ISSN 2218-5836 (online)

World Journal of *Orthopedics*

World J Orthop 2017 December 18; 8(12): 853-967

Published by Baishideng Publishing Group Inc

World Journal of Orthopedics

Contents Monthly Volume 8 Number 12 December 18, 2017

Contents

World Journal of Orthopedics
Volume 8 Number 12 December 18, 2017

ABOUT COVER

Editorial Board Member of *World Journal of Orthopedics*, Chunfeng Zhao, MD, Professor, Research Scientist, Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN 55905, United States

AIM AND SCOPE

World Journal of Orthopedics (*World J Orthop*, *WJO*, online ISSN 2218-5836, DOI: 10.5312) is a peer-reviewed open access academic journal that aims to guide clinical practice and improve diagnostic and therapeutic skills of clinicians.

WJO covers topics concerning arthroscopy, evidence-based medicine, epidemiology, nursing, sports medicine, therapy of bone and spinal diseases, bone trauma, osteoarthropathy, bone tumors and osteoporosis, minimally invasive therapy, diagnostic imaging. Priority publication will be given to articles concerning diagnosis and treatment of orthopedic diseases. The following aspects are covered: Clinical diagnosis, laboratory diagnosis, differential diagnosis, imaging tests, pathological diagnosis, molecular biological diagnosis, immunological diagnosis, genetic diagnosis, functional diagnostics, and physical diagnosis; and comprehensive therapy, drug therapy, surgical therapy, interventional treatment, minimally invasive therapy, and robot-assisted therapy.

We encourage authors to submit their manuscripts to *WJO*. We will give priority to manuscripts that are supported by major national and international foundations and those that are of great basic and clinical significance.

INDEXING/ABSTRACTING

World Journal of Orthopedics is now indexed in Emerging Sources Citation Index (Web of Science), PubMed, PubMed Central and Scopus.

FLYLEAF

EDITORS FOR THIS ISSUE

Responsible Assistant Editor: *Xiang Li*
Responsible Electronic Editor: *Ya-Jing Lu*
Proofing Editor-in-Chief: *Lian-Sheng Ma*
Responsible Science Editor: *Li-Jun Cui*
Proofing Editorial Office Director: *Xiu-Xia Song*

NAME OF JOURNAL
World Journal of Orthopedics

ISSN
ISSN 2218-5836 (online)

LAUNCH DATE
November 18, 2010

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Quanjun (Trey) Cui, MD, Professor, Department of Orthopaedic Surgery, School of Medicine, University of Virginia, Charlottesville, VA 22908, United States

Bao-Gan Peng, MD, PhD, Professor, Department of Spinal Surgery, General Hospital of Armed Police Force, Beijing 100039, China

EDITORIAL BOARD MEMBERS
All editorial board members resources online at http://www.wjgnet.com/2218-5836/editorialboard.htm

EDITORIAL OFFICE
Xiu-Xia Song, Director
World Journal of Orthopedics
Baishideng Publishing Group Inc
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: editorialoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLISHER
Baishideng Publishing Group Inc
7901 Stoneridge Drive,
Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLICATION DATE
December 18, 2017

INSTRUCTIONS TO AUTHORS
http://www.wjgnet.com/bpg/gerinfo/204

ONLINE SUBMISSION
http://www.f6publishing.com

WJO World Journal of Orthopedics

Submit a Manuscript: http://www.f6publishing.com

World J Orthop 2017 December 18; 8(12): 861-873

DOI: 10.5312/wjo.v8.i12.861

ISSN 2218-5836 (online)

MINIREVIEWS

New insights in the treatment of acromioclavicular separation

Christiaan J A van Bergen, Annelies F van Bemmel, Tjarco D W Alta, Arthur van Noort

Christiaan J A van Bergen, Department of Orthopaedic Surgery, Amphia Hospital, Breda 4818 CK, The Netherlands

Annelies F van Bemmel, Tjarco D W Alta, Arthur van Noort, Department of Orthopaedic Surgery, Spaarne Gasthuis, Hoofddorp 2134 TM, The Netherlands

ORCID number: Christiaan J A van Bergen (0000-0001-8336-9070); Annelies F van Bemmel (0000-0001- 9618-7428); Tjarco D W Alta (0000-0002-3512-7840); Arthur van Noort (0000-0003-1389-9708).

Author contributions: All authors equally contributed to this paper with conception and design, literature review and analysis, drafting and critical revision and editing, and approval of the final version.

Conflict-of-interest statement: No potential conflicts of interest. No financial support.

Manuscript source: Invited manuscript

Correspondence to: Christiaan J A van Bergen, MD, PhD, Surgeon, Department of Orthopaedic Surgery, Amphia Hospital, Molengracht 21, Breda 4818 CK, The Netherlands. cvanbergen@amphia.nl
Telephone: +31-76-5955000

Received: August 22, 2017
Peer-review started: September 16, 2017
First decision: October 23, 2017
Revised: November 27, 2017
Accepted: December 5, 2017
Article in press: December 5, 2017
Published online: December 18, 2017

Abstract

A direct force on the superior aspect of the shoulder may cause acromioclavicular (AC) dislocation or separation. Severe dislocations can lead to chronic impairment, especially in the athlete and high-demand manual laborer. The dislocation is classified according to Rockwood. Types Ⅰ and Ⅱ are treated nonoperatively, while types Ⅳ, Ⅴ and Ⅵ are generally treated operatively. Controversy exists regarding the optimal treatment of type Ⅲ dislocations in the high-demand patient. Recent evidence suggests that these should be treated nonoperatively initially. Classic surgical techniques were associated with high complication rates, including recurrent dislocations and hardware breakage. In recent years, many new techniques have been introduced in order to improve the outcomes. Arthroscopic reconstruction or repair techniques have promising short-term results. This article aims to provide a current concepts review on the treatment of AC dislocations with emphasis on recent developments.

Key words: Acromioclavicular dislocation; Rockwood classification; Coracoclavicular ligament reconstruction; Hookplate; Arthroscopically assisted acromioclavicular reconstruction; Weaver and Dunn procedure; Conoid and trapezoid ligaments

Core tip: Current literature suggests that the decision for treatment of type Ⅲ injuries should be made on a case-by-case basis, with an emphasis on initial nonoperative treatment. Early operative treatment for grades Ⅲ-Ⅵ dislocations may result in better functional and radiological outcomes than delayed surgery. There are numerous surgical techniques presented in the literature. The authors prefer an autograft tendon reconstruction of the coracoclavicular joint without bone tunnels in combination with direct suture fixation of the acromioclavicular joint. Arthroscopic techniques are evolving but there is currently no evidence to support arthroscopic over open surgery.

van Bergen CJA, van Bemmel AF, Alta TDW, van Noort A. New insights in the treatment of acromioclavicular separation. *World J Orthop* 2017; 8(12): 861-873 Available from: URL: http://www.wjgnet.com/2218-5836/full/v8/i12/861.htm DOI: http://dx.doi.org/10.5312/wjo.v8.i12.861

INTRODUCTION

The interest in acromioclavicular (AC) joint injuries dates back to the time of Hippocrates (460-377 BC) and Galen (129-199 AD)[1]. These ancestors already noted the difficulties in correctly diagnosing and treating this type of injury. Naturally, many developments have been made since then. New insights have led to the introduction of numerous treatment techniques during the past few decades[2]. However, to date, much controversy still exists, and the optimal treatment is not available yet. Moreover, the best timing of surgery remains a topic of debate. This current concepts review aims to provide an up-to-date and evidence-based overview of relevant treatment options for AC joint dislocations, with special emphasis on most promising recent techniques.

Etiology

AC joint dislocations are common injuries among an athletic population. They account for approximately 12% of injuries of the shoulder girdle. The patient is typically male, < 30 years of age and involved in (contact) sports[3]. The typical trauma mechanism is a force that depresses the shoulder girdle, such as occurs during a fall from a cycle or during a collision in contact sports. The force depresses the scapulohumeral complex (rather than the clavicle being elevated), resulting in tears of the AC ligament and the coracoclavicular (CC) ligaments. Associated shoulder injuries are present in 18% of patients with type Ⅲ to Ⅴ dislocations; superior labral anterior posterior (SLAP) lesions being the most common[4].

Anatomy

The AC joint is a diarthrodial joint, consisting of a thin cartilage surface and an interposed fibrocartilaginous meniscoid disk. The joint capsule or AC ligament (*i.e.*, thickenings in the capsule) and the extracapsular CC ligaments provide static stability. Physiologic forces and the weight of the arm place significant translational forces in the vertical, anteroposterior and axial planes of the AC joint. Based on cadaveric studies, the AC ligaments contribute 20% to 50% of resistance to superior migration and 90% to anterior-posterior translation. The CC ligaments are formed by the conoid medially and the trapezoid laterally. They are the primary restraint to inferior and medial translation of the scapulohumeral complex in relation to the clavicle[5]. The conoid ligament is attached proximally on the posteromedial undersurface of the clavicle, typically 4.5 cm from the AC joint (47.2 mm in men and 42.8 mm in women)[6]. It tensions under loads that force the clavicle superiorly (or the scapula inferiorly). The trapezoid attaches proximally on the anterolateral aspect of the inferior clavicle, approximately 2.5 cm from the joint (25.4 mm in men and 22.9 mm in women)[6]. It tensions under medialization of the scapulohumeral complex, *i.e.*, compression of the AC joint. The delto-trapezial fascia provides dynamic stabilization to the AC joint, especially the anterolateral deltoid insertion.

Symptomatology

Patients commonly present with pain at the AC joint, following a trauma such as a fall on the shoulder. The pain is often accompanied by soft tissue swelling as well as a prominent lateral clavicle. Because of the pain, shoulder motion is reduced and patients are limited in their daily and athletic activities. Chronic instability of the AC joint can lead to tremendous impairment of shoulder function including muscle fatigue, scapular dyskinesia, subjective sensation of heaviness of the injured upper limb, and painful horizontal adduction[7].

DIAGNOSIS

The history and physical examination often provide clues to the diagnosis. The patient frequently reports a fall on the shoulder or a collision and has pain localized at the AC joint and often the trapezius muscle (pars ascendens). The patient may also note a swelling, which can be confirmed on physical examination. The patient is examined while standing or sitting. On inspection, a high lateral clavicle can be seen, compared to the uninjured side. The AC joint is tender on palpation. One should compare with the uninjured side. The shoulder range of motion is usually reduced because of the pain in the acute phase. The examiner should check the stability of the AC joint in the superior-inferior and anterior-posterior directions. For types Ⅲ and Ⅴ, the joint feels unstable when the lateral clavicle is depressed manually ("piano key" phenomena). The shoulder is passively adducted in the horizontal plain to test anterior-posterior stability[8] (Figure 1). Chronopoulos *et al*[8] reported a sensitivity of 77% for the cross body adduction test, 72% for the AC resistance test and 41% for the active compression test; the combination of all 3 tests showed a specificity of 95%.

Standard radiographs of the shoulder are obtained, including a true anterior-posterior view, a scapular Y lateral view, an axillary view (or Velpeau view modification if unable to abduct the arm), and a Zanca view of the AC joint (performed by tilting the X-ray beam 10° to 35° toward the cephalic direction and using only 50% of the standard shoulder anteroposterior penetration strength) (Figure 2). It may be useful to obtain radiographs of the opposite side for comparison. A bilateral Zanca view visualizes the ipsilateral and contralateral AC joints on one

Figure 1 Digital pictures of a patient with a type-V acromioclavicular dislocation. A: Anterior view; B: Lateral view: The shoulder is passively adducted in the horizontal plain to test horizontal stability. Note the horizontal instability in this case.

X-ray cassette, while the same orientation of the beam is maintained[9] (Figure 2). In addition, a cross-body adduction radiograph may differentiate between a stable and unstable AC joint by assessment of the degree to which the clavicle overlaps the acromion[10]. The additional value of stress views with distal traction by weights on the arms is questionable. More precise imaging techniques, such as computed tomography or magnetic resonance imaging, are normally unnecessary, unless associated injuries are suspected.

The radiographic images are assessed on the relation between acromion and clavicle, as well as the CC distance, ideally comparing left and right. Associated injuries of the shoulder girdle must be ruled out.

CLASSIFICATION

Rockwood has made a classification that is used the most widely nowadays (Figure 3)[11,12]. In type Ⅰ, neither AC nor CC ligaments are disrupted. In type Ⅱ, the AC ligament is disrupted and the CC ligament is intact (50% vertical subluxation of the distal clavicle). In type Ⅲ, both ligaments are disrupted. In type Ⅳ, the ligaments are disrupted and the distal end of the clavicle is displaced posteriorly into or through the trapezius muscle. An axillary radiographic view is particularly helpful in identifying type Ⅳ injuries. In type Ⅴ, the ligaments and muscle attachments are disrupted, and the clavicle and acromion are widely separated. In type Ⅵ, the ligaments are disrupted, and the distal clavicle is dislocated inferior to the coracoid process and posterior to the conjoint tendon. Type Ⅵ lesions are extremely rare but do occur[13]. Reproducibility and interobserver reliability of the classification is only moderate and is likely limited by the inability of a classification based on plain radiographs to fully assess a soft tissue injury[14].

In practice, the difference between type Ⅲ and Ⅴ can be subtle and confusing. There is no clear definition or consensus on how to differentiate between these types. A suggested definition is 25% to 100% superior displacement of the distal clavicle in type Ⅲ dislocations and 100% to 300% displacement in type Ⅴ[15,16]. Others describe more than 100% clavicle displacement in type Ⅲ and more than 300% displacement in type Ⅴ[7]. The CC distance can also be used to differentiate between the two types (CC distance 20% or 25% to 100% of contralateral side in type Ⅲ; CC distance more than 100% of the contralateral side in type Ⅴ)[7].

The International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) Upper Extremity Committee has made a subdivision of type Ⅲ dislocations in order to better identify patients who would benefit from surgery[15]. Type ⅢA is defined as a stable AC joint with normal scapular function and no overriding of the clavicle on the cross-body adduction view. Type ⅢB is defined as unstable with scapular dysfunction and an overriding clavicle on the cross-arm adduction view. However, it is unclear to what extent this subdivision predicts treatment outcomes.

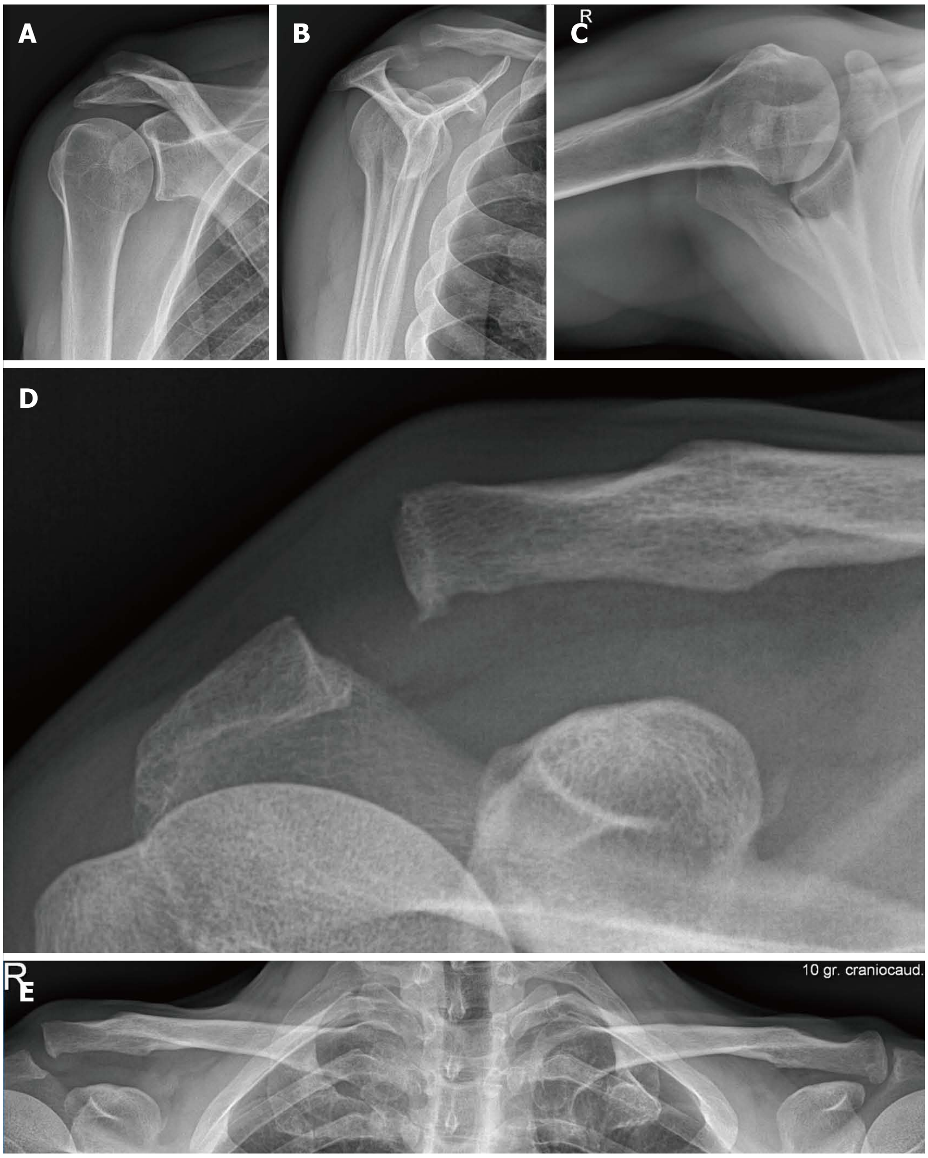

Figure 2 Standard radiographic series of the shoulder. A: A true anterior-posterior view; B: Scapular Y lateral view; C: Axillary view; D: Zanca view; E: In case of acromioclavicular separation, a bilateral Zanca view can be useful.

TREATMENT

There is general agreement that types Ⅰ and Ⅱ injuries should be treated nonoperatively in all cases[2]. Most authors suggest that types Ⅳ, Ⅴ and Ⅵ should be treated operatively[5,7]. In contrast, type Ⅲ separations have caused much debate during the past decades. In the past, many type Ⅲ lesions were treated surgically. However, it has turned out that there is no clear superior outcome after surgical treatment[17,18]. Operative treatment of type Ⅲ is sometimes reserved for high-demand laborers and athletic patients[17]. Most surgeons now generally agree that nonoperative treatment is indicated initially in all patients with type Ⅲ injuries; if unsuccessful, operative reconstruction of the AC and CC ligaments can be provided at a later stage[19,20].

Nonoperative

Nonoperative treatment is indicated for types Ⅰ and Ⅱ dislocations and consists of temporary immobilization with a sling or collar and cuff for 1 to 3 wk. Early range-of-motion exercises are encouraged. Daily and athletic activities are resumed when the pain permits. Heavy lifting and contact sports are usually postponed until 6 wk. Unsatisfactory outcomes in conservative treatment may be explained by persistent instability, especially a horizontal component of instability[21].

Open surgery

Numerous surgical repair or reconstruction techniques have been published. In 2013, the number of different surgical techniques described was 162[2]. These techniques can basically be grouped in four categories: (1) Fixation of the AC and/or CC with hardware including screws and K-wires; (2) hook plates; (3) fixation of the CC with suture buttons; and (4) reconstruction of the CC ligaments with autograft or allograft tendon[16]. Whichever construct is used, it needs to maintain the

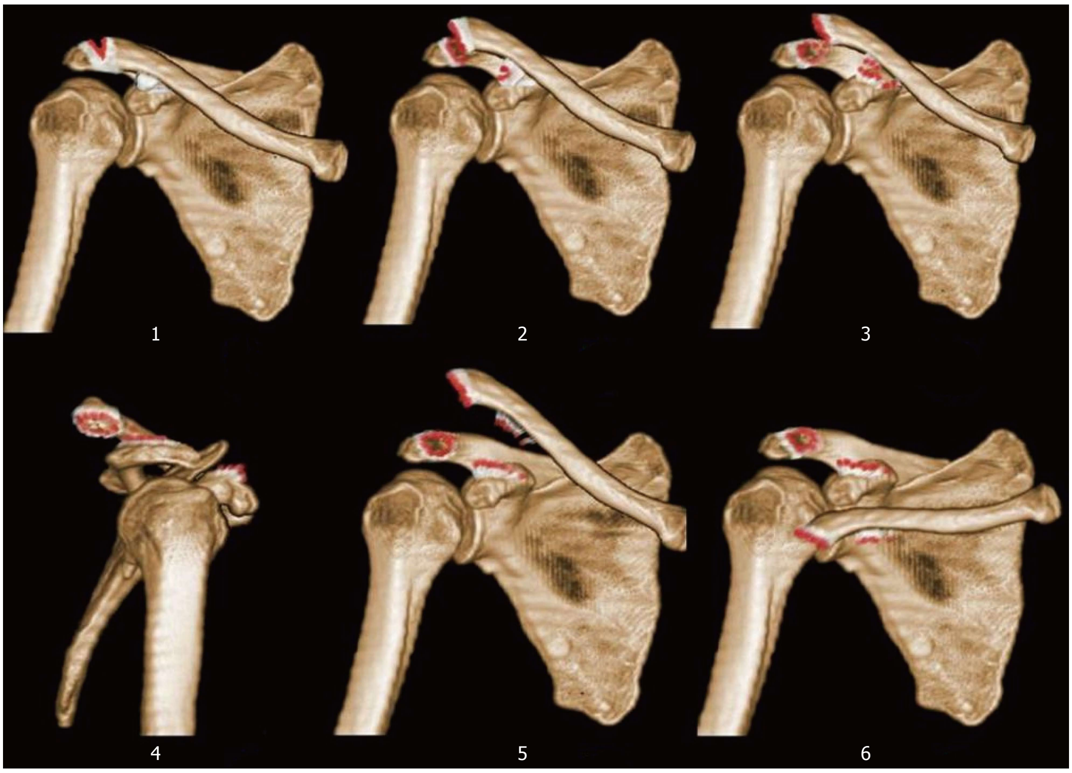

Figure 3 Rockwood classification (Case courtesy of Dr Roberto Schubert, Radiopaedia.org, rID: 19124).

reduction long enough for the biological healing process to be able to take place.

Hardware fixation: Previously, temporary trans-articular K-wire fixation of the AC joint has been used in combination with direct ligament repair. However, this technique has led to unsatisfactory outcomes, including K-wire breakage, migration and loss of reduction[7]. Likewise, CC cerclage or screw fixation such as the Bosworth screw have led to unacceptable risk of screw breakage[10]. Some remove the screw after 6 to 8 wk to avoid this complication. Even with adequate screw positioning, hardware failure and obligatory screw removal have decreased the popularity of this technique.

Hook plate fixation: The hook plate is a metal device that keeps the AC joint in a reduced position by hooking its tip under the acromion and fixing it to the clavicle with screws[18]. It can be used alone or in conjunction with other methods of ligament repair.

The joint separation is either reduced and then the hook plate is positioned, or the hook plate is inserted with the hook under the posterior aspect of the acromion and then pushing the plate segment against the distal end of the shaft of the clavicle, in that way levering the clavicula downwards. Most of the time the 4-hole (shortest) hook plate can be used. Either the hook can be adjusted to the morphology of the acromion or the plate can be adjusted to the morphology of the distal clavicle.

The advantage of this technique is that it provides a strong and stable construct. There are case series that report acceptable results of hook plate fixation[22,23]. A disadvantage is that the plate crowds the subacromial space, causing subacromial impingement, rotator cuff lesions, and even acromial stress fractures due to the hook[24]. The hook makes a pinpoint contact with the undersurface of the acromion, which might explain why complications commonly occur after hook plate fixation[25]. Furthermore, pain or discomfort is experienced because of the hardware[16]. Because of these reasons, removal of the plate is routinely required after 3 to 4 mo, making a second operation necessary[18,22,23]. This in turn can lead to loss of reduction[22,23].

The Canadian Orthopaedic Trauma Society recently completed a multicenter-randomized clinical trial involving hook plate fixation *vs* nonoperative treatment of 83 AC dislocations[18]. Disability and Constant scores were better in the nonoperative group after 3 mo but the differences disappeared at 1 and 2 years. In contrast, radiographic reduction was better in the operative group at all time points but there were more complications and reoperations in this group[18]. The necessity of implant removal, uncertain superiority over nonoperative management, and the higher incidence of complications are important considerations of hook plate fixation.

Suture button CC fixation: Suture buttons have been introduced as an alternative to simple suture fixation to anatomically repair the CC ligaments. These devices consist of two metal buttons that are connected by thick nonabsorbable sutures. The buttons are locked behind the clavicle and coracoid drill holes and the sutures function as the CC ligaments[16,26]. Biomechanical studies have shown that suture buttons have comparable biomechanical strength as compared to the native ligaments[26,27].

The technique has the advantage of allowing minimally invasive implantation as well as sustaining some range of motion between clavicle and scapula. However, single CC suture button fixation has appeared to be biomechanically inferior to the native CC ligaments *in vivo*[26]. The single-button technique has resulted in high failure rates due to knot slippage, suture breakage, button migration, fractures[28-30] and large or misdirected drill holes[29] as well as failure to address the AC joint capsule[31-33]. Because of high rates of failure with the use of single buttons, the use of multiple suture buttons is now advocated to restore both the conoid and trapezoid ligaments (improving horizontal and vertical instability) and reduce the failure risk[26]. For example, Struhl and Wolfson[34] used a mini-open technique with a continuous loop double endobutton in combination with a lateral clavicle resection. Recently, these authors have added a figure-of-8 ultratape suture through drill holes in the acromion and clavicle to directly augment AC joint stability[34].

Suture button fixation has several advantages, particularly the ability for minimal soft tissue disruption and generally satisfactory outcomes. However, caution should be used as these constructs have been associated with remaining anterior-posterior instability and a risk of hardware issues[35]. Suture button fixation has higher shoulder function scores and lower postoperative pain when compared to hook plate fixation; however, there are higher complication rates[36].

CC ligament reconstruction: The Weaver and Dunn procedure was first described in 1972 and utilizes the native coracoacromial (CA) ligament in AC joint reconstructions. This technique involves the distal clavicle excision in combination with transfer of the CA ligament from the acromion to the distal clavicle remnant in an attempt to restore AC stability[37]. The procedure has been studied extensively, demonstrating up to a 30% failure rate and only approximately 25% biomechanical strength when compared to intact CC ligaments[16,38]. The modified procedure supplements the ligament transfer with a direct CC fixation or hook plate[38,39]. There are a few studies that reported inferior results of the modified procedure compared to anatomic CC ligament reconstruction technique using autogenous semitendinosus graft[40-43].

The utilization of autograft or allograft for the anatomic reconstruction of the CC and AC ligaments in acute AC joint dislocation has rapidly gained popularity in the past few decades. In 2003, Lee *et al*[42] biomechanically compared the strength and stiffness of the native CC ligament with that of reconstructions with CA ligament or free tendon grafts. They reported that tendon grafts had strengths equivalent to the native CC ligament strength, and were significantly stronger than the CA ligament reconstruction.

There are numerous techniques to reconstruct the CC ligaments. Mazzocca *et al*[38,44] used a semitendinosus autograft to reconstruct the anatomical configurations of the trapezoid and conoid ligaments, as well as the AC ligaments, without use of supplemental CC or AC stabilization. With this technique, the lateral 1 cm of the clavicle is excised. A soft-tissue tunnel is created under the coracoid. Two bony tunnels are drilled in the clavicle; one 4.5 cm from the AC joint (positioned slightly posteriorly to reconstruct the conoid ligament) and one 2.5 cm from the AC joint (positioned slightly anteriorly to reconstruct the trapezoid ligament). The graft is passed through the tunnels in a figure-of-eight fashion, and fixed proximally using interference screws while the AC joint is reduced with upper displacement of the scapulohumeral complex. Finally, the lateral limb of the graft is sutured to the acromion to reconstruct the AC ligament.

We use an autograft tendon reconstruction technique of the CC joint without bone tunnels in combination with direct suture fixation of the AC joint (Figure 4). The semitendinosus tendon is harvested. A Sabelhouw incision is made and the lateral clavicle is resected. A double nonabsorbale suture is passed through small drill holes in the lateral clavicle and the acromion for AC joint repair. The coracoid process is exposed through the deltopectoral interval. The semitendinosus tendon is directed under the coracoid and over the clavicle for CC joint repair (it is passed from the medial aspect of the coracoid to the posterior aspect of the clavicle to mimic the conoid ligament and from the lateral aspect of the coracoid to the anterior aspect of the clavicle to mimic the trapezoid ligament). The AC joint is reduced by elevation of the arm, the AC joint sutures are tightened, and the semitendinosus is secured with interrupted nonabsorbable sutures over the clavicle. Advantages of this technique without bone tunnels or interference screws are low costs, avoidance of iatrogenic fracture risk, no foreign body use (except for sutures), and the same biomechanical strength as anatomic repair with bone tunnels[45]. We have treated 23 patients with Rockwood type 4 or 5 lesions with use of this technique, of whom five were failures from elsewhere. All patients indicated that they would undergo the procedure again and were satisfied with the cosmetic outcome. They were able to participate in work and sports without restrictions. Two complications occurred; one patient had a temporary frozen shoulder and another had a recurrence due to a fall after 6 wk.

Arthroscopic surgery

Minimally invasive AC joint reconstruction and repair techniques have been developed since the introduction of arthroscopic shoulder surgery. Although arthroscopically assisted AC reconstruction should be used by skilled arthroscopists only, it has the possible advantages of the minimally invasive nature, direct visualization of

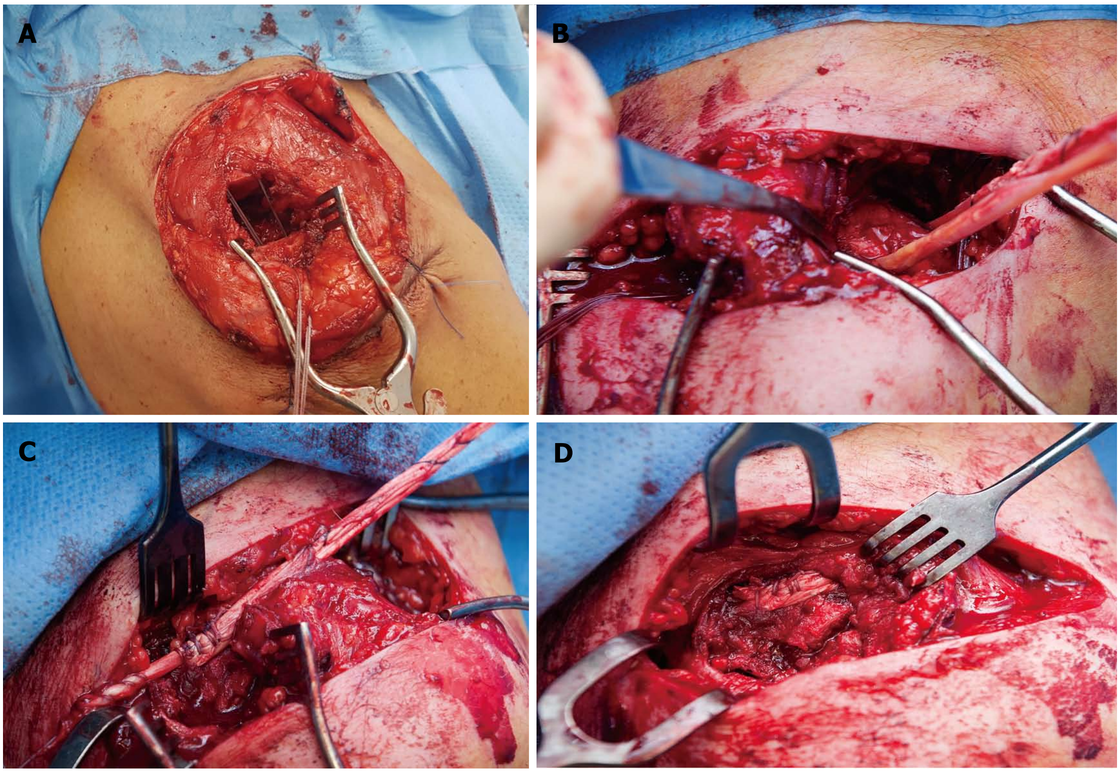

Figure 4 Intra-operative pictures of an autograft tendon reconstruction technique of the coracoclavicular joint without bone tunnels in combination with direct suture fixation of the acromioclavicular joint. A: The lateral clavicle is resected, and a double nonabsorbale suture is used for AC joint repair; B-D: A semitendinosus tendon is passed under the coracoid and over the clavicle for CC joint repair. AC: Acromioclavicular; CC: Coracoclavicular.

the reduction and placement of coracoid fixation, the possibility to address additional pathologies, and the deltotrapezial fascia can remain attached[46,47]. A further advantage of arthroscopic treatment is a diagnostic glenohumeral arthroscopic evaluation. Concomitant injuries are common in AC joint dislocations and may occur in up to 20%-25% of patients[47-49].

Suture button fixation is typically used with arthroscopically assisted AC repair. Initially, one button was used for repair. Murena *et al*[49] described arthroscopic treatment of type Ⅲ-Ⅳ acute AC dislocation with a double flip button. They found excellent clinical results in terms of Constant score (mean 97 points) and patient satisfaction, but a disappointing radiological result with a partial loss of reduction due to distal migration of the flip button within the upper third of the clavicle in one-fourth of the cases, at a mean follow-up of 31 mo. However, because of a high failure risk of one-button repair, either multiple suture buttons or augmentation techniques are used nowadays. An example of a multiple suture button technique is that by Imhoff *et al*[47]: Anatomic CC ligament reconstruction utilizing double Tight Rope (Arthrex Inc., Naples, FL, Italy) suspensory fixation. This dual anatomic technique aims to reproduce the native conoid and trapezoid ligaments. The surgical procedure is begun with a diagnostic shoulder joint arthroscopy, followed by arthroscopic preparation of the coracoid undersurface through the rotator interval. After a guided superior skin incision and AC joint reduction, the conoid and trapezoideal tunnels are drilled with use of a drill guide system. The two TightRope devices are inserted through the tunnels and fixated. The longest follow-up case series of double suture button fixation in 23 patients reported a high satisfaction rate (96%) after 58 mo but eight radiographic failures were noted[47].

An example of augmentation in arthroscopic-assisted reconstruction of AC joint instability is the technique by DeBerardino *et al*[46]: CC ligament reconstruction with an allograft augmented GraftRope (Arthrex Inc., Naples, FL, Italy) system. This technique utilizes an arthroscopically placed fixation with a GraftRope construct augmented with an allograft (or autograft) centrally. After glenohumeral joint arthroscopy, the subacromial bursa is debrided and the AC joint visualized. Joint reduction is checked with fluoroscopy. Following clearance of the coracoid base, the tunnel is drilled with use of a drill guide through a small incision over the clavicle. A semitendinosus or tibialis tendon is passed through the implant system before it is inserted with use of a passing suture. An interference screw is placed between the graft limbs for final construct fixation.

A technique to perform the Weaver-Dunn procedure in an all-arthroscopic way is described by Boileau *et al*[50] This procedure also starts with debridement of the undersurface of the base of the coracoid process through the rotator interval. Then the scope is moved to anterior, where the CA ligament is released from the acromion (with a chip of bone remained attached to the ligament). Thereafter, a lateral clavicle resection is performed, and the medullary canal of the clavicle is enlarged and deepened with a burr. Then, the CC reduction and fixation is performed with use of a double-button system. Finally, the bone-ligament transfer of the CA ligament is pulled in the created cavity of the lateral clavicle and fixed through a second drill hole on the superior cortex. A mean follow-up of 36 mo is now available for a group of 57 patients[51]. Two patients experienced a recurrent dislocation and 6 patients a partial loss of reduction. The Subjective Shoulder Value ranged from 54% to 85%, and 96% of the patients were satisfied with the procedure and the cosmesis[51]. There are no randomized controlled trials comparing the outcomes of open *vs* arthroscopically assisted or all-arthroscopic techniques. Arthroscopic techniques in case series are relatively safe procedures, with equivalent outcomes to open surgery, but demonstrate a distinct complication profile[39,46,47,52-58]. Arthroscopic suture button techniques generally demonstrate good radiographic outcomes but significant hardware irritation.

Postoperative management

The rehabilitation programs differ between surgical techniques. In general, a sling is provided and progressive range-of-motion exercises up to 90 degrees elevation are begun early after surgery for 6 wk. After this initial period, range-of-motion and strengthening exercises are gradually increased. Non-contact sports can be resumed after 3 mo. Generally, contact athletes are allowed unrestricted sport activities after 6 mo.

TIMING OF SURGERY

Accurate reduction in AC dislocation is considered easier when surgery is performed earlier after injury[59,60]. However, there is no clear definition of early and delayed surgery. Rockwood and Young[12], have noted that acute pain generally disappears 2-3 wk after an AC dislocation. Therefore, approximately 3 wk seems a clinically relevant dividing line.

A recent review of Song *et al*[60] summarized eight studies comparing acute and delayed surgical treatment of AC dislocation. The dividing line between early and delayed surgery was defined as 3, 4 and 6 wk after injury. They concluded that early surgery (< 3 wk) has better reduction and clinical outcomes than delayed surgical treatment (> 3 wk) and no significant difference in the complication rate[60]. The studies included in this review used several different methods of reconstruction and this limits the strength of this conclusion.

Delayed surgery is necessary for patients with AC dislocations that failed conservative treatment or with intolerance for early surgical treatment. Adam *et al*[3] reported higher rates of deformity recurrence and poorer functional outcome in chronic cases. On the other hand, other studies report satisfactory results after surgical treatment of chronic AC dislocations[48,52,59,61].

In conclusion, early surgery for grade Ⅲ-Ⅴ dislocations may result in better functional and radiological outcomes, with a reduced risk of loss of reduction compared with delayed surgery[7,54,60]. However, a nonoperative trial period of 6 mo seems justified for type Ⅲ lesions, based on high satisfaction rates and normal functionality in 80% of patients[62]. For example, Rolf *et al*[63] treated patients early at a mean of 10, or delayed at a mean of 7.7 mo (after failure of conservative treatment).

OUTCOMES

Many shoulder scoring systems are used to determine functional outcomes in the literature. Unfortunately, none of these is specific for AC dislocations. In a review of eight studies, more than 30 shoulder scoring systems were applied[60]. This makes reliable comparison of studies difficult.

A Cochrane review in 2010 reported data from three studies (174 participants) and found no significant difference in movement, strength, or function between surgically and conservatively treated patients[64]. Another review in 2013, which specifically looked at Rockwood type Ⅲ AC dislocations in eight studies (247 participants), showed the objective and subjective shoulder function outcome was better in the operative group (especially in young adults), though the rate of complications and radiographic abnormalities were higher[17]. The rehabilitation time was shorter in the conservative group but the cosmetic outcome was worse.

AC dislocation is a typical sports related injury[65]. Therefore, resumption of sports and work are important outcome aspects. Recently, a retrospective review of Dunphy *et al*[66] showed that most patients (77%) were able to return to work following nonsurgical management of type Ⅴ injuries after six months but had limited functional outcome scores. Patients who are treated nonoperatively for a Rockwood type Ⅲ AC dislocation need roughly half the time to return to work and sport, compared with patients treated operatively[2,7,67]. Manual workers treated surgically returned to work after an average of 11 wk, compared with 4 wk after nonsurgical treatment[67]. Gstettner *et al*[68], however, reported that operative treatment of Rockwood type II AC dislocation resulted in more patients returning to the same level of activity at work (82% *vs* 63%). The level of sports did not differ (67% *vs* 65%). In Rockwood type Ⅴ, overhead athletes require more time to resume their sports activity[69]. In minimally invasive anatomic CC reconstructions of type Ⅲ AC dislocation, 100% return to sports rates has been reported; however, the influence of type of sport was not considered[56,70].

The main concern when comparing outcome data is the lack of long-term outcome studies. We performed a literature search of comparative studies with a minimum of 4 years of follow-up (Table 1). We found five studies and classified the operative techniques in the four categories described above[39,52-59]. There were one randomized controlled trial and four retrospective cohort studies. The studies described early and delayed treatment of type Ⅲ-Ⅴ dislocation, as well as different operative techniques. Generally, few statistically significant differences were found between the groups

Table 1 Characteristics of comparative studies with a minimum 4-yr follow-up

Ref.	Type of study	LE	Rockwood classification (No. of patients)	Operative technique (No. of patients)	Category[1]	FU (yr)	Outcome
Boström Windhamre *et al*[55] 2010	Retrospective case control	Ⅲ	Delayed type Ⅲ-V (47)	Weaver-Dunn and PDS suture (23)	3	6.1	Constant score: $P > 0.05$ SPADI: $P \geq 0.05$
				Weaver-Dunn and hookplate (24)	2		QuickDASH: $P > 0.05$ VASa: $P = 0.03$ (in favor of PDS) Subluxation: $P > 0.05$
Kovilazhikathu Sugathan *et al*[56] 2012	Retrospective cohort	Ⅳ	Early type Ⅲ (7)	Open reduction and internal fixation + tension band wiring (7)	1	6.3	OSS: $P = 0.05$ Complications: 71% (early), 9% (delayed)
			Delayed type Ⅲ (11)	Modified Weaver-Dunn procedure with PDS suture (11)	3		
Motta *et al*[52] 2012	Retrospective case control	Ⅲ	Early type Ⅲ-V (34)	CC reconstruction with LARS (34)	3	5.4	Reduction[a]: $P < 0.05$ (in favor of early reconstruction)
			Delayed type Ⅲ-V (17)	CC reconstruction with LARS (17)	3		Constant score: $P > 0.05$ SST: $P > 0.05$
Fauci *et al*[59] 2013	RCT	I	Delayed type Ⅲ-V (40)	Allograft (semitendinosus) (20)	4	4	Constant score[a]: $P = 0.01$
				Synthetic ligament (LARS) (20)	3		Reduction: $P > 0.05$
Jensen *et al*[39] 2014	Retrospective comparative study	Ⅲ	Early type Ⅲ-V (56)	Hookplate (30)	2	4	VAS: $P > 0.05$
				Double TR technique (26)	3		SST: $P > 0.05$

[a]Statistically significant difference ($P < 0.05$); [1]Four categories: (1) fixation of the AC and/or CC with hardware including screws and K-wires; (2) hook plates; (3) fixation of the CC with sutures or suture buttons; and (4) reconstruction of the CC ligaments with autograft or allograft tendon. LE: Level of evidence; FU: Follow-up; SPADI: Shoulder pain and disability index; QuickDASH: Disabilities of the arm, shoulder and hand score; VAS: Visual analogue scale; OSS: Oxford shoulder score; LARS: Ligament augmentation and reconstruction system; RCT: Randomised controlled trial; SST: Simple Shoulder Test; TR: Tight rope.

(Table 1). The main differences included more pain experienced by patients treated with a hookplate *vs* PDS sutures, a better reduction and less complications after early reconstruction *vs* late reconstruction, and better Constant scores in allograft *vs* artificial ligament reconstruction[39,52,55,56]. Literature showed no conclusive evidence for outcome of conservatively or operatively treatment of Rockwood type Ⅲ-Ⅴ AC dislocations. Overall, physically active young adults seem to have a slight advantage in outcome when treated operatively. Randomized controlled trials that compare long-term outcomes of nonoperative treatment with different surgical techniques are needed in order to draw firm conclusions.

COMPLICATIONS

Patients with complications have significantly lower clinical scores, suggesting that the presence of complications appears to be the only predictor of poorer clinical outcomes[13,14,35,71]. Complications after surgical treatment range from 27% to 44%[13,28]; the main being infection (4% to 8%), hardware complications (4%) and further surgery (13%)[68]. In a recent review of four studies, 12 (13%) complications were found in 96 patients after early surgery and 14 (18%) complications are occurred in 79 patients after delayed surgery[60].

Hookplate fixation has an overall complication rate of 11%[23] and an infection rate of 5%[7]. Long-term retention of the plate may lead to acromial osteolysis or fracture, which implies that a second surgery is required to remove the plate after 3 mo, when the ligaments have healed[52,55,57].

Clavert *et al*[35] prospectively reported a complication rate of 27% in 116 primary anatomic button fixations. There were 16 cases of hardware failure resulting in symptoms or loss of reduction. Forty-eight patients also had persistent dislocation of > 150%. Singh[72] reported secondary progressive loss of reduction in 7 out of 9 patients after a mean of 3.1 mo. Three patients underwent revision.

Millet *et al*[73] presented a review of 12 studies that reported complications following anatomic CC ligament reconstruction with biologic grafts and described an overall complication rate of 40%. The most serious complications were graft failure, hardware complications, and distal clavicle and/or coracoid fractures as a result of the bone tunnels. Coracoid/clavicle fractures remain a significant complication that occur predominately in techniques utilizing bone tunnels[74].

The rate of surgical complications in the literature following arthroscopic reconstruction of the CC ligaments varies from 13% to 27% and can reach 40% if postoperative loss of reduction is taken into account[27]. The five most commonly documented complications of arthroscopic fixation are superficial infection (4%), shoulder pain (27%), CC calcification (32%), fracture (5%), and loss of reduction (27%)[74].

Thus, many studies have reported postoperative loss of reduction (17% to 80%) after open anatomic reconstruction with autogenous tendon graft or arthroscopic assisted fixation with suture buttons[13,14,28,35,75]. However, a partial loss of reduction does not appear to influence the overall functional results[22,63].

Nowadays, the cosmetic outcome is becoming more and more important for patients. However, the surgeon should consider the preference of a better cosmetic outcome against the higher complication rate in surgically treated patients.

RECENT DEVELOPMENTS

There has been an exponential increase in the number of publications on surgical AC joint reconstruction and repair over the past few years[2]. Recent studies have concentrated on minimally invasive or arthroscopic anatomical reconstruction of the CC ligaments[2,7,13,58,76]. Although many improvements have been made, some questions still remain: How many drill holes are needed in the coracoid and clavicle? Which type of graft should be used? And, should only the CC ligaments be reconstructed or both the CC and AC?

Bone tunnels are commonly used for anatomic reconstruction of the CC ligaments. Because the conoid and trapezoid ligaments attach in different areas of the clavicle and the coracoid, making two holes in both bones looks appealing. However, the use of multiple tunnels is technically demanding and increases fracture risk[27,74]. Jerosch *et al*[77] in a biomechanical study evaluated eight different AC reconstruction techniques. They found the best restoration of anatomy with suture anchor fixation in the base of the coracoid process.

The historical choice of material for stabilization of de CC ligament mainly depends on the clinical setting and timing of surgery, with synthetic material (sutures or tape) in the acute and tendon graft in the chronic injury[75]. Today, most surgeons agree that a biological augmentation is required in chronic cases to enhance the healing potential of the torn structures[5,59,63]. Laboratory studies have shown that anatomic reconstruction with double graft tendons have native-like biomechanical properties[19] and clinical data are promising[52].

Since horizontal instability of the AC joint may result in chronic pain and functional shoulder impairment[78], there is a raising focus on the relevance of specific techniques to improve horizontal stability. Schneibel *et al*[78] described persistent horizontal instability in 41% of cases after isolated CC double ligament stabilization, and developed an all-arthroscopic, radiographically assisted technique that uses a triangular AC cerclage in conjunction with the CC reconstruction to provide better horizontal stability[51,78]. Saier *et al*[79] showed biomechanically that only combined AC and CC reconstruction can adequately restore physiological horizontal AC joint stability. In addition, a recently published study showed that triple-bundle reconstruction including AC graft augmentation yielded superior clinical and radiological outcome than single-bundle CC reconstruction[52].

CONCLUSION

The aim of the current review was to provide an up-to-date and evidence-based overview of relevant treatment options for AC joint dislocations.

The recently published literature has significant limitations, namely a paucity of high quality trials and long-term follow-up. Most of the studies include heterogeneous populations with varying severities and chronicity of injury. Also, the existence of many different surgical techniques prevents the drawing of firm evidence-based conclusions.

The available evidence does provide some important clues. Operative treatment of Rockwood Ⅲ AC joint dislocations results in better cosmetic and radiological results and similar function but longer time off work and increased complication rates compared with conservative treatment[7,17,61]. Current literature suggests that the decision for treatment of type Ⅲ injuries should be made on a case-by-case basis, with an emphasis on initial nonoperative treatment[2]. Early operative treatment for grades Ⅲ-Ⅴ dislocations may result in better functional and radiological outcomes, with a reduced risk of infection and loss of reduction compared with delayed surgery.

Various operative techniques have been described. However, most techniques do not anatomically restore the complex articulation of the AC joint. Anatomical CC ligament reconstruction may result in optimal functional and radiological outcomes. The conoid and trapezoid ligaments have unique anatomic alignments and different functions. Each ligament should be considered during operative treatment[39,43].

Arthroscopically assisted AC reconstruction has the possible advantages of the minimally invasive nature, better visualization of the coracoid and the possibility to detect associated glenohumeral lesions, but demonstrates a distinct complication profile in the less experienced arthroscopist. There is currently no evidence to support arthroscopic rather than open surgery, as comparative studies are not available.

Further studies are needed especially in terms of randomized controlled trials and long-term outcomes to confirm stability of the AC joint and optimal functional results.

REFERENCES

1 **Babhulkar A**, Pawaskar A. Acromioclavicular joint dislocations. *Curr Rev Musculoskelet Med* 2014; **7**: 33-39 [PMID: 24431027 DOI: 10.1007/s12178-013-9199-2]

2 **Beitzel K**, Cote MP, Apostolakos J, Solovyova O, Judson CH, Ziegler CG, Edgar CM, Imhoff AB, Arciero RA, Mazzocca AD. Current concepts in the treatment of acromioclavicular joint dislocations. *Arthroscopy* 2013; **29**: 387-397 [PMID: 23369483 DOI: 10.1016/j.arthro.2012.11.023]

3 **Adam FF**, Farouk O. Surgical treatment of chronic complete acromioclavicular dislocation. *Int Orthop* 2004; **28**: 119-122 [PMID: 15224170 DOI: 10.1007/s00264-003-0520-3]

4 **Tischer T**, Salzmann GM, El-Azab H, Vogt S, Imhoff AB. Incidence

of associated injuries with acute acromioclavicular joint dislocations types III through V. *Am J Sports Med* 2009; **37**: 136-139 [PMID: 18725652 DOI: 10.1177/0363546508322891]

5 **Mazzocca AD**, Spang JT, Rodriguez RR, Rios CG, Shea KP, Romeo AA, Arciero RA. Biomechanical and radiographic analysis of partial coracoclavicular ligament injuries. *Am J Sports Med* 2008; **36**: 1397-1402 [PMID: 18375786 DOI: 10.1177/0363546508315200]

6 **Rios CG**, Arciero RA, Mazzocca AD. Anatomy of the clavicle and coracoid process for reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 2007; **35**: 811-817 [PMID: 17293463 DOI: 10.1177/0363546506297536]

7 **Modi CS**, Beazley J, Zywiel MG, Lawrence TM, Veillette CJ. Controversies relating to the management of acromioclavicular joint dislocations. *Bone Joint J* 2013; **95-B**: 1595-1602 [PMID: 24293587 DOI: 10.1302/0301-620X.95B12.31802]

8 **Chronopoulos E**, Kim TK, Park HB, Ashenbrenner D, McFarland EG. Diagnostic value of physical tests for isolated chronic acromioclavicular lesions. *Am J Sports Med* 2004; **32**: 655-661 [PMID: 15090381 DOI: 10.1177/0363546503261723]

9 **Zanca P**. Shoulder pain: involvement of the acromioclavicular joint. (Analysis of 1,000 cases). *Am J Roentgenol Radium Ther Nucl Med* 1971; **112**: 493-506 [PMID: 5570359 DOI: 10.2214/ajr.112.3.493]

10 **Barnes CJ**, Higgins LD, Major NM, Basamania CJ. Magnetic resonance imaging of the coracoclavicular ligaments: its role in defining pathoanatomy at the acromioclavicular joint. *J Surg Orthop Adv* 2004; **13**: 69-75 [PMID: 15281402]

11 **Rockwood CA**. Disorders of the acromioclavicular joint. In: Rockwood CA, Matsen FA, editors. The shoulder. 4th ed. Philadelphia: WB Saunders, 2009: 453-526

12 **Rockwood CA Jr**, Young DC. Disorders of the acromioclavicular joint. In: Rockwood CA jr, Matsen FA III (eds). The shoulder. Philidelphia: Saunders, 1990: 413-476

13 **Shin SJ**, Yun YH, Yoo JD. Coracoclavicular ligament reconstruction for acromioclavicular dislocation using 2 suture anchors and coracoacromial ligament transfer. *Am J Sports Med* 2009; **37**: 346-351 [PMID: 19022989 DOI: 10.1177/0363546508324968]

14 **Gorbaty JD**, Hsu JE, Gee AO. Classifications in Brief: Rockwood Classification of Acromioclavicular Joint Separations. *Clin Orthop Relat Res* 2017; **475**: 283-287 [PMID: 27637619 DOI: 10.1007/s11999-016-5079-6]

15 **Beitzel K**, Mazzocca AD, Bak K, Itoi E, Kibler WB, Mirzayan R, Imhoff AB, Calvo E, Arce G, Shea K; Upper Extremity Committee of ISAKOS. ISAKOS upper extremity committee consensus statement on the need for diversification of the Rockwood classification for acromioclavicular joint injuries. *Arthroscopy* 2014; **30**: 271-278 [PMID: 24485119 DOI: 10.1016/j.arthro.2013.11.005]

16 **Lee S**, Bedi A. Shoulder acromioclavicular joint reconstruction options and outcomes. *Curr Rev Musculoskelet Med* 2016; **9**: 368-377 [PMID: 27645218 DOI: 10.1007/s12178-016-9361-8]

17 **Korsten K**, Gunning AC, Leenen LP. Operative or conservative treatment in patients with Rockwood type III acromioclavicular dislocation: a systematic review and update of current literature. *Int Orthop* 2014; **38**: 831-838 [PMID: 24178060 DOI: 10.1007/s00264-013-2143-7]

18 **Canadian Orthopaedic Trauma Society**. Multicenter Randomized Clinical Trial of Nonoperative Versus Operative Treatment of Acute Acromio-Clavicular Joint Dislocation. *J Orthop Trauma* 2015; **29**: 479-487 [PMID: 26489055 DOI: 10.1097/BOT.0000000000000437]

19 **Ceccarelli E**, Bondì R, Alviti F, Garofalo R, Miulli F, Padua R. Treatment of acute grade III acromioclavicular dislocation: a lack of evidence. *J Orthop Traumatol* 2008; **9**: 105-108 [PMID: 19384625 DOI: 10.1007/s10195-008-0013-7]

20 **Mascioli AA**. Acute dislocation. In: Canale ST, Beaty JH, editors. Campbell's operative orthopaedics. 12th ed. Philadelphia: Elservier, 2013: 3027-3032 [DOI: 10.1016/B978-0-323-07243-4.00060-8]

21 **Tauber M**, Valler D, Lichtenberg S, Magosch P, Moroder P, Habermeyer P. Arthroscopic Stabilization of Chronic Acromioclavicular Joint Dislocations: Triple- Versus Single-Bundle Reconstruction. *Am J Sports Med* 2016; **44**: 482-489 [PMID: 26657259 DOI: 10.1177/0363546515615583]

22 **Salem KH**, Schmelz A. Treatment of Tossy III acromioclavicular joint injuries using hook plates and ligament suture. *J Orthop Trauma* 2009; **23**: 565-569 [PMID: 19704271 DOI: 10.1097/BOT.0b013e3181971b38]

23 **Kienast B**, Thietje R, Queitsch C, Gille J, Schulz AP, Meiners J. Mid-term results after operative treatment of rockwood grade III-V acromioclavicular joint dislocations with an AC-hook-plate. *Eur J Med Res* 2011; **16**: 52-56 [PMID: 21463981 DOI: 10.1186/2047-783X-16-2-52]

24 **Imhoff AB**, Chernchujit B. Arthroscopic anatomic stabilization of acromioclavicular joint dislocation. *Oper Tech Sports Med* 2004; **12**: 43-48 [DOI: 10.1053/j.otsm.2004.04.002]

25 **Yoon JP**, Lee YS, Song GS, Oh JH. Morphological analysis of acromion and hook plate for the fixation of acromioclavicular joint dislocation. *Knee Surg Sports Traumatol Arthrosc* 2017; **25**: 980-986 [PMID: 26792567 DOI: 10.1007/s00167-016-3987-3]

26 **Lädermann A**, Gueorguiev B, Stimec B, Fasel J, Rothstock S, Hoffmeyer P. Acromioclavicular joint reconstruction: a comparative biomechanical study of three techniques. *J Shoulder Elbow Surg* 2013; **22**: 171-178 [PMID: 22541912 DOI: 10.1016/j.jse.2012.01.020]

27 **Walz L**, Salzmann GM, Fabbro T, Eichhorn S, Imhoff AB. The anatomic reconstruction of acromioclavicular joint dislocations using 2 TightRope devices: a biomechanical study. *Am J Sports Med* 2008; **36**: 2398-2406 [PMID: 18765674 DOI: 10.1177/0363546508322524]

28 **Martetschläger F**, Horan MP, Warth RJ, Millett PJ. Complications after anatomic fixation and reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 2013; **41**: 2896-2903 [PMID: 24007761 DOI: 10.1177/0363546513502459]

29 **Cook JB**, Shaha JS, Rowles DJ, Bottoni CR, Shaha SH, Tokish JM. Clavicular bone tunnel malposition leads to early failures in coracoclavicular ligament reconstructions. *Am J Sports Med* 2013; **41**: 142-148 [PMID: 23139253 DOI: 10.1177/0363546512465591]

30 **Schliemann B**, Roßlenbroich SB, Schneider KN, Theisen C, Petersen W, Raschke MJ, Weimann A. Why does minimally invasive coracoclavicular ligament reconstruction using a flip button repair technique fail? An analysis of risk factors and complications. *Knee Surg Sports Traumatol Arthrosc* 2015; **23**: 1419-1425 [PMID: 24170189 DOI: 10.1007/s00167-013-2737-z]

31 **Dawson PA**, Adamson GJ, Pink MM, Kornswiet M, Lin S, Shankwiler JA, Lee TQ. Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments to acromioclavicular stability. *J Shoulder Elbow Surg* 2009; **18**: 237-244 [PMID: 19111475 DOI: 10.1016/j.jse.2008.08.003]

32 **Debski RE**, Parsons IM 4th, Woo SL, Fu FH. Effect of capsular injury on acromioclavicular joint mechanics. *J Bone Joint Surg Am* 2001; **83-A**: 1344-1351 [PMID: 11568197 DOI: 10.2106/00004623-200109000-00009]

33 **Fukuda K**, Craig EV, An KN, Cofield RH, Chao EY. Biomechanical study of the ligamentous system of the acromioclavicular joint. *J Bone Joint Surg Am* 1986; **68**: 434-440 [PMID: 3949839 DOI: 10.2106/00004623-198668030-00019]

34 **Struhl S**, Wolfson TS. Continuous Loop Double Endobutton Reconstruction for Acromioclavicular Joint Dislocation. *Am J Sports Med* 2015; **43**: 2437-2444 [PMID: 26260466 DOI: 10.1177/0363546515596409]

35 **Clavert P**, Meyer A, Boyer P, Gastaud O, Barth J, Duparc F; SFA. Complication rates and types of failure after arthroscopic acute acromioclavicular dislocation fixation. Prospective multicenter study of 116 cases. *Orthop Traumatol Surg Res* 2015; **101**: S313-S316 [PMID: 26545944 DOI: 10.1016/j.otsr.2015.09.012]

36 **Arirachakaran A**, Boonard M, Piyapittayanun P, Kanchanatawan W, Chaijenkij K, Prommahachai A, Kongtharvonskul J. Post-operative outcomes and complications of suspensory loop fixation device versus hook plate in acute unstable acromioclavicular joint dislocation: a systematic review and meta-analysis. *J Orthop Traumatol* 2017; **18**: 293-304 [PMID: 28236179 DOI: 10.1007/s10195-017-0451-1]

37 **Weaver JK**, Dunn HK. Treatment of acromioclavicular injuries, especially complete acromioclavicular separation. *J Bone Joint Surg Am* 1972; **54**: 1187-1194 [PMID: 4652050 DOI: 10.2106/00004623-197254060-00005]

38 **Mazzocca AD**, Santangelo SA, Johnson ST, Rios CG, Dumonski ML, Arciero RA. A biomechanical evaluation of an anatomical coracoclavicular ligament reconstruction. *Am J Sports Med* 2006; **34**: 236-246 [PMID: 16282577 DOI: 10.1177/0363546505281795]

39 **Jensen G**, Katthagen JC, Alvarado LE, Lill H, Voigt C. Has the arthroscopically assisted reduction of acute AC joint separations with the double tight-rope technique advantages over the clavicular hook plate fixation? *Knee Surg Sports Traumatol Arthrosc* 2014; **22**: 422-430 [PMID: 23124627 DOI: 10.1007/s00167-012-2270-5]

40 **Beitzel K**, Obopilwe E, Chowaniec DM, Nowak MD, Hanypsiak BT, Guerra JJ, Arciero RA, Mazzocca AD. Biomechanical properties of repairs for dislocated AC joints using suture button systems with integrated tendon augmentation. *Knee Surg Sports Traumatol Arthrosc* 2012; **20**: 1931-1938 [PMID: 22210515 DOI: 10.1007/s00167-011-1828-y]

41 **Hegazy G**, Safwat H, Seddik M, Al-Shal EA, Al-Sebai I, Negm M. Modified Weaver-Dunn Procedure Versus The Use of Semitendinosus Autogenous Tendon Graft for Acromioclavicular Joint Reconstruction. *Open Orthop J* 2016; **10**: 166-178 [PMID: 27347245 DOI: 10.2174/1874325001610010166]

42 **Lee SJ**, Nicholas SJ, Akizuki KH, McHugh MP, Kremenic IJ, Ben-Avi S. Reconstruction of the coracoclavicular ligaments with tendon grafts: a comparative biomechanical study. *Am J Sports Med* 2003; **31**: 648-655 [PMID: 12975181 DOI: 10.1177/03635465030310050301]

43 **Tauber M**, Gordon K, Koller H, Fox M, Resch H. Semitendinosus tendon graft versus a modified Weaver-Dunn procedure for acromioclavicular joint reconstruction in chronic cases: a prospective comparative study. *Am J Sports Med* 2009; **37**: 181-190 [PMID: 18818433 DOI: 10.1177/0363546508323255]

44 **Mazzocca AD**, Edgar CM, Beitzel K, Imhoff AB, DeBerardino TM, Arciero RA. Open reconstruction of acute and chronic acromioclavicular joint instability. In: Craig EV, editor. Master techniques in orthopaedic surgery: the shoulder. 3rd ed. Philadelphia: Wolters Kluwer, 2013: 231-242

45 **Woodmass JM**, Esposito JG, Ono Y, Nelson AA, Boorman RS, Thornton GM, Lo IK. Complications following arthroscopic fixation of acromioclavicular separations: a systematic review of the literature. *Open Access J Sports Med* 2015; **6**: 97-107 [PMID: 25914562 DOI: 10.2147/OAJSM.S73211]

46 **DeBerardino TM**, Pensak MJ, Ferreira J, Mazzocca AD. Arthroscopic stabilization of acromioclavicular joint dislocation using the AC graftrope system. *J Shoulder Elbow Surg* 2010; **19**: 47-52 [PMID: 20188268 DOI: 10.1016/j.jse.2009.12.014]

47 **Venjakob AJ**, Salzmann GM, Gabel F, Buchmann S, Walz L, Spang JT, Vogt S, Imhoff AB. Arthroscopically assisted 2-bundle anatomic reduction of acute acromioclavicular joint separations: 58-month findings. *Am J Sports Med* 2013; **41**: 615-621 [PMID: 23371472 DOI: 10.1177/0363546512473438]

48 **Hosseini H**, Friedmann S, Tröger M, Lobenhoffer P, Agneskirchner JD. Arthroscopic reconstruction of chronic AC joint dislocations by transposition of the coracoacromial ligament augmented by the Tight Rope device: a technical note. *Knee Surg Sports Traumatol Arthrosc* 2009; **17**: 92-97 [PMID: 18836701 DOI: 10.1007/s00167-008-0633-8]

49 **Murena L**, Vulcano E, Ratti C, Cecconello L, Rolla PR, Surace MF. Arthroscopic treatment of acute acromioclavicular joint dislocation with double flip button. *Knee Surg Sports Traumatol Arthrosc* 2009; **17**: 1511-1515 [PMID: 19554311 DOI: 10.1007/s00167-009-0838-5]

50 **Boileau P**, Old J, Gastaud O, Brassart N, Roussanne Y. All-arthroscopic Weaver-Dunn-Chuinard procedure with double-button fixation for chronic acromioclavicular joint dislocation. *Arthroscopy* 2010; **26**: 149-160 [PMID: 20141978 DOI: 10.1016/j.arthro.2009.08.008]

51 **Gastaud O**, Trojani C, Boileau P. Shoulder Concepts Arthroscopy. Arthroplasty and Fractures, 2014: 247-266

52 **Motta P**, Bruno L, Maderni A, Tosco P, Mariotti U. Acromioclavicular motion after surgical reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2012; **20**: 1012-1018 [PMID: 21811856 DOI: 10.1007/s00167-011-1627-5]

53 **Metzlaff S**, Rosslenbroich S, Forkel PH, Schliemann B, Arshad H, Raschke M, Petersen W. Surgical treatment of acute acromioclavicular joint dislocations: hook plate versus minimally invasive reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2016; **24**: 1972-1978 [PMID: 25209209 DOI: 10.1007/s00167-014-3294-9]

54 **Arirachakaran A**, Boonard M, Piyapittayanun P, Phiphobmongkol V, Chaijenkij K, Kongtharvonskul J. Comparison of surgical outcomes between fixation with hook plate and loop suspensory fixation for acute unstable acromioclavicular joint dislocation: a systematic review and meta-analysis. *Eur J Orthop Surg Traumatol* 2016; **26**: 565-574 [PMID: 27334621 DOI: 10.1007/s00590-016-1797-4]

55 **Boström Windhamre HA**, von Heideken JP, Une-Larsson VE, Ekelund AL. Surgical treatment of chronic acromioclavicular dislocations: a comparative study of Weaver-Dunn augmented with PDS-braid or hook plate. *J Shoulder Elbow Surg* 2010; **19**: 1040-1048 [PMID: 20452245 DOI: 10.1016/j.jse.2010.02.006]

56 **Kovilazhikathu Sugathan H**, Dodenhoff RM. Management of type 3 acromioclavicular joint dislocation: comparison of long-term functional results of two operative methods. *ISRN Surg* 2012; **2012**: 580504 [PMID: 22779002 DOI: 10.5402/2012/580504]

57 **Ye G**, Peng CA, Sun HB, Xiao J, Zhu K. Treatment of Rockwood type III acromioclavicular joint dislocation using autogenous semitendinosus tendon graft and endobutton technique. *Ther Clin Risk Manag* 2016; **12**: 47-51 [PMID: 26811685 DOI: 10.2147/TCRM.S81829]

58 **Kraus N**, Haas NP, Scheibel M, Gerhardt C. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations in a coracoclavicular Double-TightRope technique: V-shaped versus parallel drill hole orientation. *Arch Orthop Trauma Surg* 2013; **133**: 1431-1440 [PMID: 23843136 DOI: 10.1007/s00402-013-1804-8]

59 **Fauci F**, Merolla G, Paladini P, Campi F, Porcellini G. Surgical treatment of chronic acromioclavicular dislocation with biologic graft vs synthetic ligament: a prospective randomized comparative study. *J Orthop Traumatol* 2013; **14**: 283-290 [PMID: 23649818 DOI: 10.1007/s10195-013-0242-2]

60 **Song T**, Yan X, Ye T. Comparison of the outcome of early and delayed surgical treatment of complete acromioclavicular joint dislocation. *Knee Surg Sports Traumatol Arthrosc* 2016; **24**: 1943-1950 [PMID: 25119054 DOI: 10.1007/s00167-014-3225-9]

61 **Kim SH**, Lee YH, Shin SH, Lee YH, Baek GH. Outcome of conjoined tendon and coracoacromial ligament transfer for the treatment of chronic type V acromioclavicular joint separation. *Injury* 2012; **43**: 213-218 [PMID: 21890137 DOI: 10.1016/j.injury.2011.08.003]

62 **Rasmont Q**, Delloye C, Bigare E, Van Isacker T. Is conservative treatment still defensible in grade III acromioclavicular dislocation? Are there predictive factors of poor outcome? *Acta Orthop Belg* 2015; **81**: 107-114 [PMID: 26280863]

63 **Rolf O**, Hann von Weyhern A, Ewers A, Boehm TD, Gohlke F. Acromioclavicular dislocation Rockwood III-V: results of early versus delayed surgical treatment. *Arch Orthop Trauma Surg* 2008; **128**: 1153-1157 [PMID: 18038141 DOI: 10.1007/s00402-007-0524-3]

64 **Tamaoki MJ**, Belloti JC, Lenza M, Matsumoto MH, Gomes Dos Santos JB, Faloppa F. Surgical versus conservative interventions for treating acromioclavicular dislocation of the shoulder in adults. *Cochrane Database Syst Rev* 2010; **(8)**: CD007429 [PMID: 20687087 DOI: 10.1002/14651858.CD007429.pub2]

65 **Li X**, Ma R, Bedi A, Dines DM, Altchek DW, Dines JS. Management of acromioclavicular joint injuries. *J Bone Joint Surg Am* 2014; **96**: 73-84 [PMID: 24382728 DOI: 10.2106/JBJS.L.00734]

66 **Dunphy TR**, Damodar D, Heckmann ND, Sivasundaram L, Omid R, Hatch GF 3rd. Functional Outcomes of Type V Acromioclavicular Injuries With Nonsurgical Treatment. *J Am Acad Orthop Surg* 2016; **24**: 728-734 [PMID: 27579816 DOI: 10.5435/JAAOS-D-16-00176]

67 **Bannister GC**, Wallace WA, Stableforth PG, Hutson MA. The management of acute acromioclavicular dislocation. A randomised prospective controlled trial. *J Bone Joint Surg Br* 1989; **71**: 848-850 [PMID: 2684990]

68 **Gstettner C**, Tauber M, Hitzl W, Resch H. Rockwood type III acromioclavicular dislocation: surgical versus conservative treatment. *J Shoulder Elbow Surg* 2008; **17**: 220-225 [PMID: 18249565 DOI: 10.1016/j.jse.2007.07.017]

69 **Porschke F**, Schnetzke M, Aytac S, Studier-Fischer S, Gruetzner PA,

Guehring T. Sports activity after anatomic acromioclavicular joint stabilisation with flip-button technique. *Knee Surg Sports Traumatol Arthrosc* 2017; **25**: 1995-2003 [PMID: 27565482 DOI: 10.1007/s00167-016-4287-7]
70 **De Carli A**, Lanzetti RM, Ciompi A, Lupariello D, Rota P, Ferretti A. Acromioclavicular third degree dislocation: surgical treatment in acute cases. *J Orthop Surg Res* 2015; **10**: 13 [PMID: 25627466 DOI: 10.1186/s13018-014-0150-z]
71 **Rush LN**, Lake N, Stiefel EC, Hobgood ER, Ramsey JR, O'Brien MJ, Field LD, Savoie FH 3rd. Comparison of Short-term Complications Between 2 Methods of Coracoclavicular Ligament Reconstruction: A Multicenter Study. *Orthop J Sports Med* 2016; **4**: 2325967116658419 [PMID: 27504468 DOI: 10.1177/2325967116658419]
72 **Singh B**, Mohanlal P, Bawale R. Early failure of coracoclavicular ligament reconstruction using TightRope system. *Acta Orthop Belg* 2016; **82**: 119-123 [PMID: 26984664]
73 **Millett PJ**, Horan MP, Warth RJ. Two-Year Outcomes After Primary Anatomic Coracoclavicular Ligament Reconstruction. *Arthroscopy* 2015; **31**: 1962-1973 [PMID: 25998014 DOI: 10.1016/j.arthro.2015.03.034]
74 **Warth RJ**, Martetschläger F, Gaskill TR, Millett PJ. Acromioclavicular joint separations. *Curr Rev Musculoskelet Med* 2013; **6**: 71-78 [PMID: 23242975 DOI: 10.1007/s12178-012-9144-9]
75 **Choi NH**, Lim SM, Lee SY, Lim TK. Loss of reduction and complications of coracoclavicular ligament reconstruction with autogenous tendon graft in acute acromioclavicular dislocations. *J Shoulder Elbow Surg* 2017; **26**: 692-698 [PMID: 27765500 DOI: 10.1016/j.jse.2016.09.014]
76 **Xiong C**, Lu Y, Wang Q, Chen G, Hu H, Lu Z. Anatomical principles for minimally invasive reconstruction of the acromioclavicular joint with anchors. *Int Orthop* 2016; **40**: 2317-2324 [PMID: 27590201 DOI: 10.1007/s00264-016-3283-3]
77 **Jerosch J**, Filler T, Peuker E, Greig M, Siewering U. Which stabilization technique corrects anatomy best in patients with AC-separation? An experimental study. *Knee Surg Sports Traumatol Arthrosc* 1999; **7**: 365-372 [PMID: 10639655 DOI: 10.1007/s001670050182]
78 **Scheibel M**, Dröschel S, Gerhardt C, Kraus N. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations. *Am J Sports Med* 2011; **39**: 1507-1516 [PMID: 21436458 DOI: 10.1177/0363546511399379]
79 **Saier T**, Venjakob AJ, Minzlaff P, Föhr P, Lindell F, Imhoff AB, Vogt S, Braun S. Value of additional acromioclavicular cerclage for horizontal stability in complete acromioclavicular separation: a biomechanical study. *Knee Surg Sports Traumatol Arthrosc* 2015; **23**: 1498-1505 [PMID: 24554242 DOI: 10.1007/s00167-014-2895-7]

P- Reviewer: Fanter MJ, Vulcano E, Zak L **S- Editor**: Ji FF
L- Editor: A **E- Editor**: Lu YJ

Published by **Baishideng Publishing Group Inc**
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com