Current Concepts in the Surgical Management of Acromioclavicular Joint Injuries

David Epstein, M.D., Michael Day, M.S., and Andrew Rokito, M.D.

The acromioclavicular (AC) joint is comprised of the articulation between the distal end of the clavicle and the acromion, functioning to anchor the clavicle to the scapula and shoulder girdle. AC joint injuries are common, accounting for 9% of all injuries to the shoulder girdle. The majority of these injuries occur in males during their third decade of life who participate in sports such as football, hockey, rugby, or skiing with a male to female ratio of approximately 5:1. Among professional rugby players, injuries to the AC joint is the most common shoulder injury, comprising 32% of all shoulder injuries sustained during competition. Kelly and Warren looked at 1,534 injuries to NFL quarterbacks between 1980 and 2001 and found that approximately 15% of these injuries were to the shoulder. Of the shoulder injuries, 40% were to the AC joint. This article will serve as a review of relevant anatomy, biomechanics, diagnosis, classification, and historical treatment of AC joint injury, with a focus on current surgical techniques of acromioclavicular and coracoclavicular (CC) ligament reconstruction.

Anatomy and Biomechanics

The acromioclavicular joint is a relatively subcutaneous diarthrodial joint lined with hyaline cartilage and an interposed intra-articular meniscal structure. The role of this meniscal homologue is negligible, and it is thought to degenerate by the age of 40. Forming the medial aspect of this joint is the clavicle, which functions as an intercalary strut between the axial skeleton and the upper limb via the acromioclavicular and coracoclavicular ligaments, which anchor it to the scapula. The joint can often be a source of pain as the patient advances in age, with innervation from the lateral pectoral, axillary, and supraclavicular nerves. The AC joint has a variable inclination ranging from nearly vertical to 50° of obliquity from lateral to medial in the coronal plane.

The coracoclavicular ligaments play an important role in linking scapulohumeral motion and scapulothoracic motion. Shoulder abduction and forward elevation causes both rotational and translational motion, both in the anterior-posterior and superior-inferior planes, at the AC joint. The clavicle itself is capable of rotating up to 40° to 50°. However, the coracoclavicular ligaments allow the scapula to rotate downward as the clavicle rotates upward, a phenomenon referred to as synchronous scapuloclavicular motion, with only 5° to 8° of motion occurring at the AC joint. Up to 5° of motion may also occur between the coracoid and the clavicle. If the AC joint is fixed, either by fusion or hardware crossing the joint, there will be a loss of motion and failure of hardware secondary to the coupling of clavicle rotation with scapular motion and arm elevation. Recently, Sahara and colleagues performed a three-dimensional (3D) kinematic analysis of the acromioclavicular joint using magnetic resonance imaging (MRI) and observed that the scapula rotated 35° on an axis that passed through the insertions of the acromioclavicular and coracoclavicular ligaments on the acromion and coracoid process, respectively. They also showed that with abduction, the lateral clavicle translated 3.5 mm in the AP and 1 mm in the superior directions.

Stability of the joint is conferred by both static and dynamic constraints. The static constraints are the acromioclavicular ligaments, the coracoclavicular ligaments, and the coracoacromial ligament. The acromioclavicular ligaments surround the AC joint and are comprised of the superior, inferior, anterior, and posterior ligaments.
combination, these ligaments form the greatest restraint to displacement of this joint in the anterior and posterior directions. It is estimated that they provide 90% of the constraint to horizontal motion of the AC joint. Cadaveric sectioning studies have shown that the superior ligament accounts for 56% of resistance against posteriorly directed force, with the posterior ligaments accounting for 25%. It is important to spare these ligaments when performing distal clavicle excision to avoid iatrogenic AC joint instability. An excision of the distal clavicle of less than 1 cm may result in an increase posterior translation of the clavicle by 32%. The primary dynamic stabilizers of the AC joint are the trapezius muscle posteriorly and deltoid muscle anteriorly. The origin of the deltoid and the insertion of the trapezius muscles merge with the superior acromioclavicular ligament and contribute to its strength with contraction of the muscular fibers (Fig. 1).

The coracoclavicular ligaments are the conoid ligament posteromedially and the trapezoid ligament anterolaterally. The trapezoid ligament originates from an anterolateral position on the angle of the coracoid and courses to the clavicle in a superolateral direction to insert at the trapezoid line on the inferior clavicle. The conoid ligament originates postero-medially on the angle of the coracoid and courses superomedially to insert on the postero-inferiorly located conoid tubercle, just posterior and medial to the trapezoid insertion. Both ligaments originate posteriorly to the pectoralis minor insertion on the coracoid. In contrast to the capsular AC ligaments, these ligaments are vital to vertical stability of the joint and also serve to guide synchronous scapulohumeral motion by attaching the clavicle to the scapula. Biomechanical studies by Fukuda and coworkers have shown that the conoid ligament plays a primary role in constraining anterior and superior displacement of the clavicle while the trapezoid is an important stabilizer in axial compression toward the acromion process. It is, therefore, important to consider reconstructing both the AC and CC ligaments when faced with a displaced AC joint injury. Rios and associates, using dry osteology specimens, found that while absolute differences in the origin of the CC ligaments exist between men and women, the ratio of these origins to total clavicle length is constant. The ratio of the distance to the medial edge of the conoid tuberosity divided by clavicle length is 0.31 and for the trapezoid, 0.17. This allows the surgeon to predict the origin of the conoid and trapezoid ligaments accurately and to correctly create bone tunnels to reconstruct the anatomy of the CC complex.

Recently, Salzmann and coworkers, using cadaveric specimens, evaluated the dimension and orientation of the coracoclavicular footprints with respect to bony landmarks. The authors found that the footprint of the conoid on the coracoid was 4.4 mm in the mediolateral plane and 9.6 mm in anteroposterior plane, and the footprint of the trapezoid was 5.7 mm by 15.2 mm, respectively. The mean distance between the footprint centers was 10.1 ± 4.2 mm. This has important implications when considering anatomic reconstruction of the coracoclavicular ligament complex.

Procedures about the coracoid are relatively safe procedures. The lateral cord of the brachial plexus is at greatest risk during dissection about the tip of the coracoid, and the axillary nerve is at greatest risk during dissection about the base of the coracoid.

**Mechanism of Injury**

The relatively subcutaneous nature of this joint and its paucity of soft tissue protection predispose it to injury from either indirect or direct mechanisms. Indirect mechanisms are less common and occur as a result of a fall onto an outstretched upper extremity, whereby the force of the fall drives the proximal humerus into the overlying acromion. This forces the scapula superiorly and medially and often indirectly injures the acromioclavicular ligaments, while sparing the coracoclavicular ligaments. More commonly, the mechanism of injury occurs during a direct fall or blow onto

![Figure 1](image_url)
the lateral aspect of the shoulder with the arm adducted. The inherent strength and stability of the sternoclavicular joint transfers energy to both the acromioclavicular and coracoclavicular ligaments. As the upper extremity and scapula are displaced inferiorly, the clavicle can no longer displace inferiorly with the scapula as the first rib obstructs it, thereby transmitting this force to the AC and CC ligaments as well as the deltotrapezial fascia.19

**Classification**

Early classification of AC joint injuries by Tossy and colleagues20 and Allman21 were based on radiographic displacement and the degree of ligamentous damage. They were initially graded I through III, and Rockwood later added types IV through VI to the classification system.22 The rising type correlates with greater displacement and higher levels of ligamentous injury.

Type I: This typically low-energy injury involves a sprain to the AC ligaments only. The CC ligaments are spared by the absorption of the impact by the AC ligaments. With the AC and CC ligaments intact, radiographic imaging appears normal.

Type II: As the energy imparted to the shoulder is increased, the AC joint capsule and ligaments are ruptured, and the distal clavicle is thereby rendered unstable in the horizontal plane. The CC ligaments remain intact, and there may be slight elevation of the clavicle on radiographs; however, the displacement is less than 100% of the diameter of the distal clavicle, and the radiographic CC distance is increased less than 20%.7

Type III: This higher energy injury represents a complete disruption of both the AC and CC ligaments, which leads to complete dislocation of the AC joint. The insertion of the deltotrapezial fascia remains intact. Radiographs demonstrate displacement of the clavicle greater than 100% of the diameter of the distal clavicle, and the radiographic CC distance is increased 20% to 100%.22

Type IV: This injury involves a complete rupture of the AC and CC ligaments with posterior displacement of the distal clavicle into the trapezius fascia. It is important in this setting to evaluate the SC joint as concomitant anterior dislocation can occur.

Type V: This higher energy variant of a type III injury represents a complete disruption of both the AC and CC ligaments, which leads to complete dislocation of the AC joint. The deltotrapezial fascia is stripped from its attachment to the clavicle. Radiographs demonstrate displacement of the clavicle greater than 300% of the diameter of the distal clavicle, and the radiographic CC distance is increased 100% to 300% (Fig. 2).

Type VI: This rare injury involves inferior displacement of the clavicle either subacromial or subcoracoid behind the conjoined tendon. The mechanism involves severe hyperabduction and external rotation of the arm combined with scapular retraction. It results from high-energy trauma and neurovascular impairment is often present prior to reduction.23

**Physical Examination and Radiographic Analysis**

A detailed history including the mechanism of injury, location and duration of pain, and associated symptoms is vital to diagnosis an AC joint injury. History of trauma to the lateral aspect of the shoulder, often during contact sports, or a fall from height onto an outstretched hand should heighten suspicion of AC joint injury. It is important to examine the patient in a sitting or standing position, allowing the weight of the injured arm to exaggerate any deformity. Pain may be variable in nature, given the AC joints dual innervation from the suprascapular nerve and the lateral pectoral nerve; however, the diagnosis is often clinched with a visible or palpable defect noted at the AC joint that is tender to palpation.24 Palpation of the distal portion of the clavicle relative to the acromion can provide information on direction and severity of injury. Discomfort is often clinched with a visible or palpable defect noted at the AC joint that is tender to palpation.24 Palpation of the distal portion of the clavicle relative to the acromion can provide information on direction and severity of injury. Discomfort is often exacerbated with range of motion of the shoulder and with loading the joint with the cross arm adduction test, which is performed by forward elevating the arm to 90° with arm adduction. Assessment of the AC joint for stability after an acute injury may be difficult secondary to guarding; however, for subacute and chronic injuries, this should be attempted. If a type I injury is suspected, and no visible deformity is present, relief of pain with injection of a local anesthetic confirms injury.2

The Paxinos test (thumb pressure at the posterior AC joint) combined with a positive bone scan has been found to predict AC joint pathology with a high degree of confidence.25 The O’Brien active compression test is performed by having the patient forward flex the arm to 90° with the elbow in full extension and then adduct the arm 10° to 15°

![Figure 2 An anteroposterior radiograph of a Type V AC joint injury.](image-url)
medial to the sagittal plane of the body and internally rotated it so that the thumb points downward. The examiner, standing behind the patient, applies a uniform downward force to the arm. With the arm in the same position, the palm is then fully supinated, and the maneuver was repeated. The test is considered positive if pain was elicited during the first maneuver and was reduced or eliminated with the second. Pain localized to the acromioclavicular joint or “on top” is diagnostic of acromioclavicular joint abnormality, whereas pain or painful clicking described as “inside” the shoulder is considered indicative of labral abnormality. However, the sensitivity of this test for AC pathology is only 41%, with a specificity of 94%. A simple shoulder shrug may be helpful in determining if the deltotrapezial fascia has been separated from the clavicle and thereby help differentiate a type III injury from a type V injury. If the shoulder shrug reduces the AC joint, the deltotrapezial fascia can be interpreted to remain attached to the clavicle. Reduction of the AC joint can also be tested by stabilizing the clavicle in one hand and with the other hand placing an upward force on the ipsilateral elbow and assessing the joint for visible or palpable incongruity. Additionally, a thorough neurovascular assessment of the upper extremity including the cervical spine should be performed, particularly in the presence of a type VI injury. Suspicion for other associated injuries, such as clavicle, coracoid, and rib fractures, should be raised with higher injury mechanisms. Confirmation of AC joint injury involves a complete radiographic shoulder series, which is essential in the analysis and classification of these injuries. Anteroposterior, scapular Y, and axillary views are obtained. These radiographs serve to provide information regarding the nearby glenohumeral joint and can rule out coexisting pathology. The AC joint itself is visualized primarily on the AP and the axillary views. Translation in the anteroposterior plane of the clavicle relative to the acromion should be seen on the axillary view, and this is particularly helpful in confirming the diagnosis of a type IV injury. Translation in the superoinferior plane is viewed on the AP radiograph. The degree of displacement may be quantified by measuring the percentage of both the vertical displacement of the clavicle relative to the acromion and the percentage distance between the coracoid and the clavicle compared to the contralateral side. If bilateral injuries are suspected, the a normative value of 1.1 to 1.3 cm can be used, with a side to side difference of 5 mm diagnostic of complete rupture. The AC joint width is normally between 1 to 3 mm, however it may decrease with age. Often however, because the AC joint is less dense than the glenohumeral joint, it may appear over penetrated and dark on the AP radiograph. It is for this reason that the Zanca view, obtained by using 50% of the radiation and a 10° to 15° cephalic tilt, can be particularly helpful in diagnosing AC joint pathology. In addition to this radiograph, a stress view may be used to confirm joint instability or displacement. Ten to fifteen pounds of weight are hung from each wrist, and a bilateral Zanca view is obtained allowing comparison of the AC joint morphology. This view may be helpful in differentiating type II from type III injuries. However, it often proves painful for the patient and rarely provides new information to help diagnose an unstable injury; therefore, it is no longer routinely used (Fig. 3).

If an AC joint injury is suspected and displacement is seen at the AC joint but the coracoclavicular distance is normal or equal to the other side, a Stryker Notch view may be obtained with the patient in a supine position with the arm elevated parallel to the long axis of the body, and the palm placed behind the head. The radiographic beam is then angled 10° cranially.

**Treatment**

The goals of treatment for AC injuries are achieving painless range of motion of the shoulder, obtaining full strength, and exhibiting no limitation in activity. Nonoperative treatment for lower energy injuries including type I, II, and III injuries, generally results in a good outcome with the use of rest, ice, anti-inflammatory medications, and physical therapy. The treatment of type III injuries is somewhat controversial, but most favor nonoperative therapy. Operative intervention is often reserved for the types IV, V, and VI injuries.
which involve a higher-energy mechanism that results in significant instability of the acromioclavicular joint. The soft tissues about the AC joint, in particular the AC and CC ligaments, often must be reconstructed to restore functional stability. Recently, there has been a focus on anatomic reconstruction of the CC ligaments, which has gained popularity over other common methods of stabilizing the AC joint, such as the Weaver-Dunn procedure, hook-plate stabilization, and screw stabilization. Anatomic reconstruction of the CC ligaments can be performed utilizing many different techniques that vary widely in terms of arthroscopic open procedures, the use allograft tissue, and types of fixation.

**Nonoperative Treatment**

Nonoperative treatment is typically reserved for type I, II, and acute type III injuries. This involves a 7 to 10 day period of rest, immobilization, and anti-inflammatory medications followed by a course of physical therapy. Historically, braces, such as the Kenny-Howard brace, were used to treat these injuries. It acted to reduce the AC joint by applying a downward force on the clavicle and an upward force on the humerus. It was worn for 6 to 8 weeks and was associated with recurrence of deformity, skin ulcerations in up to 20% of cases, poor compliance, and muscular atrophy. As for these reasons that bracing is rarely utilized. After acute injury, the shoulder can be placed in a sling or shoulder immobilizer to decrease stress across the AC and CC ligaments; however, it is only needed as dictated by pain. As pain improves, a physical therapy program is initiated. Gladstone and colleagues have reported on a four-phase rehabilitation program for athletes involving the gradual transition from range of motion in the plane of the scapula to gradual strengthening exercises and eventual return to activity, with the progression of therapy based on the individual’s symptoms. In professional athletes who sustain an acute AC joint injury, an injection of bupivacaine is usually very successful, but does carry a slight increase in the need for distal clavicle resection at the end of the season. This is felt not to be a significant threat to the player’s career.

Nonoperative treatment of type I and II AC joint injuries may be complicated by residual instability, degenerative changes at the AC joint, distal clavicle osteolysis, and continued pain. Cox demonstrated in follow-up examinations of navy recruits with type I and II injuries that residual symptoms (36% to 48%), positive physical exam findings (43% to 77%), and radiographic changes in the joint (70% to 75%) can be quite common. Other investigators have found that 43% to 50% of patients treated nonoperatively can go on to develop post-traumatic arthritis. Mouhsine and associates found that 27% of patients who sustained type I and II injuries developed chronic AC joint symptoms at a mean of 26 months after injury that required subsequent surgical intervention. In those that did not undergo surgical intervention, only 52% were asymptomatic, with 88% of patients having radiographic changes (ossification of the coracoclavicular ligaments, degenerative changes, and distal clavicular osteolysis) on x-ray at an average of 6-year follow-up. Symptomatic AC joint injuries can be treated with open or arthroscopic distal clavicle resection with excellent results.

Type III injuries have been a topic of controversy in the orthopedic community with most surgeons favoring initial nonoperative therapy. Among team physicians of professional baseball teams, 69% preferred nonoperative therapy while 31% indicated that they would operate immediately when presented with a type III injury to a starting pitcher. In a recent Meta analysis, 1,172 patients from 24 publications were investigated. Of these, 833 were treated surgically, and 339 were treated without surgery. Eighty-eight percent of those surgically treated and 87% of those treated nonoperatively had satisfactory outcomes. The complications were the need for further surgery (59% operative vs. 6% nonoperative), infection (6% operative vs. 1% nonoperative), and deformity (3% operative and 37% nonoperative). The time required to return to activity, pain, range of motion, and strength were found to be similar in both treatment arms. The investigators concluded that power studies showed no benefit to surgical treatment for type III AC joint injuries.

Bannister and coworkers, in a prospective study of 54 patients with acute type III and V acromioclavicular dislocations, compared nonoperative treatment in a sling versus reduction and fixation with a coracoclavicular screw. Conservatively, treated patients regained movement significantly more quickly and fully, returned to work and sport earlier, and had fewer unsatisfactory results than those having early operation. However, for severe dislocations, with acromioclavicular displacement of 2 cm or more, early surgery produced better results with 70% of these patients having good or excellent results versus 20% in the nonoperative group. The authors concluded that conservative management is best for most acute dislocations, but younger patients with severe displacement may benefit from early reduction and stabilization.

It is important that a structured, active rehabilitation program is promptly initiated to decrease the risk of pain and disability after a type III AC joint injury. While some cite a potential loss of strength as an indication for surgical intervention, Tibone and colleagues demonstrated at 2-year follow-up for 20 males with type III injuries treated nonoperatively no difference in strength between the injured and non-injured extremity. Schlegel confirmed these findings relative to shoulder rotational strength, but demonstrated 17% weaker bench press relative to the contralateral extremity. This study noted a 20% (4/20) rate of subjective suboptimal outcome with conservative treatment. Shoulder strength and endurance levels of the injured shoulders of type III AC joint injuries are comparable to the noninjured side, long-term follow-up reports reveal discomfort appearing with increased intensity of activity. For patients who
Operative Treatment

Operative intervention is typically reserved for type IV, V, and VI injuries, as well as those patients in whom nonoperative management of a type III injury results in pain and disability. Additionally, the surgeon should note whether a patient complains of vertical deformity or pain over a prominent distal clavicle or pain with anterior-posterior instability; this will assist in choosing the appropriate procedure. The surgeon must take into account hand dominance, heavy laborer, position and sport requirements (quarterbacks and pitchers), and risk for reinjury. In the overhead athlete or heavy laborer, operative intervention of an acute type III injury may be indicated. Contraindications for surgery include those patients who cannot comply with postoperative restrictions and rehabilitation, or those who have concomitant severe life threatening injuries that preclude intervention.

Many investigators have proposed different surgical procedures for AC joint injuries, but there is no clear agreement about the superiority of one technique versus another. Biomechanical studies can help elucidate the evolution of surgical treatment options. Two broad categories of current surgical intervention exist: those that seek to provide fixation across the AC joint or CC joint, and those that seek to augment or reconstruct the AC or CC ligaments. A third category of surgical technique is dynamic muscle transfer, which involves the transfer of the short head of the biceps. However, this technique has fallen out of favor secondary to inferior long-term results. Early described procedures, which were often complicated by hardware failure, involved direct fixation across the AC joint, the coracoid, and clavicle, while modern techniques seek to reconstruct a more anatomic link between the coracoid and the clavicle to reduce the AC joint, such as transferring the CA ligament to augment repair. More recently, anatomic augmentation and reconstruction of the CC ligaments using various grafts and fixation methods has been described in the literature. This article will discuss several of the common methods of surgical treatment of AC joint injury such as hook plate stabilization and numerous variations of the modified Weaver-Dunn technique but will focus on the more current techniques of anatomic coracoclavicular ligament augmentation or reconstruction.

Fixation of the Acromioclavicular Joint

Early described procedures involved reducing the AC joint and restoring the normal clavicle and coracoid relationship long enough to allow primary healing of the ruptured coracoclavicular ligaments. The technique involves both closed or open reduction of the joint and repair of the AC ligaments and damaged deltoid and trapezius attachments with stabilization conferred by direct fixation across the joint with K wires, Steinman pins, and screws. Eskola and coworkers prospectively randomized 86 patients with complete dislocation of the acromioclavicular joint verified into either transfixation with two smooth Kirschner wires, two threaded Kirschner wires, or one cortical screw (Bosworth Screw). The acromioclavicular ligament was sutured and the damaged disk removed, but the coracoclavicular ligament was left unsutured. At the one-year follow-up, the results were good in 82 patients. Eight of 13 cases of osteolysis were seen with the use of the Bosworth Screw. It is possible that the use of hardware across the AC joint may worsen the intraarticular injury and may hasten the onset of joint arthrosis. In addition, hardware migration represents the most feared complication with several case reports documenting the migration of pins into life threatening locations, such as the lung, spinal cord, mediastinum, and the neck. Bending the pins or using a tension banding technique cannot absolutely prevent migration as breakage can occur.

The Hook Plate, which is commonly used in Europe, is another method of primary fixation across the AC joint. The lateral aspect of the plate “hooks” underneath the acromion, which is then fixed to the clavicle with screws, thus holding the AC joint reduced. The technique can be used to treat acute injuries, and may be combined with ligament reconstruction for chronic injuries, with good short term outcomes. It has been associated with numerous complications including wound complications, AC arthritis as high as 41%, and an extensive second surgery for hardware removal. All of these techniques require close follow-up and typically involve a second procedure for hardware removal. If the plate is not removed, secondary to normal motion occurring at the AC joint, a widening of the hook hole of the acromion may develop in the majority of patients. As a result of the consequences, this technique is rarely used.

Fixation between the Coracoid and Clavicle

An early described technique, as originally described by Bosworth, involved the use of a lag screw inserted through the clavicle into the base of the coracoid process to provide rigid fixation. This screw may be inserted through open or percutaneous techniques, and it is imperative that bicortical fixation into the coracoid is achieved. Most favor open screw insertion as percutaneous techniques have been associated with a 32% rate of technical failures. Additionally, the open technique allows for CC ligament repair. As elucidated by Rockwood, 5° of motion exists between the coracoid and the clavicle, thus failure or fatigue of the implant would be expected to occur over time. It is for this reason and the numerous reports of hardware migration that screw removal is recommended at 6 to 8 weeks. Biomechanical studies in...
cadaveric models showed that the use of a coracoclavicular screw reduced joint motion and significantly increased joint contact pressures, whereas the CC sling and CA transfer techniques resulted in a very mild increase in joint contact pressures. The investigators concluded that this could have implications for early joint degeneration when this technique is used.56

**Dynamic Muscle Transfer**

In contrast to static forms of repair, there have also been dynamic forms of reconstruction that have been described to reduce the AC joint. These techniques involve the transfer of a muscle-tendinous unit to the inferior surface of the clavicle. This creates an inferiorly directed force on the distal clavicle to actively reduce the AC joint. One technique describes the transfer of the short head of the biceps tendon, the coracobrachialis and the tip of the coracoid process to the inferior surface of the distal end of the clavicle.52,57 The reduction of the AC joint in these situations is non-anatomic and has many potential complications. These include nonunion and malunion of the graft, persistent joint instability, injury to the musculocutaneous nerve, and possibly excessive motion at the AC joint which may lead to future arthrosis. It is for these reasons that these techniques are seldom used for the treatment of acute injuries.

**Ligament Reconstruction**

Recreating a vertical constraint between the coracoid process and the distal end of the clavicle that was previously provided by the coracoclavicular ligaments should be a primary goal of surgical fixation. There are several techniques that have been described and numerous types of material that have been used. These surgical techniques can be grouped broadly into those that involve the transfer of the coracoacromial ligament with or without coracoclavicular sling augmentation (non-anatomic reconstruction), and those that seek to anatomically recreate the CC ligaments. Additionally, a combination of the above procedures may be used.

**Non-Anatomic Ligament Reconstruction**

Neviaser, in 1968, first introduced the concept of using the CA ligament for AC joint repair, in which the ligament was detached from the coracoid and transferred to the distal end of the clavicle. The repair was then augmented with fixation across the AC joint.58 The Weaver-Dunn procedure described in 1972 also utilized the CA ligament; however, this procedure involved the release of the coracoacromial ligament from the acromion, resection of the distal end of the clavicle and transfer of the CA ligament to the lateral end of the clavicle, more closely replicating the CC ligaments.59 Biomechanical studies have shown that this non-anatomic transfer of the CA ligament alone is only 25% as strong as the native ligaments.61,62,69 This prompted several investigators to publish modification of the original technique with augmentation provided by a coracoclavicular augmentation2,29,59 (Fig. 4). The modified Weaver-Dunn technique involves the use various types of materials, for example heavy suture or surgical tape, allograft, or autograft, which are placed around the base of the coracoid and through the distal end of the clavicle and fixed in place with various fixation means, such as suture anchors, suture buttons, and interference screws. Securing the clavicle and coracoid recreates the vertical stability previously provided by the coracoclavicular ligaments. The materials that have been described include suture anchors, sutures, Mersilene tape, allograft, and autograft materials.52,63 The suture or graft is placed around the base of the coracoid using a curved suture passer, placing the axillary nerve at the greatest risk of injury.18 Once passed around the base of the coracoid, the suture or graft is then tied around or through the distal end of the clavicle. A cadaveric biomechanical study by Baker and colleagues showed that passing the suture through the junction of the middle and anterior 1/3 of the clavicle provided a more congruent reduction of the joint and better resisted anterior displacement of the clavicle.64 Complications of this technique include suture cut-out, aseptic foreign-body reaction, and clavicle osteolysis, which can result in failure.65,66 Augmentation of the modified Weaver-Dunn technique using allograft tissue, such as semitendinosus or peroneus brevis, can provide for more biologic fixation after acute or chronic injury.57,68 Biomechanical studies have shown comparable strength between allograft augmentation and the native CC ligaments.69,70

In addition to the open technique, Lafosse and coworkers...
described an all-arthroscopic technique for coracoclavicular ligament reconstruction by ligamentoplasty after acute or chronic acromioclavicular joint dislocation. The investigators dissect the CA ligament from the undersurface of the acromion and reinsert it to the inferior clavicle by transosseous suture fixation. Additional fixation or sling augmentation may be used.

The majority of the literature offers new technique descriptions and small case studies. Biomechanical in vitro studies do evaluate and compare various reconstructive techniques in terms of strength of the material and the repair and the stability of the AC joint following repair. Lee and associates examined in a cadaveric model various tendon grafts to No. 5 Mersilene suture, 5 mm Mersilene tape, and Coracoacromial ligament transfer. Of these, they found the tendon grafts to offer the strongest repair. In addition, they found the most secure method of graft fixation was to tie the graft into a knot with supplemental sutures. Other biomechanical studies have supported that supplemental fixation should be used to augment a Weaver-Dunn reconstruction.

Outcomes of the original Weaver-Dunn procedure were acceptable, with 11 of 15 patients reporting good outcomes. Three failures were noted secondary to loss of reduction, and one patient had a complete failure requiring reoperation. Numerous modifications to improve the Weaver-Dunn technique have since been described, including sutures, tapes, or synthetic grafts. Outcomes for these techniques have been favorable overall, although the literature consists mostly of small retrospective series.

Kumar and colleagues recently reviewed 15 patients with chronic type III AC dislocations who underwent a Weaver-Dunn reconstruction modified with Mersilene tape. Fourteen of 15 patients reported good to excellent results at a mean of 27 months. Two patients had moderate pain and stiffness but were improved compared to prior surgery. Two patients also had a painless clavicular prominence, but subluxation was not quantified with radiographs.

Morrison and colleagues used Gore-TEX to augment the Weaver-Dunn technique and found good or excellent outcomes in 12 of 14 patients at a mean follow-up of 44 months. One patient had a complete re-dislocation requiring revision, but the investigators contributed this to noncompliance. In a comparative study, Pfahler and coworkers looked retrospectively at the Weaver-Dunn technique augmented with looped polydioxanone (PDS) suture versus the Bosworth screw and acromioclavicular tension band wiring. In addition to avoiding hardware removal, the PDS augmentation technique had superior clinical outcome scores and no complications at short-term follow-up.

Several investigators have described transferring a small acromial bone block with the coracoacromial ligament. Kawabe and associates used a small clavicular screw to fix the bone block and used heavy nonabsorbable suture for coracoclavicular augmentation. They reported an excellent result in 37 of 41 patients at a mean follow-up of 7 years. Two patients had clavicular subluxation but were asymptomatic at final follow-up. Shoji and coworkers used suture to secure the bone block rather than the screw. They reported patient satisfaction in 14 of 15 patients with acute and chronic AC joint dislocation at a mean of 2.1 years. One patient had clavicular subluxation but achieved full painless range of motion.

Weinstein and colleagues reported increased failures with late reconstruction. They compared acute (less than 3 weeks) and chronic (greater than 3 weeks) Weaver-Dunn techniques augmented with nonabsorbable suture in 44 patients. At a mean follow-up of 4 years, good to excellent results were observed in 96% with acute reconstruction versus 76% in the late reconstruction group, although this did not reach statistical significance. Four patients with poor outcomes had all had late reconstruction. Two of these patients had complete loss of reduction requiring reoperation, and two had continued pain and weakness, which prevented them from returning to their job. The investigators concluded that their technique was successful in both acute and chronic injuries but recommended reconstruction prior to 3 months if surgery is indicated.

In a prospective study, Tienen and associates examined 21 athletes with acute type V AC dislocations. They performed a modified Weaver-Dunn technique augmented with acromioclavicular suture fixation and no distal clavicle resection. Eighteen of 21 patients returned to sport within 2.5 months and had a good to excellent outcome at a mean of 35 months. Three patients with inferior results were found to have anterior clavicular subluxation or dislocation at final follow-up. This demonstrated a correlation between antero-posterior instability and poor clinical outcome, which is frequently cited as a potential limitation of the modified Weaver-Dunn technique.

The modified Weaver-Dunn procedure with suture anchor coracoclavicular fixation has become a popular method of AC joint reconstruction. Several small retrospective series have recently been published. Other techniques for providing fixation from the coracoid to the clavicle include a suture anchor technique, which utilizes suture anchors placed into the coracoid with suture placed through a tunnel drilled in the clavicle and around the clavicle. This serves to assist in maintaining AC joint reduction while a modified Weaver-Dunn or allograft reconstruction heals. For acute injuries, this technique provides fixation while the CC ligaments heal; for chronic injuries, this technique can provide stability while biologic supplemental fixation heals. This obviates the need for sub-coracoid dissection, thereby minimizing the risk to neurovascular structures.

Shin and coworkers reported on 29 patients with acute type V AC dislocations. Three patients had complete superior dislocation, and two had 50% superior subluxation within 3 weeks of the procedure. One case was secondary to a fall. Despite the high incidence of reduction loss, they found good to excellent functional results in all patients at mean
follow-up of 28 months. There were no reoperations.\textsuperscript{80}

Friedman and colleagues reported outcomes on 24 patients with type III or type V AC injuries or group 2 (type 2) distal clavicle fractures. Eighteen of 22 patients had full strength and painless range of motion at 3 months and at a mean of 33 months. Four patients had early loss of reduction secondary to documented noncompliance. Two of these patients underwent reoperation with a similar procedure and remained asymptomatic at a minimum follow-up of 15 months. An additional patient underwent reoperation for osteophyte and knot excision 7 months after surgery and remained asymptomatic at 30 months.\textsuperscript{81}

Choi and associates reviewed a series of 20 patients with acute type III, IV, and V AC dislocations. At a mean follow-up of 41.2 months, 17 of 20 patients reported being satisfied or very satisfied with their result. Two of 20 patients had a slight loss of reduction at the time of final follow-up; however, their functional outcome was good. Similar to the aforementioned studies, their results indicate that anatomic reduction may not always correlate with functional outcome.\textsuperscript{79}

Several reports on the outcome of the modified Weaver-Dunn technique with a coracoclavicular screw have shown good results; the caveat being that this necessitates a second surgery for removal of hardware. Kumar and coworkers reported on 14 patients with both acute and chronic AC dislocation. Twelve of 14 were found to have excellent results and two with good results at a mean follow-up of 2.8 years. Two screws were removed prematurely secondary to infection, but only minor subluxation was observed at final follow-up in these two patients.\textsuperscript{82}

Guy and colleagues reported results in 23 patients with chronic AC dislocations at a mean follow-up of 5.2 years. They found good or excellent results in 19 of 23 patients (87\%) when examining strength, range of motion, and patient satisfaction. Four patients with inferior results all had one or more distal clavicle resections prior to reconstruction. All patients underwent screw removal between 12 and 16 weeks, and all but one patient had maintenance of reduction at final follow-up. The investigators concluded that the Rockwood screw was a reliable method of temporary fixation in AC reconstruction.\textsuperscript{83}

Pavlik and associates retrospectively examined 17 patients with chronic grade III AC injuries at a mean follow-up of 36.6 months. A distal clavicle resection was not performed. They reported 11 excellent and 6 good results, with a mean Constant score of 91.2. One patient had a partial loss of reduction after screw loosening and late posttraumatic arthritis. His complaints were partially resolved with conservative treatment. Given their outcomes, the authors believed that preservation of the distal clavicle is a successful alternative in young patients at short term follow-up.\textsuperscript{84}

**CC Ligament Repair**

Various methods of providing fixation between the coracoid and the clavicle, with or without CA ligament transfer, have been reported in the literature. Devices such as the Arthrex Tightrope, which consists of a round button, an oblong button, and #5 high-strength solid core suture materials, are designed to stabilize the AC joint by reconstructing the CC ligaments with non-rigid fixation. This imparts stability while allowing normal rotational motion of the clavicle. In acute AC joint injuries, the tightrope can be used to impart stability and allow for the native ligaments to heal. However, for chronic injuries, the Arthrex GraftRope\textsuperscript{TM}, which allows for combined allograft and suture fixation, can be used to confer biologic healing of the reconstructed CC ligaments (Fig. 5). The use of flip buttons in CC ligament reconstruction has been shown to reach the level of the native coracoclavicular ligament complex as it has been quantified in the literature.\textsuperscript{85,86} When using this technique, one must be aware of the proximity of neurovascular structures at the base of the coracoid to avoid iatrogenic injury.

Wellmann and coworkers studied minimally invasive techniques to repair acromioclavicular dislocations using a flip button and suture technique. They found the construct to be as strong as the native ligaments.\textsuperscript{86,87} The double endobutton technique takes advantage of the mechanical strength of

---

**Figure 5** Clinical photograph (A) depicting Type V AC joint injury with AP radiograph (B) of the same patient. Intraoperative photo (C) of GraftRope\textsuperscript{TM}\textsuperscript{(g)} device used to reconstruct the CC ligaments. Final radiograph (D) revealing near anatomic reduction of the AC joint.
the closed loop endobutton. Endobutton fixation works by increasing surface area to spread out tensile forces. Benefits of the technique have been extensively reported in the ACL reconstruction literature. A key advantage in applying endobutton fixation to acromioclavicular reconstruction is the ability to gain adequate stabilization of the joint, while avoiding the need to wrap suture around the coracoid or clavicle. This prevents the known complications of sutures eroding through bone over time. The technique also recreates the vectors of both the conoid and trapezoid portions of the coracoclavicular ligaments. It is a permanent device that requires no removal. The device is strong enough to provide adequate stabilization, but not rigid, allowing normal rotational motion of the clavicle. If the procedure is performed acutely, less than 4 weeks after injury, the native ligaments are allowed to heal.\textsuperscript{80,87} Double endobutton repair is another promising method of coracoclavicular fixation. Little evidence is available, but in a recent study by Wellmann and coworkers, they reported excellent radiologic and clinical results in 15 patients at short-term follow-up. They used a double flip button (Flipack; Karl Storz, Tuttingen, Germany) and found no subluxations or dislocations of the acromioclavicular joint. They recommend its use in acute grade III-V injuries and suggested using a tendon graft for revision or chronic injuries.\textsuperscript{87}

Wolf and Pennington originally described an arthroscopic technique that involves passing sutures through tunnels created through the distal clavicle and coracoid with an arthroscopic subcoracoid drill guide.\textsuperscript{88} An arthroscopic approach allows the secure fixation of acromioclavicular joint dislocations with theoretically less morbidity of comparable open approaches. Using these techniques combined with a mini-open distal clavicle resection, 31 of 35 patients had good to excellent results with no, or minimal pain, excellent cosmesis, complete return to activities, and were satisfied with the procedure at their 12- to 36-month follow-up.\textsuperscript{89} However, four patients had to be revised 6 to 16 weeks postoperatively due to an error in placement of the coracoid tunnel that resulted in the suture cutting through an inadequate bone bridge.

**CC Ligament Reconstruction**

Reconstruction of the CC ligaments in the literature is described as a ligament reconstruction between the coracoid and the clavicle, unlike non-rigid fixation of the clavicle to the coracoid as described earlier. This is similar to a modified Weaver-Dunn reconstruction; however, it is performed without transfer of the CA ligament.

Pennington described the addition of a semitendinosus graft to a suture reconstruction, which adds biologic fixation to the construct, thus providing long term stability to the reconstruction of the coracoclavicular ligamentous complex.\textsuperscript{90}

Outcomes were first reported for revision of failed modified Weaver-Dunn procedures. Jones and associates reported the results of a single case using semitendinosus autograft and found excellent results at two years.\textsuperscript{91} LaPrade and Hilger reported on two patients and also found excellent clinical results at over two years.\textsuperscript{92} A series of 12 patients who underwent revision for CC instability was reviewed by Tauber and colleagues. They found good to excellent results in all 12 patients and significant reduction of antero-posterior translation. No complications were reported.\textsuperscript{93} Nicholas and coworkers treated nine highly active patients using semitendinosus allograft for both acute and chronic type V AC joint dislocations. Their technique was not truly anatomic, as they drilled a single vertical hole in the clavicle and looped the graft around the coracoid to minimize the possibility of fracture. Functional and radiographic outcomes were excellent in all patients at a minimum of 1-year follow-up.\textsuperscript{70}

A recent prospective trial by Tauber and colleagues compared anatomic CC ligament reconstruction with semitendinosus autograft to the modified Weaver-Dunn technique for chronic AC joint dislocation in 24 patients (12 in each group). They found statistically significant improvements in Constant and JSES scores, as well as increased subjective satisfaction with anatomic CC ligament reconstruction at a mean follow-up of 37 months. No serious complications were observed. This study is the first to demonstrate a possible clinical superiority with anatomic CC reconstruction for AC joint dislocation. Although longer term evidence is needed, these results are encouraging in the treatment of chronic AC dislocations.\textsuperscript{94}

Recent literature suggests that a true anatomic reconstruction, in an attempt to recreate the conoid and trapezoid ligaments, may offer an advantage in preventing both recurrent subluxation and anterior-posterior instability compared to a modified Weaver-Dunn procedure.\textsuperscript{61} Using a free tendon graft, the technique attempts to recreate the original anatomy of the coracoclavicular ligaments using bone tunnels in the distal clavicle and coracoid. A recent anatomic study using both fresh frozen and dry osteology specimens revealed that although the origin of the coracoclavicular ligaments differ in male and female, the ratio of these origins relative to clavicle length remain constant. The investigators suggest that the medial edge of the bone tunnel for the reconstructed conoid ligament be created posteriorly on the superior clavicle at a point representing 30% of the clavicle length (measured intraoperatively), and the trapezoid ligament be centered over the midportion of the clavicle at a point 17% of clavicle length as measured from the AC joint.\textsuperscript{16} Mazzocca and coworkers, in a biomechanical cadaveric study, revealed that the double-bundle anatomic reconstruction with free semitendinosus tendon graft is equal to both modified Weaver-Dunn technique and arthroscopic reconstruction with suture loop in preventing superior displacement and provides a significant reduction in anterior-posterior translation when compared to a modified Weaver-Dunn.\textsuperscript{81} For this reason, this procedure may be used for treatment of a symptomatic AC joint injury after a
primary surgery failed to restore anteroposterior stability using traditional AC repair and reconstruction techniques. Additionally, the usage of a graft offers the advantage of a scaffold for revascularization as compared with suture loop, which will fail over time with cyclic loading.

Most now favor the use of a doubled semitendinosus autograft or tibialis anterior allograft, which is either looped around the coracoid or fixed to the coracoid with suture anchors or a biotenodesis screw. The graft is then fixed to the clavicle with two interference screws in two separate bone tunnels that approximate the normal anatomic location of the CC ligaments. While some routinely resect the distal clavicle, not doing so may confer additional stability and in an acute repair, allow the AC ligaments to heal properly. The downside of this is the risk of developing AC joint arthritis in the future. Tunnel widening has been reported as a potential complication of CC ligament reconstruction.

Recently, Carofino and Mazzocca and colleagues reported on the outcome of 16 patients with a type III or V injury who underwent anatomic coracoclavicular ligament reconstruction. The investigators results with this technique were encouraging; with the average ASES score increasing from 53 preoperatively to 92 postoperatively at an average of 21-months follow-up. There was only one loss of reduction noted, with a mean side-to-side difference of the coracoclavicular space of less than one millimeter.

**Postoperative Rehabilitation Protocol**

The postoperative protocol varies for these different techniques, but typically it involves the use of a sling or shoulder immobilizer for a period of 4 to 6 weeks to allow the reconstruction to heal. This provides support for the involved upper extremity when in an upright position. Limited supine passive and active assisted range of motion is initiated as early as 7 to 10 days postoperatively while strengthening and upright range of motion is typically restricted until 6 weeks. Unsupported shoulder range of motion with the patient in an upright position should be until the reconstruction has had time to develop biologic stability, typically 4 to 6 weeks after surgery. The sling or shoulder immobilizer can be removed at this time with active range of motion and strengthening of the scapular stabilizers encouraged. Shoulder range of motion is initially limited to 90° of forward elevation, 90° of abduction, 30° of external rotation, and internal rotation to the chest wall. Weight training is initiated at 8 to 12 weeks followed by return to non-contact athletic activity at three to six months. Peak strength is often obtained by 9 months, whereby patients can return to contact activities. It has been suggested that use of various types of tendon grafts may allow a more accelerated rehabilitation program.

**Complications of Operative Fixation**

The complications of operative treatment include loss of fixation, fracture or failure of the reconstruction material, or failure of the reconstruction to biologically organize, which can lead to persistent pain and instability. This loss of reduction can be as high as 44% and varies by technique. Other complications include migration of the implant, infection, neurovascular injury, deltrotrapezial detachment, coracoclavicular ossification, distal clavicular osteolysis, coracoid fracture, clavicle fracture, and AC joint arthritis. As discussed earlier, implant migration has been reported with pins found in the lung, spinal canal, neck, aorta, and subclavian artery. Infection rates vary from 0% to 9%. The incidence of distal clavicular osteolysis is increased by fixation across the joint. AC joint arthritis occurs more frequently when the distal clavicle is preserved and when fixation is used across the joint. Given the high incidence of AC arthritis following these injuries, the lateral end of the distal clavicle is resected as a part of the operative procedure. In these circumstances, arthritis will only develop in the face of an incomplete resection. As discussed earlier, aseptic foreign-body reaction or infection may occur from the use of synthetic sutures. Over time the cyclic loading of the suture material or allograft passed through the clavicle may result in clavicle fracture, erosion, osteolysis, or tunnel widening. These materials may also erode through the base of the coracoid and lead to osteolysis and fracture.

**Summary**

AC joint injuries are common in contact athletics. The majority of these are types I and II, but as discussed, these are not trivial injuries and are often fraught with prolonged pain and future arthrosis. While some controversy exists regarding the treatment of type III injuries, most now agree that nonoperative therapy should be employed as patients have been found to have similar outcomes irrespective of the treatment modality. Types IV, V, and VI injuries are treated surgically. Despite a certain rate of residual subluxation or dislocation after surgery, fixation complications, and AC joint complaints, the majority of patients treated with CA ligament transfer show good to excellent results. The modified Weaver-Dunn performed with biologic fixation is superior biomechanically to those procedures performed with the use of non-biologic fixation with most series reporting clinical outcomes greater than 85% good to excellent results. CC Ligament Reconstruction performed with endobutton fixation with or without tendon augmentation can be used to treat acute AC joint injuries. Anatomic CC ligament reconstruction is a promising technique for AC joint stabilization and can be performed after both acute and chronic injury. There are few comparative studies in the literature, with the majority of evidence supporting this technique largely based on case reports and technical descriptions. However, biomechanical data is supportive of anatomic CC ligament reconstruction as a means of reliably stabilizing the AC joint. There is a need for comparative studies evaluating short and long-term outcomes of anatomic CC ligament techniques.
Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References
36. Bergfeld JA, Andrish JT, Clancy WG. Evaluation of the


