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STUDIES ON ACROMIOCLAVICULAR JOINT DISLOCATIONS – CLINICAL OUTCOMES AND RADIOLOGICAL CLASSIFICATION

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Cover illustration: John Windhamre, 10 years old, interpretation of the AC joint

STUDIES ON ACROMIOCLAVICULAR JOINT DISLOCATIONS – CLINICAL OUTCOMES AND RADIOLOGICAL CLASSIFICATION
THESIS FOR DOCTORAL DEGREE (Ph.D.)

By

Helena Boström Windhamre

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POPULAR SCIENCE SUMMARY OF THE THESIS

The aim of this thesis was to increase knowledge about ligament injuries in the acromioclavicular (AC) joint. Injuries to the AC joint are quite common and account for approximately 10% of all shoulder girdle injuries, being most frequent among younger sports-active men.

Cycling, soccer, ice hockey, alpine sports, martial arts, traffic accidents and falls on shoulder or arm are common causes of AC joint dislocations. Pain, instability and difficulty moving the shoulder, are common symptoms of AC joint dislocation. After plain radiographs of the shoulder and AC joint, the injuries can be divided into type I – VI based on Rockwood's classification, which is the most common and has been used internationally since 1984. Rockwood types I and II treated with physiotherapy, and treatment is started with physiotherapy also for type III, but is re-evaluated after approximately 3 months. If symptoms persist, surgery is possible at a later stage. Rockwood types IV, V and VI have traditionally been treated with surgery within a few weeks of the injury, and there are over 160 different surgical methods. Treatment results are monitored with radiographs, questionnaires to evaluate pain, function, subjective patient satisfaction and quality of life.

In Study I, the outcomes after treatment with one of two surgical methods for chronic AC joint dislocation types III–V, used during different time periods at the clinic, was compared. One group of patients had a modified Weaver-Dunn procedure, transfer of a ligament augmented with a braid of suture material, and the other group had the same Weaver-Dunn procedure, but augmented with a hook plate. The study failed to show significant differences in almost all of the outcome scores, except pain; the group of patients operated with a hook plate had significantly more pain during movement.

In Study II, the outcome after operative treatment of AC joint dislocation type V in the acute phase within 3 weeks was compared with the outcome after delayed treatment, i.e., more than 4 months after injury. All patients were treated with a hook plate, and the group with delayed treatment also had a ligament transfer, as described by Weaver-Dunn. At follow-up, patients treated with acute surgery achieved better results in almost all parameters, except in the shoulder-specific Constant score.

Study III was a randomized controlled trial comparing the outcome after acute surgical treatment with hook plate or non-operative treatment with physiotherapy of patients with acute AC joint dislocation type III or V. Patients were monitored regularly and followed for 2 years. After 3 months, the operated patients scored significantly worse in all parameters, but already after 6 months the differences had evened out. At 2 years, there were no significant differences in the outcome after surgery or physiotherapy.

In Study IV, the reliability of the classification system for AC joint dislocations using radiographs and computed tomography (CT) scans was evaluated by orthopedic surgeons and radiologists. A new simpler method of classification on radiographs was also tested.

The study showed that using radiographs and CT scans in combination, improved the reproducibility. The reliability of the new simpler classification was significantly better than plain radiographs, but was not significantly better than plain radiographs in combination with CT scans.

POPULÄRVETENSKAPLIG SAMMANFATTNING

Denna avhandling syftar till att öka kunskaperna om ledbandsskador i akromioklavikularleden (AC-leden). Skador i AC-leden är vanligare hos yngre fysiskt aktiva män (20–40 år). Ledbandsskadan uppstår oftast vid cykling, fotboll, ishockey eller fall på axel eller arm. Symptom som smärta, instabilitet och svårighet att röra armen, kan uppstå. Efter en röntgenundersökning av axel och AC-led delas skadorna in i typ I–VI enligt Rockwoods klassifikation, som är vanligast och har använts internationellt sedan 1984. Typ I och II enligt Rockwood behandlas med fysioterapi, och vid typ III startas behandling med fysioterapi, men utvärderas efterhand. Om symptomen från AC-leden blir kroniska kan man göra en operation i ett senare skede. Typ IV, V och VI har behandlats med operation inom några veckor från skadan, och det finns över 160 olika operationsmetoder att välja mellan. Resultat av behandlingen följs med röntgen, frågeformulär för att objektivt värdera smärta, funktion samt subjektiv patientnöjdhet samt livskvalitet.

I studie I jämfördes resultatet efter två operationsmetoder för kronisk AC-ledsluxation typ III-V, som användes under olika tidsperioder på kliniken. Den ena gruppen opererades med förflyttning av ett ledband enligt Weaver och Dunn med tillägg av en fläta av suturmaterial och den andra gruppen med samma förflyttning av ledband men med tillägg av en hookplatta. Det visade sig att skillnaderna mellan grupperna inte var signifikanta, förutom att patienterna som opererats med hookplatta hade mer kvarvarande smärta vid rörelse av axeln.

I studie II jämfördes utfallet efter operation av AC-ledsluxation typ V som opererats inom 3 veckor, akut, eller i sent skede, efter mer än 4 månader. Patienterna opererades med hookplatta, och för gruppen som opererats i sent skede även med ledbandsförflyttning enligt Weaver-Dunn. Patienterna som opererats akut hade bättre resultat i nästan alla parametrar utom i axelfunktions formuläret Constant score.

Studie III är en randomiserad kontrollerad studie av AC-ledsluxation typ III och typ V, som jämförde resultatet efter akut operation inom 3 veckor med hookplatta eller fysioterapi. Patienterna följdes regelbundet och utvärderades efter 2 år. Efter 3 månader var de opererade patienterna sämre i alla parametrar, men redan efter 6 månader hade skillnaderna jämnat ut sig. Vid 2 år fanns inga signifikanta skillnader i resultaten efter operation eller fysioterapi.

I studie IV testades tillförlitligheten av Rockwoods klassifikationssystem för AC-ledsluxationer typ III och V på vanlig röntgen och datortomografi, av ortopeder och radiologer. En ny enklare metod för att klassificera AC-ledsluxationer på röntgen testades också. Studien visade att datortomografi gjorde klassifikationen enligt Rockwood lite säkrare mellan bedömarna, men inte signifikant bättre. Den enkla klassifikationen gav den största överensstämmelsen vid upprepade bedömningar, signifikant bättre än bara röntgen, men inte signifikant bättre än röntgen och datortomografi i kombination.

ABSTRACT

Background: Acromioclavicular joint (AC joint) dislocation is a common injury among young sports-active people. The injuries are divided into types I–VI based on the Rockwood classification. The classification system has been validated in multiple studies, but the results have not been consistent. Currently, AC joint dislocations Rockwood types I and II are treated non-operatively, treatment of type III is started non-operatively, and types IV–VI are treated operatively. There is no gold standard regarding type of surgical procedure.

Aims*:* The aim of this thesis was to improve knowledge on AC joint dislocations, outcome of treatment, and reliability of radiological classification.

Materials and methods*:* Studies I and II were retrospective studies, evaluating the outcome after operative treatment for chronic AC joint dislocation Rockwood types III–V, and timing of operative treatment for Rockwood type V. Study III was an RCT, evaluating the outcome after non-operative and operative treatment for acute Rockwood type III and V dislocations. These clinical studies were based on clinical examinations, validated PROMs, radiologic evaluation and questions regarding subjective satisfaction with shoulder and cosmesis. Study IV evaluated the inter-observer and intra-observer reliability of Rockwood's classification in plain radiographs and plain radiographs in combination with computed tomography. A new simpler method for classification av AC joint injuries was evaluated.

Results: In Study I, patients operated with a modified Weaver-Dunn procedure augmented with PDS suture or with a hook plate had no significant differences in outcome, except for pain; the group with hook plate had more pain during movement. In Study II, patients with type V dislocation operated within the acute phase with a hook plate had significantly better outcome in almost all parameters than the group undergoing delayed treatment. In Study III, there were no significant differences in outcome after 2 years, between patients treated non-operatively and operatively, regardless of whether they had a type III or V dislocation. In Study IV the inter-observer and intra-observer reliability of the simple classification, when classifying Rockwood type III and V, was significantly better than the Rockwood classification using plain radiographs, but not significantly better than plain radiographs in combination with CT. Finally, the reliability of Rockwood classification using plain radiographs in combination with CT is significantly better than using plain radiographs alone.

Conclusions: A hook plate did not improve the results after operative treatment of chronic AC joint dislocation types III–V. If AC joint dislocation Rockwood type V was treated surgically, the results were better after acute surgery than after delayed surgery. Patients with acute Rockwood type III or V dislocations regained good shoulder function and subjective satisfaction with the result after 2 years, regardless of if they were treated non-operatively or operatively. Plain radiographs and CT in combination improved the reliability of the Rockwood classification type III and V, but the clinical relevance of this is unclear. The simple classification needs further investigation.

LIST OF SCIENTIFIC PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Surgical treatment of chronic acromioclavicular dislocations: a comparative study of Weaver-Dunn augmented with PDS-braid or hook plate. Boström Windhamre HA, von Heideken JP, Une-Larsson VE, Ekelund AL. J Shoulder Elbow Surg. 2010 Oct;19(7):1040-8. doi: 10.1016/j.jse.2010.02.006. Epub 2010 May 10. PMID: 20452245. HBW and JvH contributed equally to this work.

II. Acute surgical treatment of acromioclavicular dislocation type V with a hook plate: superiority to late reconstruction. von Heideken J, Boström Windhamre H, Une-Larsson V, Ekelund A. J Shoulder Elbow Surg. 2013 Jan;22(1):9-17. doi: 10.1016/j.jse.2012.03.003. Epub 2012 Apr 21. PMID: 22521386. HBW and JvH contributed equally to this work.

III. No difference in clinical outcome at two-year follow-up in patients with acromioclavicular joint dislocation type III and V treated with surgery or physiotherapy: a randomized controlled trial. Boström Windhamre H, von Heideken J, Une-Larsson V, Ekström W, Ekelund A. J Shoulder Elbow Surg. 2022 Jan 7:S1058-2746(22)00005-2. doi: 10.1016/j.jse.2021.12.003. Epub ahead of print. PMID: 35007749.

IV. Reliability of the Rockwood classification (inter-observer and intra-observer variation) for acute acromioclavicular joint dislocations type III and V. Boström Windhamre H, von Heideken J, Nordqvist A, Ekström W, Ekelund A. In manuscript.

CONTENTS

LIST OF ABBREVIATIONS

AC	Acromioclavicular
AP	Anteroposterior
CA	Coracoacromial
CC	Coracoclavicular
CI	Confidence interval
CS	Constant score
CT	Computed tomography
DASH	Disabilities of the arm, shoulder, and hand questionnaire
EQ-5D	European quality-of-life 5 dimensions
LOCF	Last observation carried forward
MRI	Magnetic resonance imaging
PDS	Polydioxanone suture
PROM	Patient-reported outcome measure
RCT	Randomized controlled trial
ROM	Range of motion
SLAP	Superior labrum anterior to posterior
SPADI	Shoulder pain and disability index
SSV	Subjective shoulder value
VAS	Visual analogue scale

1 INTRODUCTION

The acromioclavicular (AC) joint is well described in the literature, but gaps in our knowledge remain. There is no clear gold standard regarding classification, radiographic modality for diagnosis, and if treatment should be operative or non-operative, what type of surgical procedure to use and when to operate. Currently, there is not enough high-quality evidence to make recommendations on treatment, but there are promising results for non-operative treatment even for severe types of AC joint dislocation.

2 LITERATURE REVIEW

2.1 HISTORY

In early medicine, AC joint dislocations were treated non-operatively – this is mentioned already by Hippocrates in 400 B.C. After the discoveries of anesthesia and antiseptic surgery in the mid-1800s, various surgical procedures were described for AC joint dislocations in the early 1900s. Cadenat et al.[1] wrote in 1917 that Dr Samuel Cooper was to credit for the first operation of AC joint dislocation. In 1861, Dr Cooper sutured the lateral clavicle to the acromion with silver wire in three patients, and reported excellent outcomes. More surgical procedures evolved in the following years.[2]

2.2 ANATOMY AND BIOMECHANICS

The clavicle, which is shaped like an S, acts like a strut between the scapular bone and sternal bone. The joints, the sternoclavicular (SC) joint and acromioclavicular (AC) joint are both lined with cartilage. The SC joint is a saddle joint and the AC joint is a plane joint. The lateral end of the clavicle can be angled more or less toward the acromion more or less, usually around 20–30 degrees, but can also be nearly vertical or horizontal.[3]

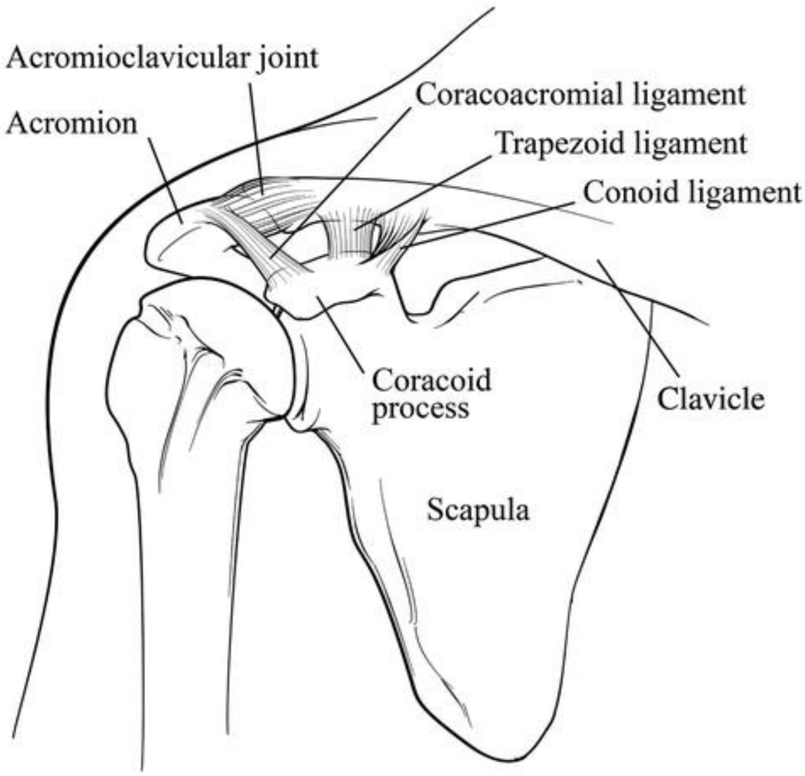


Figure 1. From: Beitzel K, Obopilwe E, Chowaniec DM, et al. Biomechanical Comparison of Arthroscopic Repairs for Acromioclavicular Joint Instability: Suture Button Systems Without Biological Augmentation. The American Journal of Sports Medicine. 2011;39(10):2218-2225. Reproduced with permission.

Between the acromion and clavicle, a fibrocartilage disk can be found in 30–80% of people.[4,5] Ligaments provide stability to the two joints (Figure 1 and 2). The AC joint consists of a capsule, which is reinforced by the AC ligaments. The AC ligaments are believed to control the antero-posterior and rotational movement of the AC joint, with the inferior parts of the capsule responsible for anterior stability and the posterior and superior parts of the capsule ensuring posterior stability.[6-13] Studies have shown that the conoid ligament also contributes to the anterior stability.[14] Attachments for the deltoid muscle, pectoralis major muscle, trapezius muscle and the coracoclavicular (CC) ligaments are found on the surface of the clavicle. The insertions of the deltoid and trapezoid muscles on the clavicle and acromion form the deltotrapezial fascia, which is believed to support the stability of the AC joint together with the superior AC ligaments.[15,16]

The CC ligaments consists of the trapezoid ligament and the conoid ligament, which are spread out like a fan. The trapezoid ligament is larger and is attached to the lateral 15–30 mm of the clavicle. The conoid ligament is attached to the conoid tubercle posterior and medial to the trapezoid ligament, 30–50 mm from the lateral end of the clavicle.[3]

The conoid ligament is mainly responsible for superior stability and the trapezoid ligament controls posterior stability together with parts of the AC ligaments.[10,11,13] The ligaments are considered to be a static reinforcement of the AC joint, while the muscles are a dynamic reinforcement. The different ligaments' contributions to the stability of the AC joint change with modification of the direction or load of the joint.[13] There is a medial coracoclavicular ligament, located medial to the CC ligaments between the clavicle and the coracoid process, which has more elastic properties than the other ligaments. It may act like a stabilizer of the CC interspace, but it is relatively unexplored compared with the other ligaments.[17]

Movement of the arm activates a complicated machinery with scapular movement along the thorax, movement of the arm in the glenohumeral joint, and the clavicle acting as a stable strut between the scapula and thorax.[18] The AC joint is a stiff joint in which the acromion can elevate and rotate 5–8 degrees.[19] The scapula is more mobile and moves by tilting anteriorly or posteriorly and rotating internally or externally and up or down.[20, 21] The scapula rotates around a midpoint in the AC joint, which is altered if the stabilizing ligaments are torn, this might result in scapular dyskinesis.[22,23] Scapular dyskinesis means dysfunctional movement of the scapula and results in pain and impaired shoulder function. Even low grades of AC joint dislocation can cause scapular dyskinesis since the tear of the AC and CC ligaments causes discontinuity in the chain of rotation around the midpoint.

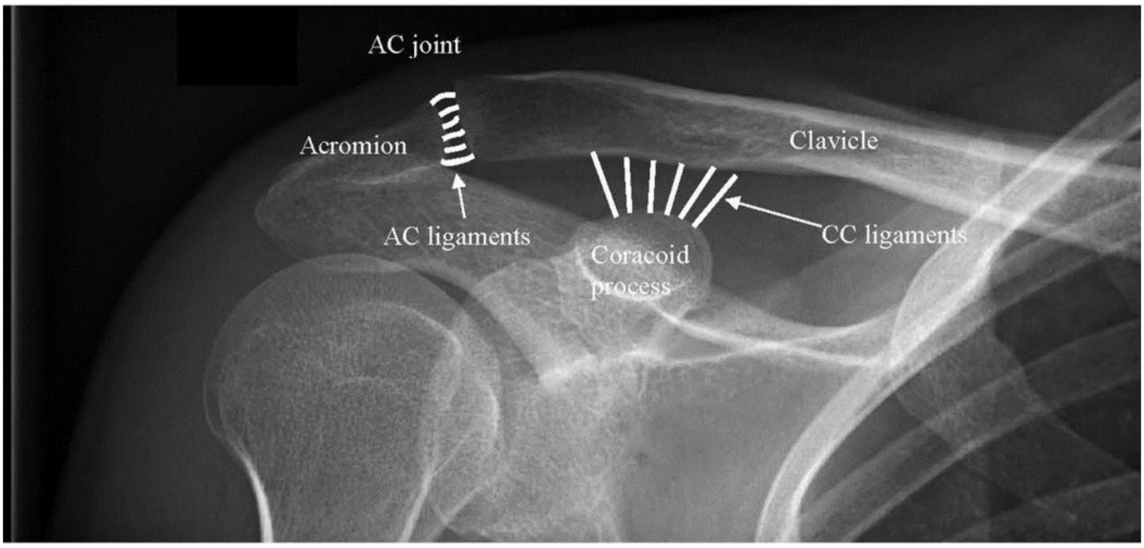


Figure 2. Antero-posterior radiograph of an uninjured AC joint, with simplified schematic drawing of the ligaments

2.3 EPIDEMIOLOGY

AC joint dislocations accounts for 9–11% of all shoulder injuries.[24-27] Injuries to the AC joint are often sports-related. Cycling, soccer, ice hockey, alpine sports, martial arts, but also traffic accidents and falls are common causes of dislocations in the AC joint.[28] Recent publications reports sports-related injuries in 42–54%.[27,29-31] The mechanism of injury can be direct or indirect. A direct injury can be described as a force/hit/blow/punch to the acromion and forces the scapula caudally, meaning that the ligaments and muscles attached to the clavicle are stretched or torn. The indirect mechanism has been described as being caused by a fall on the arm, hand or elbow that forces the caput humeri cranially, thereby tearing the AC or CC ligaments.[2]

The incidence of AC joint dislocations of any type, is approximately 19/100,000 for the adult population.[26] Similar results were found in recent studies from Sweden[31] (2.0/10,000) and Italy[29] (1.8/10,000). Male to female ratios have been reported to lie between 5:1 and 18:1.[25,26,29,32]

AC joint dislocation Rockwood types I–III are the most common, at 36%, 23% and 39%, respectively. Type IV is seen in < 1%, type V in approximately 1% and type VI in < 0.1%.[33]There are only a few publications in the literature describing case reports of type VI.[34-38]

2.4 CLASSIFICATION SYSTEMS

In 1963, Tossy[39] described three grades of acromioclavicular separations:

> “Grade 1: Strain, contusion. Pain and tenderness of the joint. No deformity apparent exteriorly or on radiographs.

Grade 2: Pain, tenderness and swollen joint. The lateral end of the clavicle can be prominent. On radiographs, the clavicle is dislocated to half a joint depth and the CC distance is increased compared with in a non-injured AC joint.

Grade 3: Severe pain. Apparent deformity of the lateral end of the clavicle. Radiographs show a dislocation greater than half a joint depth and a wide separation of the CC."

Allman[40] divided the acromioclavicular sprains into three grades in 1967:

"Grade 1: Mild trauma to the AC joint resulting in a sprain, little pain and tenderness. Radiographs show no dislocation.

Grade 2: Subluxation after more moderate trauma, with pain, tenderness and laxity. Radiographs show clavicle less than a clavicle width cranially to the acromion. Radiographs with 10 kg are recommended.

Grade 3: After severe trauma, both acromioclavicular and coracoclavicular ligaments are ruptured, resulting in a dislocation visible both exteriorly and on radiographs. The lateral end of the clavicle is cranially dislocated above the superior cortex of the acromion and completely loose."

In 1984, Rockwood added type VI and divided Tossy grade 3/Allman grade III into types III, IV and V.[2] The Rockwood classification is now the most commonly used classification of AC joint dislocations.

"Type I: AC and CC ligaments are intact. Deltoid and trapezius muscles are intact.

Type II: AC ligaments are torn, but CC ligaments are intact. Deltoid and trapezius muscles are intact.

Type III: AC and CC ligaments are torn. CC distance is 25–100% greater than on the contralateral uninjured side. Deltoid and trapezius muscles are usually detached from the lateral clavicle.

Type IV: AC and CC ligaments are torn and the clavicle is dislocated posteriorly into or even through the trapezius muscle. CC distance can be normal or not. Deltoid and trapezius muscles are usually detached from the lateral clavicle.

Type V: A more severe type III. AC and CC ligaments are torn and the clavicle is grossly displaced. The CC distance is 100–300% greater than on the contralateral uninjured side. Deltoid and trapezius muscles are detached from the clavicle.

Type VI: AC and CC ligaments are torn, and the clavicle is dislocated below the coracoid process or the acromion. CC distance can be less than on the contralateral uninjured side."

Table I. Summary based on Rockwood’s classification of AC joint injuries from Fractures in Adults.[2]

Type	AC ligaments	CC ligaments	Deltotrapezial fascia	Increase of CC distance
I	Partial disruption	Intact	Intact	Normal
II	Disrupted	Partial disruption	Intact	< 25%
III	Disrupted	Disrupted	Disrupted	25–100%
IV	Disrupted	Disrupted	Disrupted	May appear normal or increased
V	Disrupted	Disrupted	Disrupted	100–300%
VI	Disrupted	Disrupted	Disrupted	Decreased

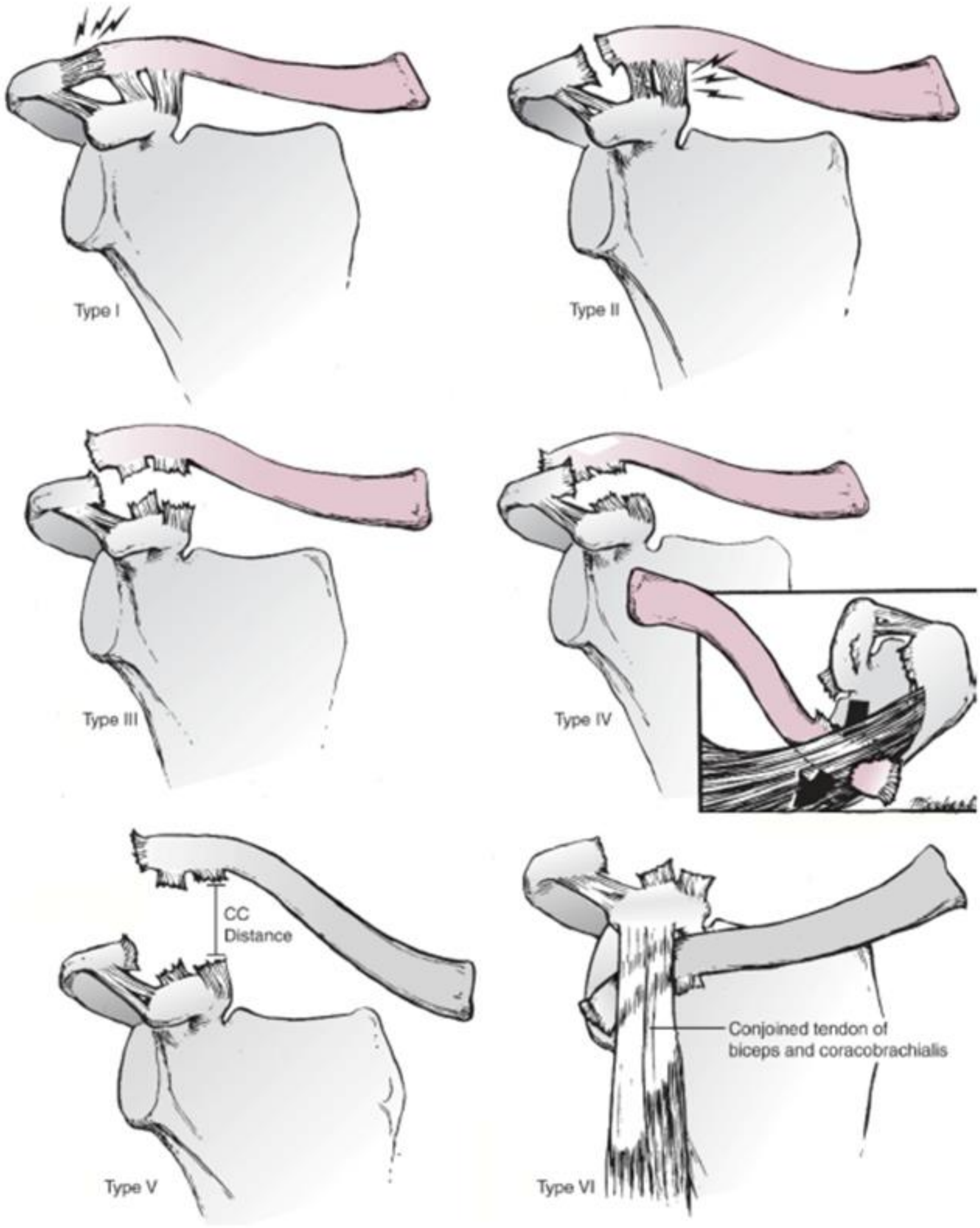


Figure 3. From: Rockwood and Greenes Fractures in Adults 7th ed, with permission from Wolters Kluwer Health, Inc.

In 2013, the ISAKOS Upper Extremity Committee[41] suggested an addition to the Rockwood classification by dividing type III into stable type IIIA and unstable type IIIB. Unstable type IIIB injuries will result in worse functional outcome and more pain. A re-evaluation was suggested at 3–6 weeks to 3 months after the acute injury and patients with persistent pain should be re-examined with a radiographic Alexander view to identify type IIIB.

Recent trials have concluded that posterior instability might be the reason why some patients with type III dislocation are not satisfied with their treatment.[42-46]

Already in 2010, dynamic radiologic evaluation of acute AC joint dislocations was suggested, with the arm in different positions to find anteroposterior (AP) instabilities which would otherwise be missed. The measurements were made in axillary radiographs by Tauber et al.[47] It was later shown that axillary views are sensitive to changes in position of the shoulder and radiographic beams, meaning that a normal AC joint might look dislocated on axillary views.[48]

Several authors have published studies evaluating inter-observer and intra-observer reliability of the Rockwood classification. Results vary from poor or fair[49-51] to moderately good[52-54] or good to excellent.[55,56]

Ng et al. found the lowest inter-observer and intra-observer agreements for classification based on to Rockwood on plain radiographs, with k κ appa 0.258 and 0.150, respectively.[50]

Schneider et al. investigated which classification method was the most reliable, and found that measured CC distance and CC index was more reliable than visual diagnosis of AC joint dislocation based on Rockwood. Both inter-observer and intra-observer reliability showed good to excellent correlation.[56]

Gastaud et al. found good to excellent inter-observer agreement and good intra-observer reproducibility for measured CC distance, while the measurements on the lateral view were good to moderate. When measuring the gleno-acromio-calvicular angle, the inter-observer and intra-observer reproducibility were only poor to fair. The authors concluded that posterior dislocation was difficult to assess on standard lateral axillary views and that dynamic instability could not be evaluated reliably.[52]

Lau et al. evaluated at the reliability of Rockwood classification types III and V, using plain radiographs from 55 patients and 6 observers. They found an inter-observer κ of 0.694 and an intra-observer κ of 0.696. The authors also concluded that standardized radiographs was absolutely necessary.[55]

Pifer et al. investigated the inter-observer reliability of Rockwood classification in different medical departments, and found that orthopedic surgeons displayed the highest inter-observer reliability (κ = 0.515) compared with radiologists (κ = 0.363) and doctors in emergency medicine (κ = 0.189).[54]

In a study by Ringenberg et al., the authors found an intra-observer agreement of kappa 0.468 and an inter-observer agreement of kappa 0.278. Unfortunately, only unilateral x-rays were provided.[51]

There have been several attempts to introduce new classification systems, but Rockwood is still the most commonly used classification for AC joint dislocations worldwide.[57] In 2014, Vaisman et al.[43] proposed the use of a new index to assess posterior dislocation, the AC width index, using Zanca views and axillary radiographs. In 2018, Zumstein et al.[58] evaluated five new radiologic measurements on radiographs for judgment of AC joint dislocations, especially Rockwood typed II and III. The authors found excellent reliability and validity for two of the measures, and proposed the use of the acromial center line to dorsal clavicle for vertical alignment and the glenoid center line to posterior clavicle for the horizontal alignment using lateral Alexander view radiographs. It was later found that these measurements were overly complicated.[59]

The circle measurement was introduced in 2021 by Murphy et al.[59] as a new way of assessing the total AC joint displacement in any plane on a lateral Alexander view. This was achieved by drawing a circle at the lateral end of the clavicle and another at the medial end of acromion and measuring the distance between the centers of these circles. The authors also suggested a new classification system based on these measurements: the ABC classification. Type A is to a minimally displaced, stable dislocation (Rockwood types I–IIIA), with a maximum of 7 mm distance between the circles. Type B, with 7–14 mm distance between the circles, corresponded to Rockwood type IIIB and type C was a severely dislocated injury, like Rockwood types IV–VI.

2.5 DIAGNOSIS

2.5.1 Clinical examination

A clinical examination involves visual inspection for asymmetry between the shoulders, hematomas, swelling around the AC joint and studying the position of the scapulae. The clinician should palpate the AC joint to locate tenderness, as well as the AC and CC ligaments and the trapezius and deltopectoral muscle attachments. Further, examination should include testing the ROM of the active and passive shoulder and of the stability of the AC joint in the anterior-posterior (antero-posterior drawer test) and cranio-caudal directions (inferior-superior motion test), including a cross-body test[41] (Figure 4). The injured side is compared with the contralateral uninjured side. Scapular motion and the glenohumeral joint should also be evaluated, since associated injuries might arise.

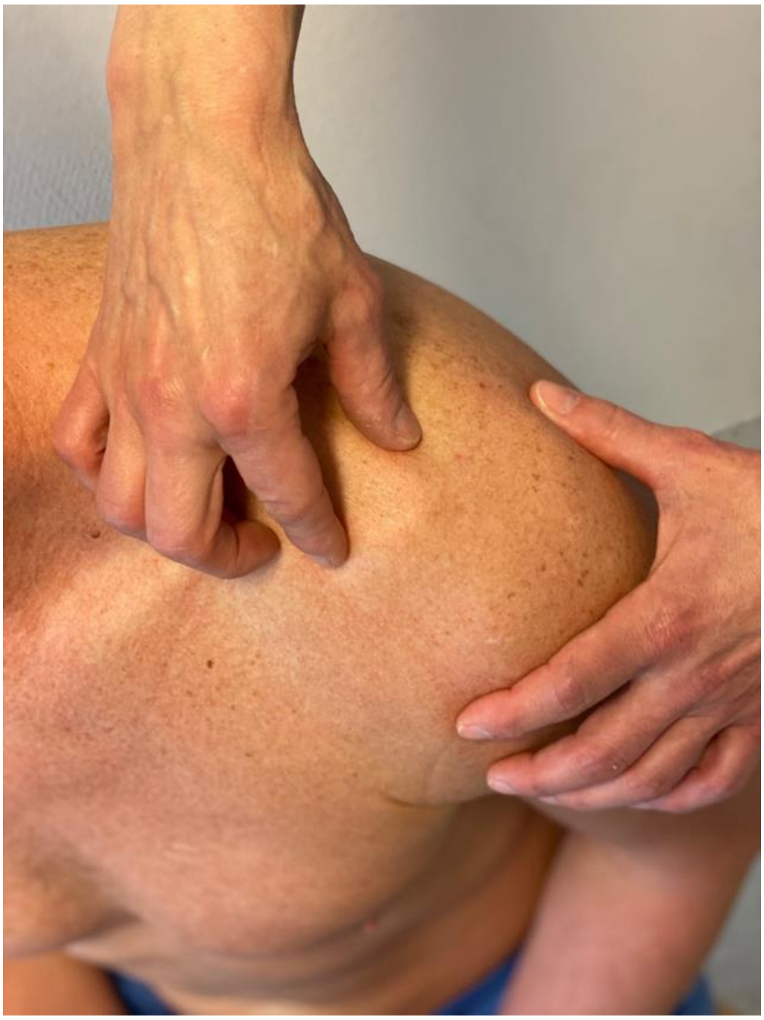


Figure 4. Examining clinical stability of the AC joint, antero-posterior drawer test. Photo with permission from the model.

2.5.2 Radiologic evaluation

Rockwood based his classification on plain radiographs and recommended an AP view in the plane of thorax, with 10–15-degree cephalic tilt to capture the clavicle off scapulae and an axillary view or a scapular lateral Alexander view, with reduced voltage for AC joint injuries.[2,60] Evaluation of the AC joints should include AP, lateral and axillar views of the shoulder and bilateral Zanca.[41] Studies have shown that axillary radiographs are not reliable for evaluation of posterior dislocation in the AC joint. The axillary view is sensitive to different angles and arm positions, and a normal AC joint can appear like an AC joint dislocation.[47,48,52] The standard axillary view have been shown to mimic posterior subluxation.[48]

The Alexander view is a lateral view with the patient holding the arm across the thorax to get a view with the scapula parallel to the body and away from the ribs, to assess horizontal instabilty.[61] Modified Alexander views, with the arm in a cross-body position, have been used to evaluate dynamic posterior translation of the clavicle.[42]

Bilateral radiographs are necessary to evaluate malalignment by comparing the injured AC joint with the contralateral uninjured side.[33, 62]

According to Rockwood, bilateral stress x-rays should be performed if necessary to separate type II from III. Patients would be standing with 10–15 pounds (4.5–7 kg) hanging in a band around the wrist.[2] In the last decade, there has been a debate on the usefulness of weighted or stressed radiographs. Bossart et al.[63] found little use for weighted radiographs since only 4% of the patients (3 out of 84) were diagnosed with a more severe injury than when using the plain radiographs without weights. In 2015, Ibrahim et al.[62] concluded that bilateral weighted comparative radiographs were necessary for correct classification of AC joint dislocation, since patients can have different positions of the clavicle in the AC joint. The articular surface of the clavicle may be over- or under-riding relative to the acromial surface of the acromion.[62] A recent prospective Swedish study found no support for weighted radiographs since no significant changes in Rockwood classification were made after weighted radiographs.[64]

A consensus process among members of the European Shoulder Associates within the European Society for Sports Traumatology, Knee Surgery and Arthroscopy, published 2021, showed that approximately 80% used radiographs without weights and the majority used the Rockwood classification.[57]

2.5.3 Other radiographic modalities

There is currently no gold standard for which radiographic modality to use when classifying AC joint injuries.

Computed tomography (CT) is the first choice when evaluating bone, fractures, multiple planes, 3D positions, angles and dislocations but is of limited use for soft tissue evaluation.[65] Patients are examined in the supine position, meaning that the ligaments supporting stability in the AC joint are not affected by the weight of the arm. Cho et al. have shown that CT does not add accuracy to the classification of AC joint dislocation.[49]

Magnetic resonance imaging (MRI) reveals details in soft tissue and injuries in the ligaments by detecting amounts of fluid, discontinuity in fibers, and edema in the bone marrow.[66] A comparison of the classification into Rockwood types I–VI from MRI with that from radiographs showed that MRI led to the same classification in 52% of cases, a more severe type in 11% and a less severe type in 36%.[60] The fact that the MRI is performed in the supine position also affects the position of scapula and the CC distance.

Ultrasound can be used to evaluate the superficial parts of the AC joint, i.e., the superior ligaments only, but the procedure is available at a low cost and involves no radiation.[65] It can also be used to assess the horizontal instability of the AC joint, and might be used to differentiate Rockwood types I–III.[67]

2.6 TREATMENT

Today, the rationale for treatment is based on low-quality evidence, expert opinions and clinical experience. There are few RCTs comparing surgical and non-operative treatment. The treatment decision is based on the degree of dislocation, and patient factors such as type of work, sports activities and age. The aim is to regain full ROM, strength and return to previous activity level.

2.6.1 Types I and II

In the literature, acute dislocations of Rockwood types I and II are almost always recommended to be treated non-operatively, with a short period of rest (7–14 days) with the arm in a sling or arm support,[2, 32, 41, 68-71] and physiotherapy when the pain subsides. Patients can expect to improve and regain ROM and strength, but may be less satisfied with the cosmetic appearance of the shoulder. Reports show that patients may experience discomfort, pain or laxity at mid-term or long-term follow-up, but more than 50% of non-operatively treated patients report good or excellent shoulder function.[69,72]

If pain persists in the chronic phase, especially if posttraumatic arthritic changes are evident on x-ray, a distal clavicle resection – the Mumford procedure – can be performed in the late phase.[73,74] Resection of the lateral clavicle using the Mumford procedure, needs to be performed with caution since new evidence shows that the horizontal stability is violated with a resection of 10 mm, even if the superior and inferior parts of the AC ligaments are intact.[75]

2.6.2 Type III

In the last decades, there has been an ongoing discussion regarding the treatment of Rockwood type III dislocations. There is evidence to start the acute treatment non-operatively, since results from RCTs have shown that non-operative treatment is equal or superior to surgical treatment.[76-81] It allows earlier return to work and sports activities and a good long-term outcome.[78,82,83] Patients can expect to regain ROM and strength[84,85] after non-operative treatment, and a large proportion of patients (80–94%)[86-88] are satisfied. After a period of rest and physiotherapy during 3–6 months, surgery is considered if pain and impaired function persist.[76,78, 82 83 89-94]

However, 17–28% of patients treated non-operatively experience disability.[95] There are reports describing persistent pain, weakness, fatigue, scapular dyskinesia, poor cosmetic appearance and problems carrying heavy loads and working above the shoulder level.[76,86 87] In a meta-analysis from 1998, Phillips et al. described the satisfaction after surgery and non-surgical treatment of AC joint dislocations types III–V. They found that 88% of the surgically treated patients and 87% of the non-operatively treated patients had a satisfactory outcome in regards of ROM, strength, pain – and that non-operatively treated patients returned to work quicker. Tang et al. found non-operative treatment to be superior to operative treatment for acute Rockwood type III dislocation in a recent meta-analysis from 2018.[96]

Surgical treatment of Rockwood type III injuries in the acute phase was recommended in one study only, reporting better Constant score (CS) for the 24 patients treated with hook plate compared with the 17 patients treated non-operatively.[97] Initial surgical treatment can be considered for younger patients with special demands, like overhead athletes or heavy laborers who perform work above the head, but there is still insufficient evidence to support this.[98]

2.6.3 Types IV–VI

There is a general consensus in the literature to treat Rockwood types IV–VI with surgery,[2,32,68,98-103] but the evidence supporting this recommendation is weak. A Cochrane report from 2019 showed low-quality evidence that surgery had no better outcome than non-operative treatment.[104] There have been only few RCTs comparing surgical with non-operative treatment.[76-81] The Canadian Orthopedic Trauma Society performed a RCT comparing non-operative treatment with hook plate for patients with type III, IV or V dislocations and found no differences in outcome, though the results were not presented separately for the different types of included AC joint dislocations.[79]

Dislocations of type IV are more difficult to diagnose since the visible dislocation is not always obvious in plain radiographs. Type IV can cause a lot of pain because of the posterior position and instability of the clavicle with possible impingement into the acromion, whether static or dynamic.[42,105] The lateral end of the clavicle might be dislocated through the trapezoid muscle. There is evidence that horizontal instability, with different grades of superior dislocation, can result in inferior outcomes.[42,47,106] Type IV is rare, and results in literature are often reported together with type III or type V. There are 2 RCTs including Rockwood IV, but none has reported the results separately.[79,81]

As regards dislocations of type V, there is only low-quality evidence for treatment, though small, non-RCT studies report good functional results after surgery.[106-109] Others fail to show superiority of one method over another.[80,110] Authors studying non-operative treatment have found that patients with type V dislocations have limited functional outcomes.[111] The RCTs comparing operative to non-operative treatment have not analyzed the different types of included Rockwood types separately, which makes it hard to draw conclusions on purely type V.[76,78,79] One RCT with long-term follow-up comparing operatively treated Rockwood type III and V dislocations with non-operative treatment, analyzed the results separately. Unfortunately, the groups are small, and includes only five patients with type V treated non-operatively.[80]

Type VI is a very rare type of dislocation, with only 13 known cases, reported in the literature and in case reports.[34-38] There is no room for non-operative treatment, since the clavicle is severely displaced inferior to the coracoid process or the acromion, and might harm the blood vessels and/or nerves in the vicinity.

2.6.4 Timing – treatment in the acute or chronic phase

AC joint dislocations of types III, IV, V and VI can be treated in the acute or chronic phase, but the treatment options vary. The definition of an acute injury is three weeks, and an injury is chronic after six weeks.[57,112-116]

In acute cases of AC joint dislocation, when the ligaments are recently torn, surgeons can rely on the biological healing potential of the ligaments, but in chronic cases surgeons have to add biological substitution, a tendon graft or a synthetic graft with biocompatible properties that allows ingrowth of soft tissue. Reducing the AC joint can also be a problem in the late phase, with torn ligaments hard to find and repair. Several studies comparing early and late treatment of AC joint dislocation types III, IV and V have concluded that early treatment yields better functional outcomes.[117,118]

However, other studies show no statistical differences in functional outcome when treating AC joint dislocations types III, IV and V in the acute versus the chronic phase.[116,119-122] In a recent systematic review, there is no significant difference in complication rates between early or delayed surgery.[123] Not all patients need surgery, especially those with type III dislocations, and there are more complications associated with surgery than with non-operative treatment.

2.7 OPERATIVE TREATMENT – SURGICAL TECHNIQUES

Currently, there is no gold standard on what kind of surgical procedure to choose.[107] There are more than 160 different surgical procedures described to treat AC joint dislocations, but a relatively large proportion of these can probably be considered out of date.[68]

Complications vary between the different techniques. The pooled overall complication rate was calculated to be 14.2% in a recent meta-analysis, and the most common complications are infection in 6.3%, fractures of the clavicle or the coracoid process in 5.7% and, hardware failure in 4.2%.[124] There were no significant difference in the prevalence of post-treatment osteoarthritis between surgical and non-operative treatment.[96]

Phemister

Two-threaded Kirschner wires temporarily transfix the AC joint, entering from the lateral acromion for acute cases. This technique can be used with CC ligament reconstruction, coracoclavicular fixation with sutures, or alone. The K wires are removed after healing of the ligaments. This older technique has a high rate of severe complications, including pin migration into the thorax or the spinal canal.[125-127]

Hook plate

The hook plate, introduced in 1976, can be used to treat acute AC joint dislocation or lateral clavicle fractures. The hook plate is a common procedure with a great advantage in the uncomplicated surgical technique. The hook is placed beneath the acromion with the tip pointing posteriorly, and the plate on the superior surface of the clavicle, secured with cortical or angle stable screws (Figure 5). The hook does not penetrate the AC joint and thus does not damage the cartilage of the joint.[128] The hook temporarily prevents the acromion from tipping backwards, decreasing internal rotation, but increasing anterior translation of the clavicle. The shoulder function improves again after extirpation of the hook plate, which is mandatory and can be considered a major disadvantage with this technique.[129-131] The hook plate has been associated with a high proportion of complications 12–40%,[79,132,133] including stiffness of the shoulder in 40%,[133] impingement in 38% or rotator cuff injuries in 15%,[134] subacromial erosion in 19-38%[99,135] and fractures of the acromion in 8%.[133]

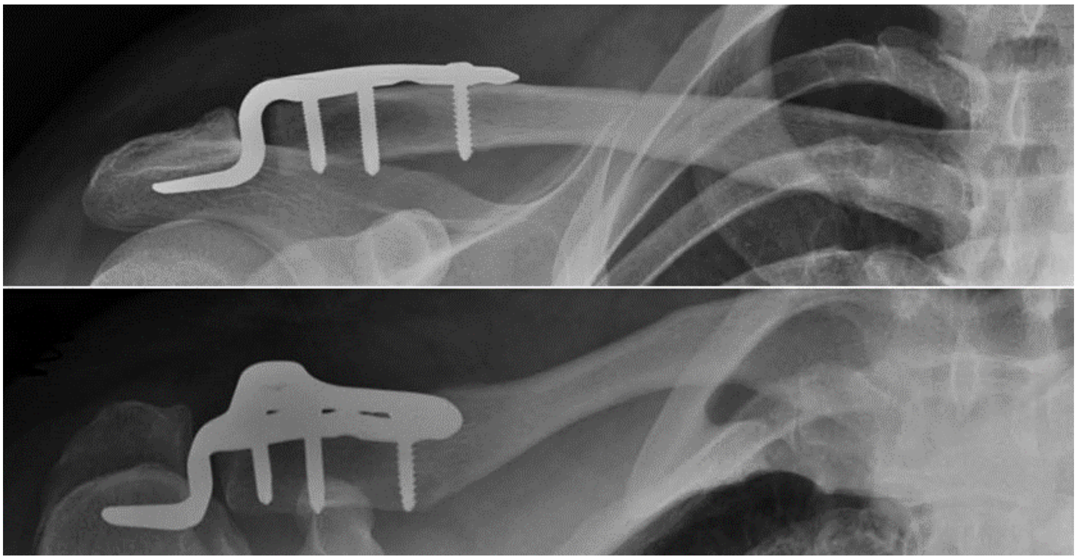


Figure 5. Radiographs consisting of two antero-posterior images, including one with 35–40° of caudal tilt of beams to assess the position of the hook plate and screws

Bosworth screw

This method involves fixation of the CC interval with a semi-threaded cortical screw through the clavicle and into the coracoid process, for acute cases. The method has a bad reputation due to the risk of misplacement of the screw, screw pull-out, hardware failure, re-dislocation and disturbing prominence of the screw head.[136-138]

Weaver-Dunn non-anatomic transfer of the coracoacromial ligament

In 1972, Weaver and Dunn described their method of lateral clavicle resection and transfer of the CA ligament to the clavicle.[139] For a long time, this was the standard procedure for treating AC joint dislocations. Several research groups have modified the original technique to avoid re-dislocation, which is the most common complication, since the transferred ligament is weaker than the ligament it is supposed to replace, the coracoclavicular ligament. Modifications of the Weaver-Dunn technique include detaching the CA ligament from the acromion with a small piece of bone, and transferring it into the opened medullary canal of the clavicle, for more predictable healing.[140,141] Another modification is adding a non-absorbable suture cerclage around the coracoid process and through drill holes in the clavicle,[116] Kirschner wires temporarily fixating the AC joint, or a Bosworth screw.[142]Reports have shown an almost 30% failure rate for chronic cases of AC joint dislocation.[116]

Synthetic ligaments - reinforcement

There are different types of a synthetic ligaments. Implants using fibers of polyethylene terephthalate, which have good biocompatibility, allows ingrowth of fibroblasts during time. Studies show that biopsies taken from the synthetic ligament have complete cellular and connective tissue ingrowth.[143] The synthetic ligament is placed under the coracoid process and secured through two drill holes with interference screws in the clavicle during reduction of the dislocation and can be used in acute or chronic cases. Other brands consist of polyester mesh with loops in each end, which are attached to the clavicle with a screw. Complications include redislocation, subluxation and clavicle fractures[112, 144]

Adjustable-loop length suspensory fixation devices (open or arthroscopic)

The adjustable-loop length suspensory fixation device is an implant system with two buttons and a loop made of strong non-absorbable suture. This implant is made to be delivered through drilled holes in the coracoid process and the clavicle, respectively. The surgery can be performed open, arthroscopic, or arthroscopically assisted. The buttons have different forms depending on brand, and can be used alone or in pairs, placed in parallel or anatomically, like the CC ligaments. There are implants with two clavicle buttons, two loops of suture, but only one coracoid button, or implants which has multiple sutures or suture tapes. There are implants where the suture is passed through the bone tunnels first, and then the coracoid button can be attached, which allows the button to be larger. There are adjustable-loop length suspensory fixation devices to be used together with a tendon graft for chronic AC joint dislocations.[46,106,107,145,146] There is currently a lot of ongoing research regarding these implants.

Sutures only

For acute repair of AC joint dislocations, double sutures are passed around the coracoid process and through one or two holes drilled in the clavicle, sometimes augmented with a separate suture over the AC joint, without any hardware.[109,147-149] Failures include a high re-dislocation rate[150]

Free tendon grafts

Chronic unstable AC joint dislocations are treated with tendon grafts wrapped around the coracoid process and through a one or two holes drilled in the clavicle stabilizing the joint.[140] Biological substitution is needed when the ligament injury is considered chronic and the healing potential has diminished. Grafts can be either autologous tendons, from semitendinosus, gracilis, palmaris longus or tibialis anterior, or from a donor. Loss of reduction and clavicle fractures are common complications, of the relatively large holes drilled in the clavicle to fit a tendon graft.[124,151]

Open versus arthroscopic techniques

Since 2001, when Wolf et al. described the first arthroscopic operation using a PDS loop passed around the coracoid process, the popularity of this technique has increased greatly.[152] We have had 20 years of arthroscopic procedures for the repair of the AC joint, but an open procedure still remains more common.[153] The approach to the AC joint has never been the problem, but an arthroscopic procedure can give information about concomitant injuries. A recent meta-analysis from 2021 investigating acute AC joint dislocations of Rockwood types III–V reported associated intraarticular injuries in 20% of cases.[154] The most common injuries were Superior Labrum Anterior to Posterior (SLAP) injury/biceps lesions, cuff lesions, labral lesions and chondral lesions and the least common were rotator interval lesions.[154] A systematic review and meta-analysis from 2018, showed no differences between arthroscopic or open surgical techniques as regards complications, reoperations or loss of reduction.[124]

Revision of failed primary fixations/chronic AC joint dislocation

Modern techniques aim to combine stabilization of the AC capsule and the CC ligaments, and for chronic cases or failed primary surgery, authors suggesting a free tendon graft for reconstructing the CC as well as the AC ligaments.[8]

2.8 NON-OPERATIVE TREATMENT

The term conservative can be used for supervised, regular rehab training with a physiotherapist, but also un-supervised training, or just skillful neglect.

The protocols for non-operative treatment are seldom described in detail in studies evaluating non-operative treatment of AC joint injuries, which makes it more difficult to evaluate treatment, replicate studies, and translate research into clinical practice.

In the literature, patients are advised to use a sling for 2–4 weeks, cryotherapy if needed, and early progressive ROM exercises, both active and passive. After 6 weeks, patients are advised to start with strengthening exercises for the rotator cuff, pectoralis major, deltoid and latissimus dorsi muscles, scapular control and loading of the arm.[79,81,89]

2.9 EVALUATION OF OUTCOME

Outcomes after treatment of orthopedic injuries and disorders can be measured in different ways: radiological examinations, ROM studies, strength measures, complications, and the patients’ subjective satisfaction. Patient-reported outcome measures (PROMs) are standardized, validated tools to evaluate health status or health-related qualities of life. Orthopedic PROMs can quantify patient outcomes after orthopedic treatment based on the patients’ objective and subjective function. There are more than 100 different PROMs for assessment of shoulder symptoms and shoulder function.[155]

Constant score

Introduced in 1987, CS[156] is one of the most widely used methods of evaluating shoulder function regardless of diagnosis.[155] CS is graded 0–100, where 100 is best possible score. It consists of four parameters: pain (0–15 points), activity level (0–20 points), ROM (0–40 points) and strength (0–25 points).

Pain during normal daily activities is evaluated on a visual analogue scale (VAS) 0–15 points in accordance with the original publication and registered as no pain = 15 points, mild pain = 10 points, moderate pain = 5 points and severe pain = 0 points. Activity level is calculated as the sum of night sleep 0–2 points, limitations during work 0–4 points, limitations during recreation 0–4 points and positioning of the hand for tasks, from below the waist up to above the head 0–10 points. ROM consists of 10 points each for full active elevation, lateral elevation (abduction), internal rotation and external elevation measured with a hand-held goniometer. Strength is measured with the arm at 90 degrees of elevation (in the plane of the scapula) with the hand in pronation. Patients are asked to bear the last week in mind when answering the subjective questions.

In Studies I-III, a dynamometer (Iso-Bex® Medical Device Solutions, Oberburg, Switzerland) was used, with the patient sitting (Figures 6 and 7). Patients were asked to hold resisted elevation for 3 seconds and this was repeated three times. If patients experienced pain during the test of strength, 0 points were recorded. The minimal clinical important difference for CS has been reported to be 10 points for rotator cuff surgery and 17 points for AC joint dislocations.[157,158]

Figure 6. Measuring strength with Iso-Bex® Figure 7. Iso-Bex® dynamometer

Subjective shoulder value

The subjective shoulder value (SSV) is the patient's subjective assessment of their shoulder as a percentage of normal, which would be 100%. This simple, easily administered score have been found to have a moderately strong correlation with the relative CS, adjusted for age and gender.[159]

QuickDASH

This is an abbreviated version of the Disabilities of the Arm, Shoulder, and Hand score, which is used for self-assessment of symptoms and function of the upper extremities.[160,161] The shortened version includes eleven questions regarding physical function and symptoms when performing daily activities, and the recall period is one week. QuickDASH is scored 0–100, with 0 being the best possible result. The score is calculated as the sum of the score for each answer (1–5) divided by the number of answered questions, subtracting one, and multiplying by 25.

Shoulder Pain and Disability Index

The Should Pain and Disability Index (SPADI)[162] is a self- administered questionnaire consisting of 13 items on two sub-scales: five questions regarding pain and eight regarding disability. The mean values of both sub-scales are averaged, yielding a score from 0–100, where 0 is the best possible result. Patients are asked to estimate the pain and disability during the preceding week.

Estimating pain using visual analogue scale

To estimate the subjective experience of pain, a VAS graded 0–10 or 0–100 was used, and patients were given information that 0 meant "no pain," and the maximum of the scale (10 or 100) meant "the worst imaginable pain".[163,164] Patients were asked to estimate their pain level at rest and during daily activities.

Quality of Life 5 dimensions

The most used questionnaire to measure health-related quality of life is the EQ-5D, which evaluates five dimensions of health status: mobility, self-care, usual activities, pain and anxiety/depression, which are converted into an index (ranging between -0.594 and 1). Patients are also asked to evaluate their state of health using a VAS graded 0–100 (EQ VAS). EQ-5D is not disease-specific and can be used in a wide range of conditions and areas.[165,166]

Radiographs

For evaluation of the AC joint dislocation, measurements are made at standardized AP views, with or without weight, and an axial and subscapular view of both the injured and the uninjured AC joint. The CC distance, the closest distance between the superior cortex of the coracoid process and the inferior cortex of the clavicle, perpendicularly, was measured bilaterally on all AP views (Figure 8).

Figure 8. Antero-posterior radiograph of an AC joint with AC joint dislocation on the left side. CC-distance is marked by white arrows.

Dislocation of the lateral end of the clavicle in the AC joint was assessed. Total dislocation was defined as the inferior cortex of the clavicle located above or on the same level as the superior cortex of the acromion (Figure 9). Subluxation was defined as the inferior cortex of the clavicle below the superior cortex of the acromion.

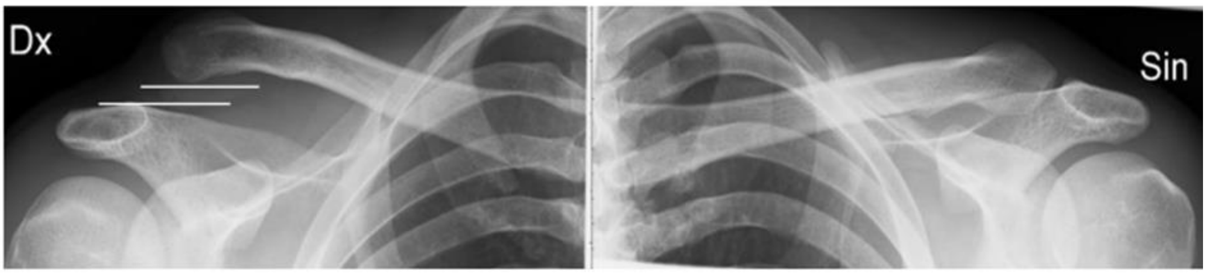


Figure 9. Antero-posterior radiograph of an AC joint with AC joint dislocation on right side. Dislocation in the AC joint is marked by white lines.

A CT scan of both shoulder and AC joint, the upper part of thorax, was performed with the patient in the supine position. The measurements on CT were performed on the frontal sections, using the image where the most superior part of the coracoid process was identified (Figure 10).

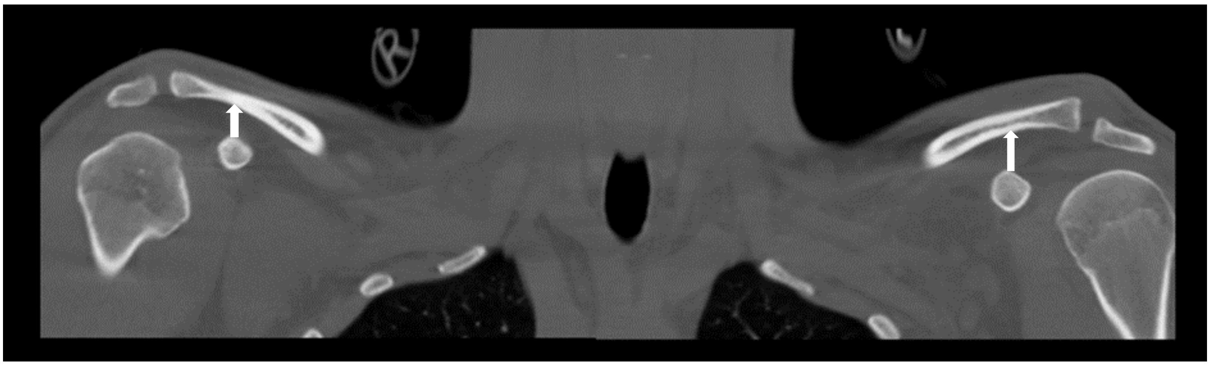


Figure 10. Antero-posterior CT scan of the upper part of thorax with AC joint dislocation on right side. CC-distance is marked by white arrows.

Cosmesis

Evaluation of cosmesis by asking patients questions regarding the subjective patient satisfaction with the appearance of their shoulders and/or scar. This can be a dichotomous yes-no question, or by using a VAS 0-100, or 0-10.

Complications

A complication was defined as an unfavorable outcome after treatment and unfavorable events affecting outcome, healing or recovery time were recorded.[167]

3 RESEARCH AIMS

The overall aim of this thesis was to improve knowledge of AC joint dislocations, outcome of treatment and reliability of radiologic classification.

Study I

The specific aim of this study was to evaluate the outcome after surgical treatment of chronic AC joint dislocation (types III–V) with the Weaver-Dunn procedure augmented with a hook plate or a braided PDS loop around the coracoid process.

Study II

The aim of this study was to compare the outcome after early or delayed surgical treatment of AC joint dislocation type V.

Study III

The aim of this prospective randomized controlled trial (RCT) was to compare the outcomes after operative treatment with hook plate with those after non-operative treatment in acute AC joint dislocation Rockwood type III or V, separately.

Study IV

The aim of Study IV was to investigate the inter-observer and intra-observer reliability when classifying AC joint dislocations of Rockwood types III and V using plain radiographs or radiographs and CT scans in combination. The study also aimed to determine if a more simplified classification regarding vertical instability on plain radiographs could be used.

4 MATERIALS AND METHODS

4.1 STUDY DESIGN

Studies I and II were designed as retrospective case control studies. A retrospective study compares a treatment or exposure that took place before the study began. Disadvantages with retrospective studies include selection bias and information bias; since the included participants are not randomized. Data might be missing since the exposure, and there might be recall bias, since time passes since the exposure. There are no predetermined protocols and no calculation of power. Case control studies can suffer from certain flaws, such as selection bias, information bias and confounding. The results of case control studies might lack external validity, if the results are cannot easily be applied in other populations.

Study III was designed as a RCT comparing surgical treatment with a hook plate to non-surgical treatment with physiotherapy only, in patients with acute AC joint dislocation Rockwood type III or V. The research group had predetermined protocols for follow up, standardized physiotherapy, surgical procedure and projections of radiography. The research protocol was published in ClinicalTrials.gov, under number NCT01725997, before the study included patients. The randomization lowered the risks of selection bias, information bias and confounding, but the risk of misclassification remained. In this study, two independent assessors judged the radiographs that were part of the inclusion criteria. The intention-to-treat principle was used to reduce the effect of patients lost to follow-up or changing treatment group. The CONSORT guidelines[168] were followed in the development and reporting of Study III.

Study IV was designed as a reliability study, an evaluation of a radiological classification system. Several observers independently classified radiographs, twice, and their results were compared to evaluate inter-observer and intra-observer reliability for the classification.

4.2 DATA COLLECTION

The patients in Studies I–II were initially treated at Capio St Görans Sjukhus, a large emergency hospital level III for patients aged 15 years or older, in Stockholm, Sweden. The included patients were re-examined at the hospital's outpatient clinic. Exclusion criteria for Studies I and II were immature bone, open dislocation, malignancy, neurovascular injury, severe osteoporosis, follow-up of less than one-year, other concomitant shoulder injuries or surgery of the shoulders. Further exclusion criteria for the study population in Study II were AC dislocation Rockwood types I–IV and VI.

In Study III, patients with acute AC joint dislocation types III and V, were referred from the emergency department at Capio St Görans Sjukhus and from five other emergency hospitals in the Stockholm area: Karolinska Universitetssjukhuset Solna and Huddinge, Danderyds sjukhus, Södersjukhuset and Södertälje sjukhus. All patients were examined and treated at Capio St Görans Sjukhus.

The radiographs in Study IV were selected randomly from the database of radiographs collected in Study III, and no patients were examined.

4.3 STUDY POPULATION

4.3.1 Study I

All medical records of patients with chronic AC joint dislocations treated surgically during 1995–2003 were identified based on diagnosis code. Patients with a chronic AC joint dislocation type III–V, treated with a Weaver-Dunn procedure augmented with braided PDS, which was the standard procedure in this clinic during 1995–2003, and patients treated with a Weaver-Dunn procedure augmented with hook plate in 1998–2006, were retrospectively reviewed.

A total of 62 patients were retrieved, of whom ten were excluded when applying the exclusion criteria above: one had bilateral AC joint dislocations, six had previous surgery to one of their shoulders, and three had a concomitant shoulder injury.

Thus, 52 patients were eligible for clinical examination and radiology. Five patients chose not to participate, and 11 did not want to come to the hospital for various reasons, but agreed to participate over the phone.

4.3.2 Study II

Medical records of patients with acute or chronic AC joint dislocation of Rockwood type V treated surgically with a hook plate at the clinic during the years 2000–2006 were retrospectively reviewed. An acute AC joint injury was treated within 4 weeks, and a chronic AC joint dislocation was treated operatively after a minimum of 4 months of non-operative treatment. Patients were included if they had pre-operative radiographs of the injured shoulder and radiographs of the uninjured shoulder pre-operatively or at follow-up.

Of the 57 patients retrieved, 16 were excluded, leaving 41 patients for clinical examination and radiology. Of the excluded patients, 13 were not treated with a hook plate, two had previous surgery of the injured or uninjured shoulder, and one had a concomitant shoulder injury.

4.3.3 Study III

Patients with acute AC joint dislocation types III and V were recruited from the orthopedic emergency departments of six hospitals in Stockholm, and then prospectively randomized to surgery with hook plate or non-operative treatment and the same rehabilitation with physiotherapy.

See Table II for inclusion and exclusion criteria. Enrollment of patients took place between 2012 and 2017. After baseline examinations, patients were randomized by a computer program to surgical treatment with hook plate and physiotherapy, or physiotherapy only and were followed for 24 months. Data were collected over the phone at 1 month, and at the hospital's outpatient clinic at 3, 6, 12 and 24 months.

Table II. Inclusion and exclusion criteria, Study III.

Inclusion Criteria	Exclusion Criteria
Acute AC joint dislocation Rockwood type III or type V	Concomitant shoulder injury, present or earlier
Age 18–65 years	Skin laceration in operation area
Availability to start treatment within 3 weeks	Open AC joint dislocation
Compliance with verbal and written instructions	Immature bone (open growth plates)
	History of malignancy
	Neurovascular injury
	Contraindication to undergo surgery
	Disability affecting working capacity

4.3.4 Study IV

In Study IV, radiographs were used to evaluate inter- and intra-observer agreement of the classification of AC joint dislocation. The cohort consisted of 25 randomly selected bilateral radiographs and CT scans, of acute AC joint dislocations types III and V from Study III.

4.4 OUTCOME MEASUREMENTS

In Studies I and II, the primary outcome score was Constant score.

The CS of the injured shoulder was compared with that of the uninjured shoulder. Secondary outcome scores were SSV, QuickDASH, SPADI, pain at rest and during movement evaluated with VAS, complications, questions regarding satisfaction with cosmesis and the result after treatment. Patients were asked to rate their degree of satisfaction with the results after surgery (excellent, good, fair, poor or unacceptable). Satisfaction with the physical appearance of the shoulder was assessed with a VAS graded 0–10 in Study I, and 0–100 in Study II. Zero meant dissatisfaction and 10 or 100, meant satisfaction or no change compared with the uninjured shoulder.

For radiologic evaluation, the preoperative bilateral radiographs were used to confirm the Rockwood classifications. At the time of the re-examination new bilateral AP views, with and without 5 kg loading of the arm, and an axial and subscapular view were taken. Two independent evaluators classified preoperative and follow-up radiographs. The CC distance and the width of the AC joint and the clavicle, was measured before and after surgery, with and without stress. The subluxation of the lateral end of the clavicle was expressed as parts of the clavicle width. The alignment of the clavicle to the acromion was evaluated in the axillary view. For statistical analysis, the postoperative radiographs were divided into three groups based on the degree of subluxation of the lateral end of the clavicle on the post-operative radiographs. Subluxation was either less than 25% of the clavicle width, 25–100% of the clavicle width or more than 100% of the clavicle width on the weighted radiographs. The degree of subluxation in the AC joint, was then be correlated to clinical outcome at follow-up.

In Study III, the primary outcome score was Constant score. At baseline, the CS of the uninjured side was used, after asking patients if their shoulders had had the same function before the injury. The CS of the injured shoulder was compared with that of the uninjured shoulder. Secondary outcome scores were SSV, QuickDASH, pain at rest and during movement evaluated with VAS, EQ-5D, complications, questions regarding satisfaction with cosmesis and the result after treatment. Patients were asked to rate their degree of satisfaction with the results after surgery (excellent, good, fair, poor or unacceptable). Satisfaction with the physical appearance of the shoulder was assessed with a dichotomous question (yes or no) and a VAS graded 0–10, where 0 meant dissatisfaction and 10 meant satisfaction or no change compared with the uninjured shoulder.

For radiologic evaluation, standardized, bilateral AP views without loading of the arm, and an axial and subscapular view were taken after the AC joint dislocation. Postoperative radiographs of the clavicle, consisting of two A-P images, including one with 35–40° of caudal tilt of the beams to assess the position of the hook plate and screws, were taken after surgery. The same standardized radiographs of the AC joint as at baseline, were taken after 24 months, but now with and without 5 kg loading of both arms in the AP view. The CC distance was measured. Two independent evaluators classified post-injury radiographs, and follow-up radiographs. CC distance was measured at baseline and at 24 months. Increase in CC distance at baseline was correlated with CS at 24 months. Increase in CC at 24 months patients was compared to CS at 24 months, with patients divided into three groups based on the increase in CC distance in radiographs at 24 months, less than 25%, 25–100%, or more than 100%.[169,170] A CT scan of the upper part of thorax, with the patient in the supine position, was performed at baseline and at final follow-up. The radiographs and CT scans from Study III were used in Study IV.

In Study IV, the outcome was inter-observer and intra-observer agreement for the Rockwood classification of AC joint dislocations Pearson product moment correlation coefficient. Observers consisting of 20 orthopedic surgeons and 3 radiologists, classified 25 patients after receiving oral and written description of the Rockwood classification, and instructions how to measure CC distance. First measurements were made in bilateral radiographs only, as suggested by Rockwood, then bilateral radiographs in combination with bilateral CT scans, and at last determine if the clavicle was totally dislocated in the AC joint or subluxated only, on radiographs (Figure 9).

4.5 INTERVENTIONS

4.5.1 Operative treatment – Surgical technique

In Study I, a modified Weaver-Dunn procedure was used augmented with either a PDS suture braid or a hook plate.

Weaver-Dunn with PDS braid augmentation

Patients were positioned in a beach chair, and administered intravenous antibiotics (2 grams of Cloxacillin) 30 minutes prior to surgery. Under general anesthesia, a saber-cut incision was made in the skin, along the lines of Langer. The fascia of the deltoid, pectoral major and trapezoid muscles was opened along the clavicle. The lateral clavicle and AC joint were visualized and cleared of remnants of meniscus and scar tissue. The lateral clavicle was resected approximately 1 cm. The CA ligament was detached with a piece of bone from the acromion. The lateral end of the clavicle was opened to make room for the piece of bone. Two Ethibond® sutures were placed in a Bunell fashion in the ligament. The CA ligament with the bone piece was transferred into the medullary canal of the clavicle. The sutures were passed through holes drilled in the superior part of the clavicle and tightened during reduction of the clavicle. A PDS® suture (no 1) braided in a 3 x 3 cord was placed in a figure of eight around the base of the coracoid process through a hole drilled in the anterior part of the lateral clavicle to protect the transferred ligament. The fascia was repaired over the clavicle with Ethibond® and the soft tissue with Vicryl® in layers.

Weaver-Dunn with hook plate

The surgical procedure was identical, but the PDS braid augmentation was replaced with a anatomic pre-contoured stainless steel hook plate, with six or eight holes in the shaft and 15- or 18-mm height of the hook (Synthes, Solothurn, Switzerland). The hook plate was used with 3.5 mm cortex screws. The sutures in the ligament were tightened before the screws of the plate were tightened. The fascia was repaired over the clavicle with Ethibond® and the soft tissue with Vicryl® in layers.

In Study II, the same modified Weaver-Dunn technique augmented with a hook plate was used for chronic dislocations as in Study I, and was compared with acute reduction with hook plate.

Acute reduction with hook plate

Patients were positioned in a beach chair, and administered intravenous antibiotics (2 grams of Cloxacillin) 30 minutes prior to surgery. Under general anesthesia, a saber-cut incision was made in the skin, along the lines of Langer. The fascia of the deltoid, pectoral major and trapezoid muscles was opened along the clavicle. The lateral clavicle and AC joint were visualized and cleared of remnants of meniscus. The remnants of the ligaments were brought closer by the reduction of the clavicle with the hook plate. The hook plate is an anatomic pre-contoured stainless-steel hook plate, with six or eight holes in the shaft and 15- or 18-mm height of the hook (Synthes, Solothurn, Switzerland). For wound closure, the fascia was repaired over the clavicle with Ethibond® and the soft tissue with Vicryl® in layers.

In Study III, the same acute reduction with hook plate was used as in Study II, but the preoperative antibiotics were changed to 600 mg Clindamycin intravenously 30–60 minutes before surgery and the hook plate design was changed to LCP® Clavicle Hook plate (Synthes, Oberdorf, Switzerland).

The hook plate was routinely removed after a minimum of 12 weeks in Studies I, II and III. No antibiotics were given prior to this procedure.

4.5.2 Non-operative treatment – physiotherapy

In Study III, the RCT, patients in the surgical and non-operative groups followed the same general rehabilitation protocol. (Table III).

Patients were advised to rest their injured arm in a sling for 2 weeks. After 2 weeks, patients were allowed to use their arm for daily activities like eating, personal hygiene and free movement below shoulder level. They were allowed a maximum loading of the arm of 1 kg during the first 6 weeks. After 6 weeks, the patients were allowed free ROM and to slowly increase weight-bearing. Sports and heavy loading were allowed 3 months after injury/surgery.

Table III. Rehabilitation protocol for acromioclavicular joint injuries

Acute phase (1–14 days after injury or surgery)

Goal	Patient well-informed regarding pain medication, oedema prophylaxis, position for rest, how to maintain personal hygiene and how to adjust and remove sling.
Restrictions	Avoid extreme positions 3–6 weeks depending on pain. Avoid heavy loading of arm.
Sling	Use Collar 'n' cuff for 10–14 days.
Training	Home training program days 1–14; movements to promote circulation and instructions regarding posture.
Information	Follow-up with physiotherapist at the hospital, at 2 and 6 weeks.

Follow-up (after day 14)

Goal	Patient well-informed regarding restrictions, pain and continued rehabilitation.
Restrictions	Avoid extreme positions of the arm during the first 6 weeks, especially outward rotation in combination with abduction. Avoid heavy loading of arm during the first 6 weeks.
Sling	Information regarding the importance of ceasing to use the sling.
Training	Home training program isometric muscle activation for the rotator cuff and controlled active movement training in a pain-free area (up to 90° flexion). After 6 weeks, free ROM and loading of > 1 kg. Loading of arm above shoulder level after 3 months.
Information	Follow-up with physiotherapist outside hospital.

4.6 STATISTICAL METHODS

Descriptive statistics such as counts, percentages, medians with interquartile ranges (IQRs, 25th percentile to 75th percentile), means, ranges, standard deviations and crosstabulation were used to analyze data on subjective and objective shoulder function and cosmesis.

Statistical significance was set at a p value of 0.05 or less (two-tailed).

Studies I and II

Mann-Whitney U-test was used to compare continuous and ordinal variables between two groups. Fisher's exact test was used for comparing dichotomous variables between two groups. The chi-squared test was used for comparing categorical variables with more than two categories.

The Kruskal-Wallis test was used for comparing the three groups with radiological subluxation at follow-up. Spearman's rank correlation was used to describe the correlation of continuous variables between the groups.

Study III

Parametric statistics were used for analysis of continuous variables. Pearson's chi-squared test was used for categorical variables (gender, injured dominant side, smoking, satisfaction with result and cosmesis). One-way analyses of variance (ANOVA) with post-hoc tests (Tukey's Honest Significant Difference) were used to compare the four groups at all timepoints, as well as to compare CS for the different groups of increased CC distance. Spearman's rank correlation was used to test for correlations between increased CC distance at baseline and CS, stratified by treatment, at 24 months.

Last observation carried forward (LOCF) was used when patients randomized to physiotherapy did not follow their treatment group for 24 months, due to surgical request, in accordance with the intention-to-treat design of the study. Data from patients absent from follow-up meetings at 1, 3 or 6 months were recorded as missing, but if patients where only absent from the follow-up at 12 or 24 months, their LOCF was used.

Study IV

The parametric test, Pearson's product moment correlation coefficient was used to determine inter-observer and intra-observer reliability when 23 orthopedic surgeons and radiologists classified 25 radiographs and CT examinations from patients with AC joint dislocation type III or V. All observers classified the patients independently and twice, with at least 4 weeks between their classifications.

The statistical program STATISTICA (version 8.0. StatSoft, Inc., Tulsa, OK) and the Statistical Program for Social Sciences, SPSS for MAC 17.0 (SPSS, Inc., Chicago, IL) was used for statistical analysis in Study I. In Study II, SPSS for MAC 19.0 (SPSS, Inc., Chicago, IL) was used. In Studies III and IV, IBM SPSS Statistics for Windows (Version 25.0. Armonk, NY: IBM Corp) was used.

4.7 ETHICAL CONSIDERATIONS

All included studies were approved by the Regional Ethical Review Board.

Studies I and II: Research Ethics Committee of Stockholm North (DNR 2007/295-31/4).

Studies III and IV: Research Ethics Committee of Stockholm North (DNR 2009/2040-31/3 and 2020-05990).

The investigations were conducted in accordance with the principles of the Helsinki Declaration,[171] which include maintaining the respect for the individual, preventing mistreatment of study participants and recognizing vulnerable groups. Study participants have the right to make informed decisions, and all eligible patients in these studies were given verbal and written information about the studies and were given time to reflect at home if necessary.

All data regarding the study participants were processed on hospital computers or a predetermined research computer in accordance with the Patient Data Act, the Patient Safety Act and the General Data Protection Regulation. Data were anonymized and presented at group level, to minimize the risk of identifying the results of any one individual. No sensitive information was collected in these studies.

All included patients in Studies I–III gave consent after being provided with information. In Study III, a RCT, randomization took place after each patient had received oral and written information and decided that they were willing to participate in either of the treatment groups. Patients were randomized by an independent person without any involvement in the study. A computer program with 1:1 allocation, stratification by Rockwood type (III or V) based on the acute post-trauma radiographs, and randomly permuted block sizes, from the website Randomization.com was used.

5 RESULTS

5.1 STUDY I

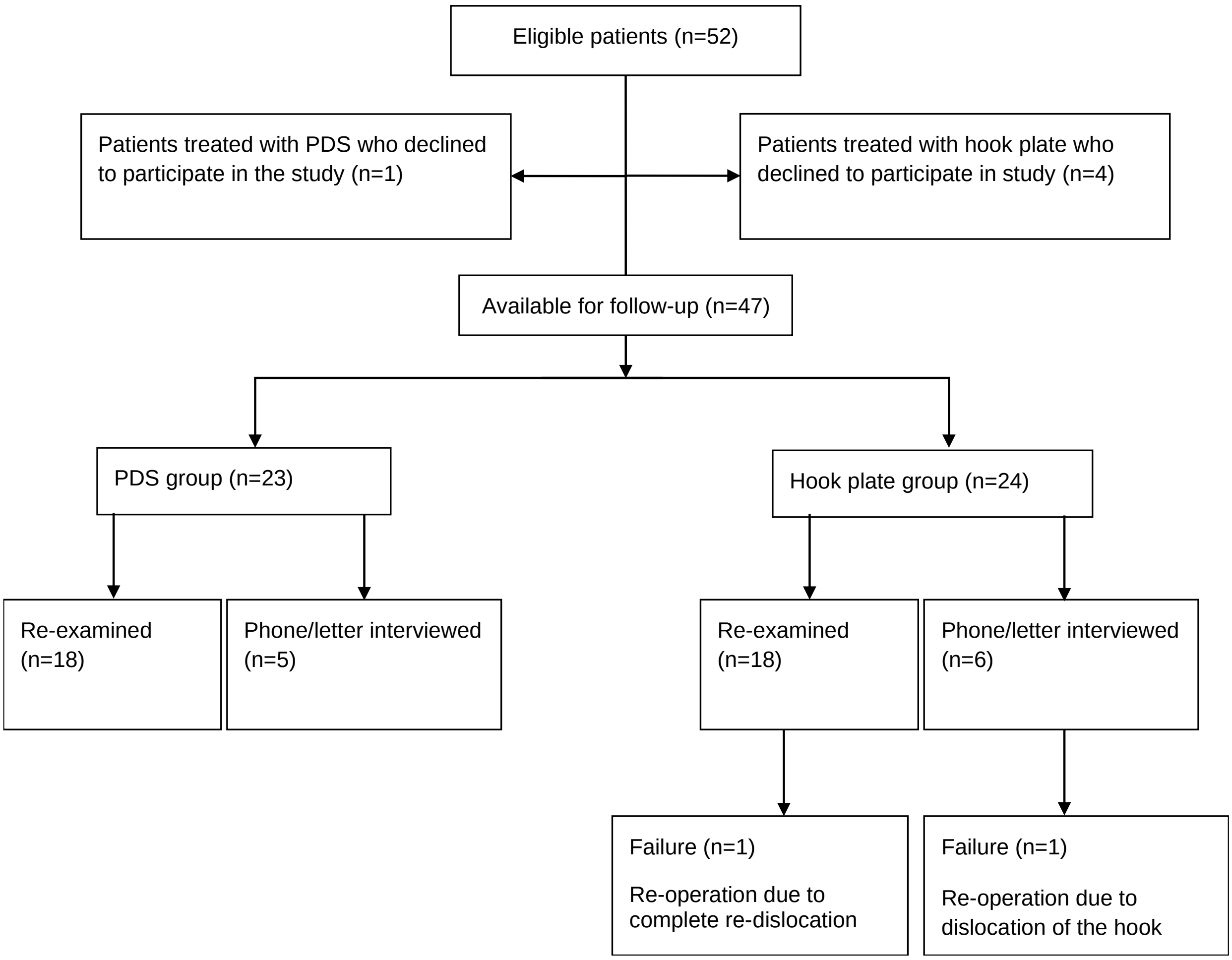


Figure 11. Flowchart Study I.

Demographic data

Patients with chronic AC joint dislocation type III–V, treated with Weaver-Dunn procedure augmented with PDS (PDS group) were examined after a mean of 102 months, and patients operated with a hook plate (hook plate group) after 45 months (Figure 11 and Table IV).

Table IV. Demographic data Study I. Included patients.

	Patients treated with Weaver-Dunn augmented with PDS n=23		Patients treated with Weaver-Dunn augmented with hook plate n=22	
	Re-examined	Phone interviewed	Re-examined	Phone interviewed
Patients (n)	18	5	17	5
Mean age at trauma (years, range)	37 (23–53)	42 (23–56)	40 (23–77)	36 (16–66)
Female (n)	9	1	4	1
Injured dominant side (n)	11	3	12	2
Mean time from trauma to surgery (months, range)	35 (7– 108)	13 (6 – 26)	47 (4 – 336)	25 (12–40)
Mean follow up time (months, range)	99 (51– 155)	114 (69– 156)	43 (18 –110)	48 (24–62)
Rockwood type III	4	2	4	2
Rockwood type IV	1	0	1	0
Rockwood type V	13	3	12	3

Functional Outcome

There was no significant difference in CS between the groups of patients treated with PDS and hook plate, mean CS 85 vs. 75, p = .21. When comparing the injured shoulder and the uninjured shoulder, patients in the PDS group had 96% of the mean CS of the uninjured shoulder, and patients in the hook plate group had 87% of the mean CS the uninjured shoulder (p = .48). There was no correlation between the time from trauma to surgery (rs = -.10, p = .51) or time from surgery to follow-up (rs = .14, p = .34) and CS. Furthermore, there were no significant differences in SPADI (mean 8 for the PDS group vs, 21 in the hook plate group, p = .19), QuickDASH (mean 16 for the PDS group vs. 20 in the hook plate group, p = .06), or SSV (mean 80 for the PDS group vs. 70 in the hook plate group, p = .13).

Patients in the PDS group experienced significantly less pain during movement, than patients in the hook plate group measured with VAS 0–100 (mean 10 for the PDS group vs. 32 for the hook plate group, p = .003). Regarding pain at rest, there was no significant difference between the groups measured with VAS 0–100 (mean 7 for the PDS group vs. 21 in the hook plate group, p = .07). In all, 87% of the PDS group and 86% of the hook plate group rated their result after surgery as good or excellent.

Radiologic Outcome

Radiologically, there was no difference in degree of subluxation in the AC joint after surgery between the groups ($p = .80$) and there was no correlation between CS at follow-up and the degree of subluxation at follow-up radiographs ($p = .41$). No correlation was found between preoperative Rockwood classification and CS at follow-up ($p = .31$).

Cosmesis

Patients in the PDS group rated the cosmetic appearance of the shoulder and scar significantly better than the hook plate group using a VAS 0–10 (mean 1.9 vs. 3.7, $p = .04$).

Complications

In the PDS group, there were two superficial infections and one early surgical revision because of complete re-dislocation. In the hook plate group, there were three superficial infections and one early surgical revision because of dislocation of the hook right after surgery. The complication rate for PDS-group was 13%, and for the hook plate group 17%.

5.2 STUDY II

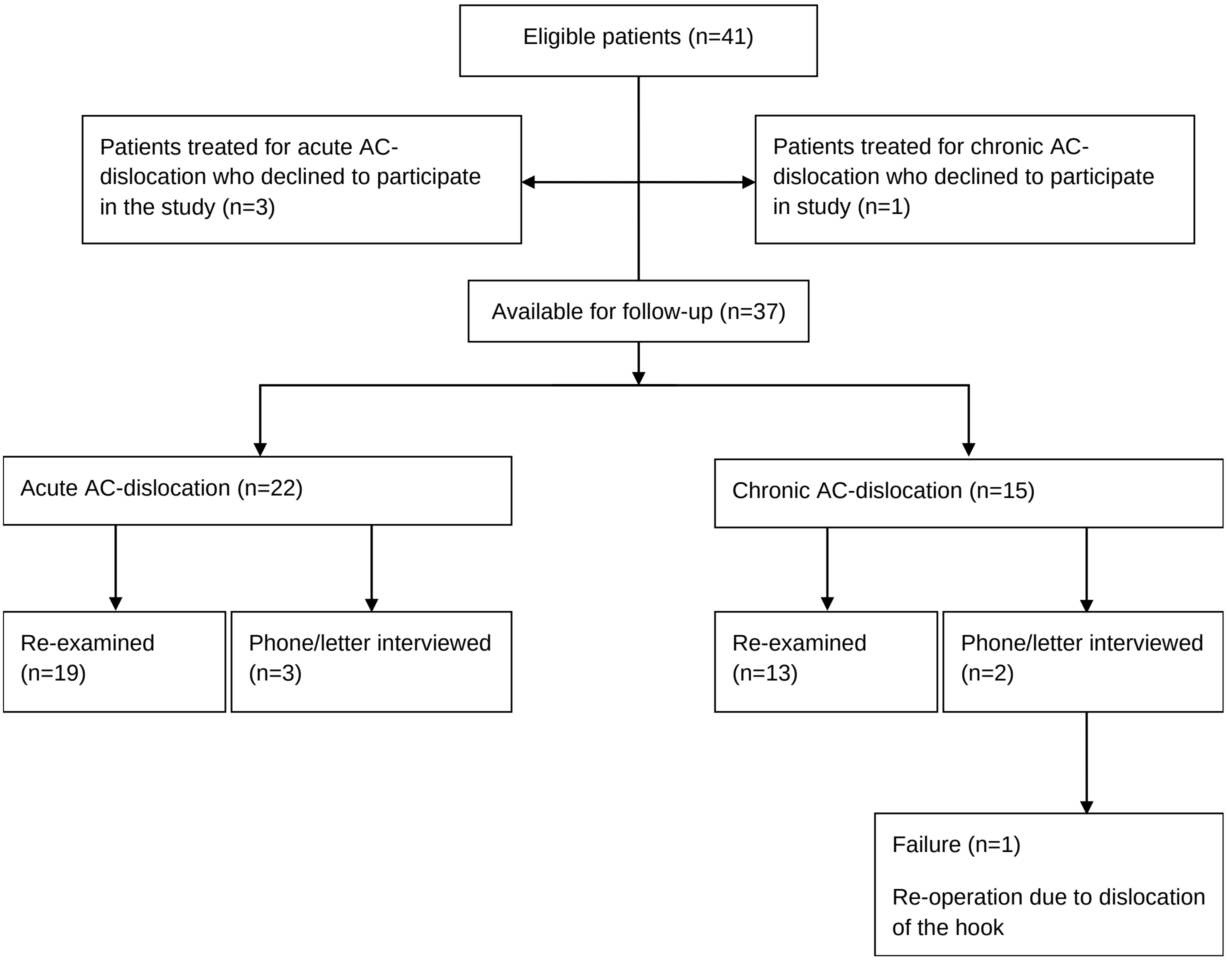


Figure 12. Flow chart Study II.

Demographic data

Patients with AC joint dislocation type V operated with a hook plate in the acute phase (acute group) were examined after a median of 32 months and patients operated later in the chronic phase, with a modified Weaver-Dunn procedure augmented with a hook plate (chronic group) after 35 months Figure 12 and Table V)

Table V. Demographic data Study II. Included patients.

	Patients treated for acute AC-joint dislocation			Patients treated for chronic AC-joint dislocation			P value*
	Re-examined	Phone/letter interviewed	Total	Re-examined	Phone/letter interviewed	Total	
Patients (n)	19	3	22	13	1	14	
Median age at trauma (years, interquartile range)	42 (33 – 50)	29 (28 – 37)	40 (29 – 49)	35 (30 – 47)	32 (32 – 32)	35 (30 – 47)	0.697
Female (n)	5	0	5	4	0	4	0.693
Injured dominant side (n)	10	2	12	10	0	10	0.485
Median time from trauma to surgery (months, interquartile range) **	0.3 (0.1 – 0.4)	0.1 (0.0 – 0.1)	0.3 (0.1 – 0.4)	22 (16 – 44)	18 (18 – 18)	22 (16 – 44)	
Median follow up time (months, interquartile range)	26 (22 – 50)	54 (46 – 61)	32 (22 – 53)	34 (26 – 42)	62 (62 – 62)	35 (26 – 47)	0.709

*Acute vs. chronic groups, Mann-Whitney U test, Pearson Chi square test and Fisher's Exact Test for testing the homogeneity between the groups

**Different duration defines the groups and was not statistical tested

Functional Outcome

There was no significant difference in CS between the groups; median CS was 91 in the acute group and 85 in the chronic group (p = .097). When comparing the injured shoulder and the uninjured shoulder, patients in the acute group had 97% of the median CS of the uninjured shoulder, and patients in the chronic group had 86% of the median CS of the uninjured shoulder (p = .443). There was no correlation between time from surgery to follow-up (rs= .112, p = .702) and CS. The acute group had a significantly better SPADI (median 0 for the acute group vs. 14 for the chronic group, p = .006), QuickDASH (median 0 for the acute group vs. 18 for the chronic group, p = .002) or SSV (median 90 for the acute group vs. 80 for the chronic group, p = .032).

Patients in the acute group experienced less pain at rest than patients in the chronic group, measured with VAS 0–100 (acute group median 0 vs. chronic group median 2, p = .014). Regarding pain during movement measured with VAS 0–100, the acute group rated significant less pain (median 2 vs. chronic group median 22, p = .005). In all, 91% of patients in the acute group and 79% in the chronic group rated their results after surgery as good or excellent.

Radiologic Outcome

Radiologically, there was no difference between the groups in increase of CC distance in the preoperative radiographs compared with in the uninjured shoulder. On average, the acute group had an increase of CC distance of 158% (range 103–240) vs. the chronic group 191% (range 108–358; $p = .123$). In the follow-up radiographs, the increase of CC distance between the injured shoulder and uninjured shoulder was on average 39% (range -37–228) in the acute group and 63% (0–139) in the chronic group ($p = .096$). There was no correlation between CS at follow-up and the degree of subluxation in the follow-up radiographs ($r_s = .122$, $p = .619$).

Cosmesis

There was no significant difference when patients in the two groups rated the cosmetic appearance of the shoulder and scar with VAS 0–100 (acute group median 25 vs. 43 for the chronic group, $p = .286$).

Complications

There was one superficial infection and one early surgical revision because of dislocation of the hook right after surgery in the chronic group. The complication rate was 5%.

5.3 STUDY III

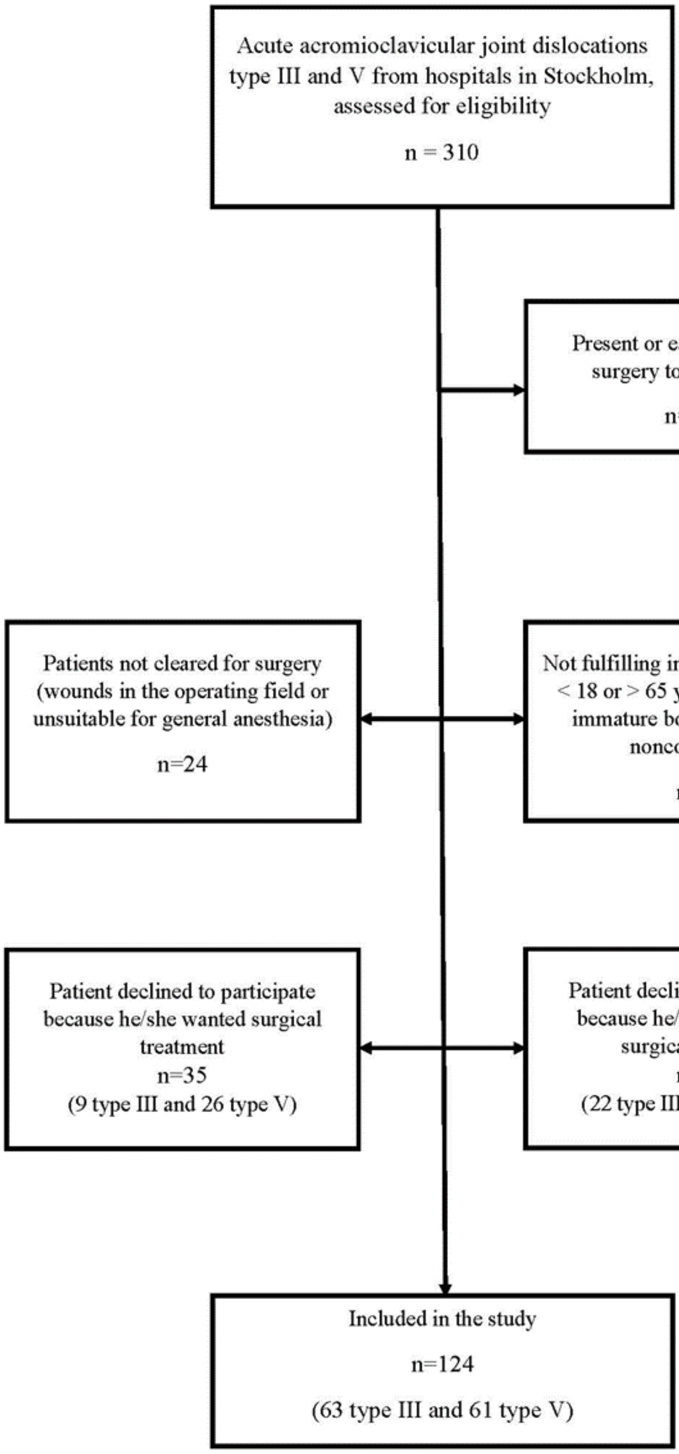


Figure 13. Flowchart Study III.

Demographic data

Enrollment stopped when 124 patients with acute AC joint dislocation type III and V had been included. The most common cause of injury was a bicycle accident, 31% of patients, followed by falls on same level 17%, and soccer 10%. There were no significant differences between the groups as regards age, gender, injured dominant arm or smoking. Patients were examined over the phone at 1 month, and in person at 3, 6, 12, and 24 months. Data were recorded for 124 patients at baseline. Three patients dropped out, leaving 121 patients at 3 months. Some patients missed one or two follow-up visits. Thus, at 6 months, 119 patients participated, and at 12 and 24 months 118 patients (95%) did so. As LOCF was used, analysis could be performed for 121 patients at 12 and 24 months. (Figure 13 and Table VI.

Table VI. Demographic data and cause of injury Study III.

Variable	**Rockwood type III**		**Rockwood type V**		
	Non-operative (n = 31)	Operative (n = 30)	Non-operative (n = 29)	Operative (n = 31)	*P**
Mean age at injury, years (range)	40 (18-63)	39 (21-57)	39 (21-63)	40 (18-64)	0.968
Male gender	28 (90)	28 (93)	28 (97)	27 (87)	0.583
Injured dominant side	15 (48)	17 (57)	17 (59)	20 (65)	0.640
Smoking	1 (3)	4 (13)	3 (10)	3 (10)	0.570
Mechanism of injury					
Cycling accident	7 (23)	11 (37)	9 (31)	11 (35)	
Other sports injury	6 (19)	7 (23)	10 (34)	6 (19)	
Fall on same level	7 (23)	4 (13)	6 (21)	3 (10)	
Soccer	2 (6)	4 (13)	2 (7)	4 (13)	
Alpine skiing	5 (16)	1 (3)	1 (3)	4 (13)	
Motorcycle accident	4 (13)	3 (10)	1 (3)	3 (10)	

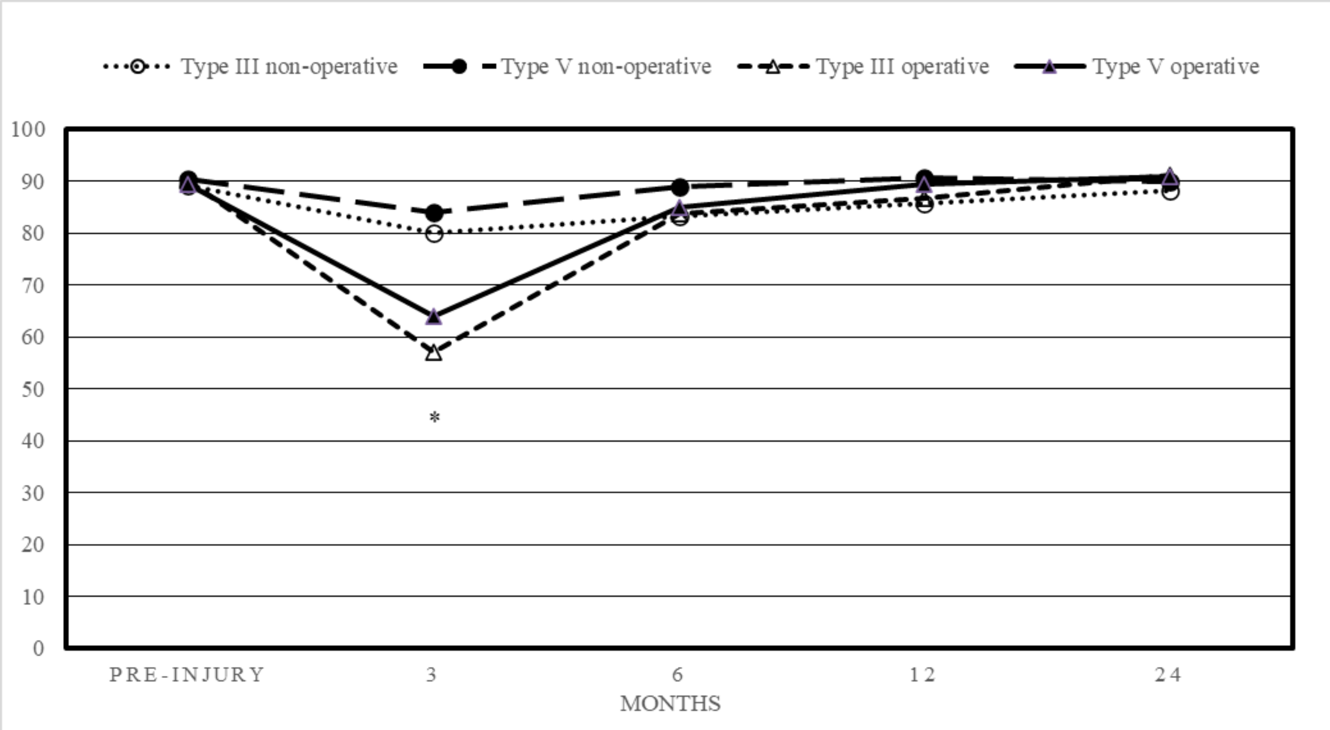
Values presented as n (%), except for age. * Oneway analysis of variance for age and Chi-Square test for gender, injured dominant side, and smoking

During the follow-up period of 24 months, 11 patients (6 type III and 5 type V) who had been treated non-operatively underwent surgery because of pain and unacceptable shoulder function. Their results are included in the non-operatively treated groups, based on the principle intention-to-treat.

Functional Outcome

There were no significant differences in the primary outcome score, CS, between the groups pre-injury, or at 6, 12 and 24 months. At 3 months, CS was significantly better for the non-operatively treated patients with Rockwood type III or V ($p < .001$). At the final follow-up, 24 months, mean CS was 88 for non-operative type III vs. 91 for operative type III and 90 for non-operative type V vs. 91 for operative type V ($p = .477$). Comparing CS for the injured shoulder versus the uninjured shoulder, non-operatively treated type III regained 96%, operatively treated type III 99%, non-operatively treated type V 97%, and operatively treated type V 98% (Figure 14).

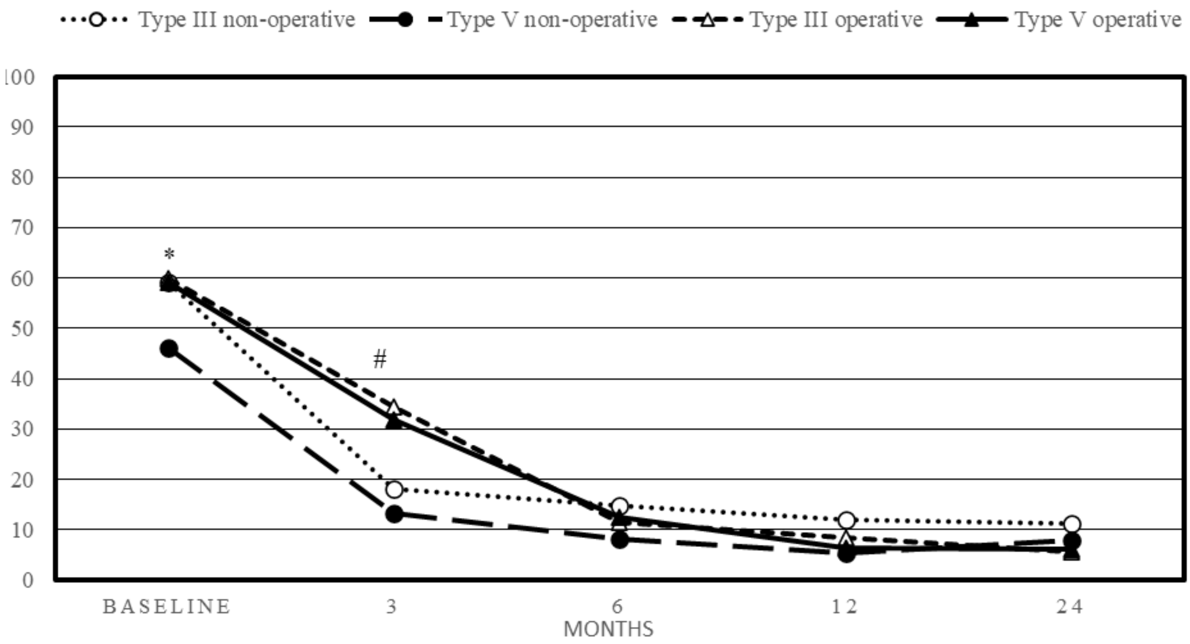
Figure 14. Average Constant score used to measure clinical function (CS; 0–100, where 100 is best possible result) at the different time points.



Oneway analysis of variance. *Significant difference (p < .001) between non-operated and operated patients (Tukey HSD test).

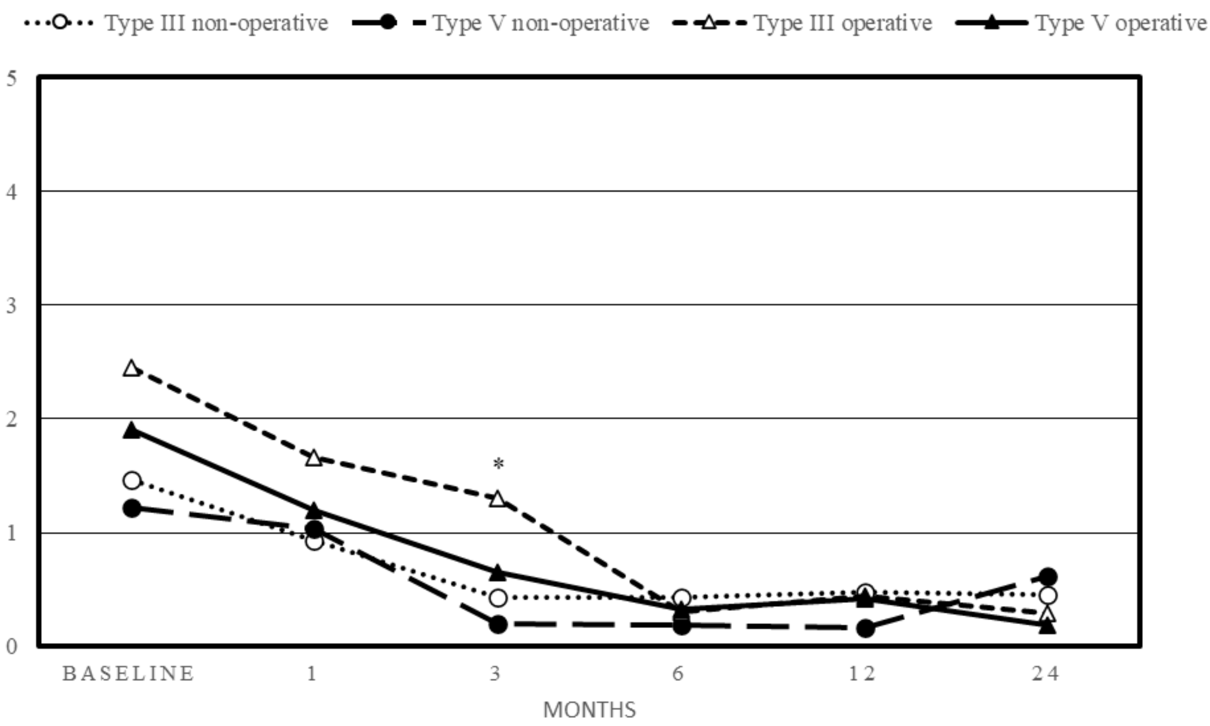
The pattern seen with CS was repeated for almost all the secondary outcome variables. At 3 months, there were significantly better results in SSV, QuickDASH, pain at rest, and pain during movement for non-operatively treated types III and V, but there were no significant differences at 6, 12, or 24 months. EQ-5D index was significantly better for non-operatively treated patients types III and V at 1 month (p = .004). There were no significant differences between the groups at 3, 6, 12, or 24 months (Figures 15, 16 and 17).

Figure 15. Average QuickDASH to measure symptoms and function of the upper extremity (0-100, where 0 is the best result), at the different timepoints



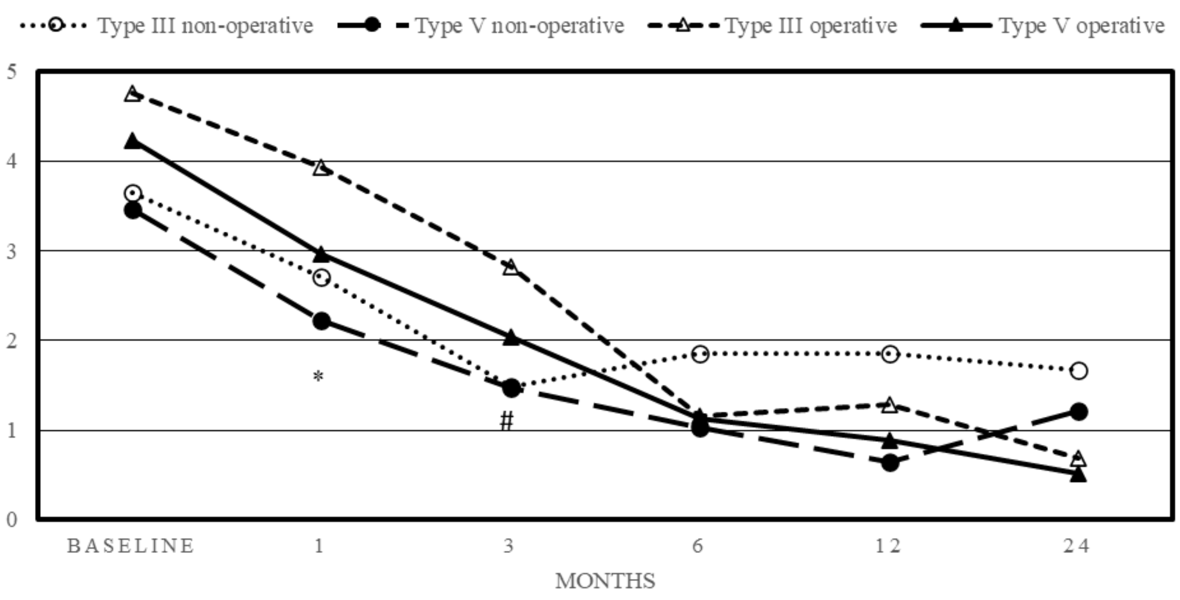
Oneway analysis of variance. Significant difference * (p =. 009) and # (p < .001) between non-operated and operated patients (Tukey HSD test).

Figure 16. Average pain at rest measured with visual analogue scale (VAS, 0–10, where 0 represents no pain) at the different time points.



Oneway analysis of variance. *Significant (p =. 009) difference between non-operated and operated patients (Tukey HSD test)

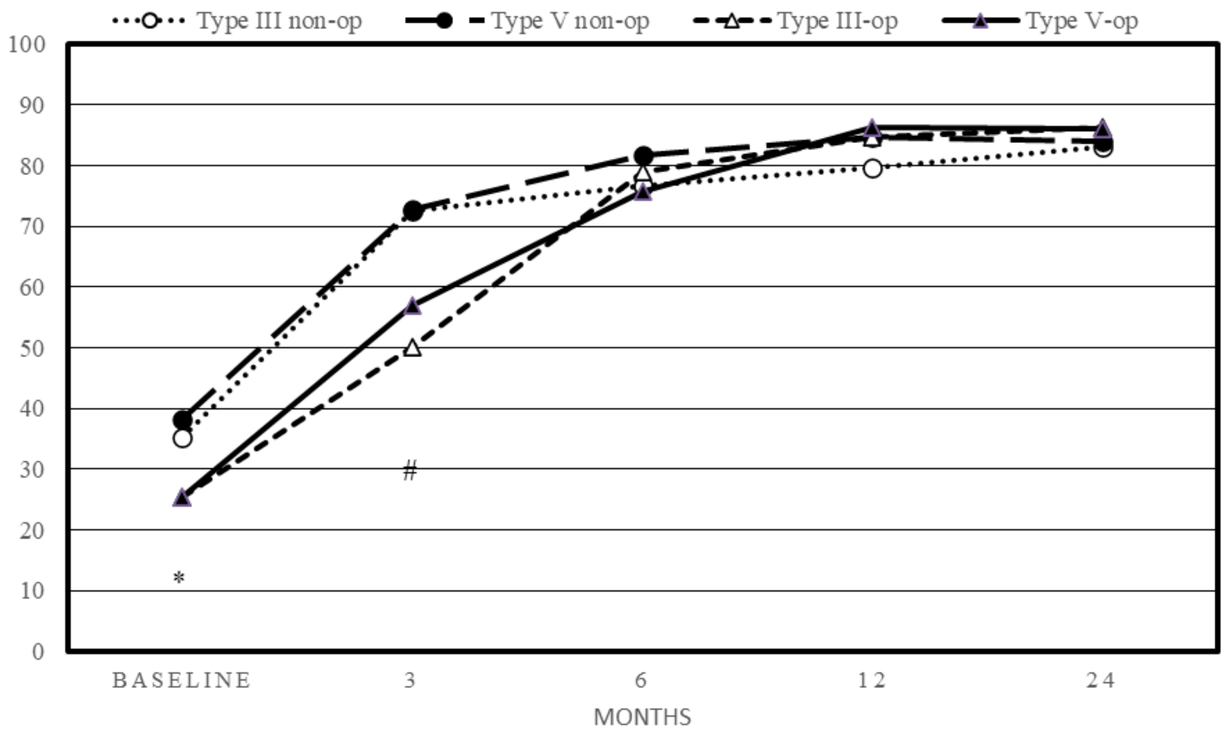
Figure 17. Average pain during movement measured with visual analogue scale (VAS, 0–10, where 0 represents no pain) at the different time points.



Oneway analysis of variance. Significant difference * (p =. 016) and # (p =. 002) between non-operated and operated patients (Tukey HSD test).

When assessing SSV for both shoulders 24 months after treatment, non-operative type III patients' injured shoulders scored 86% of the SSV in their uninjured shoulders, operative type III scored 87%, non-operative type V 86%, and operative type V 87% (Figure 18).

Figure 18. Average Subjective Shoulder Value used to measure clinical function (SSV; 0–100, where 100 is best possible result) at the different time points.



Oneway analysis of variance. Significant difference * (p = .008) and # (p < .001) between non-operated and operated patients (Tukey HSD test).

Patients rated the general result after treatment as excellent (n = 72) or good (n = 29) in 86% of cases; only 3% (n = 4) rated the result as unacceptable at 24 months. There was no significant difference between the groups (p = .398).

Radiologic Outcome

Radiologically, there was no significant correlation between the increase of CC distance at baseline and CS at 24 months, for patients treated non-operatively (rs = .037, p = .776) and operatively (rs = .035, p = .792) and there was no significant correlation between increase of CC in weighted radiographs at follow-up and CS at 24 months (p = .476).

Cosmesis

There was no significant difference between the groups when patients rated the cosmetic appearance of their shoulder with VAS 0–10 (non-operative type III 7.8, operative type III 8.1, non-operative type V 8.2 and operative type V 7.6 ($p = .721$)) or when asked if they were satisfied with the appearance of their shoulder (responses "yes" or "no"; $p = .702$).

Complications

The complication rate was 3%, with a total of 4 patients affected. Among the operatively treated patients there were one deep infection, one frozen shoulder and two complete re-dislocations after hook plate removal.

5.4 STUDY IV

Twenty-five sets of bilateral radiographs and CT scans were selected randomly from Study III. Patients had a mean age of 38 years at time of the AC joint dislocation (range 18–51 years) and 23 (92%) were male.

Three radiologists and 20 orthopedic surgeons with varying experience, including 5 shoulder surgeons, classified 25 radiographs and CT scans.

Inter-observer reliability

The inter-observer reliability of Rockwood classification when evaluating plain radiographs solely, was $r_{xy} = 0.37$ (95% confidence interval (CI) = 0.347–0.393), and $r_{xy} = 0.39$ (95% CI = 0.373–0.414) for the first and second evaluation, respectively. When observers had access to both plain radiographs and CT scans, the interobserver reliability improved to $r_{xy} = 0.54$ (95% CI = 0.522–0.560) for the first evaluation, and $r_{xy} = 0.57$ (95% CI = 0.550–0.591) for the second evaluation. For the simpler classification subluxation/total dislocation, the interobserver agreements were $r_{xy} = 0.56$ (95% CI = 0.540–0.587) and $r_{xy} = 0.51$ (95% CI = 0.490–0.537) for first and second evaluation, respectively.

Intra-observer reliability

The intra-observer reliability of Rockwood classification when evaluating plain radiographs only was $r_{xy} = 0.52$, $p < 0.001$. When CT was added to plain radiographs, the intra-observer reliability increased to $r_{xy} = 0.61$, $p < 0.001$. The simpler classification yielded the highest intra-observer agreement for classification $r_{xy} = 0.69$, $p < 0.001$.

The reliability of the simple classification, when classifying Rockwood type III and V, was significantly better than the Rockwood classification using plain radiographs [$F (1, 252) = 219.41$; $p < 0.001$] but not significantly better than plain radiographs in combination with CT [$F (1, 252) = 2.78$; $p = 0.097$]. Finally, the reliability of Rockwood classification using plain radiographs in combination with CT is significantly better than using plain radiographs alone. [$F (1, 252) = 276.02$; $p < 0.001$].

6 DISCUSSION

The question regarding non-operative treatment of AC joint dislocations arose after the first two small retrospective studies of treatment, and timing of treatment.

We were interested in the long-term outcome after surgical treatment of the chronic AC joint dislocation. Can we wait and operate patients in the chronic phase, or does acute surgery yield better results for AC joint dislocation type V? Should we recommend operative treatment to patients with acute AC joint dislocation type III and V? How can we improve classification of AC joint dislocations type III and V?

CS is recommended by the European Society for Surgery of the Shoulder and Elbow for the evaluation of general shoulder function and pain,[72] but the question has been raised if it adequately reflects the disabilities after AC joint dislocation.[92] There is no gold standard in the literature for measurement of outcome after AC joint dislocations; more than 30 different shoulder scores have been described.[123]

A recent systematic review highlighted 16 different outcome scores, of which CS was the most used, followed by the American Shoulder and Elbow Surgeons score, and the Simple Shoulder Test and VAS for evaluating pain. It recommended the use of at least four different outcome scores for the evaluation of AC joint injuries.[173] In the three clinical studies, Studies I–III, the research team used more than four outcome scores to evaluate the shoulder function.

There are new PROMs for AC joint dislocations, such as the Nottingham clavicle score, a 10 item short questionnaire validated in 2013.[174] The acromioclavicular joint instability score, (ACJI) was introduced in 2011 but is not validated yet, and is therefore not used in Studies II and III. The ACJI adds radiological assessment, including horizontal stability, to the tested items.[106]

The goal when treating patients with AC joint dislocations is to reduce pain, restore ROM, strength and stability of the AC joint. If non-operative treatment yields the same functional result, same subjective satisfaction and cosmesis, patients can avoid surgical complications, the first painful postoperative months with inferior function, and scarring, which would be better for both patients and the healthcare system.

The patients with AC joint dislocations in these studies, who had an age span of 18–65 years, did not all have the same expectations or demands of their shoulder function.

6.1 STUDY I

This study showed good clinical and subjective outcomes for patients with chronic AC joint dislocation types III–V. There was a non-significant trend towards better results in the outcome scores after the Weaver-Dunn procedure augmented with PDS. The mean CS at follow-up was in accordance with that in other publications during the same period of time, mostly cohort studies and case series with few patients treated with hook plate for chronic AC joint dislocations types III–V reporting mean CS of 91–95[99,121,175] or modified Weaver-Dunn procedures reporting mean CS of 81–92.[140,176,177]

In Study I, the CS at follow-up was not affected by the degree of dislocation in the AC joint, which has been described by several authors previously – a perfect anatomic reduction does not affect the outcome.[116, 140] The reason for this might be that an elongated ligament provides enough stability in the AC joint, but not enough stability to cause pain if posttraumatic changes appear in the AC joint.

The Rockwood classification was considerably more difficult because of the different projections of the AC joint in the preoperative radiographs, taken at various radiological departments over a period of several years. A method to measure the CC distance in parts of clavicle diameter was developed, but not validated, to overcome these difficulties, though this was time-consuming.

In Study I, 15% complications, was noted, which was in accordance with other studies using the hook plate or Weaver-Dunn, reporting 8–29% complications.[121,140,176-178]

Pain or discomfort during the period with the hook plate has been considered an expected effect of the hook in the subacromial room and symptoms were usually relieved when the hook plate was removed.[179] The position of the hook in the subacromial bursa has been confirmed in cadaveric studies.[180] This can probably lead to subacromial irritation, impingement and tendinitis of the supraspinatus tendon.

Limitations.

- This was a retrospective study with a limited number of patients, which can result in type II errors. A type II error means failure to reject the null hypothesis despite it being false or failure to recognize a significant effect because the sample size is too small.

- No power calculation was performed, because of the retrospective design.

- The follow-up period was shorter for the group treated with hook plate because of the retrospective design, since the hook plate was introduced later at the studied clinic.

- The chosen outcome variables might not adequately evaluate symptoms from the AC joint.

- The study was based on re-examined patients and patients interviewed over the phone, using the same PROMs. The re-examined patients had the possibility to sit alone and answer the questionnaires, while the phone-interviewed patients answered the questions asked.

- The CS of the re-examined patients was measured by a physiotherapist, while the phone-interviewed patients had to be instructed how to measure themselves, estimating the amount of weight they were able to lift in abduction without pain. When comparing CS for the re-examined patients with that of the phone-interviewed patients, there were no significant difference; therefore, the patients were analyzed together.

- The preoperative radiographs were not taken in a standardized way, being performed at different radiological departments over a period of several years. This might make the Rockwood classification more complicated

Strengths

- The groups were comparable demographically, in size, and in the mix of Rockwood types.

- Only two evaluators re-examined the participants.

- The same physiotherapist performed all the CS measurements.

6.2 STUDY II

The most important finding is this study was that acute surgery resulted in better outcome than delayed surgery for AC joint dislocation Rockwood type V, in all outcome scores but CS. Analyzing the CS sub-scales separately showed that patients treated with acute surgery had less pain and higher activity levels than patients treated with late surgery.

The conclusions were in line with those from the works of Rolf et al. and Weinstein et al.,[116,117] but their conclusions were based on AC joint dislocations types III–V and Allman grade 3.

Average CS in Study II was in accordance with CS reported from other studies; Salem et al. found an average CS of 97 when reviewing 25 patients with AC joint dislocations type III or V operated in the acute phase with hook plate.[181] Eschler et al. evaluated 27 patients with Rockwood type V dislocation treated early with hook plate, and 25 patients early operated with the Weaver-Dunn procedure, and reported a mean CS of 91 for the hook plate group.[99]

There was a significant difference in the degree of subluxation between the re-examined patients in the acute and chronic groups, but – as other studies have shown – there was no relation between CS and subluxation at follow-up.[116,140,181]

Limitations:

- This was a retrospective study with a limited number of patients, which can result in a type II error.

- No power calculation was performed, because of the retrospective design.

- The study included re-examined patients and patients interviewed by telephone/letter, and their evaluations of CS differed. The validated CS questionnaire described by Boehm et al. was used for the patients participating via telephone/letter.[182] When re-examined patients and interviewed patients were compared, the groups did not differ in results or demographics.

- The preoperative radiographs were not taken in a standardized way, being performed at different radiological departments over a period of several years. This might make the Rockwood classification more complicated.

- The acute group may have included patients who would have had an excellent outcome without surgery.

- The chronic group consisted of patients with persistent symptoms or a significant disability after non-surgical treatment, which caused selection bias.

- The chosen outcome variables might not adequately evaluate symptoms from the AC joint.

Strengths:

- At the time, this was the largest study on Rockwood type V comparing acute and delayed surgery.

- Few patients lost to follow-up.

- Only two evaluators re-examined the participants.

- The same physiotherapist performed all the CS measurements.

6.3 STUDY III

The most important finding was that surgical treatment with hook plate for acute type III and V dislocations resulted in no better clinical outcome than non-operative treatment.

This is in accordance with a multicenter RCT from the Canadian Trauma Orthopedic Society, where no significant differences in CS were reported between non-operative treatment and operative treatment with hook plate. The average CS was 91 for non-operative treatment and 94 for operative treatment.[79] However, in the Study III, CS was analyzed separately for type III and V injuries.

The average CS of 91 for the surgically treated patients was in line with the average CS of 94 for the surgically treated patients reported by the Canadian Trauma Orthopedic Society, as well as the CS of 86–94 reported in other trials comparing hook plate surgery for acute AC joint dislocation types III–V with various other surgical techniques.[79,158,183-186] The non-operatively treated patients' mean CS measured at 2 years (88 and 90 for types III and V, respectively) were in accordance with those in other publications reporting mean CS of 81–93 for patients vid AC joint dislocations Rockwood type III–V.[88,97,110]

The hook plate is an uncomplicated surgical procedure, with a major drawback in terms of the need of a second surgical procedure to remove the implant. There are reports of high rates of complication after hook plate surgery (8–40%),[79, 99, 132-135], but the rate in Study III was only 3%.

Today, there are newer surgical alternatives for the surgical treatment of AC joint dislocations, arthroscopic or arthroscopically assisted procedures, reporting mean CS of 89–95 after acute AC joint dislocations Rockwood type III–V.[158,186-190] Since there have been reports of up to 20% concomitant intraarticular shoulder injuries, the arthroscopic examination is an advantage.[154]

The non-operatively treated patients regained good shoulder function, with a mean CS of 88 for type III and 90 for type V injuries, and 96% and 97% of the CS for the uninjured shoulder, respectively. Since the minimal clinically important difference in CS has been reported to be 10–17 points,[157,158] it is not clear if patients treated with a more up-to-date surgical procedure would notice significantly better shoulder function.

The recovery for the surgically treated patients was slower, probably due to their having to undergo two surgical procedures. At 3 months, patients in the surgical group were examined before hook plate removal. All outcome parameters were inferior for the patients treated surgically at 3 months. Pain or discomfort during the period with the hook plate, has been considered an expected effect of the hook in the subacromial room and symptoms relieved when the hook plate was removed.[179] The position of the hook in the subacromial bursa have been confirmed in cadaveric studies[180] and can lead to subacromial pain, impingement and tendinitis of the supraspinatus tendon.[99,134,135]

Limitations:

- The number of patients was small, as 121 patients were divided into four groups, and there might be a risk of a type II error.

- During the study period, 11 patients randomized to non-operative treatment underwent surgery. For these patients, the last values for the various outcome scores recorded before surgery were used, with the results analyzed based on intention to treat. The values recorded earlier during the study were lower than the expected values at the last follow-up, 24 months, and may therefore negatively affect the results for the non-operatively treated group.

- There have been reports of varying inter-observer and intra-observer reliability when using the Rockwood classification of AC joint injuries.

- Using CS for the evaluation of AC joint symptoms might not capture the specific problems with AC joint instability.[92]

Strengths:

- RCT with predetermined, published protocols for follow-up evaluation, operative and non-operative treatment, and radiography.

- Multiple follow-ups were used.

- The number of included patients was large.

- Results were presented separately for Rockwood types III and V.

- The drop-out rate was low: 95% of included patients remained.

- One person evaluated all patients and performed all follow-ups.

- The same physiotherapist performed all CS measurements.

6.4 STUDY IV

The inter-observer and intra-observer reliability of the simple classification, when classifying Rockwood type III and V, was significantly better than the Rockwood classification using plain radiographs, but not significantly better than plain radiographs in combination with CT. Finally, the reliability of Rockwood classification using plain radiographs in combination with CT is significantly better than using plain radiographs alone.

In contrast to what was seen in this study, Cho et al. concluded that 3D CT in addition to plain radiographs did not improve the inter-observer reliability of the classification of AC joint dislocations. They found an inter-observer agreement of $\kappa = 0.214$ for the Rockwood classification using plain radiographs, and $\kappa = 0.177$ when adding 3D-CT. Intra-observer agreement was $\kappa = 0.474$ using plain x-rays and $\kappa = 0.565$ when adding 3D-CT.[49]

It is important to have a reliable and uncomplicated classification system to find the patients who could benefit from surgery, without causing harm or exposing patients to excessive radiation. The simpler classification from Study IV could be used to get an overview of which patients to examine further.

Limitations:

- No power calculation prior to this study.

- The observers had only access to parts of the CT scan.

- Patients were placed in supine position in the CT scan, which might affect the CC.

- No Alexander views since the object of this study was to evaluate vertical instability.

Strengths:

- The number of observer was large.

- The number of observations was large
  .
- Standardized radiographs.

7 CONCLUSIONS

7.1 STUDY I

Patients with a chronic AC joint dislocation type III–V treated with a Weaver-Dunn procedure augmented with a PDS braid or a hook plate regained good shoulder function and were equally satisfied with the postoperative result. However, the hook plate did not improve the result significantly in the selected clinical outcome scores, and patients had to undergo an extra surgical procedure to remove the hook plate after 12 weeks. Further, patients treated with a hook plate had significantly more pain during movement at follow-up, and were less satisfied with the cosmetic appearance of the shoulder and scar.

7.2 STUDY II

The results of this small retrospective study suggested that AC joint dislocation Rockwood type V should be treated acutely, when comparing the results after hook plate in the acute phase with the results after delayed surgery with Weaver-Dunn augmented with hook plate.

7.3 STUDY III

The results from this study showed very good outcome and patient satisfaction after acute AC joint dislocation Rockwood types III and V, regardless of operative or non-operative treatment, and did not support routine surgery with hook plate, even for type V dislocations. However, further studies are needed repeat these findings, evaluate long-term outcomes and determine if there are subgroups of patients who would benefit from acute surgery.

7.4 STUDY IV

The study showed that plain radiographs, in combination with CT scans, added precision among observers compared with when classifying acute AC joint dislocations Rockwood types III and V on plain radiographs only. The clinical relevance of this is not clear, since the addition of a CT scan causes more radiation for the patient, and takes more time and resources from the healthcare system. The simplified classification of the AC joint dislocations on plain radiographs showed a higher degree of reproducibility among observers. Further investigation is needed to validate the simpler classification and find any correlations with clinical results.

8 POINTS OF PERSPECTIVE

Since there are uncertainties regarding both classification and treatment, future research is warranted. Shoulder surgeons, orthopedic surgeons and general practitioners referring patients need a simpler classification system, including guidelines regarding horizontal instability, to avoid misclassification and unsatisfactory outcomes after AC joint dislocations.

The validity of the findings from Study III would be strengthened if the results were repeated in further RCTs. It is also important to conduct long-term follow-ups, to see if problems develop over time, such as muscular fatigue or scapula dyskinesis in the non-operatively treated patients. Larger studies are required to identify potential subgroups of patients with specific needs at work or during sports activities, who could benefit from surgical treatment in the acute phase.

Non-surgical treatment needs to be more thoroughly explored; better reporting of non-operative treatment is needed and should include attributes such as the type of training, frequency, intensity, duration, patient compliance, supervision, and reporting of adverse events and dropouts.

It would be valuable to perform prospective multicenter studies of AC joint dislocations, or studies based on national quality registries comparing outcome after operative and non-operative treatment, since it is hard to gather enough patients in one hospital or site.

Since the simpler classification of AC joint dislocations on plain radiographs resulted in better reproducibility, it would be interesting to correlate the two grades of dislocation (subluxation and total dislocation) with clinical symptoms

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