Quantified measurement of subacromial impingement

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We modified the Hawkins impingement maneuver in order to develop a quantifiable and reproducible impingement test. The involved anatomic structures were examined with magnetic resonance imaging of 3 cadaveric shoulders. The reproducibility of the clinical sign was assessed with an interobserver and intraobserver reliability test, with calculation of the intraclass correlation coefficient (ICC). The quantified Hawkins maneuver appears to be a reproducible clinical test (median interobserver ICC, 0.9331; median intraobserver ICC, 0.9748) and creates bony contact between the greater tuberosity and the anterolateral acromion. This test enables the clinician to quantify the subacromial space. (J Shoulder Elbow Surg 2003;12: 346-9.)

In 1972 Neer[10] described the clinical condition of subacromial impingement as the production of pain in the lateral region of the deltoid when, in the standing position, the affected extremity is forcibly elevated while the scapula is stabilized. This maneuver is supposed to pinch the supraspinatus tendon between the humeral head and the anteroinferior aspect of the acromion. Neer[11] described and staged the associated injuries and recommended an anterior acromioplasty for this impingement. Ever since, surgical anteroinferior subacromial decompression has been successfully performed on the basis of the clinical sign of impingement.[12,14,17]

The affected anatomic structures causing the positive impingement signs were ill defined until recently. With the existing clinical impingement tests, a different anatomic structure is tested. In the Neer test, the supraspinatus tendon is impinged under the anterolateral acromion, whereas in the Hawkins test, the supraspinatus tendon is impinged under the coracoacromial arch.[15] We use the Hawkins maneuver on a regular clinical basis. It was believed that in asymptomatic patients, the degree of internal rotation of the shoulder during the Hawkins maneuver was symmetrical. In patients with impingement syndrome, a marked limitation for this movement was found. It was also noted preoperatively that performing an acromioplasty could influence the degree of internal rotation during the Hawkins maneuver.

In practice the various impingement signs are used promiscuously, and the surgical treatment is uniform. However, Warner et al[16] emphasized the importance of the preoperative assessment of subacromial decompression in order to obtain a more predictable surgical outcome. Therefore, the preoperative quantification of subacromial impingement is considered to be a valuable clinical tool in the preoperative planning for acromioplasty.

The goals of this study were threefold: (1) to design a quantified and reproducible clinical impingement test, (2) to define its anatomic basis, and (3) to define the degree of limitation that should be considered pathologic.

Cahç et al[4] found the Hawkins maneuver to be the most sensitive impingement test. Furthermore, the literature stresses the need to eliminate the thoracoscapular compensation mechanism when impingement tests are performed: the Neer test becomes positive more rapidly when the scapula is pushed downward.[10] We, therefore, used a slightly modified Hawkins test, in which the patient lay supine with the scapula pushed caudally and locked in this position, in order to standardize the spatial position of the scapula relative to the chest. An apparatus was developed to reproduce and quantify this maneuver.

We report on (1) 3 cadaveric shoulders positioned in this apparatus and studied with magnetic resonance imaging (MRI) to define the anatomic contact, (2) the reproducibility of the quantified Hawkins maneuver, (3) a population of 95 individuals without shoulder disease examined with the above-described test, and (4) a group of 20 patients surgically treated for impingement syndrome.

MATERIALS AND METHODS

The measurement device allowed for a standardized Hawkins maneuver in dorsal recumbency so as to minimize scapular displacement and interindividual differences in

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1058-2746/2003/$35.00 + 0
doi:10.1016/S1058-2746(03)00038-7

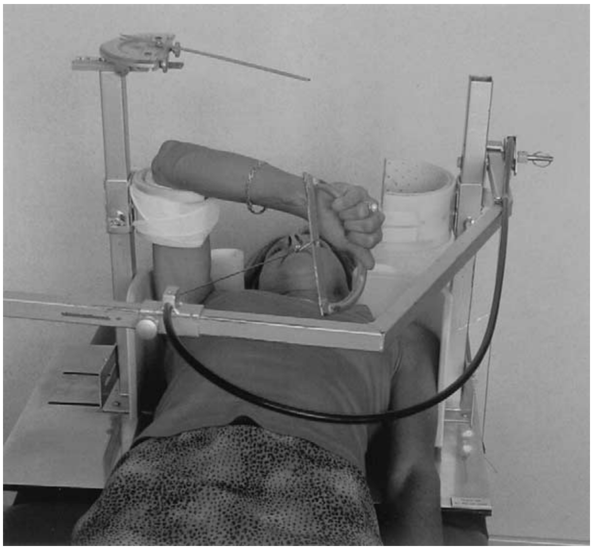

Figure 1 Patient positioning in the measurement device for the modified Hawkins maneuver.

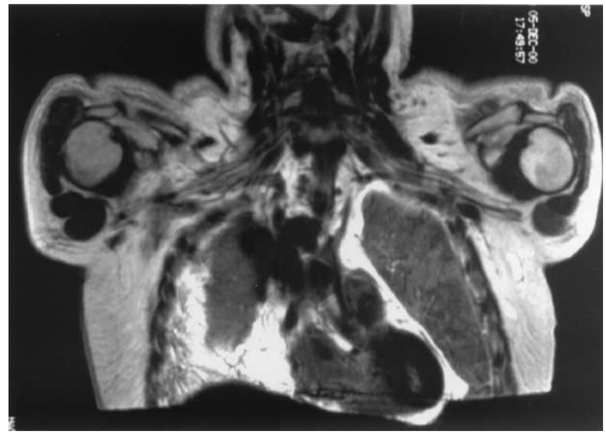

Figure 2 MR image in the coronal plane of a frozen cadaveric specimen, consistently showing bony contact between the greater tuberosity and anterolateral acromion.

scapular position (eg, thoracic kyphosis). Scapular displacement was prevented by applying a shoulder cap that depressed the shoulder in a maximally caudal and median direction. The upper arm was brought into 90° of forward flexion and fixed with straps in this position. A caudad force (2 kg) was exerted on the wrist in the coronal plane by a pulley system.

Rotation of the forearm was measured with a goniometer along the axis of the humerus, in 90° of forward flexion in the sagittal plane, with the elbow flexed to 90°, and in neutral pronation-supination of the forearm (Figure 1). In this way, internal rotation of the shoulder in 90° of forward flexion was measured with a fixed scapulothoracic joint and resulted in a quantified Hawkins test.

The preservation of the integrity of the complete shoulder girdle, including the thoracoscapular joint, was considered important in defining the affected anatomic structures. This could only be realized with MRI. However, it was impossible to use the apparatus in the magnetic resonance (MR) tunnel. Therefore, with ultrasound, we identified 3 healthy shoulders in 2 cadavers, one 48-year-old man and one 68-year-old woman. These fresh cadavers were positioned in the apparatus and subsequently frozen in the desired position of 90° of forward flexion and maximal internal rotation of both shoulders. After freezing for 48 hours at −18°C, the arms of the cadavers were removed with a saw at the level of the upper arm so that the apparatus could be removed. These fresh-frozen cadavers were then placed in the MR tunnel and imaged. Three-millimeter cuts were made in the coronal plane; one-millimeter images were made in the coronal and the sagittal plane, but their signal intensity was too low because of their frozen condition.

The interobserver reliability of the quantified Hawkins maneuver was examined by 5 investigators performing 3 measurements on 5 shoulders in healthy subjects. The intraobserver reliability was tested with 3 measurements by 5 investigators in 5 shoulders of healthy subjects. All measurements were performed with at least a 1-day interval. The intraclass correlation coefficient (ICC) was calculated.[13]

Two subject groups were studied to support the clinical use and define normal values. One hundred twenty Monsanto employees (Ghent, Belgium) who cooperated voluntarily were examined. After all subjects with shoulder pain during the Hawkins maneuver had been excluded, 95 persons remained (27 women and 58 men; 85 right-handed and 10 left-handed), with a mean age of 36 years (range, 20-59 years). We also included preoperative and postoperative measurements in 20 patients (13 women and 7 men) with a mean age of 42 years (range, 35-64 years) who were treated surgically for impingement by an open acromioplasty. All cases had a unilateral symptomatic impingement syndrome with a minimum of 3 months in a failed rehabilitation program. Clinically, all had a positive impingement sign as described by Neer[10] and a positive reinforcement sign as described by Hawkins and Kennedy.[7] All had positive radiologic signs (acromion type II or III, as described by Morrison and Bigliani[9]—tendinitis calcarea) and/or ultrasound signs (subacromial bursal effusion and/or abnormal focal echogenicity), and all had marked pain relief after subacromial infiltration of lidocaine according to Neer.[10]

RESULTS

MRI of the cadaveric shoulders consistently showed bony contact between the greater tuberosity and the anterolateral acromion (Figure 2). The coracoacromial ligament was always well visualized, and the biceps tendon was located under the coracoacromial ligament (Figure 3).

The intraobserver reliability had a median average-measure ICC of 0.9748, with a minimum of 0.9721 and a maximum of 0.9818. The interobserver reliability had a median average measure ICC of 0.9331, with a minimum of 0.7379 and a maximum of 0.9781. Even for the worst ICC, these values

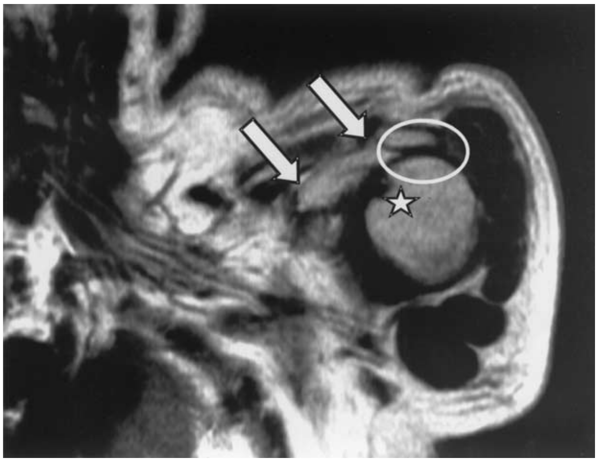

Figure 3 MR image in the coronal plane of a frozen cadaveric shoulder. The coracoacromial ligament is well visualized (*arrows*), and the biceps tendon is located under the coracoacromial ligament (*star*). *Oval*, Closed subacromial space with impingement of the supraspinatus tendon.

corresponded with an SD of equal to or less than 3.3°.

The control population behaved parametrically (Kolmogorov-Smirnov normality test).

Absolute internal rotation was 29.8° (range, 12°-54°; SD, 9.26°) for the left shoulder and 30.8° (range, 9.0°-55.0°; SD, 8.89°) for the right shoulder. The left/right difference was 0.97° (95% confidence interval, 0.43° to 2.37°) and was not statistically significant ($P = .17$, paired *t* test).

In the group treated surgically, the difference in preoperative internal rotation between the unaffected and pathologic shoulder was −24° (SD, 12.5°; 95% confidence interval of the difference, −30° to −19°). Postoperatively, the difference in internal rotation capacity was reduced to −3° (SD, 8°; 95% confidence interval of the difference, −6° to 1°).

DISCUSSION

Subacromial impingement syndrome is often referred to as a specific pathologic condition or even diagnosis. It should be emphasized that subacromial impingement is a clinical syndrome that indicates a pathologic process between the roof and floor of the subacromial space. The etiology for this syndrome is diverse, and the pathologic basis can be either intrinsic (rotator cuff disease) or extrinsic (outlet stenosis impingement).[1] The current clinical impingement tests are used promiscuously and, therefore, often fail to take into account the different etiologies of impingement syndrome.[8] Literature data indicate that acromioplasty is not the answer in every case of subacromial impingement.[5] Furthermore, Warner et al[16] expressed the need to quantify the amount of subacromial decompression in order to enhance surgical results. We, therefore, designed a measurement device that allows for reproduction and quantification of a defined anatomic contact in the subacromial space.

The first part of this study defined, by MRI, the anatomic contact tested with the standardized Hawkins maneuver. The MR images of the cadaveric shoulders consistently showed bony contact between the greater tuberosity and the anterolateral acromion and the location of the biceps tendon underneath the coracoacromial ligament.

In their anatomic study of Hawkins' test, Valadie et al[15] found a more medial contact on the coracoacromial arch, consistent with other literature data.[2,3,6] We, however, used an intact body without disturbing the thoracoscapular joint, which has not been described as yet. Moreover, we administered the Hawkins test with the patient in the supine position.

The second part of this study proved the quantified measurement of the internal rotation of the arm in forward flexion during the quantified Hawkins maneuver to be reproducible. We believe that standardization of patient positioning in dorsal recumbency and locking of the thoracoscapular movement are crucial in obtaining this degree of reproducibility.

Furthermore, in all 3 cadavers the different amounts of internal rotation were limited by the same mechanical contact as described above. We, therefore, consider the degree of internal rotation to be a clinical quantification of the gliding capacity of the subacromial space.

The clinical applicability of this test is supported in the third part of the study. None of the healthy subjects examined reported any form of inconvenience or discomfort during this measurement. Patient positioning and the measurement for both shoulders take 2 minutes on average. The preoperative and postoperative measurements in the symptomatic group, as well as the MRI findings in the cadaveric shoulders, do support the theory that any cause of obliteration of the subacromial space can result in a decreased internal rotation measurement. We suggest that this simple clinical test can aid in the preoperative assessment and guidance for treatment of patients with subacromial impingement syndrome. This idea is supported by the results in a normal population in which the internal rotation measurement was proven to be symmetrical and by the intraoperative findings showing that decompression can lead to a restoration of this symmetry. The amount of subacromial decompression needed can be guided by a restoration of symmetrical internal rotation capacity, as illustrated in Figures 4 and 5.

We are grateful to Professor Roels (Anatomy Department, University of Ghent, Ghent, Belgium) and Professor Lauwers (Veterinary School, University of Ghent, Merelbeke, Bel-

Figure 4 Preoperative assessment of internal rotation capacity.

Figure 5 Assessment of internal rotation capacity after subacromial decompression.

gium) for providing the cadaveric specimens and their kind cooperation in the execution of the cadaveric study.

REFERENCES

1. Bigliani LU, Levine WN. Subacromial impingement syndrome. J Bone Joint Surg Am 1997;79:1854-68.
2. Birnbaum K, Perscher A, Heller KD. Anatomic and functional aspects of the kinetics of the shoulder joint capsule and the subacromial bursa. Surg Radiol Anat 1998;20:41-5.
3. Burns WC, Whipple TL. Anatomic relationships in the shoulder impingement syndrome. Clin Orthop 1993;294:96-102.
4. Cahç M, Akgün K, Birtane M, et al. Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. Ann Rheum Dis 2000;59:44-7.
5. Gerber C. Massive rotator cuff tears. In: Iannotti JP, Williams GR, editors. Disorders of the shoulder: diagnosis and management. Philadelphia: Lippincott Williams & Wilkins; 1999. p. 67-9.
6. Flatow EL, Soslowsky LJ, Ticker JB, et al. Excursion of the rotator cuff under the acromion. Patterns of subacromial contact. Am J Sports Med 1994;22:779-88.
7. Hawkins RJ, Kennedy JC. Impingement syndrome in athletes. Am J Sports Med 1980;8:151-8.
8. Leroux JL, Thomas E, Bonnel F, Blotman F. Diagnostic value of clinical tests for shoulder impingement syndrome. Rev Rhum Engl Ed 1995;62:423-8.
9. Morrison DS, Bigliani LU. The clinical significance of variations in acromial morphology. Orthop Trans 1987;11:234.
10. Neer CS II. Anterior acromioplasty for the chronic impingement syndrome of the shoulder. A preliminary report. J Bone Joint Surg Am 1972;54:41-50.
11. Neer CS II. Impingement lesions. Clin Orthop 1983;173:70-7.
12. Patel VR, Singh D, Calvert PT, Bayley JI. Arthroscopic subacromial decompression: results and factors affecting outcome. J Shoulder Elbow Surg 1999;8:231-7.
13. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979;86:420-8.
14. Tibone JE, Jobe FW, Kerlan RK, et al. Shoulder impingement syndrome in athletes treated by an anterior acromioplasty. Clin Orthop 1985;198:134-40.
15. Valadie AL III, Jobe CM, Pink MM, Ekman EF, Jobe FW. Anatomy of provocative tests for impingement of the shoulder. J Shoulder Elbow Surg 2000;9:36-45.
16. Warner JJ, Kann S, Maddox LM. The "arthroscopic impingement test." Arthroscopy 1994;10:224-30.
17. Yocum LA. Assessing the shoulder. History, physical examination, differential diagnosis, and special tests used. Clin Sports Med 1983;2:281-9.