A technique for a more accurate and convenient in coracoclavicular ligament reconstruction of acromioclavicular joint dislocation

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Research Article

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A technique for a more accurate and convenient in coracoclavicular ligament reconstruction of acromioclavicular joint dislocation

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Abstract

Background:The Tight-Rope technique, as a widely accepted strategy for the treatment of acromioclavicular(AC) joint dislocation, is undergoing constant improvement due to the disadvantages of complex operation, long learning curve, reliance on clinical experience and auxiliary equipment, etc. The purpose of this study was to propose a simple and cost-effective improved Tight-Rope technique for reconstructing coracoclavicular(CC) ligament for the treatment of acute AC joint dislocations.

Methods:This was a retrospective single-center study conducted between January 2015 and March 2021, involving 23 adult patients with Rockwood Type 3 AC joint dislocations. We performed minimally invasive reconstruction of CC ligament using an improved single-tunnel adjustable Tight-Rope system assisted with a portable Kirchner wire positioning technique and the nice knot. Clinical outcomes of the length of incision, operative time, intraoperative blood loss, post-operative and the number of intraoperative fluoroscopy were assessed using the preoperative and final follow-up Constant Murley system score and postoperative complications such as infection, redislocation, implant loosening, fracture, and hardware pain.

Results:23 patients were followed up from 12 to 18 months. The length of incision was an average of (1.84±1.08) cm. The operative time was an average of (54.61±9.36) min. The intraoperative blood loss was an average of (14.57±9.76) ml. The number of intraoperative fluoroscopy was an average of (11.22±2.68). In these cases, 1 patient had loose internal fixation, 1 patient had postoperative coracoid process fracture, while no complications such as wound infection, internal fixation failure or fracture were found in the other cases. The mean constant score was (37.91 ± 10.26) preparatively, compared to (93.39 ± 6.06) at the final follow-up evaluation. The difference was statistically significant ($P < 0.05$).

Conclusions:This study proposes a simple, accurate and cost-effective technique with a short learning curve for anatomic reconstruction of acute AC joint dislocations. The preliminary clinical and radiographic results of this technique have been very encouraging.

Keywords: Acromioclavicular joint dislocation; Nice knot; Tight-Rope technique;

coracoclavicular ligament

Introduction

AC joint dislocation is part of the common shoulder injuries that occur after a direct extension of the shoulder to the shoulder or indirect extension of the abducted arm[1]. Acromioclavicular dislocations account for approximately 9% of all shoulder injuries[2]. The Rockwood staging system is often used for acromioclavicular dislocations and is subdivided into types I-VI[3]. Numerous studies have shown that Rockwood Type 3 injury can be treated surgically to restore the normal anatomy of the AC joint, re-establish joint stability and achieve good functional outcomes[4]. The treatment of AC joint dislocation includes Kirschner wire tension band internal fixation, hook plate, arthroscopically assisted Endobutton minimally invasive reconstruction of coracoclavicular (CC) ligament reconstruction, etc. However, the treatment process become complicated due to incision infection, coracoid process fracture, difficulty in placement of endobutton Plates, postoperative knot loosening and other disadvantages[5-6].

The Tight-Rope technique is a minimally invasive method for CC ligament reconstruction in AC joint dislocation of Rockwood Type 3 injury[7]. It is widely used to treat AC joint dislocation because of less soft tissue damage, less complication and good outcomes, which appears to replace standard open procedures. But traditional traumatic orthopedic surgeon was accustomed to open reduction internal fixation due to the complexity of the Tight-Rope technique, because of a long learning curve, dependence on clinical experience and the positioning of auxiliary guide devices. After a systematic review of the literature, this study investigates the use of Kirschner wire positioning technology combined with the nice knot to improve the Tight-Rope system, which makes it more accurate and simpler, and can be used for minimally reconstruction of the CC ligament. In this study, we intend to detail this technique, explain the rationale and merits behind such a technique, and report on the functional outcomes with a 1-year follow-up.

Materials and methods

This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by the ethics committee of our hospital, and all patients gave informed consent and signed informed consent. (Date:January 21, 2015/No. 3276277939)

Patient selection

Patient inclusion criteria:(1) Closed unilateral Rockwood III injury. (2) Age≥18 years; (3) Normal shoulder function before the injury; (4) Patient follows our treatment plan. Patient exclusion criteria:minimally invasive reconstruction of coracoclavicular ligament with an improved single-tunnel adjustable Tight-Rope system for Rockwood Type 3 injury; (5) Follow-up time ≥ 12 months. Patient exclusion criteria:(1) Chronic injury; (2) Patients with open injuries or vascular or nerve damage; (3) Patients with severe osteoporosis; (4) Patients with co-morbidities that cannot tolerate surgery.

From January 2015 to March 2021, a total of 23 unilateral Rockwood III AC joint dislocations patients were treated in our hospital with an improved single-tunnel adjustable Tight-Rope system, combined with Kirchner wire positioning technique and the nice knot. All patients had a closed injury and were admitted to the hospital with a positive X-ray of both shoulders and a lateral X-ray, and CT of the affected shoulder to clarify the diagnosis and improve the preoperative examination. All patients were reviewed by intraoperative and postoperative X-ray fluoroscopy. Systematic post-operative follow-up was performed.

Operative technique

All operations were performed by the same surgeon team. The patient was under general anesthesia and in the beach chair position. Affected shoulder pad height, tilts to the healthy side 30°. The shape and position of coracoid, distal clavicle and acromion were marked on the skin surface. The two strands of Tight-Rope suture (Arthrex, USA) were folded into four strands for use by cutting part of a strand. Under the C-arm fluoroscopy, a Kirschner wire was used to percutaneous puncture the upper clavicle cortex at a place about 2.0-3.0 cm from the distal end of the clavicle, and the leading and trailing edges of the clavicle were measured. A Kirschner wire (1.0 mm in diameter) was inserted into one third of the line between the leading edge and the posterior edge of the clavicle, and the placement direction of the Kirschner wire was perpendicular to the coracoid process as far as possible. The operation requires kirschner wire to be placed close to the clavicular surface （Fig 1 a）. Under the C-arm fluoroscopy, the placement position and direction of the Coracoid clavicular tunnel angle were adjusted according to the imaging parameters of the Kirschner wire. The guide wire was placed perpendicular to the upper clavicle and positioned towards the coracoid process (1.7 mm in diameter). Under the C-arm fluoroscopy, the guide wire was located in the center of the circular projection of the coracoid process on the anteroposterior X-ray film, and the guide wire was located at the highest point of the coracoid process or slightly toward the base of the lateral X-ray film, and the positioning Kirchner wire was removed （Fig 1 b-e）. A 1.0-3.0 cm incision was made at the location of the guide wire on the surface of the clavicle. A 4.5 mm diameter drill was used to establish the Upper clavicular cortex, and a soft tissue sleeve was inserted against the upper edge of the coracoid process. The coracoid canal was then established with a 3.7 mm diameter drill （Fig 1 f-g）. The first Tight-Rope plate (Anthrax, USA) was pushed through the coracoid process using a long soft tissue sleeve, and the distal side suture of the plate was pulled so that the plate was inverted and horizontally attached to the exit of the coracoid bone tunnel（Fig 1 h）. The soft tissue sleeve was removed, the second plate was placed on the clavicle, and the suture loop and reinforcement suture were placed in the holes on both sides of the plate. The acromioclavicular joint was repositioned and fixed on the Tight-Rope system using gradually tightened. After the C-arm fluoroscopy examination confirmed that the acromioclavicular joint was completely reduced, at least 3 single-knot fixation were inserted, and nice knot was used to fix the double-strand reinforcing suture. The end of the thread was cut, and the incision was sutured （Fig 1 j and Fig 2）.

Post-operative management

After the operation, the conventional wound dressing was changed, the passive function exercise of shoulder joint was conducted 3 to 5 days later, and the active function exercise was completed after hanging the affected limb with triangular towel for 3 weeks. Conventional dressing changed after surgery. The surgical time (min) was recorded as the time from skin incision to the closure of the wound. The length of incision(cm), intraoperative blood loss(ml), the number of intraoperative fluoroscopy(n) and postoperative complications as well were recorded. All patients had X-rays taken the day after surgery and were given functional exercises in a forearm sling suspension. At 3, 6, and 12 months postoperatively, the patient was followed up in the outpatient clinic, and the acromioclavicular joint was reviewed with X-ray taken, and rehabilitation and functional exercise were instructed. Before surgery and at the last follow-up, shoulder function was evaluated according to Constant-Murley score.

Statistical analysis

All data were analyzed using IBM SPSS Statistics22.0 statistical software, and parameter data, such as operative time, fluoroscopy time, and blood loss, were described as the means±SD/mean±SD (median). The *t*-test or *U*-test was used in the comparison of continuous variables between groups. Statistical significance level was set for a value of $p<0.05$

Results

Of the 23 patients included with Rockwood Type 3 injury, 13 were male patients and 10 were female patients. The patients' ages was 52.00±10.35 years. The statistical results showed that 14 were left-sided and 9 right-sided. The mechanism of injury was traffic injury in 3 cases, fall injury in 14 cases, direct violence in 3 cases. Patients' BMI was between 19 and 29 with an average of (24.51±3.01) (Table 1).

The length of incision was 1.84±1.08 cm. The operative time was 54.61±9.76 min. The intraoperative blood was 14.57±9.76 ml. The number of intraoperative fluoroscopy was 11.22±2.68. The patient's time in the hospital was 10.70±5.46 days. All patients received 14.3±1.82 months of follow-up. In these cases, 1 patient had loose internal fixation, 1 patient had postoperative coracoid process fracture, with tread by the hook plate again, while no complications such as wound infection, internal fixation failure or fracture were found in the other cases (Table 2).

The AC joint was scored on the constant-Murley scale before surgery and at the last follow-up. The constant-Murley score at the last follow-up was 37.91 ± 10.26, significantly higher than the preoperative score an average of (93.39 ± 6.06) ($P < 0.05$)(Fig 3).

Discussion

AC joint dislocation is the most common shoulder injury. The Rockwood staging system is the most extensive system in clinical treatment and is often used as an important basis for the treatment of AC joint dislocation. The Rockwood Type 3 injury includes complete rupture of the AC and CC ligament. Currently, for the Type 3 injury, it is generally advocated to obtain more reliable clinical and imaging results through ligament reconstruction and reduction dislocation, to minimize the risk of shoulder deformity. Numerous studies have shown that the Type 3 injury can be treated surgically to restore the normal anatomy of the AC joint[8-9]. There are many surgical methods for the treatment of AC dislocation, including cross Kirschner wire tension band internal fixation, double-endobutton technique and other techniques[10-12]. The hook plate is still considered the standard treatment for AC joint dislocation, while providing mechanical stability both longitudinally and horizontally. However, there is a high incidence of complications of this technique, including bone erosion, subacromial impingement, rotator cuff injury, wound infection, and fixation resection[11]. In addition, the plate has to be removed surgically a second time.

The double-endobutton technique for the treatment of AC joint dislocations was first reported by Struhl in 2007, and improved early shoulder pain and range of motion(ROM) in shoulder abduction supination and forward flexion supination[12]. However, it has some complications, including clavicle or coracoid fracture, internal fixation failure and traumatic AC arthritis[13-14]. Biomechanical studies have shown that the main reason for the failure of Endobutton system is that the strength of the suture loop is too large to damage the bone under overload condition[15]. The Tight-Rope technique proposed in recent years is considered to be an improvement of the Endobutton technique. It retains the advantages of Endobutton system and can freely adjust the length of the suture loop. Moreover, it can flexibly choose open repair, small incision special guide device, arthroscopic ligament reconstruction[16-17], which has significant advantages in stability and early clinical efficacy[18]. The standard procedure for AC joint reconstruction using the Tightrope technology still requires exposure of the coracoid process. However, there are still risks of coracoid process fracture, bone tunnel enlargement and internal fixation failure even with the help of arthroscopy and positioning and navigation instruments. In addition, Its technical defects also affect the development of this minimally invasive technology to a certain extent, such as complex technical operation, the need for sports medicine expertise, and a long technical learning curve[19-20].

After a systematic review of the literature, according to the characteristics of the Tightrope technology, authors improve the technology from the following aspects.

(1) **The single-tunnel adjustable Tight-Rope system.** At present, there is no uniform standard for the location of the clavicular tunnel when tight-rope technique is used in clinical surgery. The CC ligament include the conical ligament and the trapezoid ligament, while is an important structure against the upward and backward displacement of the distal clavicle[21]. Although studies have shown that the double tunneling technique is more suitable for the anatomical reconstruction of CC ligament, the single tunneling technique has less damage to clavicle and coracoid bone, which can reduce the risk of iatrogenic fractures and is more suitable for short stature, women or Asians[22-23]. Patzer et al.[24] also demonstrated that there was no significant difference in the clinical efficacy of single-Tight-Rope and double-Tight-Rope techniques in the treatment of Rockwood 3 and 4 injuries. Therefore, we chose the single-tunnel adjustable Tight-Rope system for minimally invasive reconstruction of CC ligament.

(2) **The Kirschner wire positioning technique to assist in the establishment of CC tunnel.** The intraoperative positioning of the coracoid tunnel is particularly difficult, especially in the absence of arthroscopic monitoring. The improper positioning of the coracoid tunnel hole close to the tip of the coracoid process may easily lead to coracoid process fracture and postoperative internal fixation failure[25-26]. Anatomical studies have shown that the proximal end of the conical ligament attaches posteromedially below the clavicle surface, usually 4.5 cm from the AC joint (47.2 mm in men and 42.8 mm in women), while the proximal end of the trapezoid attaches to the anterolateral aspect of the inferior clavicle, approximately 2.5 cm from the AC joint (25.4 mm in men and 22.9 mm in women)[27-28]. XU et al. demonstrated that the loss of postoperative joint reduction is closely related to the widening of the clavicle tunnel and the angle of the CC tunnel. A straight CC tunnel angle results in better reduction and minimizes postoperative reduction loss[29]. Based on the above, we chose to insert the needle vertically at the clavicle about 2.0-3.0 cm from the AC joint, which is close to the midpoint of the center point of the trapezoid ligament and the conical ligament. Under the C-arm fluoroscopy, the guide wire passed through the midpoint of the line connecting the medial and lateral borders of the coracoid process on the anteroposteric radiographs, which was located at the root of the coracoid process or at the posterior deviated position on the scapula outlet radiograph. A satisfactory CC tunnel can be obtained without relying on arthroscopy or guides to exposure of the coracoid process.

(3) **The intraoperative 4.5 mm coracoid tunnel is no longer used.** Numerous studies have shown that fixation failure, plate migration, suture breakage, or bone erosion after Tight-Rope fixation occurred because of coracoid tunnel establishment[30-31]. Anatomical studies of the coracoid process showed that the superoinferior thickness of the coracoid process was an average of 11.4 mm, the anteroposterior thickness was an average of 19.2 mm[32]. Imaging studies also showed that the height of the coracoid tip was an average of 9.05 mm, while the height of the middle was an average of 11.12 mm[33]. If a 4.5 mm diameter coracoid tunnel is established at the attachment of the supracoracoid conical ligament, the risk of iatrogenic coracoid fractures is significantly increased, especially in short-stature population, women, or Asians[34]. Therefore, we chose to reduce the drill diameter from 4.5 mm to 3.7 mm for the installation of smaller Tight-Rope plates, avoiding the risk of associated complications.

(4) **Nice knot.** The literature shows that postoperative loss of joint reduction is one of the most common complications in the treatment of AC joint dislocation, and postoperative CC distance is

closely related to shoulder joint function[35-36]. The Nice knot, as a simple and elective self-locking sliding two-wire knot, is widely used to fix irregular fractures in fractures, repair the separation of the joint in fixation, repair of ligament injuries, etc[37]. Biomechanical findings also confirmed that the nice knot can provide satisfactory biomechanical properties in repairing rotator cuff injuries and significantly reduce the risk of knot elongation during dynamic strain[38]. So, we uses a nice knot for reinforcement of the suture loop to avoid the internal fixation failure caused by suture abrasion and breakage.

In this study, the Kirschner wire positioning technique combined with the nice knot was used to improve the single-tunnel adjustable Tight-Rope system for minimally invasive treatment of 23 cases of AC joint dislocation. Only 1 case had internal fixation loosening, and 1 case had coracoid fracture after operation, which was treated with hook plate for the second time. Post-operative follow-up of the remaining patients showed that the shoulder function was significantly improved compared with preoperative ones. Compared with other similar technologies, we believe that the improved single-tunnel adjustable Tight-Rope technology has the following advantages:

(1) There is no need to expose the coracoid through arthroscopy, and the precise positioning of the CC tunnel can be performed with a kirschner wire and the C-arm fluoroscopy. The overall operation is simple, safe, and reliable.

(2) The Tight-Rope steel plate can be directly implanted in the surgical channel, which has the advantages of small surgical incision, short operation time, and less intraoperative blood loss, relieves the patient's early shoulder pain and obtains satisfactory shoulder ROM.

(3) There is no need to measure the length of CC ligament reconstruction during surgery to avoid fixation failure because of wrong selection of the Endobutton plate type. The suture loop and nice knot fixation of the Tight-Rope system can self-lock the compression reduction joint without Kirschner wire fixation. The suture loop is made of high molecular weight polyethylene[39], which can withstand high-strength traction and reduce the risk of internal fixation loosening and joint reduction failure.

Although the results of this study show good clinical effects and technical advantages in terms of surgical incision, operation time, and intraoperative bleeding, there are still some shortcomings in this study:

(1) Since this study is a single-center retrospective clinical case analysis, the number of cases is small and the level of evidence is relatively low, so multi-center, large-sample case analysis is needed to further confirm the results of this study.

(2) The AC ligament was not repaired in this study, and the horizontal stability of the AC joint could not be completely restored.

(3) Due to the lack of sufficient anatomical research on the coracoid process and the adjacent blood vessels and nerves, the safe range of the coracoid tunnel cannot be clearly established, and the standard quantification of intraoperative positioning operations cannot be performed. The relevant anatomical research needs to be further improved.

Conclusion

In conclusion, the minimally invasive reconstruction of the CC ligament using the single-tunnel adjustable Tight-Rope system modified by the Kirschner wire positioning and the Nice knot is an option for treating acute AC joint dislocation. This technique is a simple and cost-effective technique with the advantages of simple operation, less trauma, and a short learning curve. Preliminary clinical results are encouraging, and larger studies are needed to further validate the technology.

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Author contribution

YF Y and MW designed the study; YF Y, XF L, SH Y and MW searched relevant studies;YF Y and MW analysed and interpreted the data; YF Y wrote the manuscript; YF Y and MW approved the final version of the manuscript.

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Availability of data and materials

All data analysed in this study has been provided in the manuscript.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by the ethics committee of the Wuxi Hospital of Traditional Chinese Medicine, and all patients gave informed consent and signed informed consent. (Date:January 21, 2015/No. 3276277939)

Consent to participate

All patients provided informed consent prior

Consent for publication

Informed consent for publication was obtained from all patients.

Competing interests

The authors declare no competing interests.

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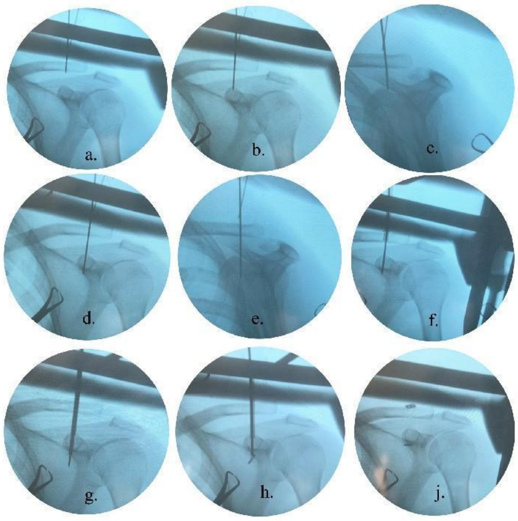

Fig.1 The specific operation steps of the improved single-tunnel adjustable Tight-Rope system

a Assisted positioning of Kirschner wire about 2.0-3.0cm from the end of the clavicle, the guide wire points to the coracoid. b,d the guide wire was located in the center of the circular projection of the coracoid process on the anteroposterior X-ray film. c,e The guide wire was located at the highest point of the coracoid process or slightly toward the base of the lateral X-ray film. f A 4.5 mm diameter drill was used to establish the Upper clavicular tunnel. g A 3.7 mm diameter drill was used to establish the coracoid tunnel. h The plate was inverted and horizontally attached to the exit of the coracoid bone channel. g.The loop and nice knot fixation of the Tight-Rope system can self-locking the compression reduction joint.

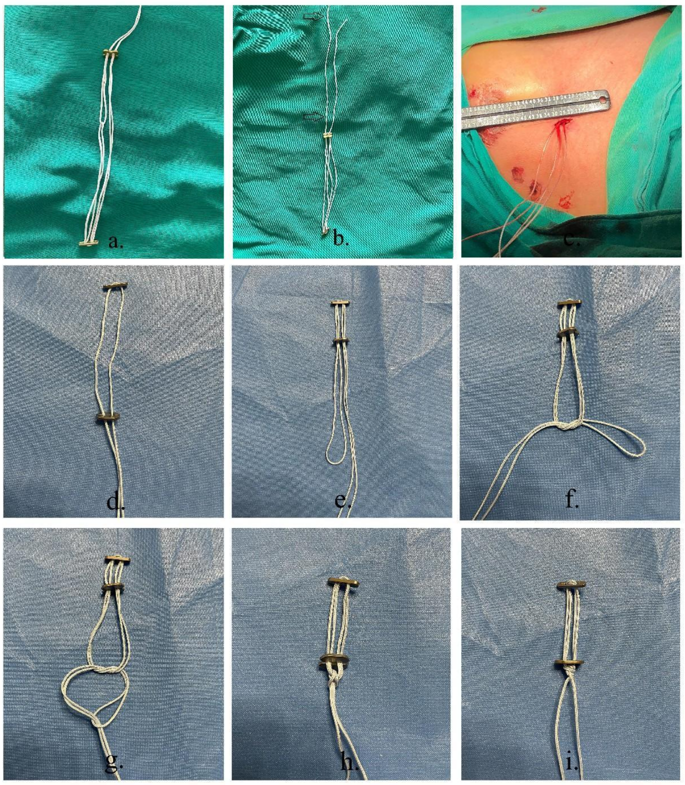

Fig.2 Introduction to the nice knot technique and Intraoperative incision.

a The Tight-Rope system (Arthrex, USA). b The two strands of Tight-Rope suture (Arthrex, USA) is folded into flou strands for use by cutting part of the suture (shown by black arrows). c Intraoperative location and size of incision. d A double-over suture is passed around the plate. e A single square knot is thrown. f,g The both limbs are passed through the loop. h The knot is dressed. j The knot is slid down and self-locking by pulling the limbs apart and the tightened knot is secured with 3 single-knota surgeon's knot. c-h For demonstration of the operation, only two of four sutures ate reserved for the nice knot.

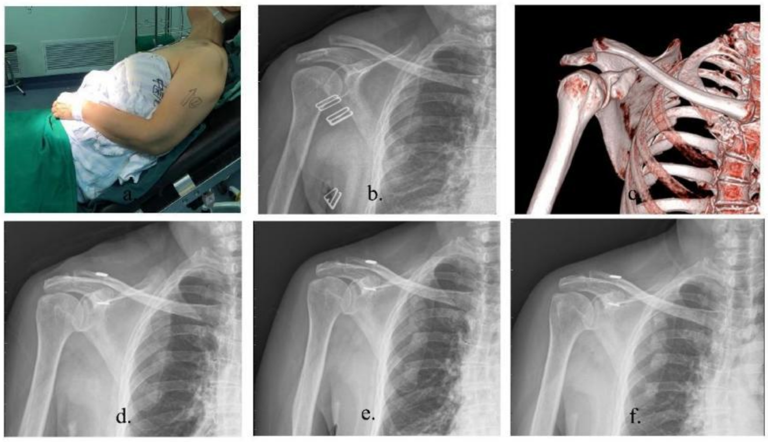

Fig.3 Introduction to the perioperative period and Imaging follow-up of patients.
a Patient in beach chair position with the arm marked and draped. b,c Pre-operative X-ray and CT evaluation and measurement of AC joint dislocation. d X-rays on the second postoperative day showed a good repositioning of the AC joint dislocation. e X-ray 3 months after surgery shows the CC tunnel is blurred. f Postoperative x-ray at 12months showed a good repositioning of the AC joint.

Table 1. Patient demographics

Variable	
No. of cases	23
Gender (M/F)	13/10
Age (Year, mean±SD)	52.00±10.35
BMI (mean±SD)	24.51±3.01
Left or Right (L/R)	14/9
Injury mechanis	
Traffic accidents	6
Fall	14
Direct violent injury	3
Follow-up time (month, mean±SD)	14.3±1.82

M Male, F Female, BMI Body Mass Index, SD Standard deviation

Table 2. Patient demographics

Operative time (min, mean±SD)	54.61±9.76

Blood loss (ml, mean±SD)	14.57±9.76
Fluoroscopy time (s, mean±SD)	11.22±2.68
Hospitalization days (d, mean±SD)	10.70±5.46
The length of incision (cm, mean±SD)	1.84±1.08

SD Standard deviation