Original Article
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Serial Changes of Fatty Degeneration and Clinical Outcomes after Repair of Medium-Sized Rotator Cuff Tears

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Background: This study was designed to longitudinally analyze quantitative intramuscular and perimuscular fat and evaluate clinical outcomes according to healing degree after rotator cuff repair.

Methods: From June 2013 through October 2018, patients who had undergone repair due to medium-sized rotator cuff tears and serial chest computed tomography (CT) preoperatively and at early (6–12 months) and late (at least 3 years) postoperative follow-ups were included. Supraspinatus (SST) intramuscular fat fraction ratio (IFFR) and perimuscular fat fraction ratio (PFFR) were calculated using chest CT. The rotator cuff integrity was categorized as healed, smaller retear (SRT), and larger retear (LRT) by comparing the preoperative tear size and retear size in shoulder CT arthrography at postoperative follow-ups. Clinical outcomes were evaluated using the American Shoulder and Elbow Surgeons (ASES) score, the University of California at Los Angeles (UCLA) shoulder rating scale, and the Constant score preoperatively and at early and late postoperative follow-ups.

Results: In the LRT group, compared with the preoperative values, there were increases in the SST IFFR and PFFR at the early ($p = 0.002$ and $p = 0.006$, respectively) and late ($p < 0.001$ and $p < 0.001$, respectively) postoperative time points. Late postoperative clinical scores (UCLA and Constant scores) were not improved compared to preoperative scores ($p = 0.156$ and $p = 0.094$, respectively). In the SRT group, there was no difference in the mean SST IFFR and PFFR between preoperative and early postoperative time points ($p = 0.766$ and $p = 0.180$, respectively), but the late postoperative values were higher than preoperative values ($p = 0.009$ and $p = 0.049$, respectively). Late postoperative clinical scores (ASES, UCLA, and Constant scores) in the SRT group improved compared to preoperative time ($p < 0.001$, $p < 0.001$, and $p = 0.016$, respectively). In the healed group, compared with the preoperative values, there was no difference in the mean SST IFFR and PFFR at postoperative time points; however, the late postoperative clinical scores (ASES, UCLA, and Constant scores) were improved (all $p < 0.001$).

Conclusions: In the SRT group, IFFR and PFFR progressed in the late postoperative period and clinical scores improved over time. However, in the LRT group, IFFR and PFFR progressed in the early and late postoperative periods and clinical scores did not improve at the late postoperative follow-up.

Keywords: *Rotator cuff, Rotator cuff injury, Arthroscopy, Computed tomography*

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Fatty degeneration of the rotator cuff muscle can develop after rotator cuff tears and is characterized by fatty infiltration and atrophy of the rotator cuff muscles. These progressive degenerative structural changes are associated with the severity and chronicity of rotator cuff tears. Therefore, fatty degeneration has been associated with clinical outcomes and prognostic factors after rotator cuff repair.[1-3] There are many studies about the effect of rotator cuff repair on fatty degeneration.[4-6] Most studies reported that fatty degeneration after rotator cuff repair progresses when a retear occurs, whereas atrophy and fatty infiltration improve after successful rotator cuff repair.[2,7,8]

However, most studies on fatty degeneration have investigated the initial changes within 1–2 years postoperatively,[9-11] and few studies have focused on serial fatty changes after arthroscopic repair. So, there is a lack of understanding of when these changes occur and how long-term clinical outcomes relate to these changes. In addition, retear groups were not classified according to comparisons between retear size and preoperative tear size. Moreover, most studies have evaluated intramuscular fat degeneration using the Goutallier classification,[12-16] but this assessment method has been shown to be unreliable. Therefore, more studies are needed to identify changes in fatty degeneration and clinical outcomes according to the degree of retear through a serial long-term follow-up.

This study aimed to quantitatively evaluate perimuscular and intramuscular fat preoperatively and early (6–12 months) and late (over 3 years) postoperative time points using chest computed tomography (CT) and evaluate clinical outcomes according to healing degree after arthroscopic rotator cuff repair.

METHODS

Patient Selection

After obtaining approval from the Institutional Review Board of Inje University Busan Paik Hospital (No. 2020-10-006), we retrospectively searched for the medical records of 514 patients who underwent arthroscopic rotator cuff repair between June 2013 and October 2018 at Inje University Busan Paik Hospital. The requirement for informed consent was waived due to retrospective nature of this study. Eligible patients were those who (1) underwent arthroscopic rotator cuff repair surgery using a suture bridge technique, (2) had a medium-sized (1–3 cm), full-thickness rotator cuff tear confirmed by preoperative magnetic resonance imaging (MRI) and arthroscopic findings, (3) underwent serial chest CT preoperatively and within 6 months to 1 year postoperatively (early follow-up) and after at least 3 years (late follow-up) from the operation, (4) underwent shoulder CT arthrography at 6 months postoperatively, and (5) had clinical scores evaluated at the preoperative, early follow-up, and late follow-up time points. We excluded patients (n = 304) with (1) partial-thickness rotator cuff tears, (2) small-sized rotator cuff tears, (3) large to massive cuff tears, (4) isolated or combined subscapularis tears, (5) irreparable rotator cuff tears or cuff tear arthropathy, (6) revision of surgical cuff repair, and (7) previous operative history around the shoulder area. Among the patients who had undergone chest CT more than twice, we selected those who had undergone preoperative CT (less than 6 months before their operations), early postoperative chest CT (between 6 months and 1 year postoperatively), and late chest CT (at least 3 years postoperatively). Among the 210 patients who were not excluded under the exclusion criteria, 106 patients were finally selected after applying the inclusion criteria (Fig. 1). A prior power analysis was performed with data from previous studies to determine the appropriate sample size to detect significant

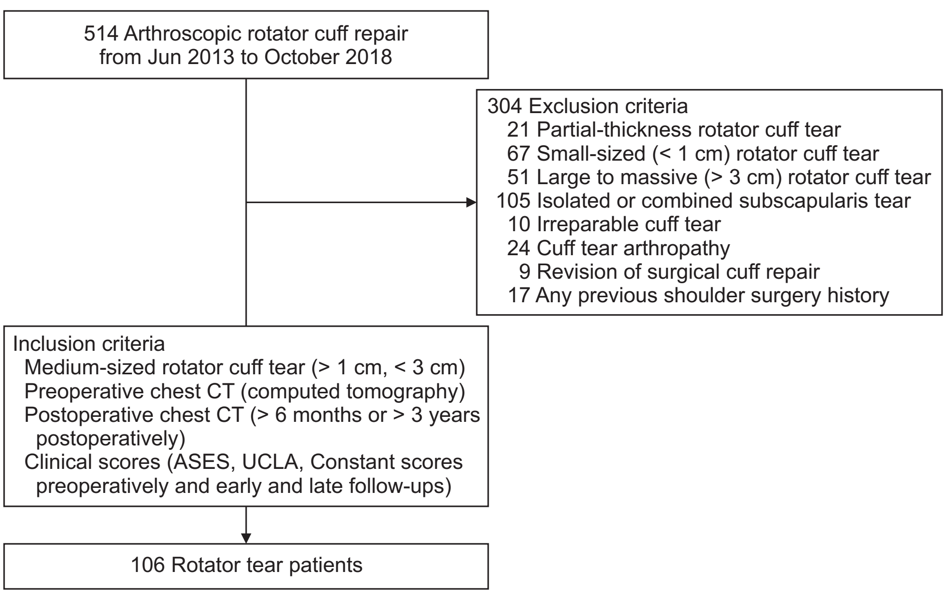

Fig. 1. Patient flowchart. CT: computed tomography, ASES: American Shoulder and Elbow Surgeons, UCLA: Shoulder Rating Scale of the University of California at Los Angeles.

changes in fat fraction values. A sample size of 15 patients per group would allow for the detection of a 2.5% difference in fat fraction values to provide a power level of 0.95 and an alpha of 0.05.[17,18] The demographic and clinical information of the study patients is summarized in Table 1.

Image Reconstruction and Analysis

The CT data were taken from a picture archiving and communication system (Phoenix-PACS) and stored as Digital Imaging and Communications in Medicine (DICOM) files. An image reconstruction program (Radiant DICOM viewer 2020.1 software) was used to import the CT DICOM files. The chest CT images were reconstructed according to the plane of the scapula (defined by landmarks placed on the scapular trigonum, the inferior angle, and the center of the glenoid).[19] The plane passing through the inferior angle, trigonum scapulae, and glenoid center of the scapula was defined as the scapular plane (Fig. 2), and images were obtained from three planes: scapular plane, axial plane (perpendicular to the scapular plane), and sagittal plane (orthogonal to the scapular and axial planes). The parasagittal images evaluated for the study were the most lateral section on which the scapular spine was still in continuity with the body of the scapula.[20] Given that the reconstruction of the axes through Radiant DICOM viewer changed the DICOM files to JPG files, we determined fat thresholds using JPG files.

The DICOM CT image files were loaded into ImageJ software (National Institutes of Health), and we set a polygonal region of interest (ROI) using a point on the bone, and −190 to −30 Hounsfield units[21,22] were substituted in the DICOM file (Fig. 3A). We measured the fat

Table 1. Demographic and Clinical Data

Variable	Healing group (n = 58)	Smaller retear group (n = 28)	Larger retear group (n = 20)	*p*-value
Age (yr)	65.4 ± 6.7	68.3 ± 4.8	67.6 ± 5.7	0.610
Age at operation (yr)	59.4 ± 4.2	62.4 ± 5.8	61.5 ± 4.8	0.103
Sex (male : female)	28 : 30	12 : 16	8 : 12	0.061
BMI (kg/m^2)	23.1 ± 5.2	24.7 ± 3.7	24.8 ± 4.1	0.754
Involvement of side (right : left)	48 : 7	22 : 5	20 : 4	0.057
Smoker	6 (10.3)	3 (10.7)	3 (15)	0.184
Past history of diabetes mellitus	9 (15.5)	6 (21.4)	3 (15)	0.535
Follow-up of late CT (mo)	50.4 ± 9.4	46.2 ± 11.8	47.7 ± 10.9	0.114
Tear size (mm)*				
Mean ML tear size	15.4 ± 4.6	15.9 ± 3.9	16.1 ± 4.4	0.475
Mean AP tear size	12.9 ± 5.2	13.6 ± 4.1	13.1 ± 5.1	0.467

Values are presented as mean ± standard deviation, number, or number (%).
BMI: body mass index, CT: computed tomography, ML: mediolateral, AP: anteroposterior.
*Tear size was calculated manually in T1 gadolinium-enhanced oblique coronal and oblique sagittal images of shoulder magnetic resonance imaging.

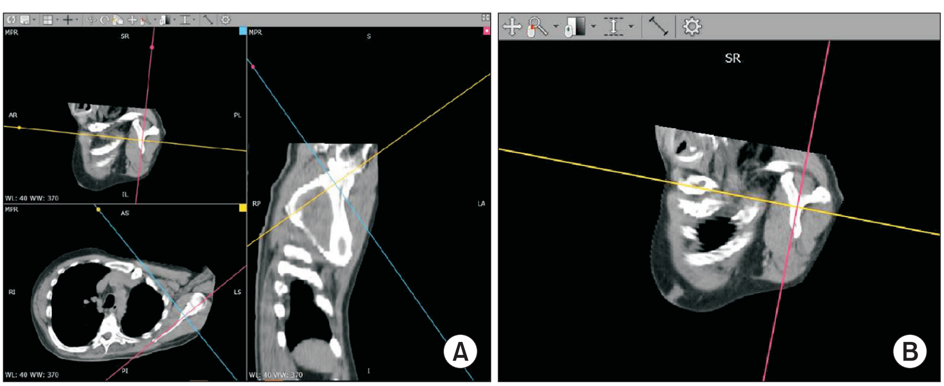

Fig. 2. Reconstruction of a chest computed tomography image with reference to the scapular plane by an image reconstruction program (Radiant DICOM viewer 2020.1). (A) First, three landmarks (scapular trigonum, inferior angle, and center of glenoid) were located in the coronal, axial, and sagittal views. (B) The plane that passes through the three landmarks was made using a plane reconstruction tool.

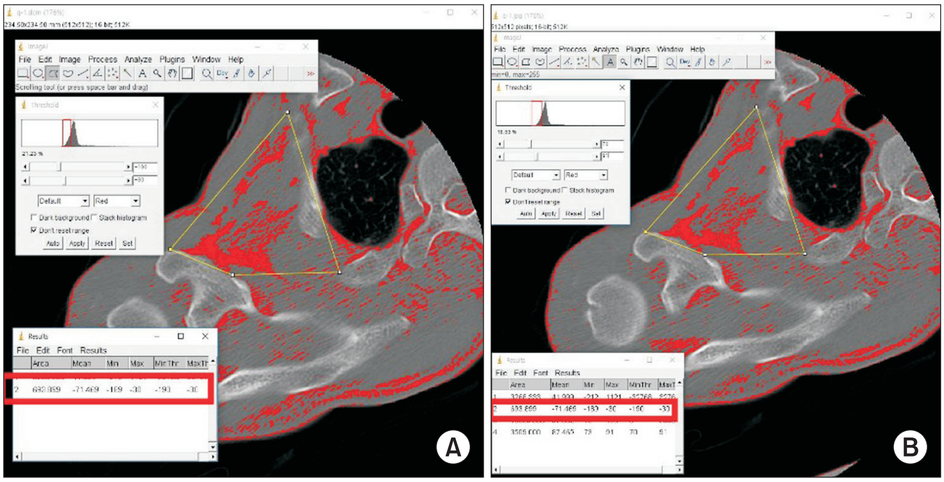

Fig. 3. Finding the threshold of fat material that makes fat values the same in Digital Imaging and Communications in Medicine (DICOM) and JPG files. (A) In DICOM files, –190 to –30 Hounsfield units estimated in a previous study were entered for calculating fat material. (B) In JPG files, we found the threshold that makes the fat value the same. In this figure, a threshold of 70–90 was used to calculate an equivalent fat value of 693.899 mm^3 in the DICOM file.

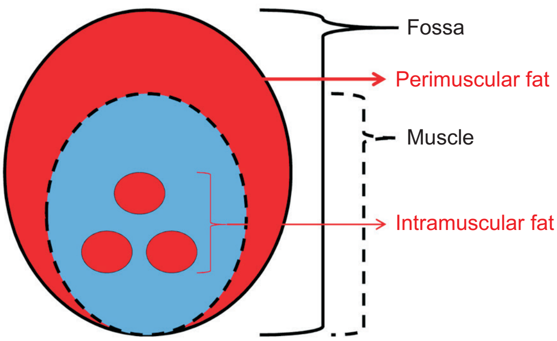

Fig. 4. Schematic explanation of the perimuscular and intramuscular fat areas. Perimuscular fat is out of muscle in the fossa. Intramuscular fat is inside muscle.

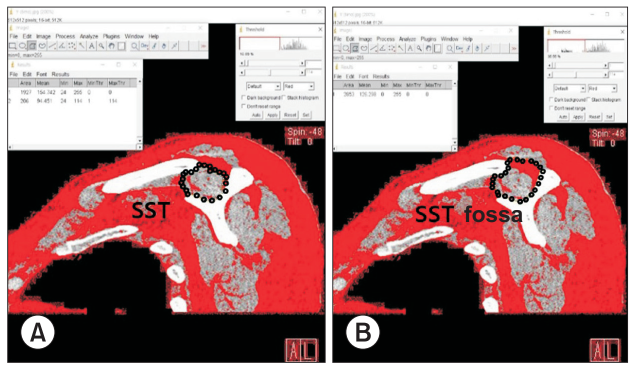

Fig. 6. Measurement of intramuscular and perimuscular fat fraction ratios in the supraspinatus (SST). (A) To measure the intramuscular fat fraction ratio, the region of interest was drawn manually around the border of the SST muscle. (B) For the perimuscular fat fraction ratio, the region of interest was drawn manually around the border of the SST muscle fossa. After the border was set, the specified area and fat values in that area were automatically calculated.

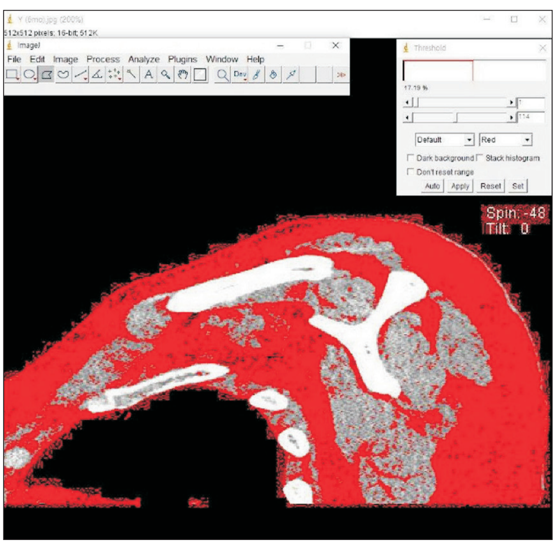

Fig. 5. A reconstructed parasagittal image of the scapular plane in a fat threshold according to a previously calculated value using ImageJ software.

fraction ratio within the ROI. After that, the JPG CT image file was again loaded into ImageJ, and the threshold value was calculated using the JPG file having the same fat fraction in the same ROI (Fig. 3B).

We defined the perimuscular fat fraction ratio (PFFR) as the proportion of fat in the supraspinatus (SST) fossa, excluding the area covered by muscle. The intramuscular fat fraction ratio (IFFR) was defined as the proportion of fat in the SST (Fig. 4). We quantitatively measured both ratios using ImageJ. The areas of the rotator cuff fossa, muscle, and intramuscular fat were measured in reconstructed parasagittal images. The reconstructed parasagittal image was loaded into ImageJ as a JPG file, and the threshold was specified using the fat threshold values from the JPG file obtained earlier (Fig. 5). We outlined the SST (Fig. 6) muscle borders and fossa manually.

Clinical Evaluation

Routine clinical assessments (American Shoulder and Elbow Surgeons [ASES] score, Constant score, and the University of California at Los Angeles [UCLA] Shoulder Rating Scale score) were performed before surgery and then at 6, 12, and 24 postoperative months by a trained research nurse not otherwise involved in the patient treatment. For the included 106 patients, preoperative and 6-month postoperative clinical outcomes were reviewed. To collect data on the late clinical outcomes, we interviewed patients again by telephone during the data collection period to ensure that clinical outcomes (pain, function, and satisfaction) were evaluated at least 3 years after surgery. Patients without data (passive and active range of motion and strength of shoulder muscle) after 3 years in our medical record were asked to visit the hospital to measure these data and only those who agreed were included in the study. Active and passive ranges of motion (forward flexion, abduction, external rotation, and internal rotation with the arm at the side) were measured with a goniometer. The strength of the rotator cuff was assessed using the IsoForceControl dynamometer (Medical Device Solutions) in forward flexion, abduction, external rotation, and internal rotation with the arm at the side.

Healing Degree Using Radiologic Evaluation

Tendon integrity was evaluated by shoulder CT arthrography at 6 postoperative months. Tissue healing was classified into three types. In anatomic healing, there was no leakage of contrast material into the subacromial bursa. In a partially healed defect, there was no leakage of contrast material into the subacromial bursa, but there was either defective healing in the sagittal plane or defective deep tissue healing. In a retear, there was leakage of contrast material into the subacromial bursa.[23)]

For the patients with retears, we measured the anteroposterior (AP) and mediolateral (ML) dimensions of the rotator cuff tear postoperatively and compared each with the initial tear. When cuff healing was associated with a complete or partial healing defect, we defined that as healing. When the AP and ML dimensions of a postoperative retear were smaller than those of a preoperative tear, we defined that as a smaller retear (SRT). When the AP or ML dimensions of a postoperative retear were larger than those of a preoperative tear, we defined that as a larger retear (LRT) (Fig. 7).

Statistical Methods

Statistical evaluation was performed by a statistician at our institution using SPSS Statistics for Macintosh, ver. 17.0 (SPSS Inc.). The paired *t*-test was used to compare the changes in the fat fraction ratios of the SST and the changes in clinical scores between preoperative, early postoperative, and late postoperative determinations. The level of significance was set at 0.05.

RESULTS

The reliability of the measurements for PFFR and IFFR in the SST was excellent, with intraclass correlation coefficients ranging from 0.754 to 0.927 for interobserver reliability and from 0.817 to 0.924 for intraobserver reliability.

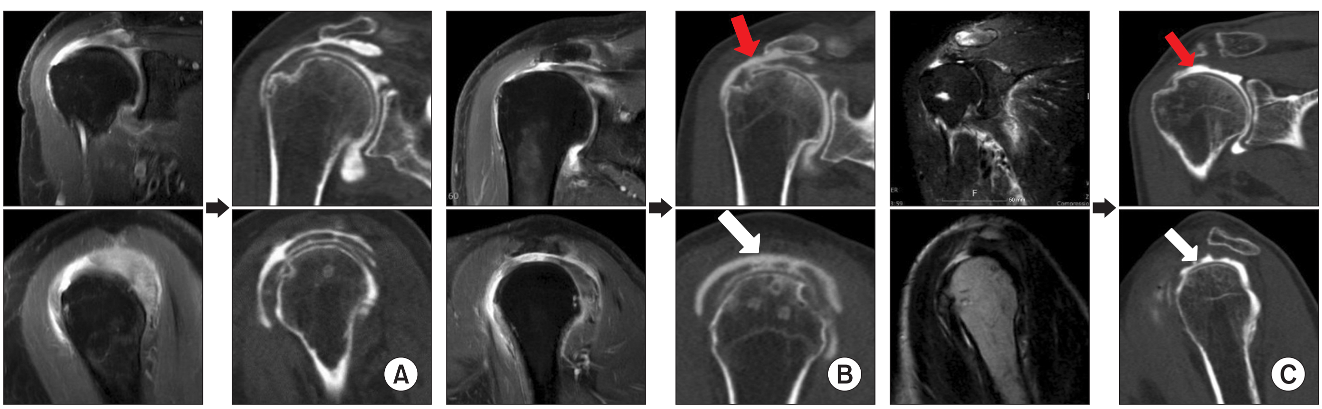

Fig. 7. Radiologic evaluation of healing degree in shoulder computed tomography arthrography at 6 months postoperatively. (A) In oblique coronal and oblique sagittal images, there is no contrast leakage in the distal portion of the supraspinatus (SST) tendon (healing group). (B) There is a defect in the distal portion of the SST tendon filled with contrast material and opacification of the subacromial bursa in the oblique coronal view (red arrow) and oblique sagittal view (white arrow), which means that there is a full-thickness retear that is smaller than the initial tear (smaller retear group). (C) There is a defect at the distal portion of the SST tendon, and the defect is larger than the initial tear in the oblique coronal view (red arrow) and oblique sagittal view (white arrow) (larger retear group).

Serial Changes in the SST PFFR and IFFR According to Healing Degree

The mean preoperative, early postoperative, and late postoperative SST PFFR values in the healed group were 21.1%, 22.3%, and 26.5%, respectively. In this regard, there was no significant change in mean PFFR in the healed group (between preoperative and early postoperative, p = 0.45). In the healed group, the mean preoperative, early postoperative, and late postoperative SST IFFP values were 3.4%, 2.8%, and 4.7%, respectively. There was no significant change in mean IFFR in this group (between preoperative and early postoperative, p = 0.503; between preoperative and late postoperative, p = 0.305).

In the SRT group, the mean preoperative, early postoperative, and late postoperative SST PFFRs were 27.5%, 28.4%, and 34.9%, respectively. There was a significant increase only between preoperative and late postoperative follow-up (p = 0.049). The mean preoperative, early postoperative, and late postoperative SST IFFRs in the SRT group were 6.6%, 8.8%, and 15.0%, respectively; there was a significant increase only between preoperative and late postoperative follow-up (p = 0.009).

In the LRT group, the mean preoperative, early postoperative, and late postoperative SST PFFRs were 24.0%, 34.9%, and 46.7%, respectively. There were significant increases in the mean PFFR of the LRT group at both postoperative time points (between preoperative and early postoperative, p = 0.006; between preoperative and late postoperative, p < 0.001). The preoperative, early postoperative, and late postoperative SST IFFRs were 6.3%, 13.1%, and 23.1%, respectively, in the LRT group, and there were significant increases in mean SST IFFR at both postoperative time points (between preoperative and early postoperative, p = 0.002 and between preoperative and late postoperative, p < 0.001) (Table 2).

Serial Changes in Clinical Outcomes According to Healing Degree

The mean ASES, Constant, and UCLA scores in the healed group were 53.8, 55.6, and 20.9 preoperatively, 70.2, 63.6, and 27.7 early postoperatively, and 92.7, 79.2, and 32.9 late postoperatively. There were significant increases in this regard (between preoperative and early postoperative and between early and late postoperative, p < 0.05). The mean ASES, Constant, and UCLA scores in the SRT group were 58.1, 59.9, and 22.3 preoperatively, 76.4, 70.1, and 28.0 early postoperatively, and 91.0, 79.6, and 32.5 late postoperatively. There were also significant increases in this regard (between preoperative and early postoperative and between early and late postoperative, p < 0.05). The mean ASES, Constant, and UCLA scores in the LRT group were 53.6, 55.6, and 19.6 preoperatively, 74.6, 67.0, and 27.2 early postoperatively, and 75.4, 65.0, and 25.0 late postoperatively. There were significant increases in the mean ASES, Constant, and UCLA scores between the preoperative and early postoperative time points (p = 0.014, p = 0.008, and p = 0.045, respectively), but there were no significant increases in UCLA or Constant scores between preoperative and late postoperative follow-up (p = 0.156 and p = 0.094, respectively) (Table 3).

Table 2. Serial Change of Fat Fraction Ratio of Supraspinatus According to Healing Degree

Healing degree	Preoperative value	Early Follow-up			Preoperative value	Late follow-up		
		Value	△ Ratio*	p-value		Value	△ Ratio†	p-value
Perimuscular fat fraction ratio (%)								
Healing	21.1 ± 4.55	22.3 ± 5.18	1.2 ± 0.75	0.450	21.1 ± 4.55	26.5 ± 6.41	5.4 ± 1.73	0.007‡
SRT	27.5 ± 5.12	28.4 ± 7.45	0.9 ± 2.12	0.180	27.5 ± 5.12	34.9 ± 8.54	7.4 ± 3.12	0.049‡
LRT	24.0 ± 6.11	34.9 ± 7.74	10.9 ± 1.43	0.006‡	24.0 ± 6.11	46.7 ± 9.33	22.7 ± 2.89	< 0.001‡
Intramuscular fat fraction ratio (%)								
Healing	3.4 ± 1.12	2.8 ± 0.64	–0.6 ± 0.75	0.503	3.4 ± 1.12	4.7 ± 1.45	1.3 ± 0.55	0.305
SRT	6.6 ± 1.74	8.8 ± 1.95	2.2 ± 0.31	0.766	6.6 ± 1.74	15.0 ± 3.44	8.4 ± 1.64	0.009‡
LRT	6.3 ± 1.59	13.1 ± 3.77	6.8 ± 2.52	0.002‡	6.3 ± 1.59	23.1 ± 3.86	16.8 ± 2.12	< 0.001‡

Values are presented as mean ± standard deviation.
SRT: smaller retear, LRT: larger retear.
*Early follow-up value minus preoperative value. †Late follow-up value minus preoperative value. ‡p < 0.05.

Table 3. Serial Change of Clinical Outcome According to Healing Degree

Healing degree		Preoperative	Early follow-up	Late follow-up	*p*-value	
					vs. Early follow-up*	vs. Late follow-up*
Healing	ASES score	53.8 ± 15.12	70.2 ± 15.26	92.7 ± 11.17	< 0.001†	< 0.001†
	UCLA score	20.9 ± 4.41	27.7 ± 4.21	32.9 ± 3.41	< 0.001†	< 0.001†
	Constant score	55.6 ± 13.51	63.6 ± 12.51	79.2 ± 13.94	0.037†	< 0.001†
SRT	ASES score	58.1 ± 13.21	76.4 ± 14.47	91.0 ± 12.24	0.003†	0.001†
	UCLA score	22.3 ± 4.51	28.0 ± 3.48	32.5 ± 3.49	0.003†	0.001†
	Constant score	59.9 ± 11.78	70.1 ± 12.22	79.6 ± 13.41	0.04†	0.016†
LRT	ASES score	53.6 ± 14.76	74.6 ± 13.58	75.4 ± 12.87	0.014†	0.016†
	UCLA score	19.6 ± 3.97	27.2 ± 4.84	25.0 ± 4.22	0.008†	0.156
	Constant score	55.6 ± 12.45	67.0 ± 13.11	65.0 ± 12.48	0.045†	0.094†

Values are presented as mean ± standard deviation.
ASES: American Shoulder and Elbow Surgeons, UCLA: Shoulder Rating Scale of the University of California at Los Angeles, SRT: smaller retear, LRT: larger retear.
*Comparison with preoperative value. †$p < 0.05$.

DISCUSSION

The most important finding of this study is that there were statistically significant changes in fatty degeneration of SST according to the degree of repaired cuff healing. In the healed group, intramuscular and perimuscular fat of SST was not increased in the serial follow-up. However, in the SRT group, intramuscular and perimuscular fat of the SST was increased at the late follow-up. In the LRT group, the intramuscular and perimuscular fat of the SST was increased at the early follow-up, which progressed until the late follow-up. These results suggest that the timing of fat degeneration varies depending on the degree of retear, whereas the results of existing studies simply reflect comparisons of a retear group and a healing group. Our result implies that if fat degeneration increased at the early follow-up and the size of the retear is larger than the initial tear, clinical outcomes in the long-term follow-up may not be satisfactory.

While many previous studies explored fatty degeneration after rotator cuff repair, most primarily focused on follow-up observation at one time point. The current study's approach of investigating fatty degeneration beyond the early postoperative time allows for a deeper understanding of the long-term effects of rotator cuff repair on fatty degeneration. Moreover, the quantitative method to assess fatty degeneration provides a more reliable and accurate evaluation compared to traditional qualitative scoring systems. The longitudinal design of the study allows for the investigation of fatty degeneration over multiple time points, providing valuable insights into the temporal dynamics of fat degeneration.

Many studies have investigated fatty degeneration after rotator cuff repair.[1,15,16] However, due to the methodological heterogeneity of published studies—i.e., differences in the size of rotator cuff tears, methods of assessing fatty degeneration, and timing of postoperative measurements—the reported results have been variable, and the conclusions have been debated. In our study, we measured preoperative, early postoperative (between 6 and 12 months), and late postoperative (at least 3 years) fatty degeneration after repairing medium-sized rotator cuff tears. In the healed group, the mean preoperative, early postoperative, and late postoperative SST IFFRs were 3.4%, 2.8%, and 4.7%, respectively. The mean PFFRs at the preoperative, early postoperative, and late postoperative time points were 21.1%, 22.3%, and 26.5%, respectively. Fatty degeneration changes in the SST muscle did not show significant changes during serial follow-up and reversal of fatty degeneration was not established in our study. These findings are similar to those of previous studies that suggest rotator cuff tendon tear-induced fatty infiltration and muscle atrophy can be stopped.[4,5,24] However, in retear groups, especially groups with LRTs, fatty degeneration in the SST muscle was associated with increased IFFRs (6.3%, 13.1%, and 23.1% in the preoperative, early follow-up, and late follow-up time points, respectively) and PFFRs (24%, 34.9%, and 46.7% in the preoperative, early follow-up, and late follow-up time points, respectively). This increased fatty degeneration after retears is also similar to findings reported from previous studies.[5,11,24,25] Wieser et al.[9] evaluated intramuscular fatty infiltration qualitatively using MRI and measured fat fraction ratios in the scapular Y view. In their study, the retear group showed an increased SST muscle's fat fraction from 7.8% preoperatively, to 10.8% at 3 postoperative months, and to 11.4% at 12 months. These findings are similar to our finding of an SST fat fraction change from 6.3% to 13.1% by the early postoperative time point (between 6 and 12 months).

Interestingly, in the SRT group, fatty degeneration had not progressed at the early postoperative follow-up, but progression of fatty degeneration was observed at the late postoperative follow-up. Our results are different from the results of most previous studies that have suggested the progression of fatty degeneration in the first 2 years in the case of retears after rotator cuff repair.[5,11,13] These differences are presumably due to differences in study subjects and the classifications of the study subjects. That is, in the previous studies, there was heterogeneity in rotator cuff tear sizes among study subjects because of a lack of tear size limitation. In addition, the differences in fatty degeneration were compared by classifying the study subjects according to the presence or absence of retears. In other words, the findings of previous studies differed from our study findings because retear patients were not classified according to comparisons between retear size and preoperative tear size. Wieser et al.[9] performed a subgroup analysis of the progression of SST atrophy and fat fraction among healed rotator cuff vs. Sugaya types 4 or 5 retears. They suggested that there were differences in atrophy and fat fraction between types 4 and 5 retears in the early postoperative period, and their findings are similar to our results in terms of the differences in fatty degeneration according to the degree of retear. We cannot confidently assert the cause for this difference in the progression of fatty degeneration in the present study, but we speculate that LRTs after repairs of medium-sized tears might progress into the infraspinatus tendon and affect the rotator cable, thus increasing fatty degeneration during the early postoperative period.

However, this study has some limitations. First, since this was a retrospective study, not all patients treated during the study period were included in the study. Patients who underwent chest CT preoperatively, along with two or more postoperative chest CT scans, were included for evaluating changes in fat degeneration. In addition, since there have been some reports showing that preoperative rotator cuff size is related to postoperative fat degeneration,[3,16] many patients during the study period were excluded from the study, such as those with subscapularis tears, partial tears, small tears, large to massive tears, irreparable tears, retears, and cuff tear arthropathy. Therefore, it was difficult to avoid selection bias and a small sample size. However, since the purpose of this study was to investigate changes in fat degeneration and clinical outcomes according to the degree of healing after rotator cuff repair, we thought that it was important to evaluate fat degeneration and clinical results in a homogeneous sample in terms of tear size.

Second, we quantified fatty degeneration in one cross-sectional area using chest CT. Various methods using CT and MRI have been introduced for the quantification of fat degeneration, and methods using both imaging modalities report similar quantitative results. However, there is a cost problem for patients associated with serial MRI measurements, and serial CT measurements are associated with a risk of radiation exposure. As a retrospective study, we evaluated patients who underwent serial chest CT. Due to the nature of tertiary hospitals as research hospitals, there were many patients with underlying diseases, and many patients underwent chest CT for evaluation of the lungs periodically after surgery. There is a difference in the patient's posture and scanning method between chest CT and shoulder CT, so there is a difference in the measurement value of fat degeneration. In fact, serial shoulder CT is thought to be a more accurate evaluation method to measure fat degeneration of the rotator cuff. However, since the purpose of this study is to measure serial changes in fat degeneration, it is meaningful to serially and quantitatively evaluate fatty degeneration in a semi-automatic method in chest CT by reconstructing it in a scapular plane. In addition, although "one cross-sectional area" method has been used in several previous studies, there is a limitation that one cross-section cannot represent the entire fatty degeneration of the rotator cuff.[26,27)]

Third, retear size was not evaluated at the final follow-up. Therefore, it is difficult to determine whether such fatty degeneration is caused by the progression of the retear itself or by fatty degeneration. Further prospective studies with longer follow-up periods may be needed. Fourth, there was a difference of 36–84 months in the late CT follow-up periods. So, there may have been other injuries or medical conditions that occurred during this period, affecting the healing of the rotator cuff. Since this study is retrospective, it includes patients who took chest CT for other reasons, and there is a possibility of selection bias. When statistically comparing the demographics of the three groups, however, it was confirmed that there was no statistical difference in the CT follow-up period. It is thought that additional research with criteria for delayed follow-up periods is needed to minimize selection bias.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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