and CC repair. In this regard, Chen et al. reported fewer acromion complications and statistical differences in reduction maintenance [17]. When compared to suspensory devices, hook plate fixation shows poorer results as shown in a recent meta-analysis which reported that both techniques offered effective outcomes in relieving the pain although the suspensory technique showed an advantage over hook plate in terms of postoperative pain [18]. In a retrospective study, Unal et al. concluded that endo-button showed superior shoulder scores in the early stages when compared with hook plate fixation [19]. **Tension band wiring** method has also been used by some authors providing functionally satisfactory results, although high rate of complications has been reported with residual subluxation or loss of reduction in more than 45% of cases [20].

The **suspensory techniques** have gained increasing popularity in recent years for the treatment of acute ACJ injuries. The advantages of these novel techniques are the minimal invasive

Fig. 2.5 DogBone suspensory technique

approach, the possibility of using arthroscopy, and there is no need for hardware removal. Several devices have been developed like the EndoButton, the TightRope, the DogBone, and the ZipTight, among others (Fig. 2.5). They all consist of metallic buttons placed on top of the clavicle and under the coracoid that are connected with a continuous loop of suture. They can be used as a single suspension device in a vertical placement, the device anchored at an isometric point of the CC ligament or in an anatomical manner with the use of two or more vertical stabilizers along the course of the CC ligaments, the latter allowing theoretically for a more physiological stabilization, restoring not only vertical but horizontal stability. Kurtoglu et al. presented recently their series of 25 patients treated with a suspensory loop device. The results were favorable in terms of functional recovery and pain relief. However, the major disadvantage found was radiological loss of AC joint reduction, which occurred in six cases [21]. In a study focusing on reduction loss after arthroscopic suspensory fixation of acute acromioclavicular dislocations, Çarkçi et al. found a 25% reduction loss of more than 3 mm. This loss did not create a statistically significant difference in Constant scores, but AC joint-specific tests, subjective evaluation, and aesthetic subjective satisfaction values were significantly impaired. The authors advocate that reduction maintaining is crucial for excellent functional and aesthetic results after fixation of the AC joint with a double-button device [22]. Özcafer et al. published their experience with the use of TightRope for the treatment of type V ACJ dislocations. In a series of 19 patients, the authors concluded that TightRope device can provide anatomical restoration in patients with acute type V ACJ dislocations without subluxation at the final follow-up examination at 1 year postop [23]. Wang et al. compared two popular suspensory devices, TightRope and EndoButton, in a retrospective case-control study. The authors concluded that there were no significant differences between the two groups regarding the Constant-Murley score and the coracoclavicular distance during the follow-up [24].

Biological augmentation is not advocated for acute injuries; however, some authors have developed techniques that use biological grafts that may be of interest in certain cases, like the one described by Ruzbarsky et al. of arthroscopic allograft CC ligament reconstruction [25].

Although the aforementioned techniques using metallic buttons have shown good clinical results, complication rates published are high, ranging from 20% to 44%. Another concern is the adverse clinical results by residual horizontal instability after CC ligament repair. Some authors have proposed the use of **suture anchors** on the coracoid to address vertical and horizontal stabilities simultaneously, advocating the use of small diameter tunnels to reduce the risk of fractures. Liu et al. reported on the use of CC ligament reconstruction using two suture anchors and ACJ augmentation using two strands of non-absorbable heavy sutures on high-grade AC dislocations. In their series of 29 patients, they obtained good clinical and functional results, with radiographs showing two partial loss of reduction, whereas no horizontal displacement was found, and one superficial wound infection and no neurovascular complications were recorded after a mean follow-up of 28 months [26]. Teixeira et al., in a recent publication, also

stress the importance of addressing the horizontal instability of the ACJ when treating these injuries. The authors propose the achievement of additional horizontal stability through superior AC ligament repair using suture anchors [27]. Suture anchor fixation and double-button fixation technique have been recently compared by Topal et al., concluding that both techniques are reliable treatment methods that are not superior to one another and can yield excellent functional outcomes [28]. Hahem et al. have recently published an arthroscopically assisted coracoclavicular and horizontal acromioclavicular fixation technique in a modified figure-of-eight configuration using two strong FiberTape cerclage sutures [29].

The introduction of the arthroscopy for the treatment of ACJ injuries is nowadays well accepted, providing several advantages over open procedures. These techniques offer superior visualization of the base of the coracoid and require less soft tissue dissection and smaller incisions than open procedures. In addition, it allows the surgeon to identify and treat possible associated injuries within the glenohumeral joint and subacromial space. Arthroscopically assisted anatomic reconstruction using a suspensory device, with no need of a biological augmentation in acute injuries, was the consensus achieved by shoulder experts which has been recently published [6].

2.7 Chronic Injuries

If the initial trauma occurred more than 3 weeks before treatment, these cases should be considered chronic due to ligament limited healing capacity of both CC and AC ligaments from that point. The choice of treatment of chronic ACJ dislocation is controversial. In general, it is deemed necessary in chronic cases to perform arthroscopically assisted biologic reconstruction to recreate not only CC ligaments but also AC ligaments. Since less healing response is expected, the more surgical stability, increased by biological augmentation, is recommended. Biomechanical studies have demonstrated that combined AC and CC ligaments reconstruction provides better results than isolated CC reconstruction [30]. The transposition of the coracoacromial ligament from the acromion to the distal clavicle, keeping the coracoid insertion, was described by Weaver and Dunn in 1972. To improve mechanical stabilization, Weaver-Dunn procedure has been combined with suspensory button devices by other authors with good results [31]. Ranne et al. reported on the results of a series of 58 patients with chronic acromioclavicular separations treated with arthroscopic coracoclavicular ligament reconstructions using semitendinosus autografts. Constant and Simple Shoulder Test scores were determined before and 2 years after surgery, and general patient satisfaction also was assessed. In addition, the coracoclavicular distance was measured using anteroposterior radiographs taken 2 years after surgery. Eighty-five percent of the patients reported excellent subjective outcomes. Constant and Simple Shoulder Test scores showed significant improvement at 2 years postoperatively. The mean coracoclavicular distance increased from 10.5 ± 3.4 to 12.4 ± 3.9 mm ($P = 0.009$), two coracoid fractures were observed, one patient experienced a deep infection, and two patients had superficial postoperative infections. The authors conclude that coracoclavicular ligament reconstruction is a challenging procedure, but satisfactory results can be achieved with careful patient selection and good technique [32]. The use of synthetic ligament has been also described with favorable results [33], and some authors have introduced a technical variation that combines synthetic ligament reconstruction and anatomic allograft reconstruction of the CC ligaments. Yeranosian et al. reviewed the results of this combined technique on 10 patients with chronic ACJ dislocations, showing good clinical and functional results at a mean follow-up of 2 years. The authors concluded that this technique using a synthetic ligament along with an anatomic allograft coracoclavicular ligament reconstruction is a safe, effective alternative [34]. Romano et al. have recently reported on the use of a new device based on a permanent implantable TubeTape with integral eyelet which is looped around the coracoid, together with a titanium button for clavicle attachment, the Infinity-Lock Button

System. After a retrospective study of 15 patients, the authors concluded that this technique is effective for treatment of chronic grade III ACJ dislocation, resulting in elevated satisfaction ratings and predictable outcomes [35]. Cano-Martínez et al. also reported in the use of vertical and horizontal stabilization without biological augmentation. In a series of 21 patients after a mean follow-up of 49 months, the authors reported no significant differences with the uninjured shoulder of the Constant score and Acromioclavicular Joint Instability Scoring System. The radiological results were as well satisfactory [36].

Postoperatively, either for acute or chronic cases, a shoulder sling is recommended for immobilization for 3 weeks, with a limitation of range of motion with no activities of daily living for the first 6 weeks and a free range of motion 6 weeks after surgery [6].

2.8 Conclusions

Acromioclavicular joint (ACJ) dislocation is a frequent lesion, especially in young active patients and mainly attributable to sport-related injuries. The overall incidence is 2.0 per 10.000 person-years and constitutes 11% of all shoulder injuries. The most commonly used classification is the one from Rockwood that categorizes these injuries in type I to VI. The diagnosis is essentially based on plain X-ray, although CT is of use for the assessment of horizontal translation. Conservative treatment is the rule for ACJ injuries with no displacement or upward displacement of less than 50% (Rockwood type I and II). Management of type III injuries is today a source of controversy, but it is recommended conservative management initially and only resorting to surgery when the trial of nonoperative management fails. Regarding surgical treatment, arthroscopically assisted anatomic reconstruction using a suspensory device, with no need of a biological augmentation is the general recommendation, whereas biological reconstruction of coracoclavicular and acromioclavicular ligaments with tendon graft is advocated in chronic cases. Complications are not infrequent out of these techniques, and prospective well-designed studies are needed to standardize the operative approach of ACJ injuries.

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3 Calcific Tendinopathy of the Rotator Cuff in Adults: Operative Versus Nonoperative Management

E. Carlos Rodríguez-Merchán, Hortensia De la Corte-Rodríguez, Carlos A. Encinas-Ullán, and Primitivo Gómez-Cardero

3.1 Introduction

Rotator cuff calcific tendinitis (RCCT) is a frequent pathologic condition affecting the rotator cuff, principally happening in women in their forties [1–3]. Commonly, patients complain of a low-degree subacute shoulder pain augmenting during the night [3]. Plain radiography and ultrasound (US) are the imaging tests of choice [4], permitting easy identification of focal calcium depositions in the RC tendons, mainly in the supraspinatus (80%) and less commonly in the infraspinatus and subscapularis tendons (15% and 5% of all cases, respectively) [2].

Conversely, magnetic resonance imaging (MRI) is not usually indicated in this setting due to the well-known limitations of this imaging technique in the assessment of RCCT, even though it is considered the crucial imaging test to exclude other pathologic conditions of the shoulder [5–7]. RCCT is a self-limiting condition that can be completely asymptomatic in chronic stage and not in need of management. Nevertheless, in some cases, it can represent a painful and disabling condition, especially when considering the acute stage [3]. Discomfort intensity affects the selected management: conservative (rehabilitation medicine and oral anti-inflammatory medication) if pain is mild or more invasive (shock waves, surgery, and imaging-guided irrigation) when symptoms are more severe. Shock wave lithotripsy was shown to be not always resolving [8], and, at present, there is no standard of care for RCCT [1, 9].

Over the last years, US-guided percutaneous irrigation of calcific tendinopathy (US-PICT) has become more and more universally utilized [10] because of its minimal invasiveness compared to surgery and its radical impact on calcifications in comparison to shock waves, since mineralized deposits are disaggregated and removed outside the tendon [11, 12]. Moreover, it has been previously reported how US-PICT makes easier rapid shoulder function recovery and pain alleviation [13]. The technique is usually carried out with 16- to 21-gauge needles under local anesthesia. It is shown that even interventional or minor surgical techniques may be associated with a significant psychological burden in patients, possibly producing discomfort and anxiety [14].

The purpose of this chapter is to analyze recent literature evaluating the clinical outcomes of nonoperative and operative treatment for calcific tendinopathy of the shoulder.

E. C. Rodríguez-Merchán (✉) · C. A. Encinas-Ullán
P. Gómez-Cardero
Department of Orthopedic Surgery, "La Paz" University Hospital-IdiPaz, Madrid, Spain

H. De la Corte-Rodríguez
Department of Physical Medicine and Rehabilitation, "La Paz" University Hospital-IdiPaz, Madrid, Spain

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3.2 Pathogenesis

In 2020 Cho et al. identified differentially expressed genes associated with extracellular matrix degradation and inflammatory regulation in calcific tendinopathy utilizing RNA sequencing [15]. They identified 202 differentially expressed genes (DEGs) between calcific and adjacent normal tendon tissues of rotator cuff using RNA sequencing-based transcriptome analysis. The DEGs were highly enriched in extracellular matrix (ECM) degradation and inflammation-related processes. Further, matrix metalloproteinase 9 (MMP9) and matrix metalloproteinase 13 (MMP13), two of the enzymes associated with ECM degradation, were encountered to be highly upregulated 25.85- and 19.40-fold, respectively, in the calcific tendon tissues compared to the adjacent normal tendon tissues. Histopathological analyses indicated collagen degradation and macrophage infiltration at the sites of calcific deposit in the rotator cuff tendon. This study could help to better understand the pathogenesis associated with calcific tendinopathy [15].

3.3 Imaging

RCCT has a typical imaging presentation: in most cases, calcific deposits appear as a dense opacity around the humeral head on conventional radiography (Fig. 3.1), as hyperechoic foci with or without acoustic shadow at ultrasound and as a signal void at magnetic resonance imaging (Fig. 3.2) [16]. Nonetheless, we have to take into account the possible unusual presentations of RCCT and the key imaging features to correctly differentiate RCCT from other RC conditions, such as calcific enthesopathy or RC tears. Other presentations of RCCT to be considered are intrabursal, intraosseous, and intramuscular migration of calcific deposits that may mimic infectious processes or malignancies. While intrabursal and intraosseous migration are quite common, intramuscular migration is an unusual evolution of RCCT. It is important also to know atypical regions affected by calcific tendinopathy as biceps brachii, pectoralis major, and deltoid tendons [16].

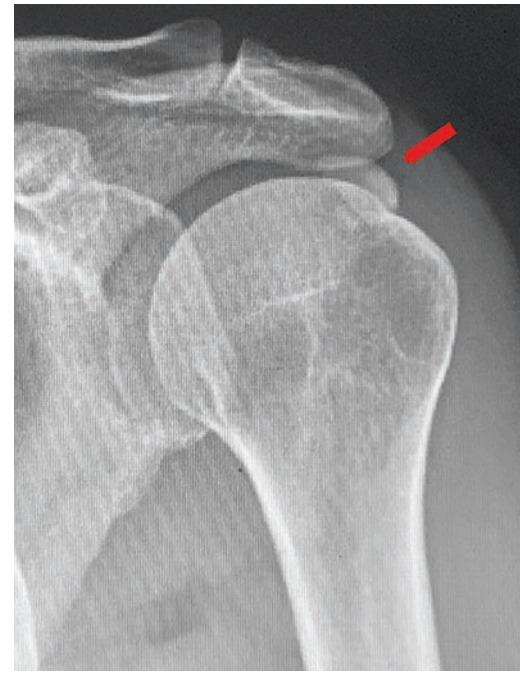

Fig. 3.1 Anteroposterior radiograph showing calcific tendinitis (arrow)

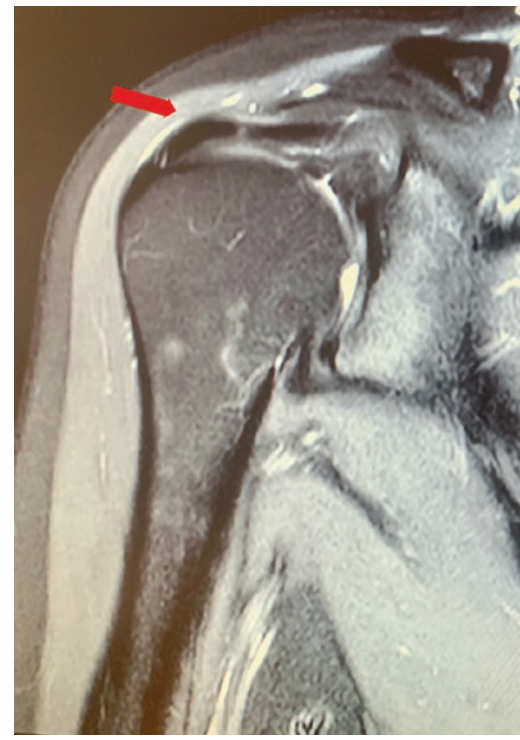

Fig. 3.2 Magnetic resonance imaging (MRI) showing calcific tendinitis (arrow)

An important question is to know whether MRI of the shoulder is ever appropriate in assessing patients with calcific tendinopathy of the rotator cuff. According to Beckmann et al., a shoulder MRI might be carried out for preoperative planning prior to surgical removal of calcium deposits, but even in this patient population, the prevalence of full-thickness rotator cuff tear is low [17].

In 2021, Laucis et al. compared the prevalence of rotator cuff (RC) tears on shoulder ultrasounds of patients with RC calcific tendinopathy (CaT) to that of a control group without CaT [18]. RC tears were diagnosed in 38% (19/50) of the control group (16 full-thickness) as compared to 22% (11/50) with CaT (6 full-thickness). The fewer full-thickness tears in the CaT group (12%, 6 of 50) compared to that in the control group (32%, 16 of 50) was statistically significant (P = 0.016, odds ratio 0.29). Only 7 of the 11 tears in the CaT group were in a calcium-containing tendon (3 full-thickness). The fewer calcium-containing tendon tears compared to tears in the control group was also statistically significant (P = 0.006, odds ratio 0.27). Moreover, the fewer full-thickness calcium-containing tendon tears (6%, 3/50) compared to full-thickness tears in the control group (32%, 16/50) were yet more statistically significant (P = 0.001, odds ratio 0.14). In patients with shoulder pain and CaT, Laucis et al. observed a decreased number of RC tears and especially calcium containing tendon tears, as compared to similar demographic patients with shoulder pain but without CaT [18].

In 2019, Beckman et al. compared the incidence of rotator cuff tears in the setting of calcific tendinopathy on MRI (a case controlled comparison) [19]. They found that patients presenting with indeterminate shoulder pain and rotator cuff calcific tendinopathy were not at augmented risk for having a rotator cuff tear compared with similar demographic patients without calcific tendinopathy presenting with shoulder pain. It appeared that calcific tendinopathy and rotator cuff tears likely arise from different pathological processes [19].

3.4 Treatment

According to Beckmann et al., in most cases, calcific tendinopathy is a self-limited process, typically resolving within a few weeks or months [17]. During this period, conservative treatment with nonsteroidal anti-inflammatory drugs, rehabilitation medicine, warm compresses, and possibly a corticosteroid injection into the subacromial bursa can be administered for symptomatic pain alleviation. Around 10% of patients with calcific tendinopathy will have protracted symptoms that are refractory to conservative treatment. Even in this population of patients with calcific tendinopathy and failed conservative treatment, the prevalence of full-thickness tear remains low. Extracorporeal shockwave therapy and ultrasound-guided needle techniques are efficacious in alleviating pain and resolving the calcium deposits in chronic calcific tendinopathy of the rotator cuff that has failed initial conservative management These treatments are minimally invasive and involve mostly minor complications of soreness, local bruising/ swelling, and subcutaneous hemorrhage, which happen in 10% of patients treated with ultrasound-guided needle techniques and 7%–19% of patients treated with extracorporeal shockwave therapy. Surgical removal of the calcium deposits of calcific tendinopathy is also efficacious in diminishing pain and ameliorating function by utilizing either arthroscopic or open techniques. Nonetheless, surgery is expensive and requires exposure to anesthesia and a longer recovery period compared with other less invasive treatments. For these reasons, surgery should be indicated in patients who have protracted, activity-limiting pain and have failed initial conservative and minimally invasive treatments. In this select population of patients with chronic calcific tendinopathy and prolonged refractory pain being considered for surgical removal of the calcifications, shoulder MRI may be warranted for preoperative planning [17].

3.4.1 Ultrasound-Guided Percutaneous Irrigation of Rotator Cuff Calcific Tendinopathy (US-PICT)

In 2020, Albano et al. assessed patients' experience of US-PICT. They found that US-PICT was a mildly painful, comfortable, and well-tolerated technique, regardless of any previous treatments. Patients' satisfaction was correlated with clinical benefit and full explanation of the technique and its complications [20].

3.4.1.1 US-Guided Percutaneous Irrigation of Calcific Tendinopathy of the Rotator Cuff in Patients with or Without Previous External Shockwave Therapy

In 2021, Lanza et al. compared the outcome of US-PICT of the rotator cuff in patients with or without previous external shockwave therapy (ESWT) [21]. They found that US-PICT of the rotator cuff was an efficacious technique to diminish shoulder pain and augment mobility in patients with calcific tendinopathy, both in short- and long-run time intervals. Previous unsuccessful ESWT did not affect the result of US-PICT.

3.4.1.2 Efficacy of Ultrasound-Guided Percutaneous Treatment of the Rotator Cuff Calcific Tendinopathy with Double Needle Technique

According to Saba et al., US-PICT with double needle was a dependable and reproducible procedure for treatment of the RCCT and their clinical symptoms, when conservative treatment was insufficient [22]. Only patients with calcification at least 5 mm in size with and with acute pain and functional limitation were selected. All patients had a shoulder radiograph to compare it with posttreatment. The patient was placed supine and disinfected profusely. Then percutaneous local anesthesia (Lidocaine 10 mg/mL) was carried out utilizing 25-gauge (G) needle, along the path chosen for the treatment and for both needles. Then, two 18 G needles were introduced into the calcification, with the first needle that must be inserted in a deep position. With a 20 mL syringe prefilled with saline and lidocaine (the irrigation of the calcification could be painful), pressure was applied to one of the two needles. It is possible to insert a 20 G needle into each needle to remove calcium that may obstruct needle tips. During the technique, the needle can also be moved to other areas to be treated, depending on the size and shape of the calcification. The duration of the treatment depended on the size and the hardness of the calcification. After the destruction of the calcification, the fragments pushed by the physiological solution were able to exit by from the other needle positioned inside the calcification creating a washing circuit. Finally, infiltration into the subacromial-subdeltoid bursa (SASD) with cortisone (Betamethasone dipropionate 1 mL) was performed [22].

3.4.1.3 US-PICT: Redefining Predictors of Treatment Outcome

In 2020, Vassalou et al., tried to identify prognostic factors affecting the clinical result in patients treated with rotator cuff US-PICT, by assessing the grade of calcium removal, the size and consistency of calcific deposits, and baseline level of shoulder pain and functionality [23]. The conclusion was that large calcifications and low-grade pain at baseline are correlated with short- and long-run pain amelioration. The grade of calcium removal did not impact pain or functional improvement beyond 1 week. Augmented calcification size, cystic appearance, and low-grade baseline pain predicted complete pain recovery at 1 year [23].

3.4.2 External Shock Wave Therapy (ESWT)

3.4.2.1 Focused, Radial, and Combined ESWT

A study with level 1 evidence (randomized control study) compared the clinical, functional, and ultrasonographic results of focused, radial, and combined ESWT in the management of calcific shoulder tendinopathy [24]. In the three studied