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Original article

Is coracoclavicular stabilisation alone sufficient for the endoscopic treatment of severe acromioclavicular separation (Rockwood types III, IV, and V)?

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ARTICLE INFO

Article history:
Received 2 July 2015
Accepted 31 August 2015

Keywords:
Acromioclavicular joint disruption
Acute
Rockwood types III-IV-V
Arthroscopic stabilisation

ABSTRACT

Background: The primary objective was to evaluate correlations linking anatomical to functional outcomes after endoscopically assisted repair of acute acromioclavicular joint disruption (ACJD).

Hypothesis: Combined acromioclavicular and coracoclavicular stabilisation improves radiological outcomes compared to coracoclavicular stabilisation alone.

Material and methods: A prospective multicentre study was performed. Clinical outcome measures were pain intensity on a visual analogue scale (VAS), subjective functional impairment (QuickDASH score), and Constant's score. Anatomical outcomes were assessed on standard radiographs (anteroposterior view of the acromioclavicular girdle and bilateral axillary views) obtained preoperatively and postoperatively and on postoperative dynamic radiographs taken as described by Tauber et al.

Results: Of 116 patients with acute ACJD included in the study, 48% had type III, 30% type IV, and 22% type V ACJD according to the Rockwood classification. Coracoclavicular stabilisation was achieved using a double endobutton in 93% of patients, and concomitant acromioclavicular stabilisation was performed in 50% of patients. The objective functional outcome was good, with an unweighted Constant's score $\geq 85/100$ and a subjective QuickDASH functional disability score ≤ 10 in 75% of patients. The radiographic analysis showed significant improvements from the preoperative to the 1-year postoperative values in the vertical plane (decrease in the coracoclavicular ratio from 214 to 128%, $P = 10^{-6}$) and in the horizontal plane (decrease in posterior displacement from 4 to 0 mm, $P = 5 \times 10^{-5}$). The anatomical outcome correlated significantly with the functional outcome (absolute R value = 0.19 and $P = 0.045$). We found no

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statistically significant differences across the various types of constructs used. Intra-operative control of the acromioclavicular joint did not improve the result. **Implantation of a biological graft significantly improved both the anatomical outcome in the vertical plane ($P=0.04$) and acromioclavicular stabilisation in the horizontal plane ($P=0.02$).** The coracoclavicular ratio on the anteroposterior radiograph was adversely affected by a longer time from injury to surgery ($P=0.02$) and by a higher body mass index (BMI) ($P=0.006$). High BMI also had a negative effect on the difference in the distance separating the anterior edge of the acromion from the anterior edge of the clavicle between the injured and uninjured sides, as assessed on the axillary views ($P=0.009$).

Conclusion: This study demonstrates that acute ACJD requires stabilisation in both planes, i.e., at the coracoclavicular junction and at the acromioclavicular joint. Coracoclavicular stabilisation alone is not sufficient, regardless of the type of implant used. **Implantation of a biological graft should be considered when the time from injury to surgery is longer than 10 days.** The weight of the upper limb should be taken into account, with 6 weeks of immobilisation to unload the construct in patients who have high BMI values.

Level of evidence: II, prospective non-randomised comparative study.

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1. Introduction

Acromioclavicular joint dislocation (ACJD) is among the main focusses of controversy in traumatology. The six-grade classification system devised by Rockwood is widely used in published studies. Although a consensus seems to exist regarding the management of type IV ACJD (irreducible posterior dislocation of the clavicle) and type V ACJD (major collapse of the upper limb with a coracoclavicular distance more than double the normal value), no clear recommendations exist for type III ACJD, for which the available meta-analyses fail to provide definitive conclusions [1,2]. The numerous and diverse open surgical techniques were not compared before the introduction of endoscopic methods. Endoscopic surgery for ACJD is designed to ensure stabilisation, at least in the vertical plane, and in some cases also in the horizontal plane, generally using the double endobutton technique [2].

Whether repairing an oblique ligament plane by a vertical suspension procedure makes good sense deserves discussion. Furthermore, the suspension system is disrupted at two sites, raising the issue of whether a good outcome can be obtained by repairing only the coracoclavicular site. Also unclear is whether horizontal acromioclavicular stabilisation is mandatory. Finally, the use of synthetic ligaments to replace the cruciate ligament at the knee has been abandoned, suggesting that a biomaterial containing a small fibroblast population may not be ideal for suspending the upper limb under the clavicle and that a biological graft might be preferable.

The primary objective of this study was to evaluate potential correlations linking anatomical and functional outcomes of endoscopic ACJD repair. The working hypothesis was that combined acromioclavicular and coracoclavicular stabilisation improves radiological outcomes compared to coracoclavicular stabilisation alone and that this improvement translates into better clinical outcomes.

2. Material and methods

2.1. Study design

A prospective multicentre study was sponsored by the French Society for Arthroscopy (Société française d'arthroscopie [SFA]). The head investigators were Fabrice Duparc (Rouen) and Johannes Barth (Grenoble). Patients were recruited over the 12-month period from July 2012 to July 2013 by 22 surgeons in 14 surgical centres. Clinical and radiological follow-up was provided until July 2014

to ensure that data were available for three time points, namely, preoperatively and 3 and 12 months postoperatively.

2.2. Inclusion and exclusion criteria

Inclusion criteria were severe acute ACJD (types III, IV, or V) treated surgically within 21 days of the injury. Exclusion criteria were presence of a fracture, concomitant lesions (cuff tear or labral damage), or glenohumeral osteoarthritis. The operative technique was at the discretion of the surgeon but had to consist at least in endoscopically assisted coracoclavicular stabilisation. Both acromioclavicular stabilisation and augmentation with biological tissue were optional. Patients were included anonymously using CALIMED® software (CALIMED, Marseille, France).

2.3. Outcome assessments

The clinical evaluations included an assessment of pain intensity on a visual analogue scale (VAS), determination of the QuickDASH score to assess subjective functional impairment, and determination of Constant's score to assess objective function.

Standard radiographs including a comparative anteroposterior view of the acromioclavicular girdle and an axillary view were obtained preoperatively and postoperatively. Postoperatively, the protocol described by Tauber et al. [3] was followed to obtain dynamic radiographs in order to assess persistent horizontal instability defined as a greater than 12° difference between 0° of flexion (neutral position) and 60° of flexion, when measuring the Gleno-Acromio-Clavicular Angle (GACA) on the affected side.

2.4. Statistical analysis

The CALIMED database was locked and the data exported to an Excel file. Statistical tests were carried out at the Rouen Biostatistics Department, by J.F. Ménard. Qualitative variables were displayed in contingency tables and compared using the Chi² or Fisher's exact test. Medians were compared using the Mann-Whitney and Kruskal-Wallis tests. Spearman's correlation coefficient was computed for quantitative variables.

The primary anatomical outcome measure was the ratio of the coracoclavicular distances on the injured over the unweighted uninjured sides (in the vertical plane). For function, the primary outcome measure was Constant's score.

Secondary measures for anatomical outcomes were the difference in coracoclavicular distance between the injured and uninjured sides in the vertical plane, the difference in acromioclavicular

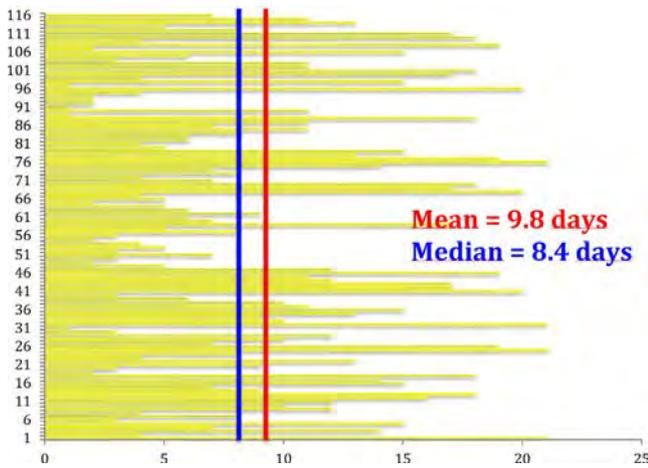


Fig. 1. Time from injury to surgery.

distance between the injured and uninjured sides in the horizontal plane, and the difference in the glenoacromioclavicular angle defined by Tauber et al. [3] the results are given in results section about horizontal instability. Secondary functional outcomes were the VAS pain score and the QuickDASH score.

3. Results

3.1. Patients

Among 140 patients surgically treated for ACJD, 116 were included at the acute phase, including 96 (83%) men. Mean age was 37 years (20–67) and mean body mass index (BMI) was > 25 kg/m². Mean time from injury to surgery was 10 days (1–21) (Fig. 1). The dominant side was affected in 50 (53%) patients. No risk factors for ACJD were identified. One patient had a history of ipsilateral clavicular fracture and another of surgery for contralateral ACJD.

Only 10% of patients had no sporting activities, whereas 56% participated in recreational sports and 34% in contact sports. The occupation was manual in 51% of patients and sedentary in 39%; 5% of patients were professional athletes, 3% had no occupation, and 2% were retired. The injury occurred during sports in 57% of patients (Fig. 2 for the distribution across types of sport), a traffic accident in 38%, and a domestic accident in 5%.

In the Rockwood classification, 48% of injuries were type III, 30% type IV, and 22% type V.

Distribution of sporting activities before surgery

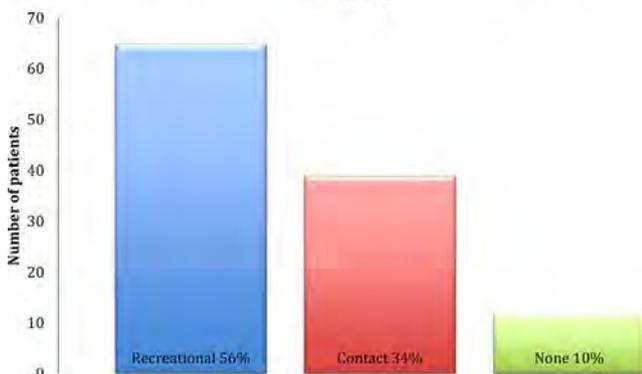


Fig. 2. Distribution of patients according to sporting activities.

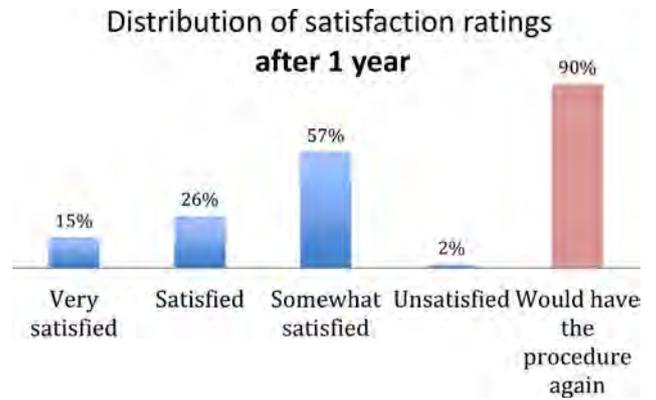


Fig. 3. Patient satisfaction.

3.2. Operative technique

The only surgical procedure required by the study protocol was endoscopic coracoclavicular stabilisation. This procedure was performed using the double endobutton technique in 93% of cases. Acromioclavicular stabilisation was performed also in 50% of patients. Table 1 details the procedures performed.

3.3. Postoperative care

The duration of immobilisation was 21 to 30 days in 53% of patients and 31 to 45 days in 47% of patients. Immobilisation was with an orthopaedic vest in 61% of patients, a simple sling in 34%, and another device in 3%; no immobilisation was used in 2% of patients.

3.4. Complications

Early loosening occurred in 3 patients, including 1 who required revision surgery. Complications were recorded in 24 (20.7%) patients and consisted of infection ($n=2$), reflex sympathetic dystrophy ($n=7$), distal clavicle osteolysis ($n=1$), device impingement ($n=5$), coracoid process fracture ($n=1$), and late device failure ($n=8$). Revision surgery was performed in 3 patients: 1 patient each underwent lavage to treat infection, removal of an endobutton that was causing discomfort under the skin, and repeat stabilisation after disassembling of the initial construct.

3.5. One-year functional outcomes

At the 1-year time point, clinical data were available for 105 (90.5%) patients and radiological data for 98 (84.5%) patients. Only 41% of patients reported being very satisfied or satisfied, although 90% would have the procedure again (Fig. 3). Fig. 4 reports the VAS pain scores 3 and 12 months after surgery. In 73% of patients, there was little or no pain (VAS score, 0–2). After 3 and 12 months, 55% and 90% of patients, respectively, had returned to work; this parameter was not influenced by whether the injury was work-related (Fig. 5). Full return to previous sporting activities was reported by 27% of patients after 3 months and 73% after 12 months, with no noticeable difference between recreational and contact sports (Fig. 6). Fig. 7 reports the mean and distribution of Constant's score values. The functional outcome was good (unweighted Constant's score $\geq 85/100$ in 82% of patients). The QuickDASH subjective functional disability score was ≤ 10 in 75% of patients (Fig. 8).

Table 1
Details on the surgical procedures.

Coracoclavicular stabilisation (116)	Double endobutton (99) (46 Dog Bone™, 41 TightRope®, 11 Twinbridge®, 1 ZipLoop™)	Cerclage (16)	Weaver and Dunn (palmaris longus graft) (1)		
Additional fixation (6)	4 V-shaped fibretape	1 V-shaped double Dog Bone™	1 MaxBraid		
Biological graft (6)	6 Weaver and Dunn including 1 combined with a palmaris longus graft			42 by opening	
Intra-operative control (86)	44 by Xray				
Acromioclavicular stabilisation (63)	36 pants-over-vest suture	13 fixations by temporary pinning	4 reverse Weaver and Dunn	5 isolated control	5 direct sutures

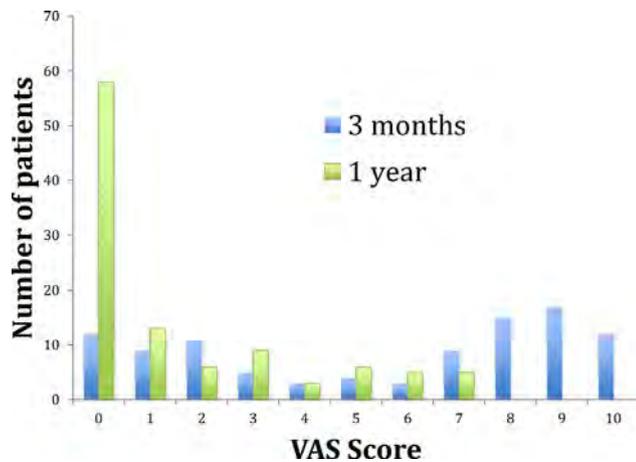


Fig. 4. Pain intensity 3 and 12 months after surgery.



Fig. 6. Return to sports (NR: not relevant). Sports subgroups, after 1 year. Recreational (n=58): full return in 76% and partial return in 12% of patients. Contact (n=36): full return in 72% and partial return in 11% of patients.

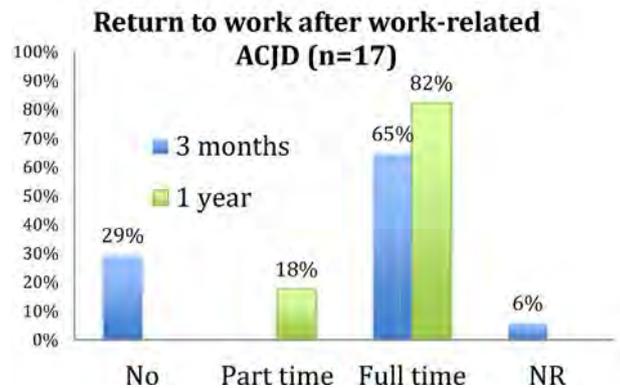


Fig. 5. Return to work (NR: not relevant).

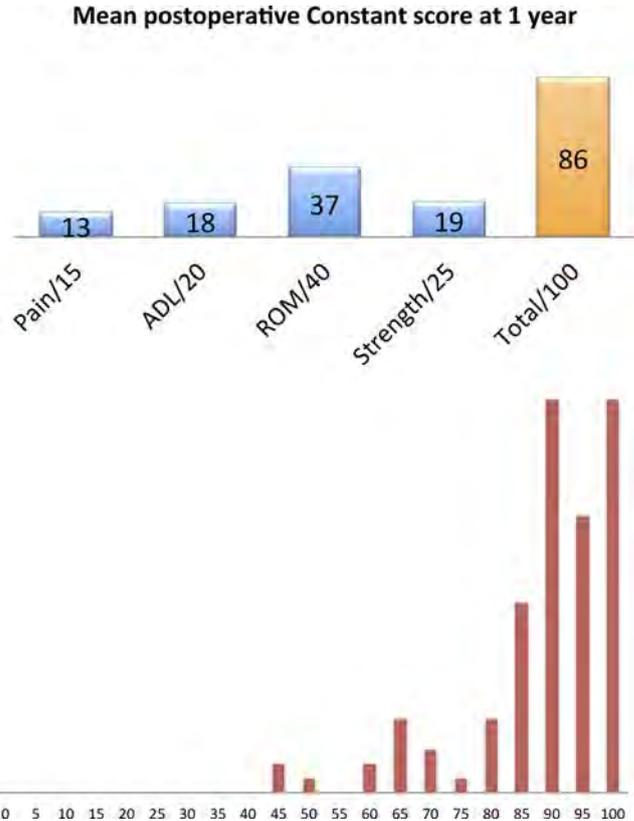


Fig. 7. Mean and distribution of Constant's score values. ADL: activities of daily living; ROM: range of motion. 82% of patients had an unweighted Constant's score ≥ 85 after 1 year.

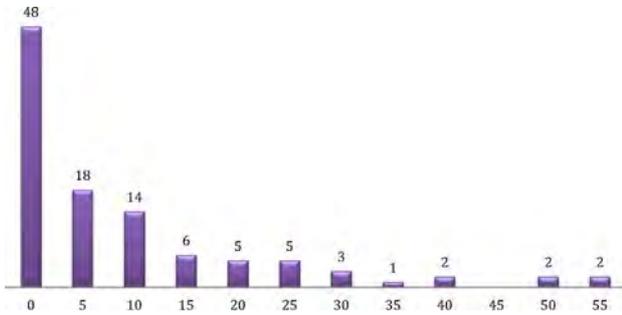


Fig. 8. QuickDASH score. 75% of patients had a QuickDASH score ≤ 10 after 1 year.

3.6. One-year radiological outcomes

The analysis in the vertical plane of the acromioclavicular girdle on the anteroposterior view and the difference in coracoclavicular distance between the injured and uninjured sides (Fig. 9) showed a significant improvement in mean values between the preoperative and 1-year evaluations (9.1 mm and 2 mm, respectively; $P < 10^{-6}$). Similarly, the mean ratio of coracoclavicular distances between the injured and uninjured sides (coraco-clavicular index) improved significantly (214% and 128%, respectively; $P < 10^{-6}$) (Fig. 10).

The analysis in the horizontal plane on the axillary view and the difference in the distance from the anterior edge of the acromion to the anterior edge of the clavicle (Fig. 11) revealed a significant

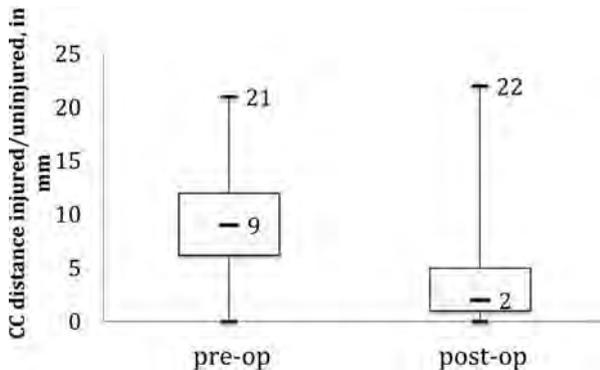


Fig. 9. Coracoclavicular distance after 1 year measured on both sides on an anteroposterior radiograph of the acromioclavicular girdle. Difference in CC distance between the injured/uninjured sides before and after surgery. Mean values: 9.1 mm preoperatively and 2 mm postoperatively. $P < 10^{-6}$.

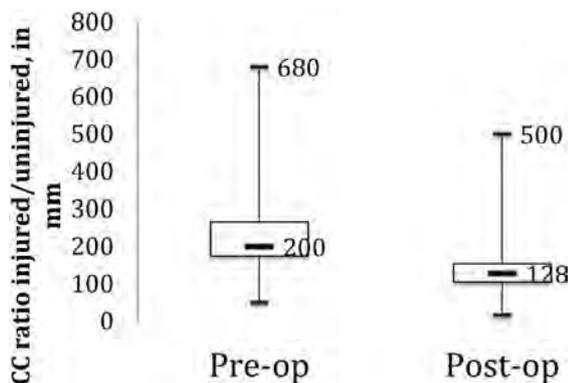


Fig. 10. Coracoclavicular index after 1 year measured on both sides on an anteroposterior radiograph of the acromioclavicular girdle. Ratio of CC distance on the injured/uninjured sides before and after surgery. Ratio of CC distance on the injured/uninjured sides before and after surgery. Mean values: 214% preoperatively and 128% postoperatively. $P < 10^{-6}$.

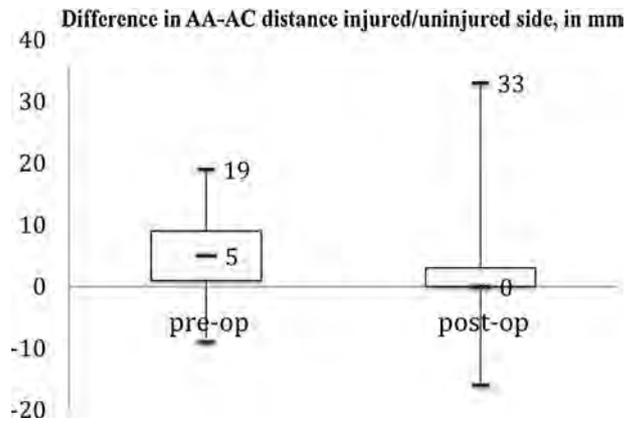


Fig. 11. Horizontal displacement after 1 year measured on both sides on axillary views (distance from the anterior edge of the acromion [AA] to the anterior edge of the clavicle [AC]). Mean values: 4.15 mm preoperatively and 0 mm postoperatively. $P < 10^{-5}$.

improvement in mean values from the preoperative to the 1-year time points (4.2 mm and 0 mm, respectively; $P < 10^{-5}$). Thus, significant improvements were documented postoperatively in all planes.

The analysis of horizontal dynamic instability according to Tauber et al. [3], through the measurement of the GACA, indicated that the acromioclavicular joint was stable in 79% of patients after 12 months (Fig. 12) with a GACA inferior to 12° .

3.7. Correlations

Initial ACJD severity as assessed according to Rockwood correlated with Constant's score after 1 year. The anatomical outcomes were not significantly associated with either patient satisfaction or the immobilisation modality.

In contrast, the anatomical outcome correlated with the functional outcome. On the overall series, the anatomical outcome (coracoclavicular index between injured and non injured sides on the AP view) correlated significantly with the functional outcome (unweighted Constant score). Fig. 13 shows on the graph an absolute R value = 0.19 and $P = 0.045$. Higher values for the coracoclavicular ratio on the anteroposterior radiograph or for the difference in the distances separating the anterior edge of the acromion from the anterior edge of the clavicle on the axillary views were significantly associated with higher pain scores ($P = 0.0009$) and lower QuickDASH values ($P = 0.05$).

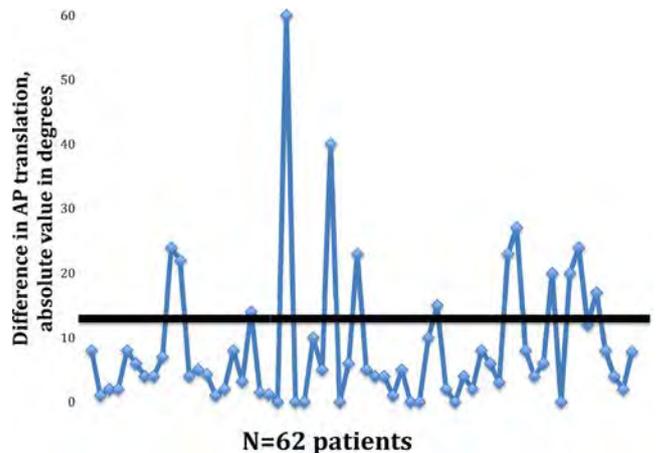


Fig. 12. Dynamic horizontal instability (Protocol described by Tauber et al. [3]). AP: anteroposterior. 13 patients had glenoacromial angle values greater than 12° (instability according to Tauber et al. [3]).

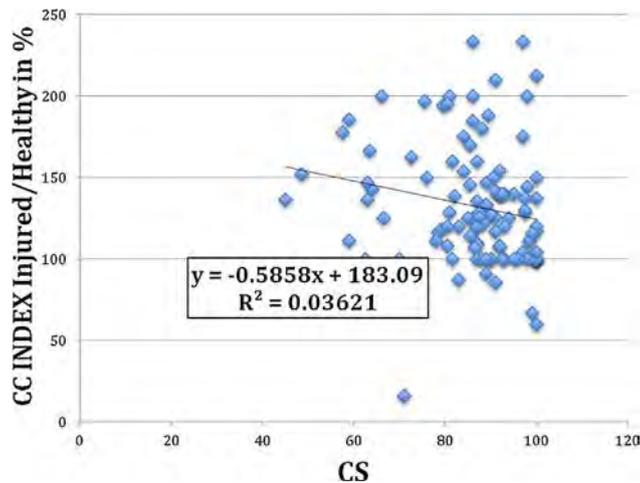


Fig. 13. CC Index Injured/Healthy correlated with unweighted Constant Score (CS) : IRI = 0.19. $P = 0.045$.

A higher value for the coracoclavicular ratio on the antero-posterior radiograph was significantly associated with a worse Constant's score value ($P = 0.002$).

No significant differences were found according to the material used or to whether visual or radiological control of the joint was performed intraoperatively. In contrast, the use of a biological tissue graft was associated with better results for the coracoclavicular distance and ratio ($P = 0.04$). Stabilisation of the acromioclavicular joint was associated with improved horizontal stability ($P = 0.02$).

The VAS pain score, Constant's score, and QuickDASH score were not significantly influenced by BMI, age, or time from injury to surgery. In contrast, a longer time from injury to surgery was associated with worse coracoclavicular ratio values on the antero-posterior radiograph ($P = 0.02$). A higher BMI was associated with worse coracoclavicular ratio values on the anteroposterior radiograph ($P = 0.006$) and with a greater difference in the distance from the anterior edge of the acromion to the anterior edge of the clavicle on the axillary views ($P = 0.009$).

4. Discussion

The objective functional result in our study (Constant's score, 85/100) is at the lower end of the previously reported range (from 84 in a study by Yoo et al. [4] to 96 in another by Lädermann [5]). Greater initial severity of the injury as assessed according to Rockwood influenced the final outcome, in keeping with a study by Wolf and Pennington [6].

A major finding from our study is that the anatomical outcome correlates with the functional outcome (IRI = 0.19 and $P = 0.045$). Obtaining this information was the primary objective of our study. Thus, accurate anatomical reduction is a prerequisite to a good functional outcome. This finding is at odds with the suggestion by some authors [7] that secondary loss of reduction may have no effect on the functional outcomes. Isolated coracoclavicular stabilisation using the double endobutton technique seems insufficient to provide lasting stability of the acromioclavicular joint [8]. Our study established clearly that the radiological outcome was significantly influenced by concomitant acromioclavicular stabilisation ($P = 0.02$), as well as by using a biological graft ($P = 0.04$), although this last result should be viewed with caution as only 6 patients were managed with this technique.

Loss of reduction after treatment with a double endobutton alone may be ascribable to insufficient strength of the implant and absence of acromioclavicular stabilisation.

Authors who advocate isolated coracoclavicular stabilisation rely on either biomechanical or biological methods. Biomechanical methods for increasing biomaterial strength include increasing the number of double endobuttons [8,9] and using larger-diameter synthetic grafts [10,11]. However, Milewski et al. documented a non-negligible risk of fractures of the coracoid process and clavicle [12] and therefore advised decreasing the diameter of the tunnels drilled in the clavicle, refraining from drilling tunnels within 15 mm of the acromioclavicular joint, and keeping a distance of at least 20 mm between two clavicular tunnels. They also recommended either wrapping around the coracoid process rather than drilling it or, if a tunnel is drilled, keeping its diameter as small as possible and first improving the exposure of the base of the coracoid process. Cook et al., however, reported significant loss of reduction when the clavicular tunnel was in an excessively medial position, i.e., medial to the lateral fourth of the clavicle (for the conoid ligament). The main effects of all these recommendations are to complicate the planning and execution of the procedure and inducing a risk of decreased reproducibility, most notably in emergency departments staffed mainly by junior surgeons. Whatever the case, all these constructs are anatomical inasmuch as they follow the orientation of the conoid and trapezoid ligaments. Unfortunately, our study was unable to demonstrate any differences across the various implant types. The other method used consists in implanting a biological autograft [4,13,14]. We found that using an anatomical or non-anatomical graft was significantly associated with better radiological outcomes. In contrast to Modi et al., we did not detect a superiority of anatomical constructs over non-anatomical constructs (Weaver and Dunn type) [15,16].

The determining factor seemed to be control and stabilisation of the acromioclavicular joint, combined with coracoclavicular stabilisation, in agreement with many previous reports [5,17,18]. We also showed that intra-operative image amplifier guidance failed to improve the quality of the reduction.

Surgical indications in acute ACJD remain highly controversial, particularly for Rockwood type III lesions [1,19]. Our finding that good-quality anatomical reduction was associated with improved functional outcomes may seem to support surgical treatment. However, our study cannot determine whether surgery is desirable, since there was no control group treated non-operatively. In addition, Cho et al. recently reported poor inter-observer reproducibility of the Rockwood classification [20], suggesting possible misclassification of patients across the various types of severe ACJD.

Our finding that a higher BMI was associated with poorer anatomical outcomes is worthy of comment. Severe ACJD results in drooping of the scapula and of the rest of the upper limb, since the suspending acromioclavicular and coracoclavicular ligaments are torn. Thus, in patients with high BMI values, the heavy upper limb may place greater stress on the construct. Thus, one would expect that prolonged support (> 30 days) of the upper limb by a simple sling would improve the anatomical outcome.

Another factor that markedly influenced the anatomical and functional outcomes was the time from injury to surgery. This finding is consistent with previous studies indicating that treatment should be provided within 3 weeks [19,21,22]. In our study, the interval was even shorter (< 10 days). Surgery should undoubtedly be performed at the early inflammatory phase, before cell repair mechanisms become active, to increase the likelihood of spontaneous ligament healing.

Coracoclavicular implants from many different manufacturers were used. In 93% of patients, these implants were double endobuttons. A systematic literature review by Beitzel et al. identified 120 articles describing 162 reconstruction techniques, none of which appeared superior over the others [19].

Strengths of our work include the number of patients, which was larger than in any other published case-series studies of surgically

treated acute ACJD; the prospective study design; and the high 1-year follow-up rates (90.5% for the clinical evaluation and 84.5% for the radiographs). We obtained a uniform population, with most patients (93%) being treated using a double endobutton. Furthermore, that 50% of patients were also treated with acromioclavicular stabilisation provided high statistical power for demonstrating that stabilisation at two sites (acromioclavicular and coracoclavicular) was the more effective option.

The main limitation of our study is without doubt the classification of ACJD severity according to the Rockwood classification, whose reproducibility has been challenged [20]. Furthermore, even when using a standardised protocol in a prospective study, radiographs may be difficult to interpret, particularly as the imaging technique varies across centres. Finally, as with all multicentre studies, the wide variability and diversity of the techniques used and large number of investigators no doubt generated numerous sources of bias.

5. Conclusion

Anatomical reduction and stabilisation in both the vertical and the horizontal plane are required to ensure good functional outcomes after 1 year. This study demonstrated the need for performing stabilisation in both planes, i.e., at the coracoclavicular and acromioclavicular sites. Coracoclavicular stabilisation alone is not sufficient, regardless of the implant used. Therefore, the acromioclavicular joint must be approached routinely, as the first step of the procedure. This joint is the only reliable landmark for achieving good anatomical stabilisation before controlling the coracoclavicular junction. We advocate the use for coracoclavicular stabilisation of a simple and reproducible method providing optimal preservation of the coracoid and clavicular bone stock and subsequently ending the procedure by carefully repairing the acromioclavicular joint capsule and the deltoid and trapezius fascia. In addition, surgery should be performed within 10 days after the injury. Regardless of the time to surgery, the concomitant use of a biological graft is associated with improved preservation of the anatomical reduction. Caution is in order in patients whose BMI is greater than 25 kg/m², as the weight of the upper limb may compromise the anatomical reduction. Other risk factors are insufficient duration of immobilisation and use of an immobilisation method that does not prevent the downward displacement of the upper limb. Further studies are needed to assess the usefulness of surgical treatment for Rockwood type III ACJD.

Disclosure of interest

The authors declare consulting income from Arthrex (Dr. Barth) and from Mitek and Tornier (Pr. Clavert).

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