Classification of the morphology of the acromioclavicular joint using cadaveric and radiological analysis

The aim of this study was to establish a classification system for the acromioclavicular joint using cadaveric dissection and radiological analyses of both reformatted computed tomographic scans and conventional radiographs centred on the joint. This classification should be useful for planning arthroscopic procedures or introducing a needle and in prospective studies of biomechanical stresses across the joint which may be associated with the development of joint pathology.

We have demonstrated three main three-dimensional morphological groups namely flat, oblique and curved, on both cadaveric examination and radiological assessment. These groups were recognised in both the coronal and axial planes and were independent of age.

Injection and minimally invasive surgical excision of the acromioclavicular joint are commonly performed procedures. In order to improve clinical efficiency and reduce potential complications, both require a detailed appreciation of the morphology of the joint.

The acromioclavicular joint is a plane diarthrodial joint formed from the outer surfaces of the lateral end of the clavicle and the articular end of the joint. The joint capsule, which is reinforced superiorly by the superior acromioclavicular ligament and inferiorly by the inferior acromioclavicular ligament, the superior being the stronger of the two, and by the coracoclavicular ligament, which is composed of trapezoid (lateral) and conoid (medial) parts.

Varying inclinations have been described at the articulating ends of the clavicle and acromion, but the shape of the joint has been examined only with respect to its inclination in the coronal plane.

The aim of this study was to use cadaveric dissection and radiological analysis to classify the morphology of the acromioclavicular joint in a way that might be of practical use both anatomically and clinically.

Materials and Methods

Cadaveric assessment. A total of 79 joints were analysed in 41 cadavers, 17 male and 24 female, with a mean age of 81.2 years (54 to 96).

The specimens were systematically prepared and standardised with respect to the plane of dissection and the degree of exposure. The acromioclavicular joint was stripped down to its capsule, and an oscillating saw was used to make transverse and coronal cuts through the joint and the articulating ends of the acromion and clavicle. Assessment of acromioclavicular joint morphology was made with respect to the true axis of the acromioclavicular joint and not to the cadaveric axis as the acromioclavicular joint axis has a variation with respect to cadaveric axis. The shapes of the articulating surfaces of each side of the acromioclavicular joint were assessed visually in both transverse and coronal planes and recorded.

Radiological assessment. The morphology of the acromioclavicular joint was assessed radiologically on both the reformatted CT scans and on conventional radiographs centred on the joint. A total of 78 acromioclavicular joints were assessed using CT in 39 patients of which there were 62 males and 16 females, with a mean age of 58.6 years (31 to 91). All were examined on a GE Lightspeed 16-slice system (GE Healthcare, General Electric Company, Chalfont St Giles, United Kingdom). Patients who had previously undergone CT angiography of the head and neck were identified because these scans are performed with the arms by the patient’s side. For scanning, the patient lay supine on a head rest. The set parameters for imaging were slice thickness 0.625 mm; interval 0.625 mm; pitch 0.938:1; limit 440 mAs; field of view 40 cm; and
imaging matrix 512 × 512 pixels. Axial images were reconstructed on a bony algorithm and reformatted at 3 mm slice thickness with an increment of 1.3 mm, centred on the acromioclavicular joint in the true coronal and transverse planes of the joint. The method of assessment of both the cadavers and the CTs was as much as possible duplicated in order to provide representative and comparative datasets of the 3D morphology of the acromioclavicular joint to allow meaningful comparison and analysis between the two groups.

Anteroposterior (AP) radiographs centred on the acromioclavicular joint were analysed from 82 patients, 64 of whom were male and 25 female, with a mean age of 39.8 years (15 to 88). These patients had previously undergone acromioclavicular joint centred radiographs at our institute. There were seven patients with bilateral radiographs. Those of dislocated acromioclavicular joints and fractures of the lateral end of the clavicle were excluded. The radiographs were taken in a standardised manner, with the arms by the patient’s side holding a 3 kg weight, and the horizontal beam centred over the acromioclavicular joint. The morphology of the joint was subsequently assessed in the coronal plane.

Statistical analysis. Two observers (TCS, RA) independently analysed the datasets from the CT scans and radiographs. Student’s t-tests at the 5% level were used to compare individually the frequency of each of the specific morphologies determined on cadaveric and CT analysis, and their frequency within the cadaveric and radiological datasets. Statistical differences were sought for each morphology, both between the cadaveric and CT datasets and between the cadaveric and radiologic observations. Pearson’s product moment correlation coefficient was used to analyse the comparability of the frequency of the different morphologies between those recorded in the cadaveric, CT and radiologic datasets. Inter-observer variability κ analysis was performed with respect to the classification of the morphology made by the observers to assess the degree of consensus between them.

Results

Cadaveric assessment. Each cadaveric acromioclavicular joint was classified as flat, oblique or curved in both transverse and coronal planes (Fig. 1). The oblique subgroup in the transverse plane was subclassified into oblique anterior, with the most distal end of the clavicle inclined anteromedially, and oblique posterior, when the most distal end was inclined posteromedially (Table I).

Radiological assessment. A similar classification in the coronal and axial planes was noted on examination of the reformatted CT subgroup (Fig. 2) and on plain assessment of the AP radiographs centred on the acromioclavicular joints. Analysis of these datasets confirmed the three main 3D types of morphology seen in the cadaveric specimens (Fig. 3) (Table I). The frequency of flat, oblique and curved shapes was similar in the three studies (Table II). On assessment, 8.9% of the joints in the cadavers, 6.6% from the reformatted CT scans and 3.4% in the radiographs could not be classified because of significant degenerative changes (Table I).

There was no significant difference (Student t-test, p > 0.05) between the frequency of flat, oblique or curved joints on cadaveric examination, CT analysis or the radiological appearance. A good correlation was noted between the three investigations, with Pearson’s product moment correlation coefficients of r = 0.81 and r = 0.92 for the cadaver/CT and CT/radiological findings, respectively. Inter-observer variability studies of the classification
produced a κ value on CT analysis of κ = 0.89 and on acromioclavicular joint centred conventional radiographs of κ = 0.85.

Discussion
We have classified the three-dimensional morphology of the acromioclavicular joint into three main groups, namely flat, oblique and curved. This classification was independent of the age of the cadaver or patient. There was no significant difference (p > 0.05) between the populations studied in terms of the frequency of the three main groups and their subtypes.

Previous cadaveric studies have described varying angles of torsion of the acromioclavicular joint and have classified the joint into three groups with respect to the inferomedially angulated plane.3,4 However, we are not aware of any studies of the normal variants of the 3D shape of the acromioclavicular joint on cadaveric specimens or on radiological examinations.

We were able to subdivide each of the three main shapes of the acromioclavicular joint types on both cadaveric and CT analysis and on review of the conventional radiographs. We recognise that our study may be criticised on the grounds that the mean age of the cadavers studies was 81.2 years. However, radiological analyses performed on younger patients demonstrated that there was a significant statistical (p = 0.04) correlation between the cadaveric and radiological appearances and the frequencies of the three main joint shapes described.

The degree of movement at the acromioclavicular joint has been studied for many years. An early view that there

<table>
<thead>
<tr>
<th>Acomioclavicular joint three-dimensional shape</th>
<th>% on cadaveric analysis</th>
<th>% on CT analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat-flat</td>
<td>34.2</td>
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<tr>
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<td>Flat-oblique posterior</td>
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<td>Flat-curve</td>
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<tr>
<td>Oblique-oblique anterior</td>
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<td>7.9</td>
</tr>
<tr>
<td>Oblique-oblique posterior</td>
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<td>9.9</td>
</tr>
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<tr>
<td>Curve-curve</td>
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<td>9.2</td>
</tr>
<tr>
<td>Degenerate</td>
<td>8.9</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Fig. 2
Reformatted coronal CT images of the three main shapes of the AC joint, showing equivalent points within the reformatted images of each subtype of joint. Asterisks indicate equivalent points within the joints.

Fig. 3
Diagrams of the three main three-dimensional shapes of the AC joint.
was only minimal movement in all planes\textsuperscript{5} has been challenged by fluoroscopic studies.\textsuperscript{6} Rockwood and Matsen\textsuperscript{7} hypothesised that the joint had a relatively synchronous 3D movement with the scapula. Three-dimensional studies of the acromioclavicular joint using open MR imaging have supported rotational movements within it.\textsuperscript{8} It seems reasonable to assume that any movement that occurs at the acromioclavicular joint would be affected by its shape, and that repetitive movement, along with variations of the joint morphology, might contribute to differing degrees of attritional damage. Previous evidence of morphological variation of the acromioclavicular joint was provided by De Palma.\textsuperscript{1} This noted, in a study of 66 cadaveric acromioclavicular joints, varying angles of torsion of the joint. He suggested classifying the acromioclavicular into three groups with respect to the inferomedially angulated plane of the joint: type 1 (average angulation of 16°), type 2 (average angulation of 26°) and type 3 (average angulation of 36°). He also described an association between acromioclavicular joint pathology and type 1 joints which was thought to be secondary to an increased shearing force on the articular surface.

The acromioclavicular joint provides a structural connection between the scapula and clavicle which facilitates support of the shoulder complex on the thorax. The configuration of the joint may influence the biomechanics when loaded. The areas of articulation within the joint are small, whereas the load transmitted is high, producing high stresses through the joint. Load transmitted across a flat or curved joint may be relatively uniform, whereas a more oblique joint may provide higher stresses at specific asymmetrical points, which could promote damage to the articular cartilage and arthritic change.

In a diseased acromioclavicular joint an appreciation of its three-dimensional morphology will aid access to the joint with a needle or for decompression. A more oblique or curved joint would require a correspondingly more acute angle of entry in the coronal plane to best navigate the superior to inferior course of the joint. The information required to assess the morphology of the joint may be obtained by using a good-quality radiograph centred on the joint.

The relatively exposed nature of the joint increases its risk of a traumatic injury. Because shape makes a significant contribution to the stability of a joint when other stabilising influences, such as the strength of the ligaments and capsule, have been lost, it could theoretically influence the possibility of dislocation as a result of trauma. In cadaveric studies, the intra-articular disc has been described as undergoing rapid degeneration with pronounced severity from the second decade of life. Eburnation and arthritic bony changes were noted to follow.\textsuperscript{1} Biomechanical analyses of the different shapes of the joint which we have described may help clarify how the movements of this joint are related to pathological change.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References