Acromioclavicular Joint Injury and Repair

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Abstract

The acromioclavicular (AC) joint is commonly injured in athletes participating in contact and overhead throwing sports. Injuries range from simple sprains to complete ligamentous disruption, and they are classified by the established Rockwood grading system. High-grade injuries are associated with fractures around the AC joint and disruption of the superior shoulder suspensory complex, a ring of osseous and ligamentous structures at the superior aspect of the shoulder. Radiographs are the mainstay of imaging of the AC joint, with magnetic resonance imaging reserved for high-grade injuries to aid classification and plan surgical management. Low-grade AC joint injuries tend to be managed conservatively, but a wide range of surgical procedures have been described for higher grade injuries and fractures around the AC joint. This review illustrates the anatomy of the AC joint and surrounding structures, the imaging features of AC joint injury, and the most commonly performed methods of reconstruction and their complications.

Keywords
- ► acromioclavicular joint
- ► anatomy
- ► imaging
- ► magnetic resonance imaging
- ► acromioclavicular joint surgery

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Injury to the acromioclavicular (AC) joint is common during both contact and overhead throwing sports, with injury severity ranging from simple sprains managed conservatively to complex joint disruption with associated fractures requiring surgical fixation. Despite the frequency of injury, dedicated imaging of the AC joint is less commonly performed than for injuries to the glenohumeral joint and rotator cuff. As a result, radiologists are often less familiar with the anatomy, range of patterns of traumatic injury, and surgical fixation techniques involving the AC joint. This review summarizes the anatomy of the AC joint and describes the range of injuries, their imaging appearances, and their management.

Anatomy

Clavicle

The clavicle is an S-shaped bone that articulates with the sternum medially and the acromion laterally. The lateral clavicle is flattened and has bony prominences on the inferior surface that serve as sites of ligamentous attachment, namely the conoid and trapezoid ligaments.[1] The conoid tubercle is located at the posterior aspect of the clavicle at the junction of the middle and lateral third, and the trapezoid ridge extends anterolaterally across the undersurface of the lateral clavicle[2] (►**Fig. 1**). The clavicle connects the axial and appendicular skeleton and has several functions, including preventing the shoulder collapsing into the body, suspending the scapula, and protecting the underlying neurovascular structures.[3] The clavicle is a major site of muscular attachment, with the pectoralis major attaching to the anterior surface of the medial two thirds and the deltoid attaching to the anterior surface of the lateral third.[2] The trapezius attaches to the posterior aspect of the lateral third of the clavicle.[2]

Acromion

The acromion is the anterior protuberance of the spine of the scapula and is subcutaneous, making it particularly vulnerable to sporting injury.[4] The deltoid attaches to its roughened lateral surface, and the AC ligaments attach to the anterior tip of the acromion.[1] The clavicle borders the medial surface of the acromion and articulates via the medial facet at the AC joint.[2]

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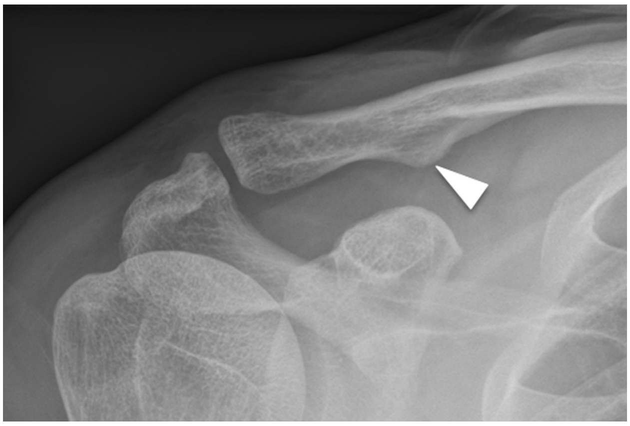

Fig. 1 Normal anatomy of the acromioclavicular (AC) joint. Zanca projection radiograph of the AC joint showing the conoid tubercle on the undersurface of the lateral clavicle (arrow head).

Acromioclavicular Joint

The AC joint is a planar synovial joint between the lateral clavicle and anteromedial surface of the acromion.[5] The articular surface consists of hyaline cartilage until early adulthood when it is replaced by fibrocartilage.[1] The orientation of the AC joint varies considerably; an overriding clavicle is most common with an angle of inclination measuring up to 50 degrees, and the joint is incongruous in ~ 20% of the population.[5] The AC joint capsule is relatively weak but reinforced by several static and dynamic stabilizers (►**Fig. 2**).

Static Stabilizers

Static stabilizers of the AC joint include the AC, coracoclavicular (CC), and coracoacromial (CA) ligaments.[6] The role of the AC ligament is to prevent posterior translation of the clavicle at the AC joint, and traditionally it was described as four capsular thickenings circumferentially enveloping the joint.[7] More recently, two major bundles of the AC ligament were described: the superoposterior and anteroinferior bundles.[6] The superoposterior ligament is well developed and traverses obliquely from the anterior acromion to the posterior edge of the distal clavicle.[6] The anteroinferior bundle is thin, has a variable attachment, and is not present consistently.[6]

The AC joint contains a fibrocartilage articular disk, varying in both size and shape, that is in continuity with the joint capsule and cushions the joint surfaces.[8,9] Two major disk types have been observed in anatomical studies, namely meniscoid and complete disks, with the meniscoid variant much more common.[5,10] It is believed that the disk plays little functional role in adults and starts to degenerate as early as the second decade of life, with significant degeneration by the fourth decade.[8,9]

The CC ligament, an important static stabilizer responsible for vertical stability of the AC joint, is composed of distinct conoid and trapezoid ligaments[8] (►**Figs. 2** and **3**). The trapezoid ligament is larger, quadrangular in shape, and extends from the coracoid to the distal clavicle along the trapezoidal ridge.[4] The conoid ligament is vertically oriented, with the clavicular insertion twice as wide as its coracoid

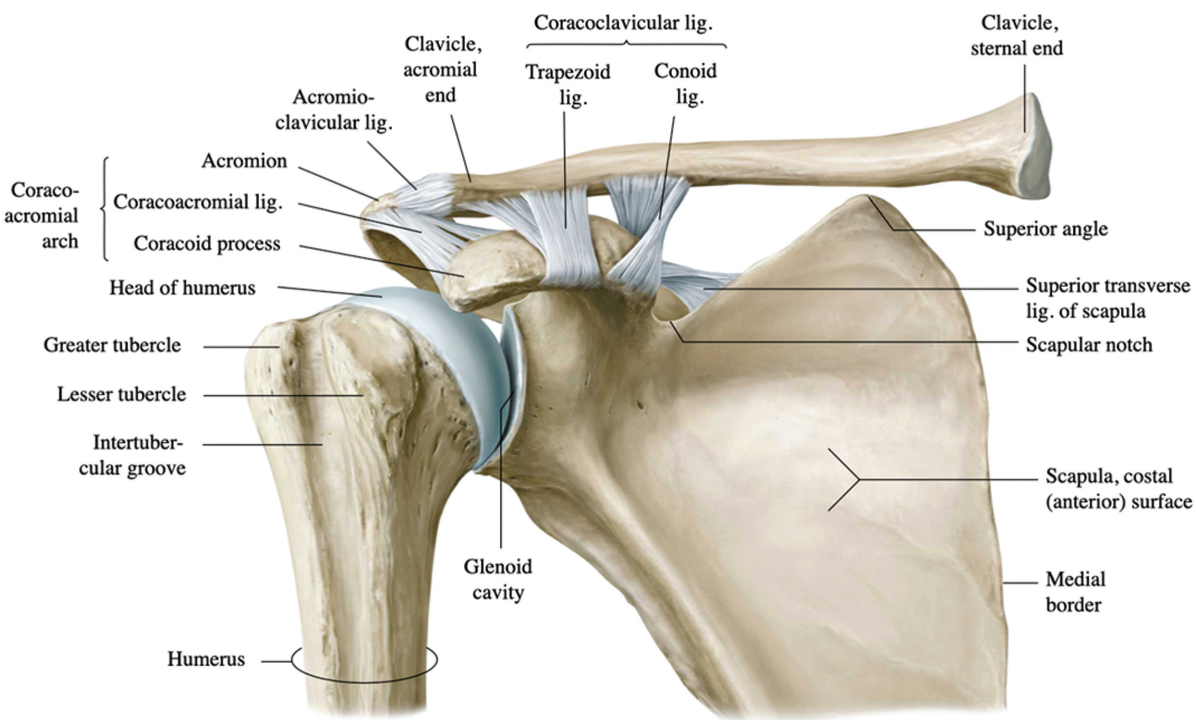

Fig. 2 Anatomy of the acromioclavicular (AC) joint. Diagram shows the AC, coracoacromial, and coracoclavicular ligaments and their osseous attachments. Reproduced with permission from Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy. General Anatomy and Musculoskeletal System. Illustrations by Voll M and Wesker K. 3rd Edition. New York: Thieme Medical Publishers; 2020.

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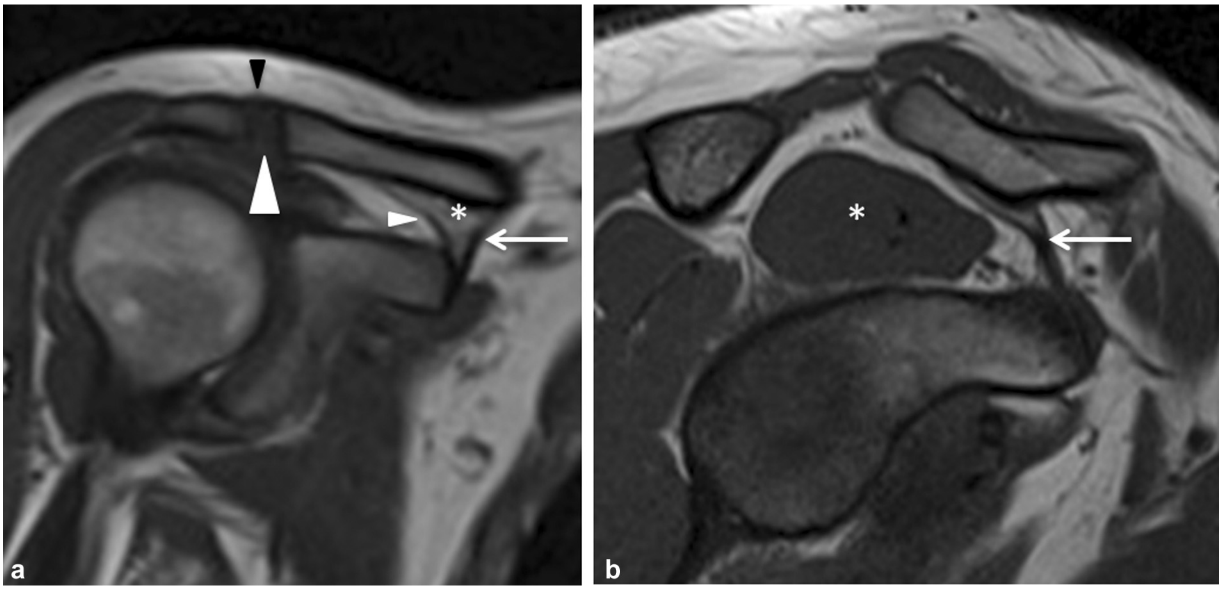

Fig. 3 Normal magnetic resonance imaging anatomy of the acromioclavicular (AC) joint. (**a**) Coronal-oblique T1 image showing the conoid (arrow) and trapezoid (small white arrowhead) components of the coracoclavicular (CC) ligament, with fat between the two portions (asterisk). The superior (black arrowhead) and inferior AC ligaments (large white arrowhead) at the AC joint are uniformly hypointense on all sequences. (**b**) Sagittal-oblique T1 image showing the conoid portion of the CC ligament (arrow) anterior to the supraspinatus muscle belly (asterisk).

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attachment, leading to its conical shape.[9] The anatomy of both components is highly variable; the trapezoid ligament spans a region 1.5 to 3 cm from the joint margin, and the conoid ligament attaches 3 to 5 cm medial to the joint line.[1]

The CA ligament is a triangular ligament that extends from the lateral coracoid and attaches to the anteromedial and anteroinferior surface of the acromion (►**Fig. 2**).[11] Although the ligament provides reinforcement to the inferior capsular ligament, anatomical studies showed that the ligament does not contribute to AC joint stability.[12]

Dynamic Stabilizers

The dynamic stabilizers of the AC joint include the deltoid muscle anteriorly and the trapezius posteriorly. The deltoid has a broad origin arising from the lateral third of the clavicle, acromion, and lateral two thirds of the spine of the scapula, with insertion onto the deltoid tuberosity of the lateral humeral shaft.[4,13] The trapezius is a large broad muscle arising from the occiput, nuchal ligament, and C7–T12 spinous processes, and attaching onto the lateral clavicle, acromion, and spine of the scapula.[4]

Acute AC Joint Injury

Injuries to the AC joint account for ~ 12% of injuries to the shoulder; however, this figure is likely to underestimate the true incidence because patients with low-grade injuries are less likely to seek medical attention.[14] Most patients are young adults between 20 and 40 years of age with a sex distribution of 8:1 in favor of men.[15] In young men, contact sports are the most common cause of AC joint injury, such as football, rugby, and hockey, and the AC joint is injured in a third of professional rugby players with shoulder injuries.[16] Across other sports, cycling and alpine skiing have a notably high incidence of AC joint injury due to either direct impact or a fall onto an outstretched hand, with the joint involved in ~ 20% of shoulder injuries.[17,18]

The mechanism leading to AC joint injury can be direct or indirect. A direct blow to the outer aspect of the shoulder with the arm held by the side in adduction is most common, usually occurring during contact sports as well as falls onto the shoulder. The direct force to the superior AC joint drives the acromion and clavicle inferiorly and medially, and the joint capsule and ligaments are the first to fail. Indirect trauma to the AC joint is less common, involving a fall onto an adducted arm driving the humeral head against the inferior acromion.[14] Indirect trauma typically results in lower grade injury, with disruption of the AC ligaments but preserved CC ligaments.[19]

Patients typically present with pain and swelling to the superior shoulder, holding the injured arm in an adducted and supported position for symptomatic relief.[20] The main clinical finding is tenderness to the AC joint; a step between the acromion and lateral clavicle is evident in higher grade injuries.[14]

Imaging AC Joint Injury

Radiographs

Radiographs are the primary imaging modality for the investigation of suspected AC joint injury and typically all that is required for diagnosis. The AC joint can be seen on a standard anteroposterior (AP) projection of the shoulder; however, evaluation is limited in ~ 30% patients due to variable joint angulation and superimposition of overlying structures.[21] The preferred projection in the context of trauma is the Zanca view, an AP projection with 10 to 15 degrees cephalad angulation[21] (►**Fig. 1**). This projection reduces overlap of the scapula and clavicle, enabling subtle fractures to be identified as well as reducing radiation dose.[4]

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On plain radiographs, AC joint injury is suggested by an increase in the AC joint width and CC distance. The normal value for the AC joint space is no more than 7 mm in men and 6 mm in women, and the joint space normally decreases with age.[22] The CC distance normally measures < 13 mm, with a > 50% increase suggesting complete dislocation of the AC joint.[19]

Comparison views of the contralateral AC joint are also valuable in accounting for normal variations in anatomy that can be particularly helpful for low-grade injuries.[21] Weight-bearing views have been proposed to help distinguish between grade 2 and grade 3 injuries, but their use is controversial, with one study finding that in only 4% of cases did weight-bearing views unmask a grade 3 injury not appreciated on the initial radiograph.[23] There is also limited value clinically because both grade 2 and grade 3 injuries are usually managed conservatively, and most shoulder surgeons do not routinely rely on weighted radiographs to plan management.[24]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is performed to aid diagnosis and surgical planning in up to 10% of patients presenting with high-grade AC joint injuries.[4] In addition to assessing the ligamentous attachments of the AC joint, MRI facilitates assessment of the adjacent structures, such as the rotator cuff, glenohumeral joint, and neurovascular bundle. Anatomy of the AC joint and associated ligaments is best detailed on T1 or proton-density-weighted imaging; however, edema and fluid resulting from injury are more readily identified on fluid-sensitive fat-saturated T2 sequences.[25–27]

Standard imaging sequences include fat-saturated coronal-oblique proton-density and T2 sequences parallel to the anterior acromion to facilitate accurate assessment of the CC ligament[25] (►**Fig. 3**). These sequences are supplemented with fat-saturated proton-density axial sequences and T1 and fat-saturated T2 sequences oriented in the sagittal-oblique plane, all with a 3-mm slice thickness. MRI can more accurately classify the grade of AC joint injury, with grade 1 injury upgraded in up to 50% and grade 2 upgraded in up to 20% of patients.[27] However, Nemec et al reported that MRI downgrades the severity of AC joint injury in 36.4% of patients.[26]

The use of a flexible surface coil leads to improved image quality when compared with a standard shoulder coil, due to improved patient comfort, and it is a better fit for athletes with a developed muscular shoulder girdle.[28,29]

Computed Tomography

Computed tomography (CT) can be useful for imaging complex fractures around the AC joint not adequately assessed on radiographs, aiding surgical planning. CT does not improve the reliability of classification of AC joint injuries when compared with plain radiographs, however, and it is not used routinely for the assessment of acute injury.[30] CT is the modality of choice for assessing the degree of fracture union when nonunion is suspected on radiographs, as well as assessing bone stock and tunnel dimensions if revision AC joint surgery is being considered.[31]

Classification Systems

Isolated AC Joint Injury

Tossy et al described a three-point injury classification of the AC joint based on the degree of damage to the AC and CC ligaments that subsequently was adapted by Rockwood to consider horizontal as well as vertical instability.[32,33] The Rockwood classification is the most widely used system for grading AC joint injury and planning management (►**Table 1**).

Rockwood Grade 1

Rockwood grade 1 injury consists of a sprain of the AC ligaments with no involvement of the CC ligaments[25] (►**Fig. 4a**). There may be soft tissue swelling surrounding the AC joint, but radiographs are otherwise normal.[19] Appearances on MRI are nonspecific and include a tear of the superior AC ligament, manifesting as signal hyperintensity on fluid-sensitive sequences, as well as marrow and adjacent soft tissue edema in the acute setting[25] (►**Fig. 4b–d**).

Rockwood Grade 2

Grade 2 injury results in disruption of the AC joint capsule and ligaments with intact or partial-thickness tearing of the CC ligaments, resulting in horizontal instability of the AC

Table 1 Rockwood classification of acromioclavicular joint injury[33]

Grade	AC ligaments	CC ligaments	Deltopectoral fascia	Displacement of clavicle	AC distance	CC distance
1	Intact/ Sprained	Intact	Intact	None	Normal	Normal
2	Disrupted	Intact or sprained	Intact	$\leq$ 50% superior	Widened	Mildly increased
3	Disrupted	Disrupted	Disrupted	100% superior	Widened	Increased $\leq$ 100%
4	Disrupted	Disrupted	Disrupted	Posterior	Clavicle displaced posteriorly	Can be normal
5	Disrupted	Disrupted	Disrupted	> 100% superior	Not applicable	Increased > 100%
6	Disrupted	Disrupted	Disrupted	Inferior	Clavicle displaced inferiorly	Negative

Abbreviations: AC, acromioclavicular; CC, coracoclavicular.

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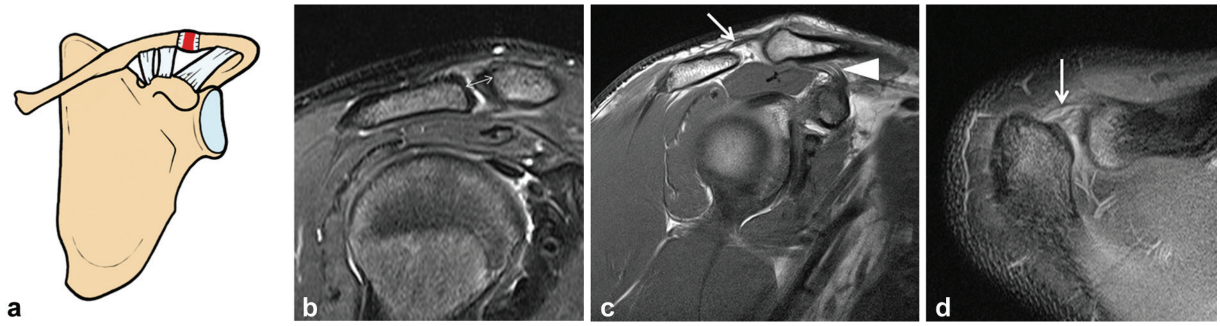

Fig. 4 Rockwood grade 1 acromioclavicular (AC) joint injury. (**a**) Diagram shows the features of grade 1 injury with sprained AC ligaments. (**b**) Proton-density (PD) fat-saturated coronal-oblique, (**c**) T1 sagittal-oblique, and (**d**) PD fat-saturated axial magnetic resonance imaging sequences showing edema surrounding the intact AC ligaments (arrows), with a normal AC joint distance (double-headed arrow). The coracoclavicular ligaments remain intact (arrowhead).

joint clinically[4] (►**Fig. 5a**). Radiographs show a widened AC joint (measuring > 7 mm), a normal or mildly elevated CC distance, and minor elevation of the lateral clavicle.[19] MRI shows complete rupture of the AC ligaments, with marrow edema on either side of the joint and soft tissue edema[25] (►**Fig. 5b**). The sprained CC ligaments are edematous on fluid-sensitive sequences, but ligamentous integrity is maintained.[25]

Rockwood Grade 3

The hallmark of grade 3 injury is complete rupture of the CC ligaments in addition to the AC ligaments, resulting in both vertical and horizontal instability[4] (►**Fig. 6a**). CC ligament injury results in elevation of the lateral clavicle with a CC distance measuring > 13 mm, which is asymmetrical to the uninjured side. The lateral clavicle may be elevated relative to the acromion, but this alone should not be used to diagnose AC joint injury in the absence of a raised CC distance[19] (►**Fig. 6b**). On MRI, there is loss of the normally hypointense CC ligaments on T1 imaging, and associated fluid and hematoma are best appreciated on fluid-sensitive sequences (►**Fig. S1**). The deltoid and trapezius muscles may also be detached from the distal clavicle, best appreciated on coronal-oblique fluid sensitive sequences.

Rockwood Grade 4

In grade 4 injury, posterior force to the acromion drives the scapula posteroinferiorly, resulting in posterior displacement of the lateral clavicle at the AC joint, in addition to rupture of the AC joint and CC ligaments[19] (►**Fig. 7a**). Appearances on an AP radiograph can simulate grade 2 injury, and posterior displacement of the clavicle is best appreciated on axial or lateral projections[19] (►**Fig. 7b, c**). MRI shows ligamentous injury similar to grade 3 injury, and buttonholing occurs when the lateral clavicle pierces the trapezius muscle or the fascia.

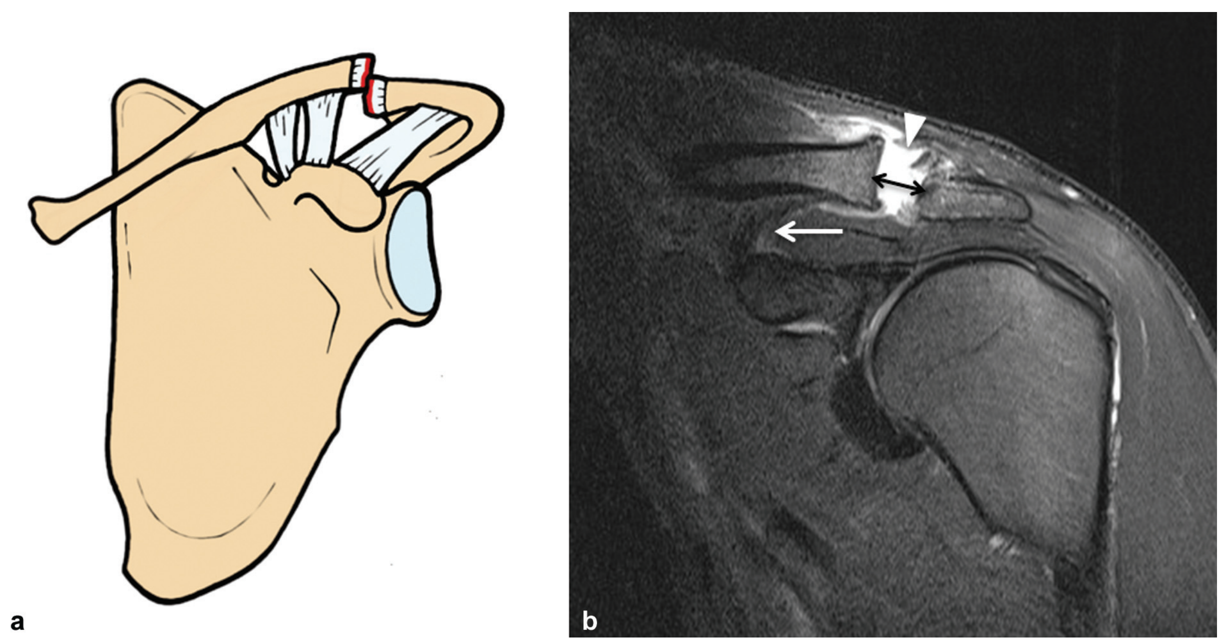

Fig. 5 Rockwood grade 2 acromioclavicular (AC) joint injury. (**a**) Diagram shows the features of grade 2 injury with complete disruption of the AC ligaments and mild elevation of the lateral clavicle. (**b**) Coronal-oblique proton-density fat-saturated magnetic resonance imaging sequence in a 32-year-old diver showing disruption of the AC ligaments (arrowhead) with widening of the AC joint (double-headed arrow). The coracoclavicular ligaments remain intact (arrow).

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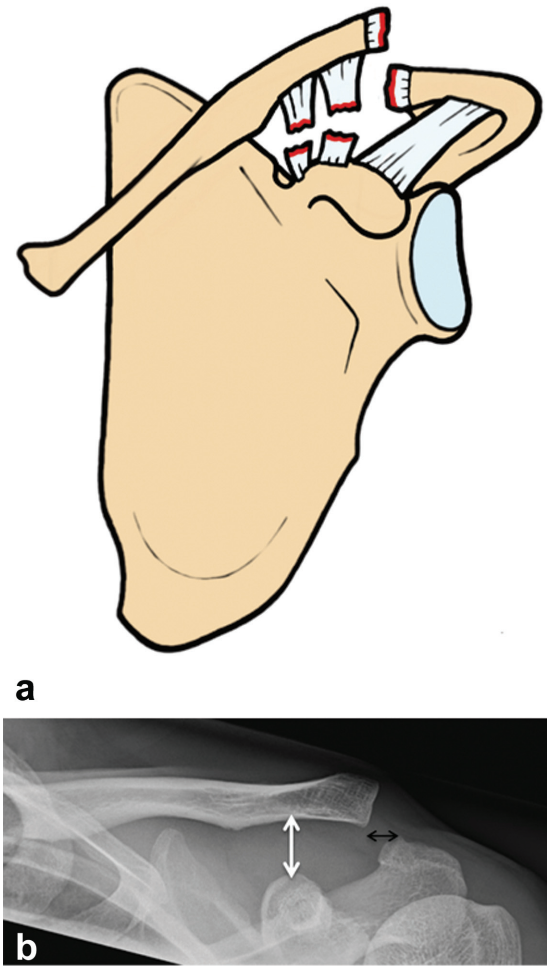

Fig. 6 Rockwood grade 3 acromioclavicular (AC) joint injury. (**a**) Diagram shows the features of grade 3 injury, with complete disruption of the AC and coracoclavicular (CC) ligaments with superior displacement of the lateral clavicle. (**b**) Posteroanterior radiograph in a 28-year-old rugby player shows elevation of the lateral clavicle above the superior border of the acromion (black double arrow). The CC distance (white double-headed arrow) is less than twice the uninjured side.

Rockwood Grade 5

Grade 5 AC joint injury is a more severe form of grade 3 injury, composed of complete tears of the trapezius and deltoid attachments to the lateral clavicle (►**Fig. S2**). The injury results

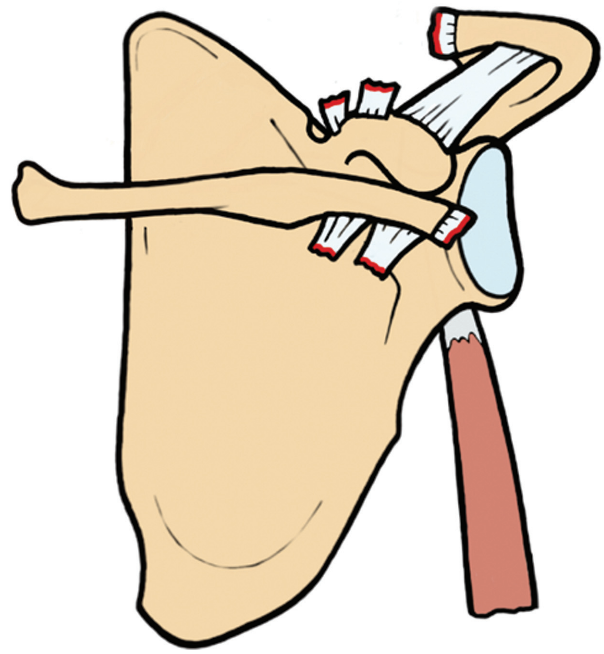

Fig. 8 Rockwood grade 6 injury. Diagram shows complete disruption of the acromioclavicular and coracoclavicular ligaments with inferior displacement of the lateral clavicle.

in marked superior displacement of the clavicle due to unopposed action of the sternocleidomastoid muscle.[25] The hallmark of grade 5 injury on radiographs is a markedly increased CC distance, with an interval measuring between 100% and 300% more than the uninjured joint.[33] On MRI, however, the CC distance is less marked because in the supine position, the weight of the arm does not affect the CC distance and the scapula is relatively fixed.[34] The extent of injury to the deltoid and trapezius is readily identified on MRI, manifesting as muscle fiber disruption and edema, best demonstrated on sagittal fluid-sensitive sequences.

Rockwood Grade 6

Grade 6 AC joint injury is rare, resulting in inferior displacement of the clavicle at the AC joint, and it is frequently associated with other injuries (►**Fig. 8**). The mechanism of injury involves a force to the superior clavicle with the

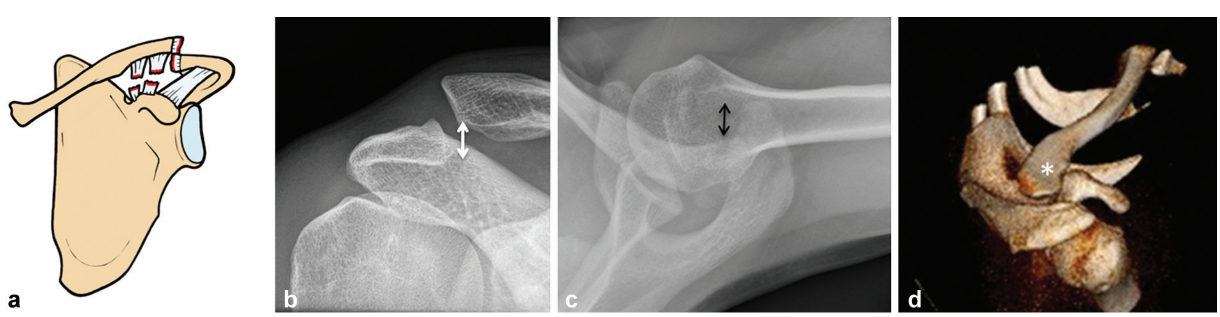

Fig. 7 Rockwood grade 4 acromioclavicular (AC) joint injury. (**a**) Diagram shows complete disruption of the AC and coracoclavicular ligaments with posterior dislocation of the lateral clavicle. (**b**) Anteroposterior radiograph shows elevation of the lateral clavicle at the AC joint (double arrows), but the posterior displacement is not well demonstrated and is only appreciated on (**c**) the axial projection (black double arrow). (**d**) Three-dimensional reconstructed computed tomography confirms posterior dislocation of the lateral clavicle (asterisk) at the AC joint.

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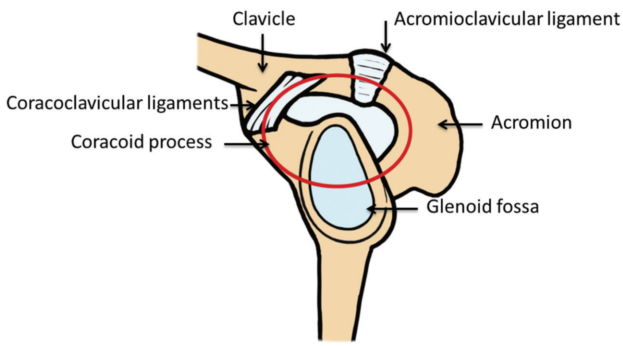

Fig. 9 Superior shoulder suspensory complex (SSSC). Diagram detailing the osseoligamentous components of the SSSC.

shoulder abducted and the scapula retracted.[33] The distal clavicle dislocates inferiorly to the acromion or coracoid, with a reduction in CC distance seen on radiographs when compared with the contralateral joint.[25] There is disruption of the AC ligaments alone on MRI, and the CC ligaments are preserved.[19]

Fractures Around the AC Joint

High-grade injuries to the AC joint are associated with other injuries around the shoulder, such as fractures to the coracoid process, clavicle, and acromion. The superior shoulder suspensory complex (SSSC) is a ring of bony and soft tissue structures at the superior aspect of the shoulder that aids in the classification and management of injuries involving the AC joint.[35] The ring is composed of the glenoid process, the coracoid process, the CC ligaments, distal clavicle, AC joint, and acromial process[35] (►**Fig. 9**). The superior strut is the middle clavicle; the inferior strut is the lateral scapular body and medial glenoid neck.[36] The SSSC is important biomechanically, serving as a point of musculotendinous and ligamentous attachment, as well as connecting the upper limb with the axial skeleton.[36]

Goss described the double disruption theory, whereby if the SSSC is disrupted in two or more places, its integrity is breached and potentially unstable anatomically.[35] This increases the likelihood of adverse outcomes, such as nonunion, reduced strength, and osteoarthritis; thus these injuries are more likely to be treated surgically.[37]

Coracoid Fractures

Fractures of the coracoid are rare, accounting for up to 13% of scapular fractures, and typically the result of high-energy trauma and associated with other injuries.[38,39] Ogawa et al described the most commonly used classification of coracoid fractures, according to the relationship to the CC ligament[38] (►**Fig. 10**).

Type 1 fractures are located proximal to the CC ligaments and usually secondary to a direct force.[38,39] Type 1 fractures are stabilized by the surrounding soft tissues, and the CC ligaments are frequently undisplaced, best demonstrated on CT or MRI[39] (►**Fig. 11**). Type 2 fractures are avulsion fractures distal to the CC ligaments secondary to abrupt muscle contraction and not associated with AC joint instability[38,39] (►**Fig. S3**).

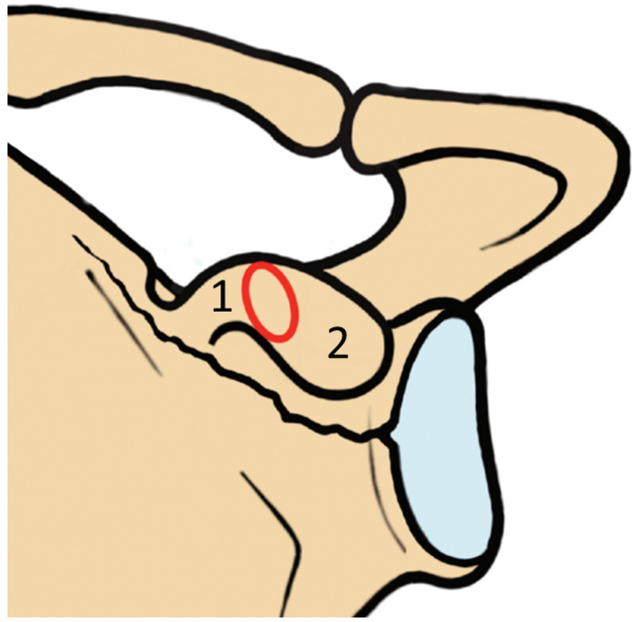

Fig. 10 Coracoid fracture classification. Type 1 fractures occur proximal to the coracoclavicular ligament attachment (red circle); type 2 fractures occur distally.[38]

Distal Clavicle Fractures

Fractures of the distal clavicle are less common than midshaft fractures, accounting for 10 to 30% of fractures; however, nonunion is more common distally.[40,41] There is a bimodal distribution of distal clavicle fractures, with sports injuries most common in men between 30 and 50 years of age.[40] The most commonly used classification was first described by Neer in 1968 and identified fractures depending on their relationship to the CC ligaments on plain radiographs.[42] This system was subsequently revised by Craig into a five-grade system that is more helpful in determining management and prognosis[43] (►**Fig. 12**).

Based on this modified classification, type 1 fractures occur lateral to the CC ligament; they are minimally displaced and extra-articular[42,43] (►**Fig. S4**). Type 2 fractures

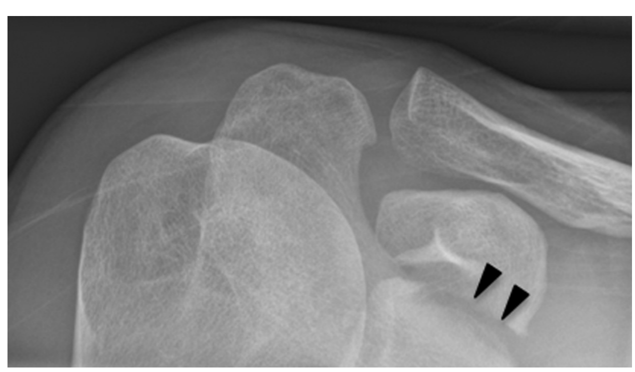

Fig. 11 Type 1 coracoid fracture in a 31-year-old hockey player. Zanca projection radiograph shows a fracture through the base of the coracoid process (arrowheads).

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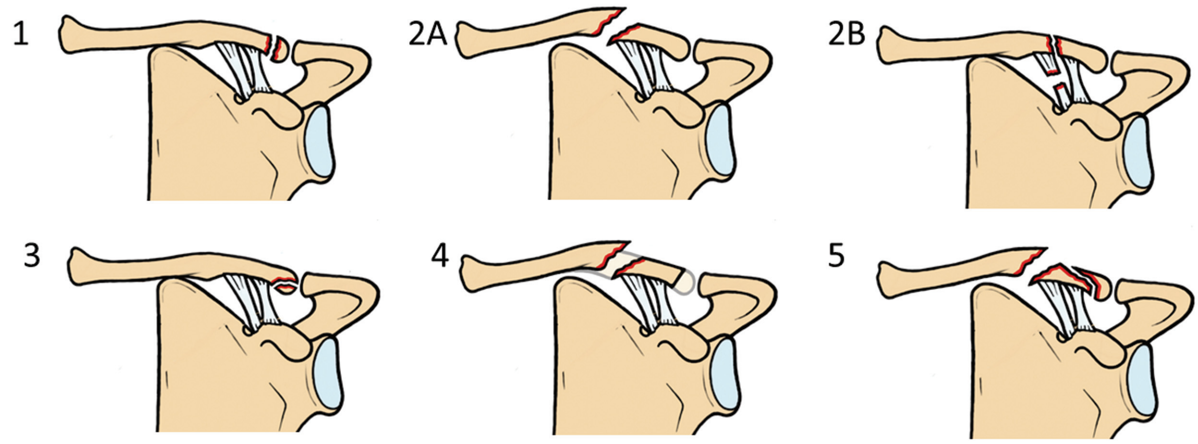

Fig. 12 Classification of fractures of the lateral clavicle.[43]

occur medial to the CC ligaments and are divided into two subtypes; type 2A fractures are medial to both components of the CC ligament, and type 2B fractures occur between the conoid and trapezoid ligaments, with rupture of the conoid ligament.[42] Type 3 fractures are similar to type 1 injuries but have intra-articular extension, involving the AC joint[42] (►**Fig. S5**). Type 4 fractures are unusual pediatric injuries and consist of a Salter-Harris type 1 fracture through the physis, with periosteal stripping medially from the CC ligament attachments to the clavicle (►**Fig. S6**). Type 5 fractures are comminuted and unstable, with only a small inferior fracture fragment remaining attached to the CC ligaments.[42]

Bipolar Fractures

Bipolar injuries occur as a result of injury to both the lateral and medial ends of the clavicle that includes fractures as well as dislocations of the AC or sternoclavicular joint.[4,44] The term "floating clavicle" is used if there is dislocation to both the AC and sternoclavicular joints with no associated fracture.[45] These injuries are frequently missed due to unfamiliarity and distracting injuries, and the entire clavicle should be assessed both clinically and radiologically. CT is useful if there is doubt following initial radiographs.[44]

Management

Isolated AC Joint Injury

The management of AC joint dislocation depends on the grade of injury. Grade 1 and 2 injuries are managed conservatively, and grade 4 to 6 injuries are generally managed operatively.[46] The management of a grade 3 AC joint injury remains controversial, but conservative treatment is generally favored and the preferred initial management for most orthopaedic surgeons in the United Kingdom.[47,48] The aim of treatment is to return the patient to their level of function and sport before injury, with a mobile pain-free shoulder.

Conservative Management

Conservative management consists of rest, ice, and simple analgesia to provide symptomatic relief.[49] A broad arm sling is typically worn for the first week, and formal physiotherapy is seldom required because weakness and shoulder stiffness are rare.[49] Up to a third of patients report pain on long-term follow-up that may be a result of degenerative change because the AC joint remains congruent.[50]

It was suggested that operative management of low-grade AC joint injuries is preferred for throwing athletes, but most athletes return to sport after conservative management without difficulty.[51] A review of injuries to the AC joint in professional American football players in the National Football League found that 98.3% of players were treated conservatively for grade 1 to 3 injuries, including quarterbacks who throw the football overhead repeatedly.[52] Surgical management leads to more time away from sport, with a mean return to play of 56.2 days compared with 9.8 days for those managed conservatively.[52]

Operative Management

AC Joint

Type 4 and type 5 AC joint sporting injuries are managed surgically, as well as the few reported cases of type 6 injury.[49] A wide range of surgical techniques have been described with none shown to be definitively superior, and there is an increasing trend for minimally invasive arthroscopic procedures. The principle of operative management is reduction of the AC joint in both the coronal and sagittal plane with restoration of AC joint stability by repairing or reconstructing the disrupted CC ligaments.[53] A rigid implant may be used to stabilize the AC joint temporarily. It must be removed once the reconstruction has healed to avoid the construct breaking or causing shoulder stiffness.[49]

Primary Repair

Direct repair of the ruptured CC and AC ligaments is possible within the first 2 weeks following injury via an open procedure, before the development of significant scar tissue.[49] Disadvantages include a high incidence of osteoarthritis, and the open incision is invasive.[54] Postoperative radiographs should confirm satisfactory reduction of the AC joint, and suture material will not be visible.

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Ligamentous Reconstruction

Most delayed ligamentous reconstructions involve resection of the lateral clavicle, followed by ligament substitution. The original procedure, described by Weaver and Dunn, involves resection of the lateral 5 to 10 mm of the lateral clavicle, followed by transfer of the CA ligament onto the clavicle[55] (►**Fig. S7**). The procedure has a high rate of failure, however, because the reconstructed ligament has only 50% of the strength and stiffness of the native CA ligament.[56]

The conjoined tendon has also been used as an autograft, involving transfer of the lateral half of the tendon onto the distal clavicle and augmentation with an EndoButton device across the CC space.[49] The conjoined tendon has better biomechanical properties than the CA ligament. However, there is a possibility of fracture if partial osteotomy of the coracoid is performed, as well as risk of musculocutaneous nerve injury.[57,58]

Recent advances in synthetic ligaments have led to these replacing the traditional Weaver-Dunn procedure.[59–61] Several different devices have been developed, most of which involve reconstructing the ruptured CC ligaments (►**Fig. 13a**). The synthetic ligaments have been demonstrated to be incredibly strong, with a pullout strength considerably higher than the tensile strength of the native CC ligament, facilitating early rehabilitation and mobilization.[62] Synthetic CC ligament reconstruction is also associated with favorable functional and pain outcomes at long-term follow-up when compared with the traditional Weaver-Dunn procedure, as well as an earlier return to work.[63]

The method of fixation varies between devices and includes clavicular EndoButton and screw fixation that are visible on the postoperative radiograph (►**Fig. 13b, c** and ►**Fig. 14**). The radiologist should be familiar with the procedure performed locally, as well as the expected device and tunnel positions.

Coracoclavicular Cerclage

CC cerclage is a well-established technique that does not rely on biological healing or temporary rigid stabilization.[64] Several suture materials have been used, including wire that will be clearly visible on postoperative radiographs, and various synthetic materials, such as Dacron, that will not[49] (►**Fig. S8**). CC cerclage is associated with redislocation

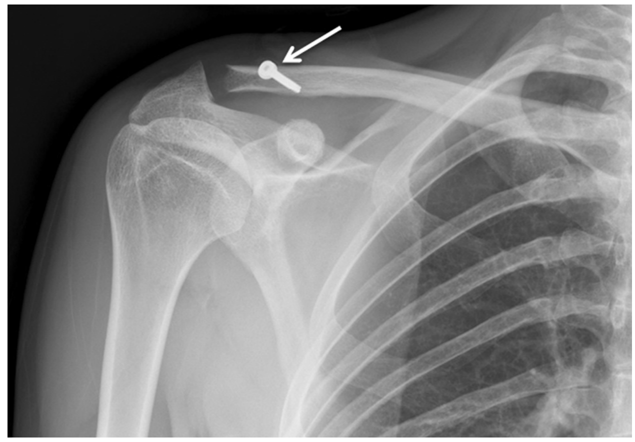

Fig. 14 Synthetic reconstruction of the coracoclavicular ligaments in a 31-year-old cyclist. Postoperative anteroposterior radiograph shows the expected position of the clavicular bicortical screw (arrow) following Nottingham Surgilig fixation.

of the AC joint on long-term follow-up and CC ligament ossification; however, these are not necessarily associated with poor outcomes.[65]

Coracoid Fractures

There is no consensus on the optimum management of coracoid fractures, but most patients are managed conservatively with sling immobilization.[66] Operative treatment is typically not required for type 1 fractures. Most patients report excellent results with conservative management and early physiotherapy.[67] The indications for operative management include symptomatic nonunion after initial conservative treatment, fracture displacement > 1 cm, and multiple disruptions to the SSSC with > 1 cm displacement.[68] Grade 2 injuries are also generally managed conservatively because operative treatment is associated with high complication rates and longer time out of sport.[69]

Surgical management consists of open reduction and internal fixation via an anterior deltopectoral approach with an incision directly overlying the coracoid.[68] The surgeon dissects down to the coracoid, enabling inspection of the integrity of the soft tissues attaching to the coracoid, including the CC ligament complex.[68] For noncomminuted type 1 fractures, typically lag screw fixation is all that is required to ensure

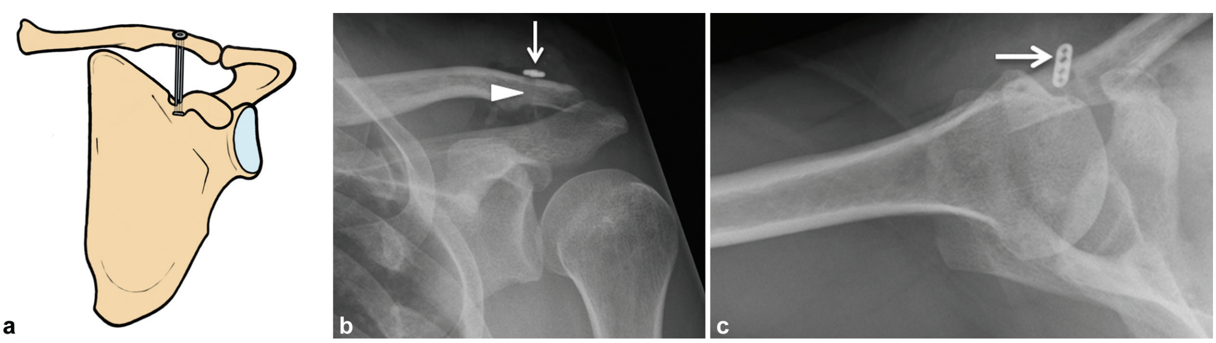

Fig. 13 Synthetic ligamentous reconstruction of the acromioclavicular (AC) joint. (**a**) Diagram illustrating synthetic coracoclavicular reconstruction. (**b**) Anteroposterior and (**c**) axial radiograph showing the expected position of the Infinity-Lock EndoButton (white arrows) and clavicular tunnel (arrowheads) postoperatively.

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stability, taking care not to injure the suprascapular nerve traversing the suprascapular notch.[68] For more complex fractures extending into the glenoid or scapular body, a posterior approach is preferred.[68] Several methods for type 2 coracoid fracture fixation have been described, such as tension band wiring and screw fixation[70] (►**Fig. S9**).

Van Doesburg et al performed a systematic review of coracoid fracture management, concluding that surgical management is effective in patients with type 1 fractures with SSSC disruption, with conservative management reserved for patients with type 2 fractures and no SSSC disruption.[66] Approximately two thirds of patients with type 2 fractures were treated conservatively, and all but one reported excellent functional outcomes.[66] Five cases of nonunion in patients were treated conservatively, but all of these were asymptomatic.[66]

Distal Clavicle Fractures

The management of distal clavicle fractures is controversial and depends on the degree of displacement and stability of the fracture. Type 1 and type 3 fractures are stable and generally managed conservatively.[40] Type 4 fractures in children are also managed conservatively, with new bone rapidly bridging the periosteal sleeve and remodeling.[4]

Modified Neer type 2 and type 5 fractures are similar. Both are considered unstable because the distal fragment is subject to inferomedial force by the weight of the arm and contraction of the pectoral muscles and latissimus dorsi, and the proximal fragment is pulled posteriorly by the trapezius.[41] These fractures are at greater risk of developing complications if managed conservatively, such as premature osteoarthritis and nonunion.[71] Numerous surgical techniques have been described, with the aim of reducing the fracture with or without fixation of the CC ligaments.[41]

Precontoured locking plates are favored for fractures with a large distal fragment because they facilitate early postoperative mobilization and do not risk subacromial impingement, since the plate does not cross the AC joint.[40] If the distal fragment is too small for screw fixation, a hook plate is a reliable alternative.[72] A subacromial hook is fixed to the undersurface of the acromion and provides distal leverage, allowing reduction of a superiorly displaced fracture fragment.[73]

Bipolar Fractures

Due to the infrequency of bipolar fractures, there is no consensus on the optimal management. Surgical management is recommended for most sporting injuries in young patients that most commonly involves plating of both the medial and lateral clavicle.[44]

Complications of AC Joint Injury and Surgery

The most common complications of AC joint injury, osteoarthritis, clavicular osteolysis, and nonunion, occur following both conservative and operative management. Other complications are specific to surgical management, such as failure of joint reduction, fractures, and infection. On follow-up radiographs, the CC ligaments are frequently ossified and not believed to be associated with symptoms[49] (►**Fig. S10**).

Osteoarthritis

Imaging is seldom used for the diagnosis of AC joint osteoarthritis. If imaging is requested, radiographs are usually all that are required, showing the characteristic changes of osteophytosis, joint space narrowing, subchondral sclerosis, and cyst formation (►**Fig. S11**). Management of AC joint osteoarthritis is typically conservative, consisting of physiotherapy and joint injections for diagnosis and symptomatic relief.[74] For persistent symptoms, surgical management entails excision of the lateral clavicle that can be performed by either arthroscopic or open techniques.[74]

Osteolysis

Osteolysis of the distal clavicle occurs in up to 10% of patients following acute AC joint injury, typically occurring several months postinjury and presenting with localized pain.[75] The pathophysiology is debated, and theories include subchondral microfracture secondary to repetitive trauma, as well as synovial invasion of the subchondral bone.[76,77] Radiographs can be normal in the early course of the disease but may progress to cortical irregularity and tapering of the distal clavicle, with subchondral cystic change[78] (►**Fig. 15a, b**). MRI is more sensitive for early osteolysis and shows marrow edema involving the distal clavicle on fluid-sensitive sequences[78] (►**Fig. 15c, d**). Management is typically conservative, with resection of the distal clavicle reserved for refractive cases.

Fracture Nonunion

The rate of nonunion of fractures around the AC joint is highest for the clavicle, with an incidence of up to 24% for patients managed conservatively.[79] Risk factors for nonunion include Neer type II injury, clavicle shortening, and fracture displacement or comminution.[80] Radiographs may be suggestive of nonunion and demonstrate the degree of callous formation, but CT is the preferred modality for the assessment of bone bridging of the fracture and confirming nonunion (►**Fig. S12**). If symptomatic, clavicular nonunion is treated surgically with resection of the distal clavicle or internal fixation, with or without bone grafting[79] (►**Fig. S13**). There are few reported cases of nonunion of coracoid fractures, and most of these patients are asymptomatic and managed conservatively.[81]

Failure of Reduction

The most common complication of surgery to the AC joint is failure of reduction, occurring in between 15% and 80% of patients.[31] Failure manifests as subluxation of the AC joint on all imaging modalities; however, management is guided by the patient's symptoms rather than imaging, with most patients managed conservatively.[31] The revision surgery performed varies, depending on the original procedure, as well as the status of the distal clavicle and coracoid. CT is useful in patients considered for surgical fixation to assess the dimensions of the

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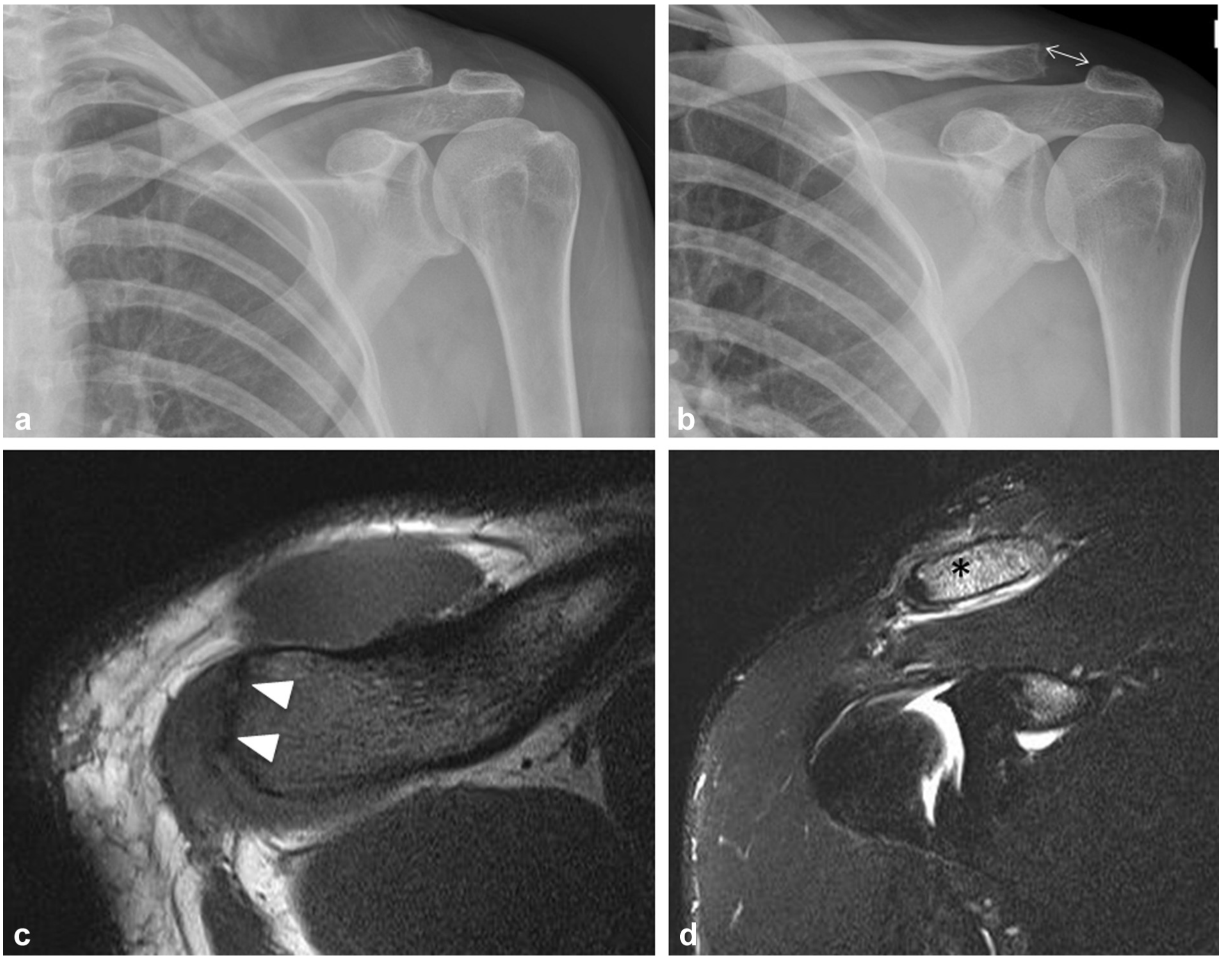

Fig. 15 Osteolysis of the distal clavicle. (**a**) Anteroposterior radiograph at the time of injury and (**b**) 12 months later showing osteolysis of the distal clavicle and an increased acromioclavicular interval (double arrow). (**c**) Axial T1 and (**d**) coronal-oblique proton-density fat-saturated magnetic resonance imaging sequences show cortical irregularity (arrowheads) and marrow edema (asterisk) of the lateral clavicle.

base of the coracoid or distal clavicular fracture fragment to plan screw or plate fixation[31] (►**Fig. S14**).

Fractures

Surgical fixation techniques that involve drilling holes through the distal clavicle and coracoid process increase the likelihood of postoperative fracture, with a prevalence of 20% reported for CC ligament reconstruction with coracoid tunneling.[82] The risk of fracture can be reduced by minimizing the tunnel diameter and adequate tunnel placement.[83] Plain radiographs are the primary modality to assess for postoperative fractures, and they can also evaluate the AC joint for disruption (►**Fig. 16**). Most minimally displaced fractures can be managed conservatively and subsequently monitored with serial imaging.[84]

Infection

Superficial postoperative wound infection is not uncommon following surgery to the AC joint and usually managed conservatively with antibiotics.[49] Deep infection is a much more serious complication, and the AC joint is particularly susceptible due to its superficial location, the extensive dissection required during surgery, and the foreign material used for fixation.[49] Deep infection manifests on MRI as fluid in and around the AC joint, changes of osteomyelitis in more

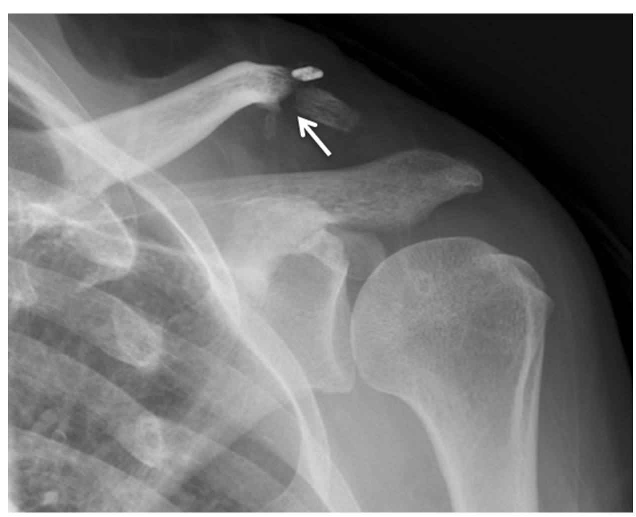

Fig. 16 Stress fracture of the lateral clavicle post acromioclavicular joint reconstruction. Anteroposterior radiograph showing linear lucency within the lateral clavicle (arrow) at the site of Infinity-Lock synthetic coracoclavicular ligament reconstruction.

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advanced cases, and eventually implant failure. Management usually consists of aggressive debridement, removal of any prosthetic material, and prolonged antibiotic therapy.

Conclusion

The AC joint is commonly damaged in young athletes, with injuries ranging from simple sprains to osseoligamentous instability requiring surgical fixation. The radiologist must have a detailed understanding of the anatomy of the AC joint, surrounding structures, and the imaging features of injury to classify the injury accurately and help guide clinical management. A knowledge of the more commonly performed surgical procedures is vital when reporting postoperative imaging, as well as familiarity with the associated complications.

Conflict of Interest
None declared.

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