Suspension Suture Augmentation for Repair of Coracoclavicular Ligament Disruptions

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Abstract Surgical reconstruction of the coracoclavicular ligament is a fundamental part of management of high-grade acromioclavicular dislocations and Type II lateral third clavicular fractures. However, no single surgical procedure is fully satisfactory because of failure or complications. We present an alternative coracoclavicular stabilization technique, which avoids the use of hardware or tendon graft, that was used in 10 consecutive patients with complete coracoclavicular ligament disruptions. These patients were followed for a minimum of 14 months (average, 34.8 months; range, 14–55 months). At the final

followup, functional outcome measurement instruments (University of California–Los Angeles shoulder rating system and Western Ontario Shoulder Instability Index) and radiographic analysis were adopted as the main outcome measures of shoulder function. The mean University of California–Los Angeles shoulder rating score and the mean Western Ontario Shoulder Instability Index aggregation score at 12 months after surgery were 33.8 (95% confidence interval, 32.8–34.8) and 93.4 (95% confidence interval, 88.2–98.6), respectively. The radiographic analysis revealed all patients had maintained reduction on radiographs at the final followup. These preliminary results suggest that this simple technique can achieve stable coracoclavicular reconstruction and facilitate healing of the repaired ligaments or fractures.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participating in the study was obtained.

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Introduction

Acromioclavicular (AC) dislocation or lateral third clavicular fracture generally occurs from direct trauma to the shoulder area, most often when a force is applied to the acromion with the arm in an adducted position [3, 7, 9, 12, 13]. The pathologic force generally follows the paths of transmission such that the energy travels through the AC ligament or the lateral third clavicle, leading to a variable extent of coracoclavicular (CC) ligament disruption [3, 9, 12]. In general, more displacement at the dislocation/fracture site leads to more severe CC ligament injuries and greater need for surgical stabilization [3, 6, 9, 12]. Bio-mechanical studies also have indicated the CC ligament plays a primary role in maintaining stability of the AC joint

or the interrelationship between the lateral third clavicle and the acromion [4, 8, 14, 21–23, 25].

Many orthopaedic surgeons recommend early surgery to prevent disabling shoulder pain, fatigue, weakness, and deformity for Rockwood high-grade (Types IV–VI) AC dislocations and Neer Type II lateral third clavicular fractures [2, 3, 7, 9, 12, 13]. Various methods for surgical treatment of these lesions have been described [2, 5, 7, 9, 10, 16, 17, 20], suggesting experts do not agree on the optimal approach. Some surgical techniques attempt to reconstruct native anatomy by directly repairing dislocated AC joints or fractured clavicles [10, 16, 17, 21]. These fixation methods using screws, pins, plates, or tendon grafts do not effectively transfer and dissipate the deforming force at the fracture/dislocation site and therefore have been linked with a high incidence of complications such as deep infection, AC arthritis, pin migration, hardware failure, and loss of fixation [10, 16, 17, 21]. Other methods highlight the significance of CC reconstruction and then apply different augmentation designs between the coracoid and the clavicle to facilitate healing of transferred grafts, repaired ligaments, or fractures [2, 5, 7, 9, 10, 16, 17, 20, 24]. To our knowledge, CC screw fixation and CC loop technique may be the most frequently adopted types of augmentation design described in the literature [1, 5, 7, 9, 21, 24]. Both approaches can successfully transfer the deforming force from the fracture/dislocation site to the fixation point on the clavicle but concentrate the deforming force over a small area. The overburden of the concentrated force on the fixation point may incur hardware failure, osteolysis, cut-through phenomena, or avulsion fracture of the clavicle [1, 5, 6, 24, 25].

Therefore, we present the technique of suspension suture augmentation, which is modified from the suture loop augmentation technique [1, 7, 22], by relocating the drill holes on the clavicle to simulate the attachment sites of conoid and trapezoid ligaments on the undersurface of the clavicle. The proposed technique has the advantage of a suspension bridge design in transferring and dissipating the deforming forces and also may improve treatment outcomes such as increasing shoulder function and daily activity, improving and maintaining radiographic outcome, and decreasing complications.

We hypothesized the suspension suture augmentation technique is an effective tool for orthopaedic surgeons when managing patients with complete disruptions of the CC ligament such as high-grade AC dislocations and Type II lateral third clavicular fractures. Our aims were to evaluate the patients treated with the proposed technique for (1) functional outcome as assessed by the University of California–Los Angeles (UCLA) shoulder rating system and the Western Ontario Shoulder Instability Index (WOSI), (2) radiographic assessment of reduction and

maintenance of reduction, (3) review of complications associated with the technique, and (4) correlation of outcome with various patient characteristics.

Materials and Methods

Between January 2002 and December 2006, 36 patients with AC dislocations or lateral third clavicular fractures were managed by the senior author (KCH) at Chang Gung Memorial Hospital. After consideration of the type of patient and their physical activity, we recommend nonoperative treatment for all Types I and II AC dislocations, most Type III AC dislocations (Rockwood classification), and nearly all Types I and III lateral third clavicular fractures (Neer classification) [3, 6, 7, 12]. Additionally, we recommend surgical stabilization for patients with Types IV, V, and VI AC dislocations, symptomatic Type III AC dislocations, Type II lateral third clavicular fractures, and symptomatic Type III lateral third clavicular fractures [3, 7, 10, 17, 24].

Of the 36 patients, 12 received surgical stabilization for their AC dislocations or lateral third clavicular fractures. We retrospectively reviewed the medical records for the presenting history, radiographs, and treatment details. Followup was performed using questionnaires and physical and radiographic examinations of the shoulders. Two patients, including one with a coracoid fracture, were excluded from the study owing to loss of followup. Final followup involved 10 patients (seven men, three women; 10 shoulders), who were included in this study (Table 1). These 10 patients were followed for a minimum of 14 months (average, 34.8 months; range, 14–55 months).

The patients ranged in age from 19 to 76 years with a median age of 34.5 years. Of the diagnoses, one was symptomatic Type III AC dislocation, five were Type V AC dislocations, and four were Type II lateral third clavicular fractures. Nine patients were injured in motorcycle versus motor vehicle accidents, and one patient was injured by falling off a motorcycle. Seven of the lesions were on the right side and three were on the left side. Complete disruption of CC ligaments was a regular intraoperative finding for all enrolled patients. To reconstruct the disrupted CC ligaments, a simple surgical technique (the suspension suture augmentation) without use of hardware or tendon grafts was performed on these patients.

General anesthesia was used, and the patient was placed in the beach chair position on the operating table. After positioning the patient, the entire shoulder, upper limb, and lateral aspect of the neck and chest were prepared with iodine and isopropyl alcohol solutions and then draped appropriately. An anterior saber-cut incision (approximately 8–10 cm in length) medial to the AC joint was

Table 1. Patient demographics

Patient	Age (years)	Gender	Occupation	Mechanism of injury	Side	Admission route	Shoulder lesion pattern	Associated lesions	Interval presurgery (days)	Hospital stay (days)	Followup (months)	Return to work (weeks)	Shoulder fatigue (Yes/No)	UCLA score	WOSI aggregation score (%)	Radiographic outcome (M/L)	Complication
1	34	Male	Labor	Fall off MC	Left	OPD	AC-III	None	30	5	55	14	No	35	100	M	None
2	76	Male	Farmer	MC vs MV	Right	OPD	LC-II	BAT, RCT, hip fx	9	5	54	20	Yes	31	82	M	None
3	20	Male	Student	MC vs MV	Left	ER	LC-II	BAT, femur fx	15	18	52	12	No	35	100	M	None
4	27	Male	Office worker	MC vs MV	Right	OPD	AC-V	None	18	4	42	12	No	35	100	M	Stitch abscess
5	54	Female	Housekeeper	MC vs MV	Right	OPD	LC-II	None	10	5	35	14	Yes	33	88	M	None
6	44	Female	Housekeeper	MC vs MV	Left	OPD	AC-V	PCL tear	30	8	33	16	No	33	86	M	None
7	19	Male	Student	MC vs MV	Right	ER	AC-V	None	1	5	23	12	No	35	100	M	None
8	26	Male	Tour guide	MC vs MV	Right	ER	AC-V	BAT, HT	9	16	22	16	No	35	100	M	None
9	35	Male	Salesman	MC vs MV	Right	ER	LC-II	None	1	6	18	14	No	33	90	M	None
10	43	Female	Farmer	MC vs MV	Right	OPD	AC-V	None	8	4	14	16	Yes	33	88	M	None

MC = motorcycle; MV = motor vehicle; OPD = outpatient department; ER = emergency department; AC = acromioclavicular dislocation; LC = lateral third clavicular fracture; BAT = blunt abdominal trauma; RCT = rotator cuff tear; fx = fracture; PCL = posterior cruciate ligament; HT = head trauma; UCLA = University of California–Los Angeles shoulder rating system; WOSI = Western Ontario Shoulder Instability Index; M/L = maintained/lost reduction.

made through the skin to expose the AC joint, lateral third clavicle, and coracoid process. The coracoid process was identified, along with the conjoined tendon, pectoralis minor, and coracoacromial ligament attachments on the coracoid. The superior aspect of the lateral third clavicle was exposed by subperiosteal dissection to allow for judgment of the normal CC ligament attachment sites on the clavicle, leaving the anterior deltoid attachment on the clavicle intact.

Two 1.8-mm superior-to-inferior drill holes were placed in the lateral end of the clavicle to simulate the normal CC ligament attachments, with one hole located at the conoid tubercle and the other at the lateral aspect of the trapezoid line [11] (Fig. 1A–C). Two strands of Number 5 Ethibond® sutures (Ethicon, Inc, Somerville, NJ) then were passed underneath and looped around the coracoid process base medially to laterally to prevent injuries to the subclavian neurovascular bundles. The medial end of the sutures was passed through the posteromedial hole on the clavicle, and the lateral end was pulled through the anterolateral hole (Fig. 1D). With the dislocation/fracture reduced and held in position by a bone clamp, the ends of the sutures were tightened and tied securely over the superior aspect of the lateral third clavicle (Fig. 1E). The ends of the disrupted CC ligament, AC ligament, or fractured clavicle then were sutured, and any obvious muscle ruptures were repaired after the suspension suture augmentation was completed.

The surgically treated shoulder was immobilized in a sling postoperatively for 6 to 8 weeks. Passive pendulum exercise in the immobilization sling was started 2 weeks after surgery and continued until 6 to 8 weeks. Patients then were allowed to start active shoulder motion, including rotator cuff exercises. Full return to work generally occurred by 12 to 16 weeks after surgery. However, patients were advised to avoid contact activities for at least 6 months after surgery.

The outcome measure instruments we used in this study included the UCLA shoulder rating system [18] and the WOSI [18, 19]. The UCLA scoring instrument assigns a score to patients according to five subclasses, pain (10 points), function (10 points), active forward flexion (5 points), strength of forward flexion (5 points), and overall satisfaction (5 points), with a total of 35 points. In this outcome score, 34 points or higher denotes an excellent result, 28 to 33 points denotes a good result, 21 to 27 points denotes a fair result, and 20 points or less denotes a poor result. The WOSI scoring instrument, a statistically approved measurement method with high reliability, validity, and responsiveness [18], comprises four subcategories: (1) physical symptoms and pain; (2) sport, recreation, and work function; (3) lifestyle and social functioning; and (4) emotional well-being. Twenty-one

Fig. 1A–E The suspension suture augmentation technique is illustrated. The locations of the drill holes (PMH = posteromedial hole; ALH = anterolateral hole) are shown on (A) the superficial surface of the lateral clavicle and (B) on the underneath surface of the lateral clavicle, with the PMH at the conoid tubercle and the ALH at the lateral aspect of trapezoid line. (C) Two 1.8-mm superior-to-inferior drill

holes are placed in the lateral end of the clavicle to simulate the normal CC ligament attachments. (D) Two strands of Number 5 Ethibond[®] sutures are passed underneath the coracoid process base, with the medial end of sutures passed through the PMH and the lateral end pulled through the ALH, respectively. (E) The two strands of sutures are knotted tightly onto the clavicle to build the suspension bridge.

items are scored by a visual analog scale measuring 100 mm horizontally placed under each question. After summing, the WOSI aggregation score is reported as a percentage by subtracting the total from 2100 and then dividing the result by 2100 [18, 19].

Anteroposterior radiographs of the chest, including bilateral AC joints, were taken for each patient at regular followup. Routinely, we used a 5-kg weight attached to the wrist of the affected side for the weightbearing radiographs. The weightbearing radiographic outcome was defined and classified as (1) maintained reduction (with a side-to-side difference less than the width of the clavicle), and (2) complete loss of reduction (with a side-to-side difference in excess of the width of the clavicle) [15]. The presence or absence of long-term erosive phenomena of the nonresorbable suture material into the clavicle also was determined at the final followup. Absence of this finding may provide indirect evidence of healing of the repaired ligaments.

Spearman's rank-based correlation coefficient (r_s) was calculated to study the relation between patient characteristics (ages, intervals before surgery, hospital stays, time of return to work) and functional outcomes (the UCLA shoulder rating scores and/or the WOSI aggregation scores). Results of this association analysis may provide a clue for patient selection (age and intervals before surgery, for example) in future studies. Correlating the functional

outcomes with the quality and maintenance of reduction is important; however, we did not perform this analysis owing to the dichotomous results in our study. Confidence Interval Analysis Version 2.0 software (University of Southampton, Southampton, UK) was used for all analyses.

Results

The patients treated by suspension suture augmentation obtained satisfactory functional results for the shoulder as assessed by the UCLA and WOSI scoring systems (Table 1). The mean UCLA shoulder rating score and mean WOSI aggregation score 12 months after surgery were 33.8 (95% confidence interval [CI], 32.8–34.8) and 93.4 (95% CI, 88.2–98.6), respectively. Among the patients, five (50%) achieved excellent functional results and the other five (50%) achieved good functional results for the shoulder, according to the UCLA shoulder rating scoring system. At the final followup, three (30%) patients reported occasional shoulder fatigue without impaired shoulder motion and strength. The satisfactory results by the UCLA score indicated the patients treated with the proposed technique could recover shoulder function smoothly. The high levels of the WOSI aggregation score revealed these patients could be anticipated to return to normal daily activities.

Fig. 2A–D (A) A preoperative weightbearing anteroposterior radiograph of the chest (Patient 7) including bilateral AC joints reveals a Type V AC dislocation. (B) A nonweightbearing radiograph taken 1 day after reconstructive surgery shows a mild overreduction. (C) A weightbearing radiograph taken 3 months after surgery reveals good reduction and maintenance of reduction. (D) A radiograph taken 1 year after surgery shows reduction was maintained without cut-through phenomena.

Regarding radiographic assessment of reduction and maintenance of reduction, all patients maintained reduction (with a side-to-side difference less than the width of the clavicle) on radiographs at the final followup (Table 1). In the group with AC dislocation, one of six patients (16.7%) was observed to have a mild overreduction on the nonweightbearing radiograph taken 1 day after reconstructive surgery (Fig. 2A–B); however, the weightbearing radiographs taken 3 months and 1 year after surgery revealed good reduction and maintenance of reduction (Fig. 2C–D). In the group with lateral clavicular fracture, all four patients (100%) were observed to have good reduction and maintenance of reduction (Fig. 3A–D). Additionally, all these patients had radiographic union as seen on radiographs taken 1 year after surgery (Fig. 3D). At the final followup, we did not observe the presence of long-term erosive phenomena of the nonresorbable suture material into the clavicle on radiographs in both groups, which may suggest healing of the repaired ligaments.

We observed only one postoperative complication related to the procedure. Patient 4 had a stitch abscess develop that was treated successfully with local dressings and antibiotics (Table 1). During regular followup, we did not observe other complications such as osteolysis, cut-through phenomena, fracture nonunion, neurovascular injuries, deep infection, and frozen shoulder.

Regarding the correlation of functional outcome with various patient characteristics (Table 2), the UCLA shoulder rating scores in these patients showed a strong positive correlation with the corresponding WOSI

aggregation scores ($r_s = 0.968$, 95% CI, 0.867–0.963). Patients' ages indicated a moderate to strong negative correlation with the functional outcome measures (UCLA scores, $r_s = -0.689$, 95% CI, -0.920 to -0.105 ; WOSI scores, $r_s = -0.915$, 95% CI, -0.980 to -0.672). In contrast, there was no association between intervals before surgery or hospital stays and the functional outcome measures (UCLA scores, $r_s = -0.216$ and -0.160 , 95% CI, -0.478 to 0.745 and -0.523 to 0.717 , respectively; WOSI scores, $r_s = 0.052$ and 0.134 , 95% CI, -0.597 to 0.660 and -0.541 to 0.704 , respectively). Time of return to work showed a moderate negative correlation with the functional outcome measures (UCLA scores, $r_s = -0.689$, 95% CI, -0.920 to -0.105 ; WOSI scores, $r_s = -0.728$, 95% CI, -0.931 to -0.181) (Table 2).

Discussion

Our aims in performing this retrospective review were to evaluate the success of the suspension suture technique for repair of complete disruptions of the CC ligament. We specifically assessed functional outcome, reduction and maintenance of reduction, complications associated with the technique, and correlation of outcome with various patient characteristics.

This investigation has several key limitations, including small number of cases, diversity of diagnosis, lack of a control group, and no support from basic science. A prospectively randomized controlled clinical trial and

Fig. 3A–D (A) A preoperative anteroposterior radiograph of the chest (Patient 5) including bilateral AC joints shows a Type II lateral third clavicular fracture. (B) A radiograph taken 1 day after reconstructive surgery reveals good CC reconstruction and fracture repair. (C) A radiograph taken 3 months after surgery shows maintained reduction and fixation. (D) A radiograph taken 1 year after surgery shows radiographic union at the fracture site.

Table 2. Association between functional outcomes and patient demographic factors

Demographic factor	Mean (range)	r_s (95% CI)	
		UCLA score (mean, 33.8; range, 32.8–34.8)*	WOSI aggregation score (mean, 93.4; range, 88.2–98.6)*
Age (years)	34.5 (19–76)	–0.689 (–0.920 to –0.105)	–0.915 (–0.980 to –0.672)
Interval presurgery (days)	9.5 (1–30)	0.216 (–0.478 to 0.745)	0.052 (–0.597 to 0.660)
Hospital stay (days)	5 (4–18)	0.160 (–0.523 to 0.717)	0.134 (–0.541 to 0.704)
Return to work (weeks)	14 (12–20)	–0.689 (–0.920 to –0.105)	–0.728 (–0.931 to –0.181)

* The r_s (95% CI) between UCLA score and WOSI aggregation score is 0.968 (0.867–0.993); CI = confidence interval; UCLA = University of California–Los Angeles shoulder rating system; WOSI = Western Ontario Shoulder Instability Index.

biomechanical studies to determine its superiority over other techniques are required in the future.

Our results indicated satisfactory functional outcomes, good reduction and maintenance of reduction on the followup radiographs, and absence of procedure-related complications such as long-term erosive phenomena. The association analysis also revealed nonelderly patients with neglected lesions may be treated successfully with the proposed technique without need of resection arthroplasty. The best conditions for application of the technique seem to be young patients treated within 30 days of injury. Resection of the distal clavicle as in the Weaver–Dunn procedure [15] appears to be unnecessary.

The suspension suture augmentation technique has several essential features and advantages. First, the proposed technique is simple and cost-effective. The only materials required to build the suspension suture augmentation are two strands of Number 5 Ethibond® sutures that pass through the

1.8-mm drill holes and are knotted tightly onto the clavicle. Motamedi et al. [21] found such a braided nonabsorbable suture has similar strength and stiffness to an intact CC ligament complex, thus protecting against physiologic loads while allowing shoulder motion. We chose nonresorbable sutures instead of biodegradable ones based on two rationales: (1) to maintain the augmentation for a longer time than those with biodegradable sutures and (2) to provide indirect evidence of ligament healing by observing the presence of long-term erosion of the material into the clavicle. Our preliminary results indicate the technique achieved stable CC reconstruction without the use of hardware or tendon grafts. All patients maintained reduction without cut-through phenomena on radiographs at the final followup.

The suspension suture augmentation has the advantage of a suspension bridge design. A suspension bridge is a type of bridge in which the main load-bearing elements are hung from suspension cables. All surgical reconstruction

procedures for CC stabilization involve compression and tension, which need to be handled by the augmentation design without buckling or snapping. Buckling occurs when the compression force overcomes an object's ability to handle compression (eg, cut-through phenomena), and snapping occurs when the tension force overcomes an object's ability to handle tension (eg, pin migration and/or breakage). The suspension suture augmentation technique transfers and dissipates these forces. The tensionized suspension sutures transfer the deforming force (eg, the weight of the injured upper extremity) from the fracture/dislocation site to the intact bony cortex between the drill holes. By relocating the drill holes to simulate the attachment sites of a CC ligament (conoid and trapezoid parts) on the clavicle, the sutures further spread the deforming force over a wider area than that of the suture loop reconstructions so that no one spot has to bear the concentrated force. Our findings indicated that the proposed augmentation method has no technique-related complications such as osteolysis, cut-through phenomena, fracture nonunion, neurovascular injuries, deep infection, and frozen shoulder. Therefore, we recommend the proposed technique as being safe for repairing CC ligament disruptions.

Results of our study showed the suspension suture augmentation technique is a simple and effective tool for orthopaedic surgeons when managing patients with complete disruptions of the CC ligament such as high-grade AC dislocations and Type II lateral third clavicular fractures. Our preliminary study indicates a suspension bridge built by two strands of Number 5 Ethibond[®] suture can achieve stable CC reconstruction and facilitate healing of the repaired ligaments and fractures without using hardware or tendon grafts.

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