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Degenerative change and rotator cuff tears

An anatomical study in 160 shoulders of 80 cadavers

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Summary. In order to determine the effects of friction and rubbing in the development of rotator cuff tear, we studied 160 shoulders of 80 cadavers (age at death 43–93 years, mean 69.3 years). Seventy-two cadavers were fixed with formalin and eight were fresh cadavers. The surface of the cuff and the undersurface of the acromion were observed macroscopically. Eight shoulders of fresh cadavers were examined by scanning electron microscopy. Ninety-eight specimens (61%) showed degenerative changes of the supraspinatus tendon. The number of tendons with degeneration and tear increased from the fifth to sixth decade of life, and the size of the tear increased with age. However, there was no sustained increase in the incidence with aging from the age of 60 to 90 years, and the percentage with degenerative changes of the cuff remained at approximately 60% in each decade. Ninety-six specimens (60%) showed degeneration of the subacromial surface. The percentage with degeneration of the undersurface of the acromion remained at approximately 60% from the sixth to ninth decade. There was a significant correlation between the severity of the changes in the rotator cuff and the subacromial surface. Scanning electron microscopy showed changes suggesting effects of friction and rubbing on the rotator cuff, such as regularly arranged wool-like spherical structures on the surface of the tendon and rounded ruptured ends of the tendon fibers. These results indicate that degenerative change of the rotator cuff is aggravated by a friction and rubbing mechanism with the undersurface of the acromion and leads to development of a complete tear.

The cause and process resulting in development of a rotator cuff tear have not yet been fully elucidated, and the accumulation of knowledge on the morphological changes of the rotator cuff is not yet sufficient. Codman [1] suggested that the cause of the cuff tear was degenerative change of the cuff. Later, Neer [4] indicated the importance of impingement by the subacromial surface and coracoacromial ligament, because of the good results achieved with a combined procedure of cuff repair and anterior acromioplasty [4, 5]. He occasionally noticed a downward projection of the acromion limited to the area covered by the coracoacromial ligament in cases of cuff tear.

Recently, the etiology of rotator cuff tear has become a subject of controversy. Ozaki et al. [7] suggested that intrinsic tendon degeneration is dominant because they found in a study of 200 cadavers cases of capsular side cuff tear in which subacromial surfaces had no degeneration. Ogata et al., [6], on the other hand, observed subacromial degeneration in cases with a normal supraspinatus tendon surface in a study of 76 cadavers, and supported the theory of a contribution by friction and rubbing by the subacromial undersurface [2, 3].

All studies reported have been performed on cadavers fixed with formalin and microstructural observation of the tendon surface has been deficient. The data on the relation between cuff degeneration and age are not suffcient. In this study, we used both formalin-fixed cadavers and fresh cadavers. The purpose of this study was to add data on the macroscopic changes of the rotator cuff and subacromial portion and to demonstrate the effect of friction and rubbing on the cuff surface by scanning electron microscopy using fresh cadavers.

Materials and methods

The study included 160 shoulders of 80 cadavers. Seventy-two cadavers were fixed with formalin and eight were fresh (10 h after death). Most of the subjects died from cerebral apoplexy, neoplasm, or cardiovascular disease, and their ages at death ranged from 43 to 93 (mean 69.3) years. They were made up of 56 males and 24 females.

Dissection of the shoulder was performed by the following method: the deltoid muscle was removed from the acromion and clavicle. The subacromial bursa was then cut at its mid portion. The surface of the cuff and bursa were examined. Next, the coracoacromial ligament was cut near the coracoid process and the ac-

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romion was detached along the acromioclavicular joint. The subacromial portion including the coracoacromial ligament was then examined. Observations were performed by macroscopic assessment and photographs were taken.

By macroscopic observation, degenerative change of the rotator cuff was classified into four grades and the undersurface of the acromion into three grades according to severity [6]. Cuff degeneration was classified as follows: grade 1: loss of the bursa on the cuff; grade 2: surface degeneration of the tendon: grade 3: clear ulcer formation on the cuff, the so-called bursal side incomplete tear: grade 4: full thickness cuff tear. The undersurface of the acromion was classified as follows: grade 1: loss of the bursa on the coracoacromial ligament; grade 2: degeneration of the surface of the ligament; grade 3: appearance of cartilage on the undersurface of the acromion.

The surface of the supraspinatus tendon in the right shoulder of the fresh cadavers were examined by scanning electron microscopy. The ages of the subjects at death ranged from 42 to 81 (mean 68.2) years. A 1-cm^2 sample was obtained from the portion to the insertion of the greater tuberosity. Double fixation of the specimens was done using 2.5% glutaldehyde and 2% osmium acid. After rinsing with 0.1 *M* phosphate buffer, the specimens were dehydrated thorough a graded ethanol series and freeze-dried to the critical point in liquid bicarbonate. Scanning electron microscopy was performed after coating with platinum in an ion coater.

Results

The macroscopic changes of the supraspinatus tendon are shown in Table 1. Ninety-eight specimens (61%) exhibited degenerative changes. The number of tendons with degeneration and tears increased from the fifth to the sixth decade. However, there was no sustained increase in incidence with aging from the age of 60 to 90 years, and the percentage with degenerative cuffs remained approxiamtely 60% in each decade. Severe degeneration was found more frequently in the older age groups than in the younger groups. These degenerations were found on the insertion of the tendon to the greater tuberosity of the humeral head. There were no significant differences in the affected side or sex.

Table 2 shows the relationship between the age and size of the tear in 18 full-thickness tears of the supraspinatus tendon. The size of the tear increased with age, and large tears of more than 3 cm long were found in cadavers 80 to 90 years old at death.

Changes in the undersurface of the acromion are shown in Table 3. Ninety-six specimens (60%) showed degeneration of the subacromial surface. There was no grade 2 or 3 change in the fifth decade. The percentages with degeneration of the undersurface of the acromion remained approximately 60% from the sixth to the ninth decade. There was no sustained increase in the incidence with age. Four specimens obtained from subjects above 90 years of age showed grade 2 or grade 3 degeneration. These changes were found at the insertion and the anterolateral portion of the coracoacromial ligament.

The relationship between the degree of degeneration of the surface of the cuff and the undersurface of the acromion is shown in Table 4. There was a significant correlation between the severity of the changes in the cuff and acromion ($P < 0.01$, χ^2 test). Thirteen cadavers that showed a partial tear of the cuff (grade 3) had grade 2

Table 1. Shoulders with degeneration and/or tear of the cuff

Age (years)	Shoulders	Degenerated cuff		Degeneration grade			
		n	[%]	1	2	3	4
40–49	10 (2)	4	40.0	2	2	0	0
50–59	24 (4)	12	50.0	4 (1)	7	1	0
60–69	46 (2)	29	63.0	6 (1)	12 (1)	5	6
70–79	46 (2)	30	65.2	8	12 (1)	3 (1)	7
80–89	30 (6)	19	63.3	4 (2)	9 (1)	3 (2)	3 (1)
90–	4	4	100	0	1	1	2
Total	160 (16)	98	61.3	24 (4)	53 (3)	13 (3)	18 (1)

( ) Fresh cadavers

Table 2. Shoulders with full-thickness cuff tears

Age (years)	Shoulders	Torn cuff		Cuff tear sizes		
		n	[%]	≤1 cm	1–3 cm	>3 cm
40–49	10 (2)	0		–	–	–
50–59	24 (4)	0		–	–	–
60–69	46 (2)	6	13.0	4	2	–
70–79	46 (2)	7	15.2	5	2	–
80–89	30 (6)	3	10.0	–	–	3 (1)
90–	4	2	50.0	1	–	1
Total	160 (16)	18	11.3	10	4	4

( ) Fresh cadavers

Table 3. Degenerative changes in acromion undersurfaces

Age (years)	Shoulders	Degenerated acromion		Degeneration grade		
		n	[%]	1	2	3
40–49	10 (2)	5	50	5	0	0
50–59	24 (4)	14	58.3	6	8	0
60–69	46 (2)	27	58.7	4 (1)	23 (1)	0
70–79	46 (2)	28	60.9	7	21 (2)	0
80–89	30 (6)	18	60	4 (1)	14 (5)	0
90–	4	4	100	0	2	2
Total	160 (16)	96	60.0	26 (2)	68 (8)	2

( ) Fresh cadavers

Table 4. Relationship between degeneration of the cuff and degeneration of the undersurface of the acromion

Cuff	Acromion			
	Normal	Grade 1	Grade 2	Grade 3
Normal	56	6	0	0
Grade 1	5	11	8	0
Grade 2	3	9	31	0
Grade 3	0	0	13	0
Grade 4	0	0	16	2

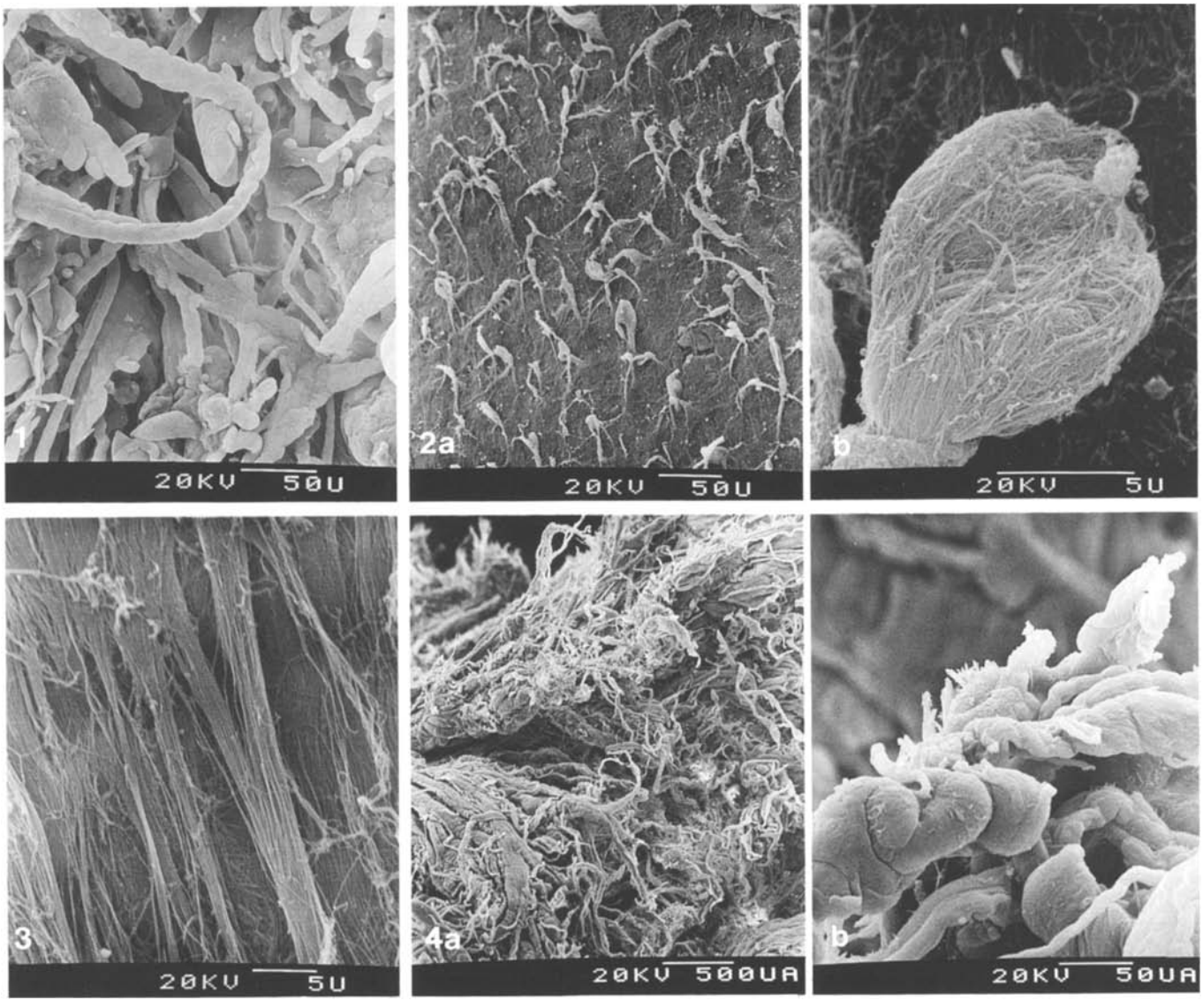

Fig. 1. In the macroscopically normal cuff, the synovial tissues of the subacromial bursa were examined by scanning microscopy

Fig. 2. a In the specimens with grade 1 degeneration, scanning electron microscopy showed regularly arranged wool-like sperical structures on the surface of the supraspinatus tendon. **b** These small spherical structures appeared to be made of fine reticulum fibers

Fig. 3. Grade 2 specimens exhibited microscopic rupture and disarrangement of the superficial fibers of the supraspinatus tendon

Fig. 4. a Grade 3 and 4 specimens showed obvious rupture of the supraspinatus tendon. **b** The ruptured ends of the tendon were shown to be rounded, like a fringe of fibers

degeneration of the acromional undersurface, such as disruption of the fibers in the ligament. Of 18 cadavers that had a complete cuff tear (grade 4), 16 also had grade 2 subacromial change and 2 had grade 3 change with proliferation of the fibrocartilage at the undersurface in two cases. However, six cadavers that had a normal acromial undersurface had grade 1 degeneration with loss of the bursa on the cuff, and eight that had a normal subacromial surface showed grade 1 or 2 degeneration of the cuff.

The microscopic examination of the cuff in the cadavers examined by scanning electron microscopy showed one normal cuff, two with grade 1 change (disappearance of the bursa), three with grade 2 change (derangement of the superficial layer of the tendon), one with grade 3 change (partial tear of the cuff) and one with grade 4 change (full thickness tear). In the macroscopically normal specimens, the synovial tissues of the subacromial bursa were confirmed on the cuff by scanning electron microscopy (Fig. 1). In the grade 1 specimens, scanning electron mciroscopy showed regularly arranged wool-like spherical structures on the surface of the tendon. These small balls appeared to be made of fine reticulum fibers (Fig. 2). Grade 2 specimens showed microscopic rupture and disarrangement of the superficial fibers of the supraspinatus tendon (Fig. 3). The ruptured ends of the tendon were shown to be rounded, having the appearance of like a fringe of fibers in grade 3 and 4 specimens (Fig. 4).

Discussion

This study demonstrated that degenerative changes of the surface of the rotator cuff increase in the fifth and sixth decades and that the degeneration increases with aging. However a cumulative increase of the numbers of subjects with degeneration of the cuff was not observed after the age of 60 years. Approximately 40% of the specimens were identified as normal in every decade until the age of 90 years. These results strongly imply that changes in the rotator cuff mainly appear in the fifth and sixth decades and then progress to a tear. However, the cuffs which do not begin degeneration in these decades may not develop a tear in the later period of aging. The number with partial tear of the cuff tear increased in the sixth decade and there was no cumulative effect in their study.

Changes of the subacromial portion were observed at the insertion and the anterolateral portion of the coracoacromial ligament. These were seen in 50% of the cadavers in the fifth decade and 60% thereafter. A sustained increased in degeneration was not observed in the subacromial surface. As the numbers of cadavers with the acromion and the rotator cuff affected were almost identical and the severity of the subacromial changes correlated significantly with those of the rotator cuff, it is suggested that the changes of the subacromial surface and the cuff affect each other's development.

Results of scanning electron microscopy support the effects of friction and rubbing on the surface of the cuff. Small wool-like structures were observed in grade 1 specimens. The sphericity of the structures and their regular arrangement suggests the effect of a perpetual to and fro movement in their development. The rounded fringe-like appearance of the tendon fibers in grade 3 and 4 specimens also implies friction between the undersurface of the acromion and the ligament.

It is still difficult to identify the initial cause of the rotator cuff tear by this study. Eight cadavers with a normal subacromial surface had already developed degeneration of the superficial tendon fibers of the cuff, implying that the rotator cuff degeneration may have started before the acromial change. On the other hand, we observed six cases of grade 1 acromial change with a normal cuff surface. Therefore, it is also possible that some anatomical changes of the undersurface of the acromion may be the initiating event in some cases.

Our observations support the possibility that degenerative change of the cuff may be aggravated to the exent of developing a tear by friction and rubbing, irrespective of the initial cause of degeneration. As degeneration of the cuff was found to start in the fifth and sixth decades, some intrinsic factors commonly found in these ages play a role in the initiation of the tendon changes.

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