Reliability of radiographic measurements for acromioclavicular joint separations

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Introduction: The treatment of acromioclavicular (AC) joint separations is controversial, particularly for Rockwood type III injuries. Rockwood type IV injuries, which correspond to horizontal instability, are very likely under-diagnosed. The objective of this study was to evaluate the inter- and intra-observer reproducibility of the Rockwood classification through an evaluation of standard radiographs, as described in the original article.

Material and methods: This was a prospective radiographic study using protocol-based data from the 2014 symposium of the French Society of Arthroscopy (SFA). Fifteen anonymized radiological records were analysed by six independent examiners on two occasions, 1 week apart. The records consisted of a comparative A/P view of the two acromioclavicular joints (Zanca view), an axillary lateral view and dynamic lateral views (Tauber protocol) to uncover dynamic horizontal instability. A detailed analysis protocol was implemented that included absolute and relative measurements on each view; the relative measurements were used to account for radiographic magnification.

Results: The inter- and intra-observer reproducibility on the A/P radiographs was good to excellent. The reproducibility was fair to good on the lateral views, but the measurements varied greatly from one subject to another, and significant errors were found with certain records. The reproducibility of the dynamic views proposed by Tauber was poor to fair.

Discussion: Radiographic analysis of AC joint separations is reproducible in the vertical plane, which makes it possible to diagnose Rockwood type II, III and V injuries. On the other hand, static and dynamic analyses in the horizontal plane do not have good reproducibility and do not contribute to make an accurate diagnosis of Rockwood type IV injuries.

Level of evidence: Level I, Diagnostic study.

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1. Introduction

The treatment of acromioclavicular (AC) joint separations is controversial. Most recent studies have focused on comparing various treatment options. Several classification systems are available to help a physician during the decision-making process. But to be effective, a classification system must be reproducible and lead to a treatment decision. The most commonly used system is the one first described by Rockwood in 1984 [1]. This classification is based on two radiographic views: the Zanca view of the AC joints [2] and an axillary lateral view. This classification system has been widely adopted and is used in published studies. Rockwood’s original article included 520 cases; a very small number of these cases (4/520) had a type IV injury, which correspond to horizontal instability that is theoretically detectable on the axillary lateral view [1]. This observation has been confirmed, and it is now accepted that horizontal plane (anteroposterior) instability is under-diagnosed and can negatively impact the functional outcomes [3]. Only three published studies have evaluated the reproducibility of this classification system so far [4–6].

The main controversy surrounds type III, IV, and V injuries. On radiographs, a Rockwood type III injury corresponds to a 25% to 100% increase in the coracoclavicular distance, while a type V injury corresponds to a 100% to 300% increase [1]. A type IV injury (horizontal instability) is similar to type II and III injuries on the AP view, but with posterior displacement of the clavicle (or more

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specifically, anterior translation of the scapula, since the clavicle is fixed to the sternum) visible on the axillary lateral view.

The French Society of Arthroscopy (SFA) symposium in 2014 specifically reviewed the results of various treatment options for acute and chronic AC separations. This led us to explore our ability to reproducibly analyse vertical and horizontal plane displacements on standardized radiographic views, using a well-defined protocol-based on published measurements methods.

The primary hypothesis of this study was that measurements made on standardized radiographs were reproducible between and within observers. The secondary hypothesis was that a patient's Rockwood injury type could be determined with certainty using his/her radiographic record.

2. Material and methods

This was a prospective radiographic study using a radiological protocol defined for the 2014 SFA symposium. This protocol, which was based on published data, sets out exactly how the radiographs should be performed. A set of 15 radiographic records were then selected from the symposium database that included:

- an AP view of both clavicles as described by Zanca [2];
- an axillary lateral view as described by Bernageau and Patte [7];
- dynamic axillary lateral radiographs with the arm in 0° and 60° forward flexion [8].

The Zanca view [2] was performed with the patient's arm hanging down and the X-ray beam tilted upward 10°; the source was placed as far back as possible so that both shoulders were in the same radiographic field of view.

The Bernageau view [7] was performed with the patient standing at a 60° angle to the plate and the forearm resting on the head [9], with the X-ray beam tilted downward 30°. In a valid image, the anterior and inferior two-thirds of the glenoid are superimposed over the coracoid process and the glenoid surface is oriented laterally.

The dynamic lateral views described by Tauber et al. [8] were performed with the patient supine and the arm abducted 90°; the X-ray beam was aimed at the axillary fossa and the cassette placed on the superior aspect of the shoulder. Two images were taken, one with the arm at 0° of forward flexion and one with 60° of flexion. As explained in the original article, this view helps to expose dynamic horizontal (AP plane) instability to make sure that Rockwood type IV injuries are not missed.

A comprehensive analysis protocol was defined before starting the study. The radiographs were digitized, made anonymous and then placed in a shared online folder (Dropbox Inc., San Francisco, CA, USA). An OsiriX DICOM viewer (Pixmeo, Switzerland) was used during the analysis. A detailed written and visual tutorial was made available to each participant (observer) and explained during a virtual meeting to eliminate any misunderstanding.

On the Zanca view, the coracoclavicular (CC) distance was measured on both sides and the ratio of injured to healthy CC calculated. This relative value was used to get around measurement variations related to distance from the source (Fig. 1). The D/A ratio was also calculated on the injured and healthy sides using this same view. This made it possible to evaluate the vertical displacement of the acromion relative to the clavicle, based on the thickness of the acromion. This measure is important because a type II injury in the Rockwood classification is defined as one where the vertical displacement is less than half the acromion's thickness. In a type III injury, the displacement is equal to the acromion's thickness, while in the type V injury, it is greater than its thickness. A reference line was drawn through the inferior margin of the acromion.

Distance “A” was the height of the acromion, between its inferior and superior margins. Distance “D” was the distance between the line through the inferior margin of the acromion and a parallel line passing through the lowest and most lateral point on the clavicle. A D/A ratio of 2 corresponded to vertical displacement of 200% of the acromion’s height, where the clavicle is on the superior margin of the acromion, as described by Rockwood [1] (Fig. 2). We also found a published measurement analogy that was based on Rockwood’s original description [5].

On the axillary view, we calculated the X/Y ratio of the acromion’s horizontal displacement relative to the clavicle, consistent with our goal of not using absolute values. This measurement was based on the Rahm and Gerber article published in 2013 [10]. The goal was to quantify horizontal instability. The first reference line was drawn through the middle of the outer quarter of the clavicle. Next, a parallel line was drawn through the most anterior and lateral margin of the clavicle to define the “Y” distance. A third line, parallel to the other two, was drawn through the most anterior margin of the acromion; this line was used to calculate distance “X”, between the anterior edge of the clavicle and the anterior edge of the acromion (Fig. 3).

For the dynamic axillary lateral views defined by Tauber et al. [8], the gleno-acromio-clavicular angle (GACA) was calculated between a line passing through the glenoid articular surface and a line passing through the anterolateral borders of the clavicle and acromion. These views were taken with the arm in 0° and 60° flexion (Fig. 4).

To obtain sufficient statistical power, the symposium’s statistician recommended having six independent observers (three senior surgeons and three residents in their final year) from five different healthcare facilities perform the radiographic analysis twice, 1
week apart. The 15 patient records were anonymized to remove name and date of birth data, and then digitized and placed online. To make the intra-observer comparison possible, each observer’s data was anonymized and entered in an online form (Google Forms, Google Inc., Mountain View, CA, USA).

To determine the inter- and intra-observer reproducibility, Kendall’s Tau was calculated with the null hypothesis being that agreement between the observers was due to chance, $P<0.05$. The Tukey–Kramer test was used for multiple comparisons and Pearson’s correlation test was used to determine the correlation between various measurements. The correlation results were labelled as either excellent ($0.81–1.00$), good ($0.61–0.80$), moderate ($0.41–0.60$), fair ($0.21–0.40$) or poor ($0.00–0.20$) [5,11].

3. Results

The inter-observer reproducibility of the CC ratio measured on the AP radiographs was good to excellent ($\text{Tau} = 0.69$ to $0.92$, $P<0.05$) while the intra-observer reproducibility was good ($\text{Tau} = 0.60$ to $0.77$, $P<0.05$). The inter-observer reproducibility for the D/A ratio measured was good ($\text{Tau} = 0.62$ to $0.67$, $P<0.05$) while the intra-observer reproducibility was excellent ($\text{Tau} = 0.66$ to $0.95$, $P<0.05$). These two measurements were significantly correlated to each other ($\text{Pearson} = 0.66$, $P<0.05$). This indicated that the vertical displacement could be quantified and was reproducible using different calculation methods.

The inter-observer reproducibility for the X/Y ratio measured on the axillary lateral view was good to moderate ($T = 0.48$ to $0.8$, $P<0.05$), as was the intra-observer reproducibility ($T = 0.49$ to $0.72$, $P<0.05$). We found large variations in the measurements on certain radiographs (mainly records 5, 11 and 12), evidence of the challenges associated with performing these radiographs and their resulting low quality, making the analysis difficult. We also found negative values (records 10 and 15), which meant the acromion was behind the clavicle; there were also multiple errors related to positive and negative values in the inter- and intra-observer measurements, despite a well-defined protocol. For example in record No. 15, three observers found negative values during the first analysis and positive ones during the second analysis.

The inter-observer reproducibility for the GACA at $0^\circ$ and $60^\circ$ was poor to fair ($\text{Tau} = 0.01$ to $0.33$, $P<0.05$) as was the intra-observer reproducibility ($\text{Tau} = 0.09$ to $0.38$, $P<0.05$). Various tests showed large discrepancies in the measurements. The average measurement was $49^\circ$ ($26–96$) for the $0^\circ$ flexion GACA and $51^\circ$ ($26–99$) for the $60^\circ$ flexion GACA. This meant that there was no significant difference between the $0$ and $60^\circ$ measurements, contrary to Tauber’s original article [8], whether the healthy or injured shoulder was measured. This implied that the horizontal displacement was difficult to evaluate on axillary lateral views and that the dynamic instability could not be reproducibly and reliably evaluated with standard radiographs.

4. Discussion

The study hypotheses were partially confirmed. Vertical displacement can be analyised accurately and reproducibly, but the horizontal displacement cannot. Only three other published studies have evaluated the reproducibility of the Rockwood classification system, or radiographic measurements, along with proposed treatments [4–6]. The results of these studies are summarised in Table 1. In a study of 28 patients and 10 observers, Cho et al. found poor inter-observer and moderate intra-observer reproducibility based on clinical and radiological analyses. Adding a CT scan does not improve the accuracy of the diagnosis and the treatment decision, which still has moderate to fair reproducibility [4]. However, the radiographs were only evaluated visually without measurements being taken or calculations being made.

Conversely, a recent study by Schneider et al. combining clinical examination with AP stress (10 kg mass) and axillary lateral views performed by 4 surgeons on 58 patients found excellent inter- and intra-observer reproducibility for the clinical and radiological evaluations in both the vertical and horizontal planes [5].
The calculations performed were similar to the ones performed in our study; however, the radiographs were not taken using a defined protocol. Lastly, Kraeutler et al. found fair intra-observer reproducibility when the radiographs of 28 patients were analysed for the Rockwood classification and a treatment decision.

The axillary lateral view has several shortcomings. Rahm and Gerber have shown that a small variation in incidence angle has large effects on the measured “X” distance, and thereby the X/Y ratio [10]. In reality, we had problems performing the Bernageau views; only the best ones were selected among the 140 records generated for this symposium. This led to large differences in the variables, even if the calculated values had moderate to good reproducibility. This measurement is also very difficult to make. The first reference line drawn is the centre line of the outer quarter of the clavicle, based on four points placed on its distal end. In our experience, these points can be placed in very different locations. In the same way, the line can be oriented in various directions, leading to large measurement variations. This happens because the distal clavicle is curved and has large anatomical variations. In addition, it may have remodelled in cases of chronic AC separation (Fig. 5).

The dynamic lateral analysis proposed by Tauber was not reproducible enough and did not contribute to refining the analysis in the horizontal plane. The difference between the radiographs taken at 0° and 60° was less than 5° (0–8.4) on both healthy and injured shoulders, whereas in the original published article, the smallest difference was 7.1° ± 5.5° on healthy shoulders [8]. We also found no differences between the average at 0° and 60° flexion between the healthy and injured shoulders.

We conducted a prospective study using a well-defined protocol for the performance, analysis and measurements of radiographs. Although it did not ask the surgeon to indicate the Rockwood injury type, by extrapolation, this classification system’s reproducibility seems compromised, and our secondary hypothesis is not likely to be confirmed. This study also had its limitations: more records could have been analysed, but we wanted to include only records with the best radiographs in order to limit bias related to how they were performed. Addition of CT scan information can improve the measurement reproducibility, even though subjective results were not improved in the Cho et al. study [4]. Finally, clinical examination of patients, which is current performed systematically, must contribute to refining the diagnosis.

This additional information can in part explain the controversy surrounding conservative or surgical treatment for Rockwood type III injuries [12–14]. In fact, several meta-analyses have been unable to draw conclusions about the superiority of conservative versus surgical treatment, or between various surgical treatments [15–17]. The problem clearly stems from the challenges associated with evaluating instability in the horizontal plane, and contributes to the under-diagnosis of type IV injuries. The answer may require a randomized study with systematic analysis of radiographs and CT scans (or MRI) in patients with AC separation.

Our findings have caused us to question the relevance of the Rockwood classification system [1], which is widely used in published studies. In a consensus statement, the ISAKOS (International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine) suggested modifying the Rockwood classification by dividing type III injuries into IIIa (stable in horizontal plane) and IIIb (unstable in horizontal plane) using comparative lateral cross-body adduction views [18]. The other option would be to use older classification systems, such as the four-stage system described by Patte [9] that integrates the clinical notion of non-reducibility. All of these avenues should be considered to improve our management of AC joint separations.

Which imaging modality is the most helpful during the diagnostic period? Some authors advocate MRI [19]; this examination makes it possible to detect clavicle impalement into the trapezial fascia and to visualize the AC joint surfaces and their relative positioning. A 3D reconstruction from CT scan images provides accurate information on the acromion’s position relative to the clavicle [20], but the patient’s lying position during the examination tends to reduce the displacement.

5. Conclusion

Radiographic analysis of AC joint separations is reproducible in the vertical plane, which makes it possible to diagnose Rockwood type II, III and V injuries. On the other hand, static and dynamic analyses in the horizontal plane did not have good reproducibility and
did not contribute to make an accurate diagnosis of Rockwood type IV injuries. Surgeons should consider doing an additional imaging examination (such as CT scan or MRI) to more accurately analyse the injuries and to make the correct treatment decision.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References