Original Research

The importance of a structured failure analysis in revision acromioclavicular joint surgery: A multi-rater agreement on the causes of stabilization failure from the ISAKOS shoulder committee

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ABSTRACT

Background: Acromioclavicular joint (ACJ) stabilizations are associated with a high overall failure rate with 9.5% of these patients requiring subsequent revision surgery. Consequently, understanding the specific cause of primary ACJ stabilization failure is paramount to improving surgical decision-making in this challenging patient cohort.

Purpose: To (1) identify risk factors and mechanisms for failure following primary arthroscopically-assisted ACJ stabilization to highlight the importance of conducting a detailed failure analysis and to (2) establish revision strategies based on real-life cases of primary failed ACJ stabilization.

Study design: Level of evidence IV.

Methods: A survey was shared internationally among members of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) shoulder committee. The survey contained failure analysis of 11 real-life cases of failed primary arthroscopically-assisted ACJ stabilization. For each case, a thorough patient history, standardized radiographs, and CT scans were provided. Participants were asked to give their opinion on bone tunnel placement, cause of failure (biological, technical, traumatic, or combined), the stabilization technique used, as well as give a recommendation for revision.

Results: Seventeen members of the ISAKOS shoulder committee completed the survey. Biological failure was considered the most common cause of failure (47.1%), followed by technical (35.3%) and traumatic (17.6%) failure. The majority deemed two modifiable factors (i.e., patient’s profession or sport) as well as non-modifiable factors (i.e., patient’s age and time from trauma to initial surgery) to be risk factors for failure. In 10 of 11 cases, the correct fixation device was used in the primary setting (90.9%; 52.8–82.4% agreement); however, in eight of those cases, the technique was not performed correctly (80.0%; 58.8–82.4% agreement). In 8 of all 11 cases, the majority recommended an arthroscopically assisted technique with graft augmentation for revision (52.9–58.8% agreement).

Conclusion: Biological failure and technical failure are the most common reason for failure in primary ACJ stabilization followed by traumatic failure. Besides, biological failure can be triggered by technical errors such as clavicular or coracoidal tunnel misplacement. Consequently, a detailed failure analysis including preoperative CT should be conducted on the causes of primary ACJ failure, and, if possible, an arthroscopically-assisted technique with graft augmentation should be prioritized in revision ACJ surgery.

Clinical relevance: ACJ stabilizations are associated with a high overall failure rate - potentially due to biological and technical properties. When encountering failed arthroscopically-assisted ACJ stabilization, a detailed failure analysis is paramount to understanding the specific cause of failure and to improve surgical decision-making in this challenging patient cohort.

Abbreviations: AC, acromioclavicular; ACJ, acromioclavicular joint; BMI, body mass index; CT, computer tomography; CC, coracoclavicular; ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine; MRI, magnetic resonance imaging; PDS, polydioxanone suture.

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What are the new findings

In the setting of revision ACJ surgery, a conducted failure analysis including preoperative CT scan should be performed, while an arthroscopically-assisted technique with graft augmentation should be prioritized.

Introduction

Achmioclavicular joint (ACJ) stabilizations are associated with an overall failure rate of 20.8% and a subsequent revision rate of 9.5% [1]. Consequently, understanding the specific cause of primary ACJ stabilization failure is paramount to improving surgical decision-making in this challenging patient cohort. As recently stated by a scoping review [2], failed ACJ reconstruction can be potentially associated with technical errors, especially clavicular and coracoidal tunnel malposition, resulting in insufficient fixation (with or without new trauma), fracture [3], or persistent instability, predominantly in the horizontal or rotational plane. As limited evidence exists on the treatment options for primary failed ACJ stabilizations, suggestions for revision surgery may be based predominantly on expert opinions or at the discretion of the surgeon.

Although a few consensus statements and expert opinions are available on classifications and timelines for acute (<3 weeks) and chronic injuries, a unified expert opinion regarding revision ACJ surgery is still lacking [4, 5]. To this, a unified gold standard on preoperative imaging and surgical approaches in primary and revision ACJ surgery has not been elucidated so far, leading to a high diversity in potential risk factors when it comes to conducting a detailed failure analysis. Subsequently, the wide variety of surgical approaches as well as imaging modalities complicates preoperative planning for revision surgery, even for experienced shoulder surgeons.

As such, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) shoulder committee, an international expert panel of shoulder surgeons across four different continents, aimed to (1) identify risk factors and mechanisms for failure following primary arthroscopically-assisted ACJ stabilization to highlight the importance of conducting a detailed failure analysis and to (2) establish revision strategies based on real-life cases of primary failed ACJ stabilization.

It was hypothesized (1) that there would be a high consensus among experienced high-volume shoulder surgeons in identifying risk factors and mechanisms for failure and (2) that there would be a high agreement in recommendations for treatment in the revision setting, besides the wide variety of surgical approaches and imaging modalities available.

Material and methods

Demographics of the ISAKOS shoulder committee

The ISAKOS shoulder committee is an international expert panel of 22 shoulder surgeons. The inclusion of members from 12 different countries and four different continents allows for a global perspective on the understanding and treatment of various shoulder pathologies, such as ACJ instability. Members of the ISAKOS shoulder committee reportedly perform up to 50 acute and up to 30 chronic ACJ stabilization procedures annually.

Data collection

Institutional review board approval was obtained prior to the initiation of the study (reference number: 429/20-S). A retrospective chart review was performed on patients presenting with failed prior arthroscopically-assisted ACJ stabilization from an institutional shoulder registry. All cases were obtained from the author’s institution between 06/2015 and 09/2020. Patients eligible for study inclusion were those 18 years or older who had previously failed arthroscopically-assisted ACJ stabilization after sustaining acute or chronic type III, IV, V, or VI ACJ dislocation. Failure was defined as loss of reduction leading to chronic scapular or glenohumeral joint dysfunction or pain, upper limb impairment, persistent vertical or horizontal instability of the ACJ, hardware failure, and fractures. A total of 11 cases were selected for review representing a variety of failed arthroscopically-assisted reconstructions.

All shoulder surgeons among the ISAKOS shoulder committee were asked for their interest in participating in this study. Those who volunteered were presented with a custom-made survey (see Supplementary Material 1) through LimeSurvey (LimeSurvey GmbH, Hamburg, Germany). The first part of the survey was designed to assess the surgeon’s experience and preference when encountering patients with acute and chronic ACJ instabilities. This part of the survey contained questions regarding the surgeons’ surgical treatment of acute and chronic ACJ dislocations—specifically regarding preoperative imaging modalities used, the need for horizontal stabilization based on the modified Rockwood classification [4], and the preferred surgical technique.

The second part of the survey contained 11 real-life cases of failed primary arthroscopically-assisted ACJ stabilizations that were presented at the author’s institution. Each case included two basic sets of data: case history and standardized radiological imaging:

- Patients’ demographics including age, gender, body mass index (BMI), age at first surgery, time interval from trauma to initial surgery, profession, sport, patients’ history including initial trauma, primary surgical technique, and, if applicable, the second trauma following surgery.
- Standardized radiological imaging including panorama a. p. view and Alexander- or y-view of the affected shoulder, following the failure of the primary ACJ stabilization procedure showing the clavicular and coracoid tunnel placement and width, one to two-slice axial and coronary computed tomography (CT) scans, and additional three-dimensional reconstructions (if available), showing the clavicular and coracoid bone tunnel position and width in relation to anatomic landmarks.

Surgeons were then asked to give their expert opinion on the causes of failure based on the data set. The questions concerned the clavicular and coracoid tunnel placement, the technique used, and the surgeon’s opinion as to the cause of failure (e.g., technical, biological, traumatic, or combination). The participating surgeons were not given any information on the causes of failure or accuracy of tunnel placement at the inception of the study. Finally, for each case, surgeons were asked which technique they would recommend for future revision. All questions, except the surgical technique for acute dislocations, chronic dislocations, and each revision, were single-choice questions. The technique used was added as free text and later categorized by M.H. and D.P.B. until consensus was achieved between both reviewers.

Statistical analysis

After the 4-month period of data entry (06–09/2021), all questionnaires that were completed were extracted from the online survey database. The number of respondents per answer and the corresponding percentage were reported.
Results

A total of 17 members of the ISAKOS shoulder committee completed the survey, from which 12 (70.6%) members reported to routinely perform ACJ stabilization in acute cases, and 13 (76.5%) reported to perform ACJ stabilization in the chronic setting. Participants reported to perform between 2 and 50 acute and 1 and 30 chronic ACJ stabilizations annually. The majority of participants (82.4%) agreed with the cut-off between acute and chronic injuries to be set at three weeks following trauma – the remaining participants set the cut-off to be at 1 week (5.9%) or 6 weeks (11.8%).

Acute acromioclavicular joint stabilization – imaging & surgical technique

In cases of acute ACJ instability, a.p. and axial view radiographs of the injured shoulder are utilized by most participants performing acute ACJ stabilization (75% and 58.3%). Half of the participants use an Alexander view X-ray. A panorama view X-ray (41.7%) or a Zanca view X-ray (33.3%) is utilized less frequently. Preoperative magnetic resonance imaging (MRI) of the injured shoulder is performed more frequently than CT (58.3% vs. 16.7%). The majority (91.7%) of surgeons who are regularly performing acute ACJ stabilizations use an arthroscopically-assisted technique (see Table 1). Only one surgeon uses an open Weaver-Dunn procedure in acute cases.

Different choices regarding graft use in the acute setting and primary AC capsule repair were reported. Most commonly, the stabilization is performed arthroscopically-assisted without a graft, but with AC capsule repair (41.7%). It was reported that the need to address horizontal instability is dependent on the severity of the injury (see Table 2) with majority agreement reached for Rockwood IV and V injuries (83.3%). Consequently, the AC capsule is addressed by 58.3% of the participants. An autograft or allograft is used by one-third of the participating surgeons that perform acute ACJ stabilization. Additionally, the vast majority of participants reported to perform over-reduction in acute cases (83.3%).

Chronic acromioclavicular joint stabilization – imaging & surgical technique

In cases of chronic ACJ instability, a.p. and axial view radiographs of the injured shoulder are utilized by most participants performing chronic ACJ stabilization (84.6% and 69.2%). Additionally, 53.8% of the participants use an Alexander view and Zanca view X-ray (53.8%). A panorama view X-ray (23.1%) is utilized less frequently. Preoperative MRI of the injured shoulder is performed more frequently than CT (61.5% vs. 15.4%). The majority (76.6%) of surgeons regularly performing chronic ACJ stabilizations uses an arthroscopically-assisted technique (see Table 3). An open Weaver-Dunn procedure, anatomic coracoclavicular ligament reconstruction (ACCR), and hook plate fixation are each performed by a single surgeon in chronic cases. One surgeon changed from an arthroscopically-assisted technique (with a graft and AC capsule repair) in the acute setting to a hook plate fixation in chronic cases.

Table 2
Respondents’ answers regarding the need for addressing horizontal instability in acute cases of acromioclavicular joint instability with regard to the Rockwood classification.

<table>
<thead>
<tr>
<th>Rockwood III</th>
<th>Rockwood IV</th>
<th>Rockwood V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it necessary to address horizontal instability in the acute setting?</td>
<td>6x “No” (50%)</td>
<td>10x “Yes” (83.3%)</td>
</tr>
<tr>
<td>5x “Uncertain” (41.7%)</td>
<td>1x “No” (8.3%)</td>
<td>1x “No” (8.3%)</td>
</tr>
<tr>
<td>1x “Yes” (8.3%)</td>
<td>1x “Uncertain” (8.3%)</td>
<td>1x “Uncertain” (8.3%)</td>
</tr>
</tbody>
</table>

Majority agreement is bolded.

An allograft or autograft is used by 76.9% of the participating surgeons that perform chronic ACJ stabilization. Majority agreement was reached on the need for addressing horizontal instability cases of chronic ACJ instability across Rockwood types III-V (Table 4). The AC capsule is addressed in 58.3% of the participants. This is, however, dependent on the severity of the injury (see Table 4). Sixty-one percent of the participants perform over-reduction in chronic ACJ stabilization. It should be noted that one surgeon changed from an arthroscopically-assisted technique (with a graft and AC capsule repair) in the acute setting to a hook plate fixation in chronic cases.

Failure analyses

Overall, biological failure was seen as the most common reason for failure of ACJ stabilization (47.1%), followed by technical (35.3%) and traumatic (17.6%) failure. A thorough analysis of each case is provided in Supplementary Material 2.

Discussion

The most important finding of this study was that among biological failure (47.1%) and technical impurities (35.3%) are considered the most common reasons for failure after ACJ stabilization followed by traumatic (17.6%) failure. Furthermore, even though an appropriate fixation technique was utilized in the primary setting, biological failure is often triggered by technical errors such as clavicular or coracoidal tunnel misplacement. Also, modifiable risk factors (i.e., patient’s profession and sport) as well as patient’s age and time interval from trauma to initial surgery may impact the risk for failure following primary arthroscopically-assisted ACJ stabilization. This may be of clinical relevance as patients at risk for failure should be informed preoperatively to enable shared decision-making. Consequently, if possible, an arthroscopically assisted technique with graft augmentation was majorly recommended for revision surgery.

In this study, the most commonly recommended surgical technique for revision ACJ stabilization was an arthroscopically-assisted technique with allograft or autograft augmentation, independent of the failure mechanism, risk factors, or bone tunnel position in the initial

Table 3
Techniques used by the respondents for chronic ACJ stabilization.

| AC – acromioclavicular; ACJ – acromioclavicular joint. |
| What is your preferred technique for chronic ACJ stabilization? (as % of the participants that perform chronic ACJ stabilizations) |
| 6x Arthroscopically-assisted technique with a graft and AC capsule repair (46.1%) |
| 2x Arthroscopically-assisted technique with a graft, but without AC capsule repair (15.4%) |
| 1x ACCR (7.7%) |
| 1x Arthroscopically-assisted technique without a graft, but with AC capsule repair (7.7%) |
| 1x Arthroscopic Weaver-Dunn procedure with a graft (7.7%) |
| 1x Hook plate (7.7%) |
| 1x Open Weaver-Dunn procedure (7.7%) |
| AC – acromioclavicular; ACJ – acromioclavicular joint; ACCR – anatomic coracoclavicular ligament reconstruction. |
arthroscopically-assisted ACJ stabilization procedure. However, when scanning the current literature, clinical data on the use of this hybrid technique for revision cases are highly limited. In a retrospective study, Kraus et al. [6] reported on 13 cases that were revised using an arthroscopically-assisted ACJ stabilization with a TightRope® and gracilis autograft augmentation for the AC and CC ligaments. At the final follow-up, the collected patient-reported outcome measures and postoperative radiographic CC-distance revealed no significant difference when compared to a control group of patients that underwent the same surgical procedure for the treatment of chronic primary ACJ instability. However, the lack of data emphasizes the need for further investigations with longer follow-up and/or larger cohorts.

Additionally, another important consideration in this review is that horizontal instability should be addressed in acute high-grade ACJ instabilities (Rockwood IV and V injuries) as well as chronic Rockwood IIIb-V injuries that failed conservative treatment [7] to minimize future failure. In these cases, using a non-absorbable, high-strength tensile suture adequately restores physiological horizontal ACJ instability when combined with CC reconstruction [8]. In chronic or revision cases, an anatomic arthroscopically-assisted ACJ stabilization should be performed to reconstruct both the AC and CC ligaments [2]. In contrast, PDS – due to its absorption over time – may not be a sufficient option. Interestingly, one volunteer acknowledged the decreasing healing potential of the AC ligaments within the first week following trauma [9], which may introduce the necessity of graft augmentation between 1 and 3 weeks after trauma in selected patients. However, the majority agreed that graft augmentation for the support of biological healing is only necessary in chronic cases of ACJ instability [5].

In this failure analysis, it was noted that survey participants usually chose between one or two surgical techniques that they recommended for revision ACJ surgery. These recommendations included (1) double-tunnel or (2) single-tunnel CC stabilization with graft augmentation and AC augmentation with a graft, (3) techniques involving a graft looped around the clavicle and coracoid without new tunnel placement, (4) hook plate fixation and graft augmentation, (5) ACCR, (6) Weaver–Dunn procedure, (7) Dewar/Weaver–Dunn procedure, (8) Weaver–Dunn procedure/conservative treatment, and (9) conservative treatment. This recommendation also reflects the current literature, according to which a few authors still rely on open procedures, such as ACCR [10], Dewar Procedure [11], Weaver–Dunn procedure [12], or hook plate fixation, as current data show satisfactory results for these patients [5,10,13,14].

Additionally, tunnel widening, which is known to increase the risk for subsequent fracture [15], was shown to commonly occur following arthroscopically-assisted and open ACJ stabilization and may be encountered in revision cases [16]. In revision cases, where coracoidal tunnel placement or increased width may raise concerns for a perioperative fracture, an allograft loop (semitendinosus or tibialis anterior) and additional suture augmentation around the clavicle and coracoid was recommended to avoid fractures of the coracoid. Alternatively, hook plate fixation may be considered in these cases. Consequently, when encountering cases of failed ACJ stabilization, CT scans allow to preoperatively (re-)evaluate bone tunnel position and size [2]. If bone tunnels are placed correctly, the re-use of the tunnels may be a valid option, achieving comparable stability to the primary reconstruction [17]. If bone tunnels are placed non-anatomically, however, bone quality including bone-marrow density and subsequent load-to-failure may be compromised, and tunnel reuse is not advised [18,19]. In failed cases, due to tunnel malposition, an anatomical reconstruction (with new tunnel placement) of the AC and CC ligaments using a tendon graft is suggested [2]. As both single-tunnel and double-tunnel suture button systems sufficiently restore ACJ stability and native biomechanical properties [20], the technique used may be at the surgeon’s discretion. However, surgeons should take into account that an increased number of tunnels is also associated with an increased risk of fracture [21]. Thus, a single-tunnel technique should be preferred over a double-tunnel technique, especially in the setting of non-reusable bone tunnels.

Although this survey provides valuable results based on an international perspective, there are some limitations that should be acknowledged. First, this study represents an expert opinion on the treatment strategies of revision ACJ stabilization rather than objective evidence. However, data on revision ACJ surgery remain limited, as such, an international perspective is presented regarding the surgical approach of acute, chronic, and revision cases of ACJ instability. Second, providing the presented radiographic and demographic data set does not allow for a detailed preoperative assessment as would be necessary in a clinical setting. Consequently, future studies should focus on objective data in order to establish an evidence-based approach to arthroscopically-assisted ACJ revisions. They should incorporate detailed guidelines regarding failure mechanisms as well as bone tunnel placement and reusability in the revision setting. Additionally, the authors of this study only presented 11 cases, which do not represent all failure causes available, especially when it comes to technical impurities. However, the data gathered from this study highlight the difficulty when encountering revision ACJ surgery, even among highly experienced shoulder surgeons. Furthermore, within this failure analysis, patterns were observed which may improve the shared decision-making between surgeons and their patients in the primary setting, especially regarding the importance of patient education regarding modifiable risk factors and their impact on failure following ACJ stabilization. Ultimately, this failure analysis may serve to further improve the treatment of high-grade ACJ re-instability and provide guidance for less experienced shoulder surgeons who infrequently perform ACJ revision surgery.

Conclusion

Biological failure and technical failure are the most common reason for failure in primary ACJ stabilization followed by traumatic failure. Besides, biological failure may be triggered by technical errors such as clavicular or coracoidal tunnel misplacement. Consequently, a detailed failure analysis including preoperative CT should be conducted on the causes of primary ACJ failure, and, if possible, an arthroscopically-assisted technique with graft augmentation should be prioritized in revision ACJ surgery.

Conflict of interest

Daniel P. Berthold, Lukas N. Muench, Pavel Kadantsev, Bastian Scheiderer, Emilio Calvo, and Maximilian Hinz report no conflict of interest. Augustus D. Mazzocca reports research grants from Arthrex Inc., is a consultant for Arthrex Inc., and receives royalties from Arthrex Inc. Sebastian Siebenlist is a consultant for Arthrex GmbH, medi GmbH & Co. KG, and KLS Martin Group. Andreas B. Imhoff is a consultant for Arthrex GmbH, Arthrosurface, and medi GmbH & Co. and receives royalties from Arthrex GmbH and Arthrosurface. Knut Beitzel is a consultant for Arthrex GmbH and receives royalties from Arthrex GmbH.
Author contributions
All listed authors have contributed substantially to this work: DPB, LNM, KB, and MH have designed the survey and collected data. DPB, LNM, PK, KB, and MH performed data analysis, literature review, and primary manuscript preparation. SS, BS, ADM, EC, and ABI assisted with interpretation of the results as well as editing and final manuscript preparation. All authors read and approved the final manuscript.

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None.

Ethical approval
This study was approved by the Ethics Committee of the Technical University of Munich (reference number: 429/20-S).

Informed consent
Informed consent was obtained from all survey participants.

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Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.jisako.2023.08.003.

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