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Abnormal Findings on Magnetic Resonance Images of Asymptomatic Shoulders*

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ABSTRACT: Magnetic resonance images of the shoulders of ninety-six asymptomatic individuals were evaluated to determine the prevalence of findings consistent with a tear of the rotator cuff. The scans were reviewed independently by two diagnostic radiologists who are experienced in the interpretation of magnetic resonance images of the shoulder. The over-all prevalence of tears of the rotator cuff in all age-groups was 34 per cent (thirty-three). There were fourteen full-thickness tears (15 per cent) and nineteen partial-thickness tears (20 per cent). The frequency of full-thickness and partial-thickness tears increased significantly with age ($p < 0.001$ and 0.05 , respectively). Twenty-five (54 per cent) of the forty-six individuals who were more than sixty years old had a tear of the rotator cuff: thirteen (28 per cent) had a full-thickness tear and twelve (26 per cent) had a partial-thickness tear. Of the twenty-five individuals who were forty to sixty years old, one (4 per cent) had a full-thickness tear and six (24 per cent) had a partial-thickness tear. Of the twenty-five individuals who were nineteen to thirty-nine years old, none had a full-thickness tear and one (4 per cent) had a partial-thickness tear. Magnetic resonance imaging identified a high prevalence of tears of the rotator cuff in asymptomatic individuals. These tears were increasingly frequent with advancing age and were compatible with normal, painless, functional activity. The results of the present study emphasize the potential hazards of the use of magnetic resonance imaging scans alone as a basis for the determination of operative intervention in the absence of associated clinical findings.

The prevalence of tears of the rotator cuff in asymptomatic individuals is largely unknown. While previous anatomical investigations^{5-8,11,12,18,19,23,25,26,33,34} have demon-

strated a spectrum of pathological changes about the rotator cuff, the frequency of findings in relation to symptoms has not been ascertained sufficiently.

A number of investigators^{9,14,15,20,21,28,30,32,35,36} have described the use of magnetic resonance imaging for the evaluation of disorders in the shoulder. Furthermore, it has been suggested^{11,16,36} that magnetic resonance imaging can be a highly sensitive and specific tool for the diagnosis of lesions of the rotator cuff.

As far as we know, only a few reports^{4,13,17,22,24} have described the findings on magnetic resonance images of asymptomatic shoulders. These studies have addressed specifically the commonly found increase in signal intensity within or around the supraspinatus tendon. While these signal abnormalities help to point out the often difficult distinction between a normal tendon and tendinosis, findings typical of tears of the rotator cuff have not been mentioned.

The present investigation was undertaken to delineate prospectively the prevalence of tears of the rotator cuff diagnosed with magnetic resonance imaging in a controlled population of asymptomatic individuals of various ages and with various levels of activity.

Materials and Methods

Prospective subjects for the study were recruited through local advertisements that requested voluntary participation in a research project for the Department of Orthopaedics at the University of Miami. One hundred and fifty-three interested persons were screened on the basis of information obtained from a detailed questionnaire regarding occupational history, athletic involvement, medical history, and handedness. The questionnaire was specifically directed to elicit any history of pain in the shoulder or neck as well as any limitations in the performance of occupational or athletic activity or of activities of daily living. Detailed profiles were obtained to assess the approximate number of hours per week and the years of involvement in work and sports-related activities from the second decade of life to the present. Individuals who had a history of operations on the shoulder or neck, symptoms related to the shoulder or neck, or functional limitations were excluded from the study. Also excluded were individuals who were pregnant or claustrophobic or who had a pace-

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maker or cerebral vascular clips. One hundred and seven individuals were initially selected from the responses to the questionnaire and had a musculoskeletal examination of both upper extremities. The extremities were assessed for atrophy, tenderness, range of motion, and strength, and specialized tests (drop-arm, impingement²³, and apprehension) were performed. Seven individuals were found to have a positive impingement sign²³; no other individual had abnormal findings. The 100 individuals who met the inclusion criteria were informed that magnetic resonance imaging was a standard diagnostic modality that uses non-invasive means in the absence of ionizing radiation. They were also informed that any results obtained would remain confidential and would be used for research purposes only. Additionally, they were told that no monetary or other benefits were to be received by the volunteers or investigators. The purpose of the investigation was not disclosed to the individuals.

Four individuals were excluded during the course of the study because of differing interpretations of their images. Thus, the scans of ninety-six individuals, forty-seven men and forty-nine women, were available for investigation. The ages of the individuals ranged from nineteen to eighty-eight years (average, fifty-three years). Eight subjects were left-hand dominant and eighty-eight were right-hand dominant. The individuals were divided into three groups according to age: nineteen to thirty-nine years old (twenty-five individuals), forty to sixty years old (twenty-five individuals), and more than sixty years old (forty-six individuals).

The individuals who were more than sixty years old were subjectively categorized as either sedentary or active on the basis of the history of occupational and athletic involvement in over-the-head activities as reported on the questionnaire. This was done to determine the association of tears of the rotator cuff with the level of activity. Individuals who gave no history of participation in either recreational or competitive athletic activities and whose occupation required little physical activity (such as office work) were considered sedentary. All others were considered active. There were twenty-eight sedentary and eighteen active individuals.

The dominant shoulder of all 100 individuals was scanned with a 1.0-tesla scanner (Magnetom SP42; Siemens Medical Systems, Iselin, New Jersey). Oblique coronal proton-density-weighted and T2-weighted spin-echo images were made with a repetition time of 2000 milliseconds. The slice thickness was four millimeters, with a 0.4-millimeter interslice gap. The field of view was twenty centimeters. Two echoes were generated at twenty milliseconds (the proton-density-weighted images) and ninety milliseconds (the T2-weighted images).

On the basis of published criteria for magnetic resonance imaging of tears of the rotator cuff^{16,30,36}, and with the realization that some of those criteria may not be

proved in all instances, we will use the term tear to represent a well defined focus of high-intensity signal on T2-weighted images displaying a discontinuity in the normal signal void of the tendon that was not evident on the proton-density-weighted scans. The findings were classified as an intact rotator cuff or as a partial-thickness tear or a full-thickness tear of the rotator cuff (Figs. 1-A through 1-D).

Images were evaluated for the presence of full-thickness and partial-thickness tears of the rotator cuff; the location, size, and extent of those tears; and the degree of muscle atrophy (subjectively assessed on the basis of muscle bulk and size and objectively assessed on the basis of the presence of high-intensity-signal linear bands consistent with fatty replacement) and tendon retraction. Degenerative changes in the acromioclavicular joint and subacromial spurs were also noted. All imaging data were reviewed independently in a blinded fashion by two of us (B. J. M. and M. B. Z.), both of whom are orthopaedic radiologists experienced in the interpretation of magnetic resonance images of the shoulder. The diagnostic parameters used for interpretation of the scans were similar to those cited in a previous report¹⁶. There were discrepancies between the two radiologists' interpretations of four of the imaging studies, and these four were eliminated from the investigation. Thus, ninety-six individuals were available for additional study.

Magnetic resonance imaging scans of an additional twenty patients who had an arthroscopically verified lesion of the shoulder or normal anatomy were intermixed with the study group to control for any observer bias of the radiologists. Six of the shoulders in the control group had an operatively documented full-thickness tear; five, a partial-thickness tear; and nine, no evidence of a tear. The film jackets and contents were identical in external appearance and number, respectively, before interpretation so that the study and the control subjects could not be distinguished. The accuracy of the radiographic interpretation in the arthroscopically verified control group was calculated.

Chi-square analysis was performed to determine the significance of the findings in relation to the age and activity level of the individual and the presence of a tear of the rotator cuff. Significance was defined at an alpha level of $p < 0.05$.

Results

Over-all, thirty-three (34 per cent) of the ninety-six individuals had evidence of a tear of the rotator cuff: fourteen (15 per cent) had a full-thickness tear and nineteen (20 per cent) had a partial-thickness tear. Thirteen (28 per cent) of the forty-six individuals who were more than sixty years old had a full-thickness tear and twelve (26 per cent) had a partial-thickness tear. Of the twenty-five individuals who were forty to sixty years old, one (4 per cent) had a full-thickness tear and six (24 per cent) had

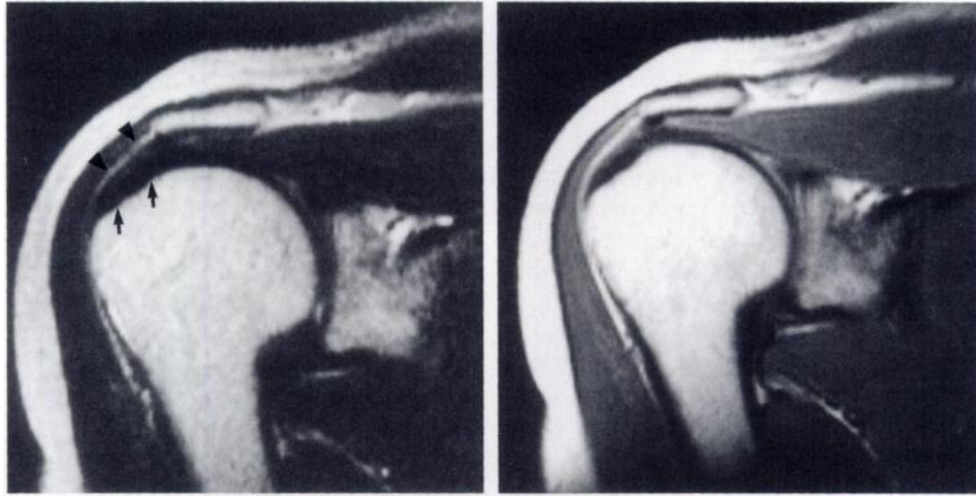


FIG. 1-A

FIG. 1-B

Figs. 1-A through 1-D: Coronal oblique magnetic resonance images.

Figs. 1-A and 1-B: A T2-weighted image with a repetition time of 2000 milliseconds and an echo time of ninety milliseconds (Fig. 1-A) and a proton-density-weighted image with a repetition time of 2000 milliseconds and an echo time of twenty milliseconds (Fig. 1-B) show a low signal intensity throughout the supraspinatus tendon (arrows). The subacromial-subdeltoid peribursal fat plane demonstrates a high signal intensity (arrowheads). The findings are compatible with an intact rotator cuff.

a partial-thickness tear. Of the twenty-five individuals who were nineteen to thirty-nine years old, none had a full-thickness tear and one had a partial-thickness tear. The prevalence of full-thickness tears in the individuals who were more than sixty years old was significantly higher than the prevalences in the two other groups ($p < 0.001$, chi-square test).

Thirteen of the fourteen individuals who had a full-thickness tear were more than sixty years old. The sizes of the fourteen lesions ranged from 0.5 to fourteen

square centimeters (average, 5.0 ± 4.3 square centimeters). All of the lesions involved the supraspinatus tendon, with variable amounts of extension into the posterior aspect of the cuff. Twelve lesions were found in the distal aspect of the tendon, at or near its insertion to the humerus, and two were found in the proximal aspect, beneath or adjacent to the acromioclavicular joint. All but one of the fourteen individuals who had evidence of a full-thickness tear had varying degrees of osteoarthritis of the acromioclavicular joint. Five of the

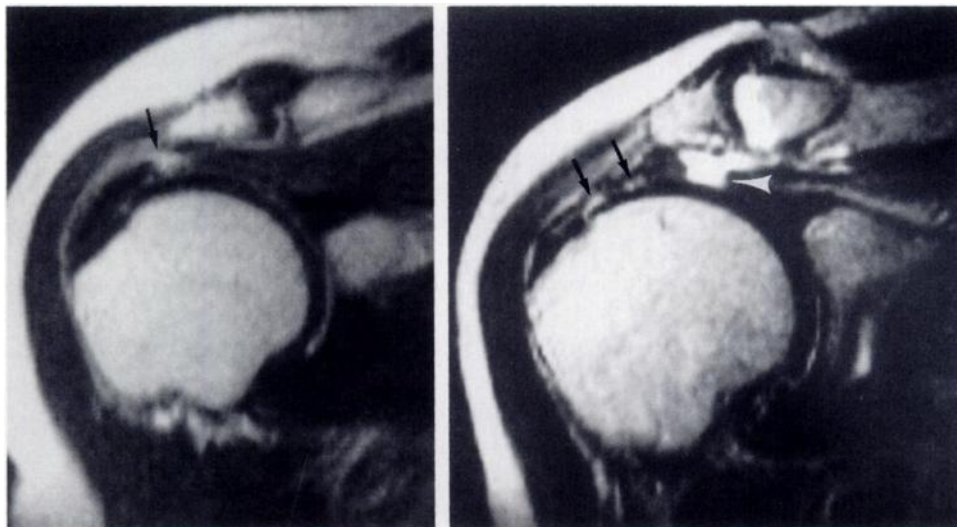


FIG. 1-C

FIG. 1-D

Fig. 1-C: T2-weighted image (repetition time, 2000 milliseconds; echo time, ninety milliseconds) showing a high signal intensity in the proximal aspect of the supraspinatus tendon extending from the bursal surface (arrow). The articular surface appears intact. These findings are consistent with a partial-thickness tear of the bursal surface of the supraspinatus tendon.

Fig. 1-D: T2-weighted image (repetition time, 2000 milliseconds; echo time, ninety milliseconds) showing a full-thickness tear. There is a high signal intensity consistent with fluid outlining a defect at the proximal aspect of the supraspinatus tendon (white arrowhead). Focal areas of fluid signal intensity are seen more distally, arising from the articular surface, and are consistent with partial tearing of the undersurface (small arrows). Moderate degenerative change of the acromioclavicular joint is evident.

fourteen had atrophy of the cuff muscles, and nine had subacromial spurs.

The prevalence of partial-thickness tears also increased significantly with age ($p < 0.05$, chi-square test). Twelve of the individuals who were more than sixty years old, six who were forty to sixty years old, and one who was nineteen to thirty-nine years old had a partial-thickness tear. Five of the tears were on the bursal surface of the tendon, seven were on the articular surface, and one was an intrasubstance tear. Six individuals had more than one partial-thickness tear that was located in at least two of the three sites just mentioned. All of the partial-thickness tears were found in the supraspinatus, with one also involving the infraspinatus tendon. Twelve of the nineteen individuals who had a partial-thickness tear had evidence of osteoarthritis of the acromioclavicular joint on the magnetic resonance images, and eleven had subacromial spurs.

Five individuals had findings on the magnetic resonance images that were consistent with both complete and partial-thickness tearing of the rotator cuff. These individuals were considered to have a full-thickness tear, as this was the more extensive of the two types of lesions.

Sixty-three (66 per cent) of the ninety-six individuals had no evidence of a tear on the magnetic resonance images. Over-all, 65 per cent (sixty-two) of the individuals had osteoarthritis of the acromioclavicular joint.

In the groups of individuals who were more than sixty years old, ten (36 per cent) of the twenty-eight who were sedentary and three of the eighteen who were active had evidence of a full-thickness tear on the magnetic resonance images. There was no significant difference between the two subgroups ($p = 0.16$, chi-square test).

Interpretation of the magnetic resonance images of the individuals in whom the diagnosis had been confirmed arthroscopically (the control group) resulted in accurate detection of all six full-thickness tears, all five partial-thickness tears, and all nine intact cuffs by each of the two radiologists. Also, as mentioned, the radiologists agreed on the diagnosis of the full-thickness and partial-thickness tears of the rotator cuff and on the diagnosis of the intact cuffs in ninety-six of the 100 asymptomatic individuals.

Discussion

A number of anatomical studies^{5,11,12,18,19,23,25,26,34} have been performed in an attempt to assess the prevalence of tears of the rotator cuff in the general population. These reports demonstrated a frequency of less than 5 to 39 per cent for full-thickness tears and of 13 to 37 per cent for partial-thickness tears. Only DePalma et al.^{7,8}, however, addressed the presence of symptoms. DePalma et al.^{7,8} attempted to select asymptomatic subjects on the basis of records of premortem clinical eval-

uation, but they noted that most of the subjects had had a history of disabling function of the shoulder. DePalma et al.⁸ recorded nine (9 per cent) full-thickness and thirty-five (36 per cent) partial-thickness tears of the supraspinatus tendon in ninety-six shoulders, with the tears ranging from one centimeter in diameter to massive separations of the rotator cuff insertion.

Other investigators^{2,3,29} have supported the contention that many tears of the rotator cuff do not interfere with normal function. Burkhart², with the use of fluoroscopy, studied kinematic patterns of glenohumeral motion in patients who had a massive tear of the rotator cuff. He noted that normal function was possible as long as the posterior aspect of the cuff was preserved to such a degree that the force couple in the transverse plane was maintained. He also concluded that the location rather than the size of the tear may be a more important factor in the resultant glenohumeral mechanics. The findings of the present study confirm the variability in the size and type of tears of the rotator cuff that is possible in individuals who do not have functional deficits.

Pettersson²⁷ made arthrograms of apparently normal shoulders and demonstrated a pathological communication between the glenohumeral joint and the subacromial bursa in thirteen (18 per cent) of seventy-one subjects. No ruptures were found in individuals who were less than fifty-five years old. Although Pettersson studied the contralateral, uninjured side of patients who had a unilateral injury of the shoulder, he did not consider the subjects to be representative of a randomly chosen normal population. However, he was able to demonstrate a preponderance of tears of the rotator cuff with increasing age.

To our knowledge, the present study is the largest investigation in which the prevalence of tears of the rotator cuff was determined prospectively, in a randomly selected population, through the use of magnetic resonance imaging. While we demonstrated an over-all frequency of full-thickness tears of 15 per cent (fourteen) of ninety-six individuals, additional analysis revealed that thirteen of these lesions occurred in individuals who were more than sixty years old. Associated findings included osteoarthritis of the acromioclavicular joint in thirteen of the fourteen individuals who had a full-thickness tear and subacromial spurs in nine. This finding is consistent with those of previous reports^{5,10,23,25,26}, indicating a strong association between age, the formation of degenerative hypertrophic spurs, and full-thickness tears of the rotator cuff. While atrophy of the rotator cuff was also noted in a small number of individuals (five), the importance of this observation and its relation to symptoms has not been determined.

We also noted an increase in the frequency of partial-thickness tears with increasing age. With regard to these tears, our data more closely resembled those of

earlier anatomical studies^{7,8,12,19,23,25}, which demonstrated that partial-thickness tears typically begin to occur between the ages of forty and sixty years.

Twenty-five (54 per cent) of the forty-six individuals who were more than sixty years old were found to have either a full-thickness or a partial-thickness tear of the rotator cuff. This finding suggests that there are age-related changes of the rotator cuff in asymptomatic individuals as identified by abnormalities typical of tears of the rotator cuff on the magnetic resonance images. Furthermore, our findings affirm that evidence of a tear of the rotator cuff alone on magnetic resonance images does not necessarily indicate associated symptoms. Relevant imaging parameters that distinguish asymptomatic from symptomatic tears and that predict which individuals may be prone to the development of pain or functional limitation are not clear. Our results highlight the importance of careful association of evidence of tears of the rotator cuff on magnetic resonance images with clinical findings in symptomatic patients and also emphasize the potential dangers of the use of magnetic resonance imaging scans alone as a basis for the determination of operative intervention.

When the reliability of the present study is evaluated, consideration must be given to the fact that the results are largely based on our ability to diagnose tears of the rotator cuff accurately with magnetic resonance imaging. Although we did not obtain operative confirmation of our findings, which is not justified in an

asymptomatic population, we were able to detect the arthroscopically verified tears of the rotator cuff in the control group with sufficiently high accuracy. In previous reports^{1,16,36}, the ability of magnetic resonance imaging to reflect tears of the rotator cuff accurately has been well established. In the largest series¹⁶, the sensitivity and specificity were 100 and 95 per cent, respectively, in the detection of full-thickness tears of the rotator cuff in ninety-one patients. Certainly, the diagnostic accuracy of magnetic resonance imaging can vary between different centers and may be related to multiple technical factors, such as the strength of the magnetic field, the design of the surface coil, the appropriateness of the cuts, and the experience of the radiologist¹⁶. Given the high diagnostic performance of magnetic resonance imaging in previously published reports^{1,16,36} and in our control group (which had operative confirmation of the tears), the interpretation of scans by more than one experienced radiologist, and concentration on only those findings consistent with defects of the tendon of the rotator cuff, the potential for diagnostic errors was minimized.

In summary, the results of the present study indicate a high prevalence of abnormal findings on magnetic resonance images, consistent with tears of the rotator cuff in asymptomatic individuals. These tears are compatible with normal, painless functional activity and occur with considerably more frequency in individuals who are more than sixty years old.

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