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Jung Youn Kim

Hallym University Kangnam Sacred Heart Hospital

Zhuan Zhong

2nd jilin hospital, jilin university

Ho Won Lee

Hallym University Kangnam Sacred Heart Hospital

Kyu-Cheol Noh (✉ Happynoh@gmail.com)

Hallym University Kangnam Sacred Heart Hospital

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Quantitative MRI measurement of muscle atrophy and fatty infiltration after rotator cuff repair

Jung Youn Kim¹, M.D. , Ph.D., Zhuan Zhong², M.D., Ho Won Lee,MD,¹,

Kyu-Cheol Noh, MD,Ph.D.^{1*}

Department of Orthopaedic Surgery, Kangnam Sacred Heart Hospital, Hallym University College of Medicine , Seoul, South Korea,¹

Department of Sports Medicine and Arthroscopy, Orthopedic Center, the 2nd Hospital, Jilin Universtiy²

Jung Youn Kim; E-mail: kimjungyounn@hanmail.net

Zhuan Zhong; zhongzhuan666@gmail.com

Ho Won Lee; lhwghm@gmail.com

Kyu-cheol Noh; Happynoh@gmail.com

* Reprint requests to

Kyu-Cheol Noh, MD

Department of Orthopaedic Surgery, Kangnam Sacred Heart Hospital, Hallym University

1 Singil-ro, Yeongdeungpo-gu, Seoul 07441, Korea

Tel : +82-2-829-5165, Fax : +82-2-964-3865

E-mail: happynoh@gmail.com

ABSTRACT

Background: It is not yet clear whether muscle atrophy and fat degeneration have improved after successful arthroscopic rotator cuff repair. Therefore, in this study, the quantitative MRI measurement was performed to evaluate the changes of muscle atrophy and fat degeneration before and after surgery more accurately and to analyze the correlation between changes in muscle atrophy and fat degeneration and clinical outcome.

Materials and Methods: From March 2013 to March 2017, 40 patients who had no retear up to 1 year after rotator cuff repair were taken before surgery, 3 days after surgery, and 1 year after surgery. Supraspinatus muscle atrophy and fat infiltration were measured quantitatively in Conventional Y view and Supraspinatus origin view. The measurement items were muscle area, occupation ratio, degree of fat degeneration (%) and area of fat degeneration (mm²). Postoperative clinical results were measured by ASES score and Constant score at 1 year. Correlation between values and scores was analyzed.

Results: Inter-measurement reliability was high (ICC = 0.933, Cronbach- α = 0.963). There was no significant change in muscle atrophy in Conventional Y-view at 1 year after surgery (Occupation ratio: $P = 0.2770$; Muscle area (mm²) $P = 0.3049$) and muscle atrophy in Supraspinatus origin view (Muscle area (mm²) $P = 0.5953$). Fatty Infiltration (%) and fat area (mm²) measured with conventional method on Y-view and showed significant difference ($P = 0.0001$). Fatty Infiltration (%) and fat area (mm²) measured with modify method on Y-view and SOV-view showed no significant difference (all $P > 0.05$). Postoperative constant score and ASES showed significant improvement compared to preoperative ($P = 0.0001$), but there was no correlation between fat infiltration and muscle atrophy. ($P = 0.653$)

Conclusion: Clinical outcome (ASES, Constant score) was significantly improved after rotator cuff repair surgery. Clinical outcome (ASES, Constant score) does not have correlation with FI & MA. Muscle Atrophy does not have change 1-year after surgery. Fatty Infiltration was improved in Y-view measured by conventional method.

Keywords: Fatty infiltration, Muscle atrophy, Arthroscopic rotator cuff repair, Supraspinatus origin view, Y-view

Retrospectively registered study: This study was retrospective in nature, and final approval of informed consent exemption by the institutional review board was obtained (HKS 2018-06-025; Hallym University Kangnam Sacred Heart Hospital Institution Review Board)

I. Introduction

Rotator cuff tear is the most common diseases in shoulder with the high incidence of individuals over 60 years old. Arthroscopic rotator cuff repair (ARCR) leads to good midterm to long-term results in most cases and become more and more popular[1, 2], however, re-tear is the most common complication of arthroscopic repair and poor outcomes also were reported .The re-tear rates of rotator cuff was from 10% up to 41% by in 6 months base on recent studies[3, 4].

Several predictive factors are known to influence the structural and clinical results. Muscle atrophy (MA) and Fatty infiltration (FI) are important prognostic factors to predict the surgical and clinical results of rotator cuff repair[5, 6]. Fatty infiltration (FI) means the replacement of muscle fibers by the fat within and around the muscle. Muscle atrophy (MA) means a decrease in the cross-sectional area of muscle, which results in reduced ability to generate force. Fatty infiltration and muscle atrophy are important for clinical decision-making in patients who suffer rotator cuff tear. It is clear that muscle atrophy and fatty infiltration progress in patients who experience a re-tear after rotator cuff repair; however, it is unknown whether they would improve after successful repair. Some researchers demonstrated that atrophy and fatty infiltration of the rotator cuff muscle were halted or reversed with successful rotator cuff repair[7, 8] while other researchers have showed them irreversible[9-12]. Therefore, it is imperative to assess FI and MA using accurate methods.

There are qualitative and quantitative parameters in the method of evaluating and classifying FI and MA. Quantitative parameters mainly use muscle area and occupation ratio[13]. Qualitative parameters of MA include Tangent sign[14] and Thomazeau classification. Qualitative parameters of FI include Goutalier classification[15, 16] and quantitative parameters include degree of fat degeneration (%) and fat area (mm^2). Both are mainly measured in T1-weighted Oblique Sagittal MRI sequences, and the locations of measurement are Conventional Y-view[17] and Supraspinatus origin view[18].

There have been many studies on whether FI and MA are improved reversibly after surgery and no change as an irreversible factor, and many studies have measured and compared serial MRI. It's controversial. While there have been reports of improvement of FI and MA after surgery, some studies show that the reduction of FI and MA is irreversible regardless of surgery.

In the previous studies, the most problem was that the parameters measured in the oblique sagittal MRI before and after the surgery were not measured at the exact same position, and that they did not accurately reflect the tendon traction that occurred during the surgery.

This study uses qualitative parameters, measured in Conventional Y-view and the supraspinatus origin view with conventional method and modified method for muscle atrophy and fat infiltration before and after surgery. The purpose of this study was to investigate whether there was a significant change in degeneration and to determine the correlation between the change of muscle atrophy and fatty infiltration and clinical outcome.

II. Materials and methods

Ethics approval and consent to participate

All methods were performed in accordance with relevant guidelines and regulations. All experimental protocols were approved by Hallym University Kangnam Sacred Heart Hospital Institution Review Board. This study was retrospective in nature, and final approval of informed consent exemption by the institutional review board was obtained (HKS 2018-06-025; Hallym University Kangnam Sacred Heart Hospital Institution Review Board.)

Patient selection

The subjects were 88 patients diagnosed as rotator cuff tears from March 2013 to March 2017. The inclusion criteria included 1) duration from March 2013 to March 2017, 2) age from 50 to 79 years old, 3) Medium to large size (2-4cm) rotator cuff tear was diagnosed by MRI, 4) who suffered the pain more than 6 months and underwent ARCR, 5) who underwent 3 times MRI including 1 time preoperative and 2 times post-operatively (3 days, 1 year). Exclusion criteria include 1) Acute traumatic tear, 2) Coexisting pathology (Malignancy, Systemic disease, infection), 3) Previous ipsilateral shoulder operation, 4) Tear size less than <2 cm or more than > 4 cm, 5) Retear after surgery (Sugaya classification IV, V). Thirty-three patients were excluded because of inaccurate shadowing or inaccurate imaging in the MR image, and a total of 40 patients were examined. (Figure.1)

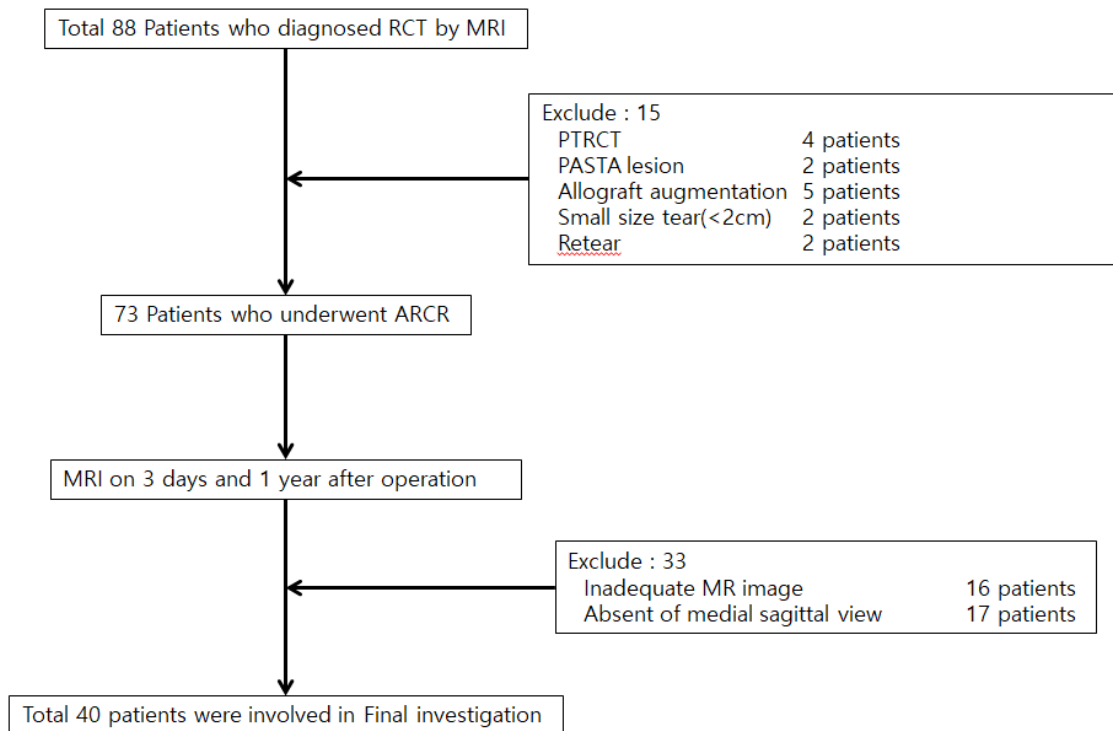


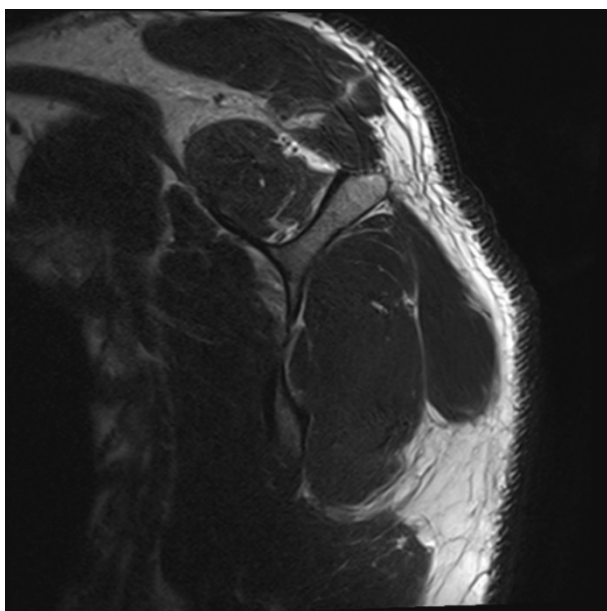
Figure 1 Patient flow chart. Total 88 patients were diagnosed rotator cuff tear by MRI. 15 patients were excluded by several criteria. Residual patients underwent ARCR, and follow up MRI was taken. 33 patients were excluded by inadequate MRI or Absent of medial sagittal view. Finally Total 40 patients were involved in final investigation.

When performing MRI segmental measurements, it is most often performed in the most lateral sagittal scapular Y-view(Figure.2), where the coracoid base and scapula body show a Y shape. [17] Most studies have been reported with evaluation at this location. However, this method of measuring Y-view is relatively inaccurate because the tendon retraction due to tear of the rotator cuff and the resulting muscle thickening in the sagittal view of the same position and the medialization of the muscle at that position are not reflected. The results of one measurement are not yet clear. Therefore, measurements were performed in the SOV view(Figure.3) with the least effect of retraction[18].



92

93 **Figure 2** The conventional Y-view, in which the coracoid base and the spine and body of the scapula form a Y
 94 shape on oblique sagittal MRI sequences.



95

96 **Figure 3** The most lateral portion of the osseous origin of supraspinatus muscle was defined as the
 97 supraspinatus origin-view (SOV)

98

The rupture size was measured using preoperative MRI and calibrated probe during arthroscopy. The index of clinical outcome was ASES and Constant score one year after surgery. Also, two experimenters blindly measured to increase the reliability of the measurement.

MRI Assessment

MRI examination was performed in all patients in neutral to external rotation position using a 3.0T magnet (Siemens Healthcare, Erlangen, Germany) with an interval of 4 mm for each sagittal slice. The total scan time was approximately 15 minutes (3.0T). Measurements were performed using the picture archiving and communication system (PACS) program (Infiniti Healthcare, Seoul, Korea) available in the medical center. Standard T2-weighted images were used for measurements according to the following method.[19]

All patients underwent the 3 sets of MRI examination including pre-operative and 2 times of post-operative MRI(3 days and 1 year). The assessment of fatty infiltration(FI) and (MA) were underwent on conventional Y-view and supraspinatus origin view(SOV). To quantify fatty infiltration(FI), FD(%) and fatty area(mm^3), the borders of each muscles were outlined manually, and the signal intensities within the boundaries were manipulated by PACS system. First, we draw outline of based muscle area. And use pseudo-color mapping function which turns the fat integrity into red. Then, can get the value of FD(%) and fatty area(mm^3) directly(Figure. 4). Because of the uncertain boundary between muscle portion and fat portion, for more accurate and precise measurement, we measured by two different methods. First, the percentage of fatty infiltration is based on estimated anatomical muscle occupying area.(Method I) The other is based on actual occupied area. (Method II) (Figure. 5)

To quantify Muscle Atrophy(MA), occupation ratio(%) and muscle area(mm^3) were measured, which is the ratio between the cross sectional area of muscle belly and its fossa on oblique sagittal Y-view of MRI. Draw the outline of estimated anatomical muscle occupying area, and actual occupied area. Then can get the value of each area(mm^3) and ratio(Figure. 6).

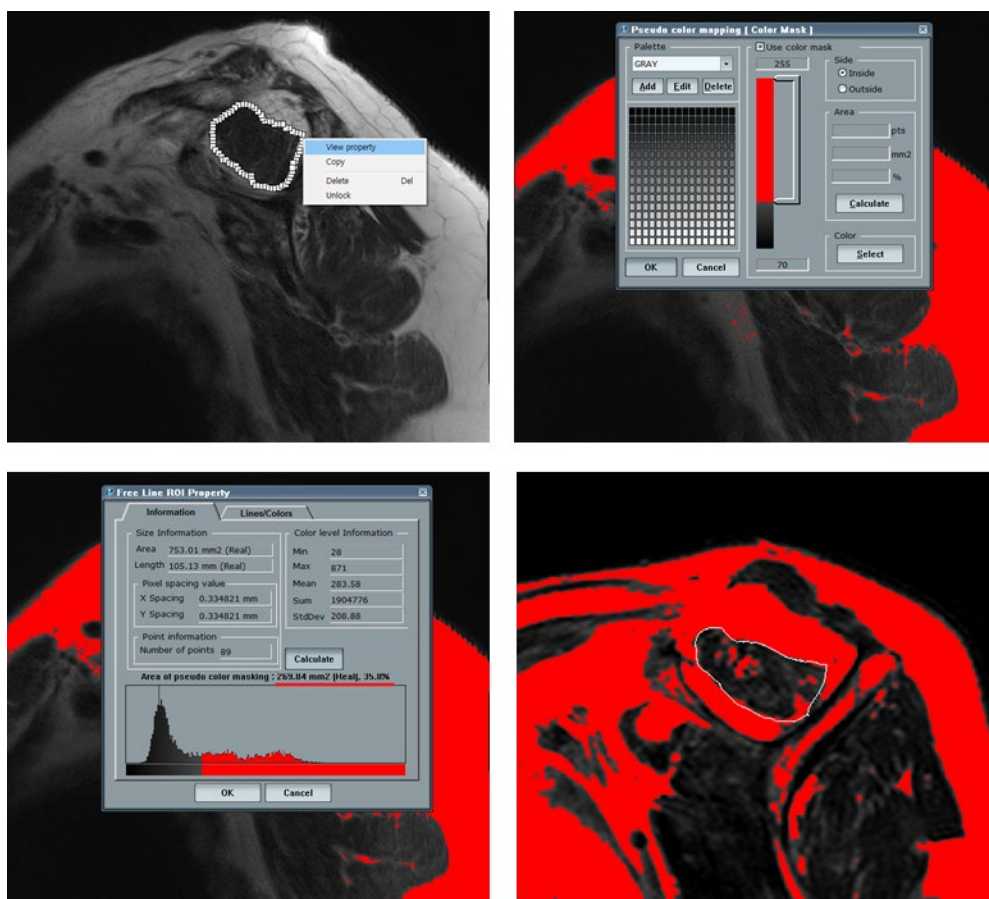


Figure 4 To quantify FD(%) and fatty area(mm²), the borders of target area were outlined manually, and the signal intensities within the boundaries were manipulated by PACS system. Using the pseudo-color mapping function in PACS system, high signal intensities, which means fat, turns into red. Then, can get the value of FD(%) and fatty area(mm²) directly



Figure 5 For more accurate and precise measurement, we measured by two different methods. First, the percentage of fatty infiltration is based on estimated anatomical muscle occupying area (Method I). The other is based on actual occupied area (Method II)

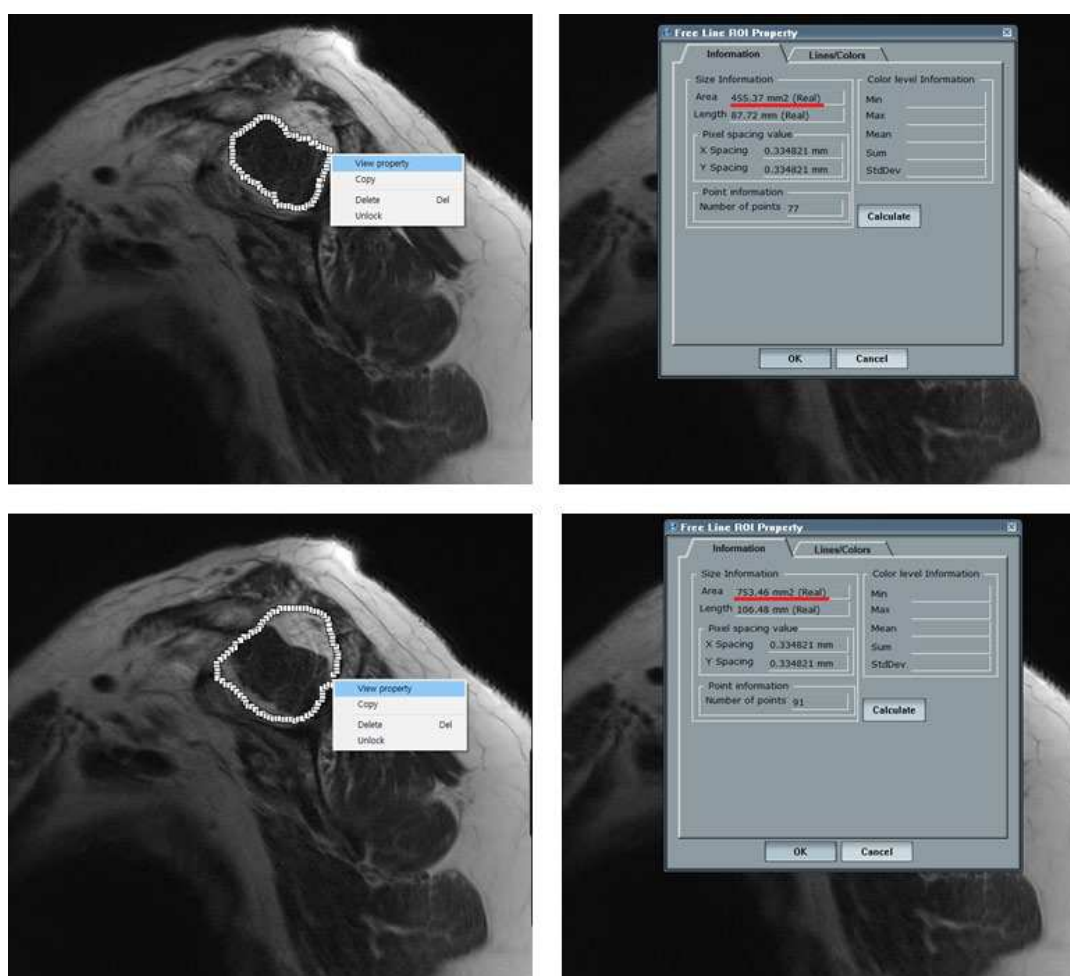


Figure 6 To quantify occupation ratio(%) and muscle area(mm^2), draw the outline of estimated anatomical muscle occupying area, and actual occupied area. Then can get the value of each area(mm^2) and ratio

To quantify FD(%) and fatty area(mm^2), the borders of target area were outlined manually, and the signal intensities within the boundaries were manipulated by PACS system. Using the pseudo-color mapping

Actually, the boundary of supraspinatus is unclear in supraspinatus origin view(SOV), factors of FI were measured only by Method II, and occupation ratio in MA also cannot be measured.

Surgical Technique: Arthroscopic Rotator Cuff Repair

All procedures were performed with patients in the lateral decubitus position with sand bag under general anesthesia. Using posterior, anterior, lateral, posterolateral portal, then systemic glenohumeral joint and

subacromial exploration was performed, the rotator cuff tear was carefully evaluated, and the anterior to posterior size, medial to lateral size, and numbers of involved tendons were documented. The footprint of the greater tuberosity was then debrided; only a minimal layer(1~2mm) of cortical bone was removed. Rotator cuff repair was performed to cover the original footprint by use of a suture bridge technique, as allowed by tension. Suture anchors were inserted through the accessory portal. The numbers of anchors used depended on tear size. Generally, 4 anchors were used. The suture bridge technique was performed. First medial-row anchors were inserted using Arthrex anchor (Iconix, Stryker, Mahwah, NJ) just lateral margin of the humeral head, and sutures were then threaded through the rotator cuff. Sutures were tied securely with the non-slide knot, and the lateral row was secured by use of lateral anchor (Reelx, Stryker, Mahwah, NJ).

All patients underwent same rehabilitation protocol, using abduction sling for 6 weeks. Pendulum exercise was started 1 week after surgery, and active assisted range of motion exercise was followed for 6 weeks after surgery.

Clinical Evaluation

Clinical evaluation was performed at 1 day before surgery and 1 year after surgery. It include The American Shoulder and Elbow surgeons (ASES) score and Constant score[20].

Statistical Analysis

About Statistical analysis the reliability of the MA, FI measurement between two observers of two trials, were evaluated with the interclass correlation coefficient (ICC, >0.8: excellent, 0.6-0.8: good, 0.4-0.6: fair, < 0.4: poor) and Cronbach- α (>0.75: excellent, 0.4-0.75: fair to good, < 0.4: poor). Repeated measure ANOVA(RM ANOVA) was used to comparing the change of MA and FI between surgery. RM ANOVA or Friedman's test (nonparametric method) was performed to analysis the change over time. All the data were analyzed using SPSS 23(Statistical Package for Social Science, version 23.0, IBM Corporation, Chicago, IL, USA) or SAS9.4(SAS Institute, Cary, NC, USA). P-values< 0.05 were considered statistically significant.

III. Results

A total of 40 patients were included (male, n = 16; female, n = 24) with an average age of 60.9 ± 7.62 years. The mean tear size was Medial to lateral 24.91 ± 5.75 (mm) and Anterior to posterior 21.42 ± 5.88 (mm). Acromioplasty was performed in 37 patients and Biceps tenotomy in 33 patients. (Table 1)

Table 1. Patient demographics

	Value
Total enrollment	40

Age	46-74
Sex (M/F)	16/24
Tear size (medium/large)	27/13
Affected side (Right/Left)	30/10
Technique (Suture bridge/single row)	12/28
Acromioplasty (Yes/No)	37/3
Biceps tenotomy (Yes/No)	33/7

171

In this study, the mean ICC value for the measured values of MA and FI was 0.933 (> 0.8 , Excellent) and the average Cronbach- α value was 0.963 (> 0.75 , Excellent). ($P < 0.0001$)

Muscle atrophy before and after surgery showed no significant change in Occupation ratio at Y-view, 0.59 ± 0.12 before surgery, 0.61 ± 0.14 after 3 days, and 0.67 ± 0.14 ($P > 0.05$) after 1 year. Muscle area showed no significant change of 396.03 ± 99.25 preoperatively, 389.77 ± 101.80 after 3 days postoperatively, and 365.54 ± 87.99 ($P > 0.05$) one year postoperatively.

Muscle area in SOV was also unchanged: 462.80 ± 106.77 preoperatively, 444.49 ± 114.89 3 days postoperatively, and 419.67 ± 101.64 ($P > 0.05$) 1 year postoperatively. (Table 2)

Table 2. Evaluation of Muscle Atrophy

			Preoperative	Postoperative 3 days	Postoperative 1 year	<i>P</i> value
Classical Y-view	Supraspinatus(n=40)	Occupation ratio	0.59 ± 0.12	0.61 ± 0.14	0.67 ± 0.14	0.2770
		Muscle area(mm ²)	396.03 ± 99.25	389.77 ± 101.80	365.54 ± 87.99	0.3049
Supraspinatus origin view	Supraspinatus(n=40)	Muscle area(mm ²)	462.80 ± 106.77	444.49 ± 114.89	419.67 ± 101.64	0.5953

Fatty Infiltration was measured by Method I. In Y-view, the change in fatty degeneration (%) was 44.22 ± 12.32 preoperatively, 39.45 ± 11.84 after 3 days postoperatively, and 35.41 ± 13.10 ($P < 0.05$) 1 year postoperatively. The fat area was also significantly changed to 281.39 ± 81.96 preoperatively, 258.47 ± 92.38 3 days postoperatively, and 202.83 ± 77.36 ($P < 0.05$) 1 year postoperatively.

On the other hand, Y-view measured by Method II showed no significant change in fatty degeneration (%): 7.71 ± 4.72 preoperatively, 11.03 ± 7.21 after 3 days, and 10.57 ± 7.11 ($P > 0.05$) 1 year after surgery. In the fat area, 197.84 ± 66.96 preoperatively, 41.12 ± 27.51 3 days postoperatively, and 36.48 ± 24.13 1 year postoperatively ($P > 0.05$).

In SOV measured by Method II, there was no significant difference in fat infiltration (%): 9.56 ± 6.11 preoperatively, 9.98 ± 7.78 after 3 days postoperatively, and 9.40 ± 8.23 ($P > 0.05$) 1 year postoperatively. (mm²), 246.55 ± 79.8 preoperatively, 43.45 ± 35.34 3 days after surgery, and 40.27 ± 40.61 1 year after surgery ($P > 0.05$). (Table 3)

196 **Table 3. Evaluation of Fatty Infiltration**

			Preoperativ e	Postoperativ e 3 days	Postoperativ e 1 year	<i>P</i> value
Classical Y- view (Method I)	Supraspinatus(n=40)	Fatty	44.22 ±	39.45 ±	35.41 ±	0.000
		Degeneration(%)	12.32	11.84	13.10	1
		Fat area(mm ³)	281.39 ±	258.47 ±	202.83 ±	0.000
			81.96	92.38	77.36	1
Classical Y- view (Method II)	Supraspinatus(n=40)	Fatty				
		Degeneration(%)	7.71 ± 4.72	11.03 ± 7.21	10.57 ± 7.11	0.147 6
		Fat area(mm ³)	197.84 ±	41.12 ±	36.48 ±	0.151
			66.96	27.51	24.13	0
Supraspinatu s origin view (Method II)	Supraspinatus(n=40)	Fatty				
		Degeneration(%)	9.56 ± 6.11	9.98 ± 7.78	9.40 ± 8.23	0.107 8
		Fat area(mm ³)	246.55 ±	43.45 ±	40.27 ±	0.122
			79.8	35.34	40.61	3

197

198 Clinical outcome

199 The clinical results showed that ASES showed a significant improvement of 72.55 ± 15.83 ($P < 0.05$) one year
200 after surgery and 50.93 ± 16.58 preoperatively, and a constant score of 71.48 ± 10.83 one year after surgery
201 compared to 59.03 ± 15.76 before surgery. ($P < 0.05$) showed a significant change. (Table 4)

202 **Table 4. Evaluation of the Clinical outcome before and after surgery**

		Preoperative	Postoperative 1 year	<i>P</i> value
Entire group(n=40)	ASES	50.93 ± 16.58	72.25 ± 15.83	<0.0001
	Constant	59.03 ± 15.76	71.48 ± 10.83	<0.0001

203

204 In addition, the correlation between the change in ASES and Constant Score and the change in FI (%) and
205 muscle area (SSE) was 0.342 ($P > 0.075$).), And the correlation coefficient with muscle area was 0.026 ($P >$
206 0.884). The correlation coefficient between the change of constant score and Fatty Infiltration (%) was 0.089 (P
207 = 0.653), and there was no correlation between muscle area (mm³) and -0.157 ($P = 0.374$). . (Table 5)

208 **Table 5. Correlation between clinical outcome and Rotator cuff**

Value difference between surgery	Fatty Infiltration(%)	<i>P</i> value	Muscle Area(mm ²)	<i>P</i> value
ASES	0.342	0.075	0.026	0.884
Constant	0.089	0.653	-0.157	0.374

209 ***Spearman correlation coefficient**

IV Discussion

Our results focus on measuring FI and MA more accurately and quantitatively than previous studies. Rather, it was measured in the Supraspinatus origin view. In addition, follow-up observation was performed before, immediately after surgery, and 1 year after surgery. The correlation between the measured changes in FI and MA and the clinical outcome was also analyzed.

FI was found to be significantly decreased in the study, but MA was significantly progressed. Most of the previous studies were also analyzed using MRI measures using various methods and criteria, but the results from the Conventional Y-view and qualitative measurements were dominant.

Chris et al.[17] have been reported that FI and MA of SST and IST recover after arthroscopic surgery. The study was performed at the MRI Classical Y-view before and three days after surgery, and the Goutallier classification and muscle area were measured and compared. Hanamo et al.[21] Reported that the MA and FI improved after the rotator cuff repair, which was measured before and after 2 years in the MRI Classical Y-view, and compared with the Goutallier classification and Occupation ratio. In this study, both the constant score and the muscle strength were compared and the postoperative scores increased. There have been reports of positive changes after surgery, including this study, but there are many studies that suggest that there is no improvement.

Chris et al.[17] Reported that the change in MA after surgery was dependent on baseline and integrity, which was measured in the conventional Y-view of MRI before, immediately after, and 1 year after surgery. Tangent sign, occupation ratio, and muscle area were measured and compared. Before surgery, the results were improved. Liem et al.[12] FI and MA were not able to improve after successful repair and were measured and compared using Goutallier classification, Tangent sign and Thomazeau classification in MRI's Classical Y-view before and after 2 years. Only the Constant score showed significant improvement. Yoo et al.[18] reported a slight increase in muscle volume after successful surgery, but no change in FI by Goutallier classification.

For the clinical results, there was a comparison between the preoperative and postoperative clinical outcomes using scores. Fanny et al.[20] reported that Surgical repair of chronic rotator cuff tendon tear can produce consistent and lasting pain relief and improvement in range of motion. Re-tear of the repair was not correlated with degradation of clinical results. Gladstone et al.[10] reported that FI and MA did not improve after surgery and that the Constant and ASES scores were significantly increased. This was compared with Conventional Y-view in MRI before and 1 year after surgery, and evaluated using Goutallier classification. The correlations between the constant score and the ASES score were compared according to the FI and MA changes, but the qualitative comparison method was used, and the correlation was negative.

The quantitative and qualitative parameters and measurement methods for FI and MA used in each study were not significantly different, and the measurement site was not significantly different with the Conventional Y-view and Supraspinatus origin view. However, many of these conflicting results are reported because the degree of retraction varies depending on the tear size, the degree of retraction also depends on the position of the

supraspinatus muscle, and the method of accurately reflecting this may be ambiguous. Because it is a sequence image rather than a continuous image, a minute error of 1-2mm in the image may also affect the results. In addition, it may be assumed that the degree of retraction also depends on the tear and repair technique of other tendons.

The clinical outcomes measured by ASES and Constant score have also been reported in many studies, but there are many opinions on the association between changes in FI and MA. Patients with poor preoperative scores tend to be selected mainly, and preoperative and postoperative scores tend to increase as one of the objectives of the operation is functional recovery. However, the correlation between the improvement of the score and the degree of change of FI and MA should be discussed under the assumption that the measurements of FI and MA are accurate. In addition, it is difficult to find a clear correlation because there is a difference between the quantitative standard and the unit of the change of score and the change amount of FI and MA itself.

The correlation between the change of FI, MA and the clinical outcome through surgery is expected to be more accurate and accurate in the future, and more sophisticated techniques such as 3D MRI are needed than the existing measurement tools.

V. Conclusion

Fatty Infiltration of supraspinatus in Conventional Y-view showed a significant change at 1 year postoperatively, but there was no significant improvement in SOV. The ASES and Constant scores showed statistically significant improvement, but there was no correlation between the change of FI and MA and the clinical results.

273 **List of abbreviations**

274 Arthroscopic rotator cuff repair (ARCR)

275 Muscle atrophy (MA)

276 Fatty infiltration (FI)

277 Supraspinatus origin view(SOV)

278 **Declarations**

279 **Ethics approval and consent to participate**

280 *Ethics approval and consent to participate*

281 All methods were performed in accordance with relevant guidelines and regulations. All experimental
282 protocols were approved by Hallym University Kangnam Sacred Heart Hospital Institution Review Board. This
283 study was retrospective in nature, and final approval of informed consent exemption by the institutional review
284 board was obtained (HKS 2018-06-025; Hallym University Kangnam Sacred Heart Hospital Institution Review
285 Board.)

286 **Consent for publication**

287 Not applicable

288 **Availability of data and materials**

289 The datasets generated during and analyzed during the current study are not publicly available due to ethical
290 concern but are available from the corresponding author on reasonable request

291 **Competing interests**

292 The authors declare that they have no competing interests

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296 **Authors' contributions**

297 JY, ZZ and HW analyzed and interpreted the patient data. KC was a major contributor in writing the
298 manuscript. All authors read and approved the final manuscript.

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371

Figures

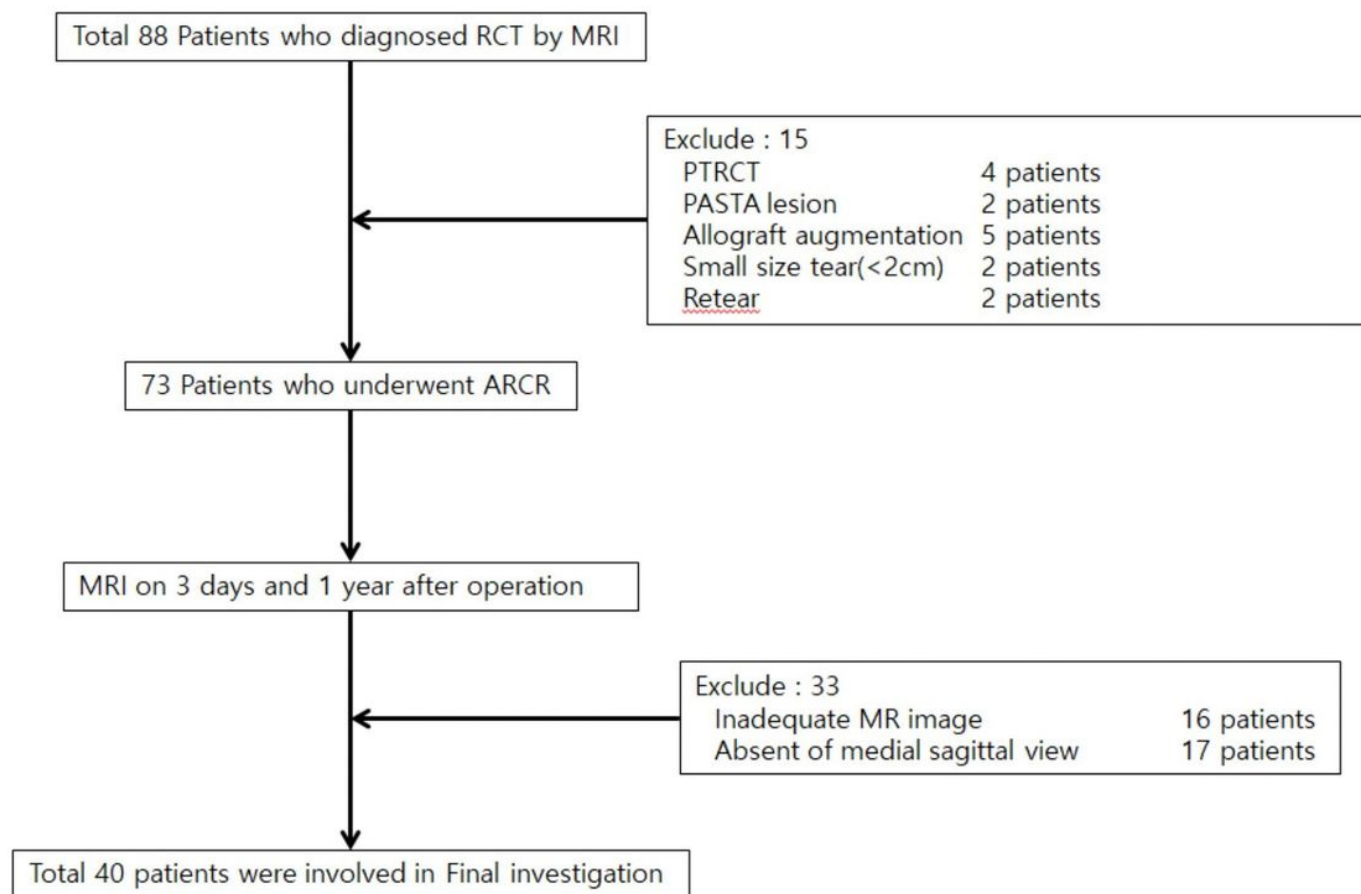


Figure 1

Patient flow chart. Total 88 patients were diagnosed rotator cuff tear by MRI. 15 patients were excluded by several criteria. Residual patients underwent ARCR, and follow up MRI was taken. 33 patients were excluded by inadequate MRI or Absent of medial sagittal view. Finally Total 40 patients were involved in final investigation.



Figure 2

The conventional Y-view, in which the coracoid base and the spine and body of the scapula form a Y shape on oblique sagittal MRI sequences.

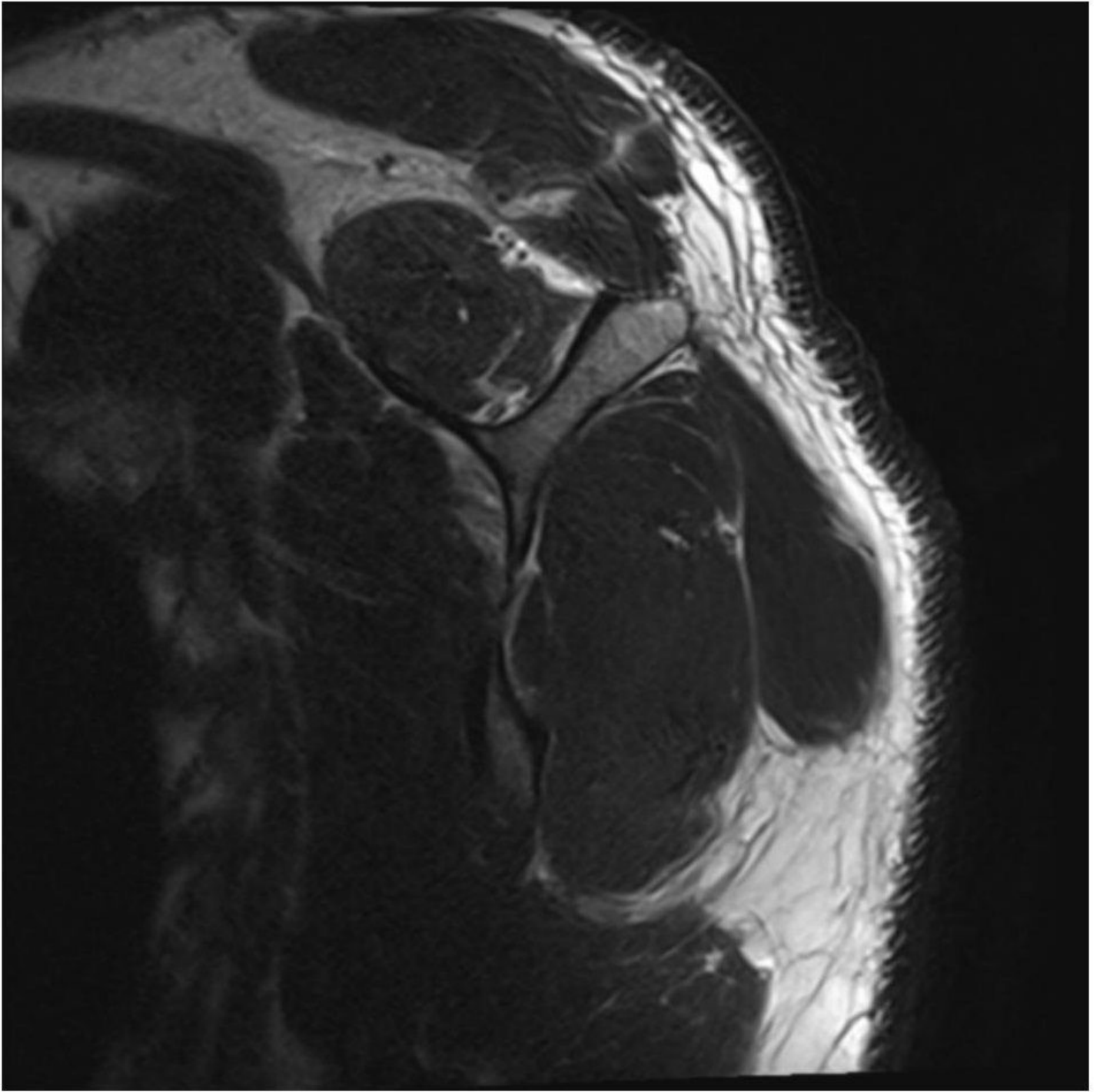


Figure 3

The most lateral portion of the osseous origin of supraspinatus muscle was defined as the supraspinatus origin-view (SOV)

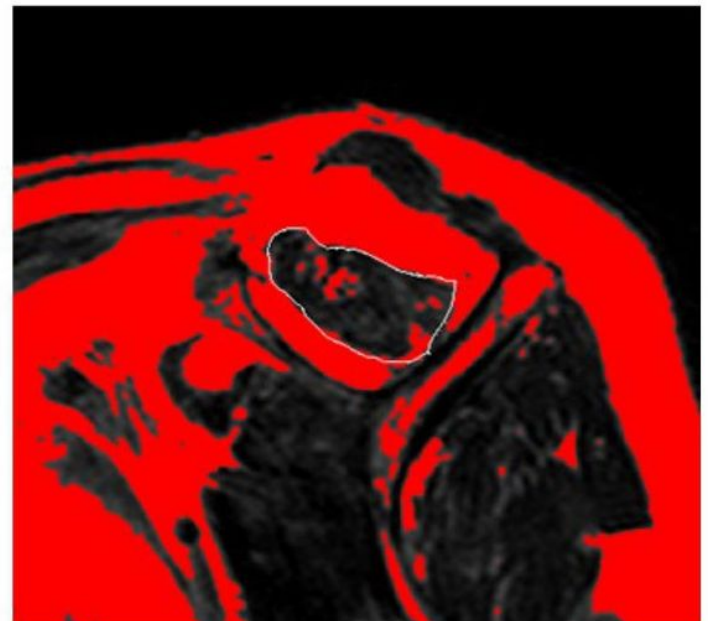
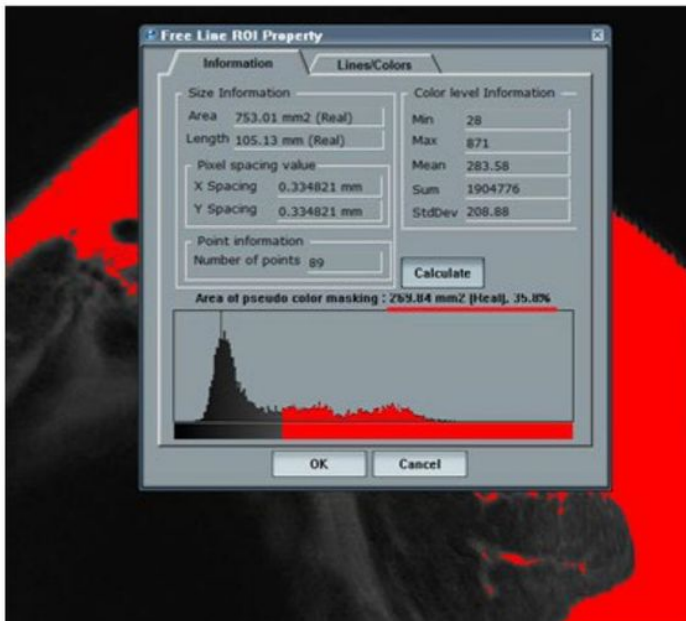
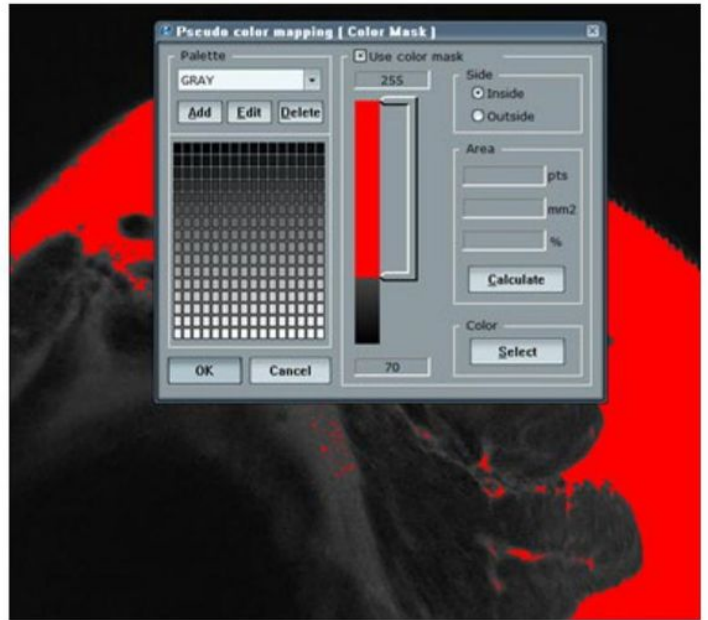
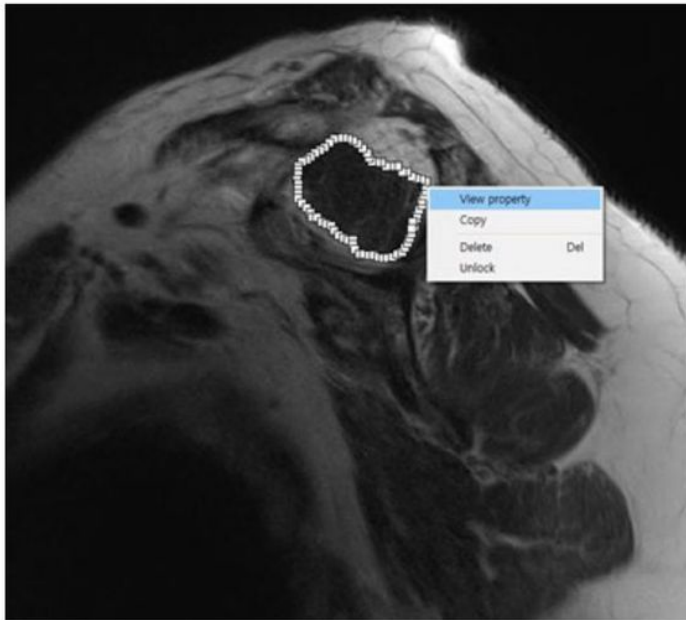


Figure 4

To quantify FD(%) and fatty area(⊠), the borders of target area were outlined manually, and the signal intensities within the boundaries were manipulated by PACS system. Using the pseudo-color mapping function in PACS system, high signal intensities, which means fat, turns into red. Then, can get the value of FD(%) and fatty area(⊠) directly

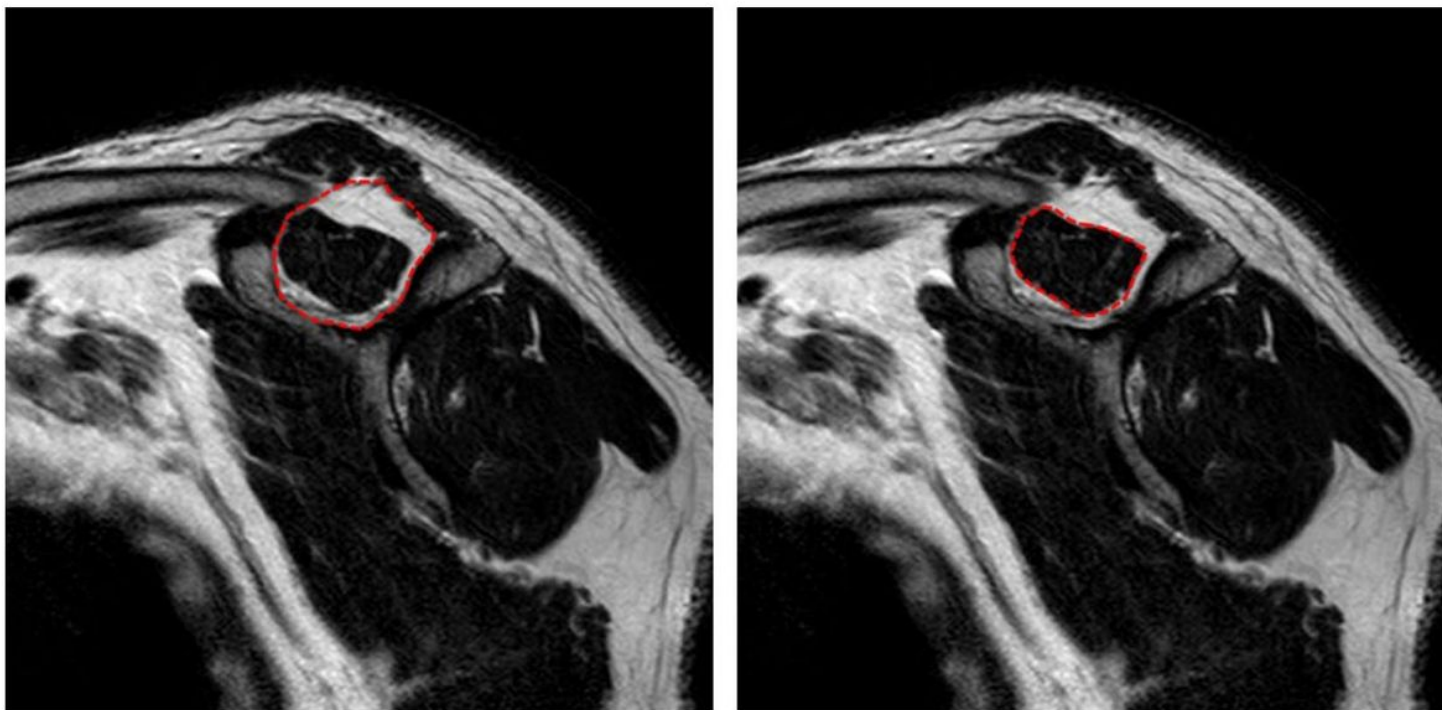


Figure 5

For more accurate and precise measurement, we measured by two different methods. First, the percentage of fatty infiltration is based on estimated anatomical muscle occupying area (Method I). The other is based on actual occupied area (Method II)

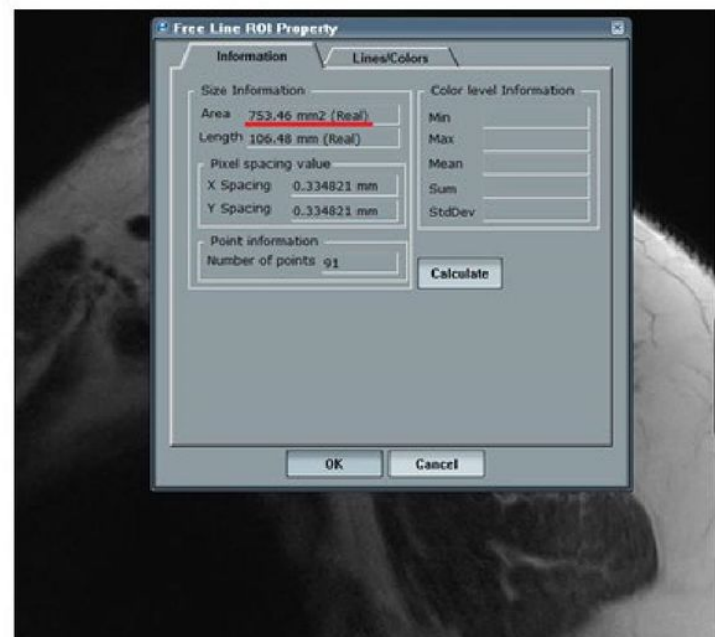
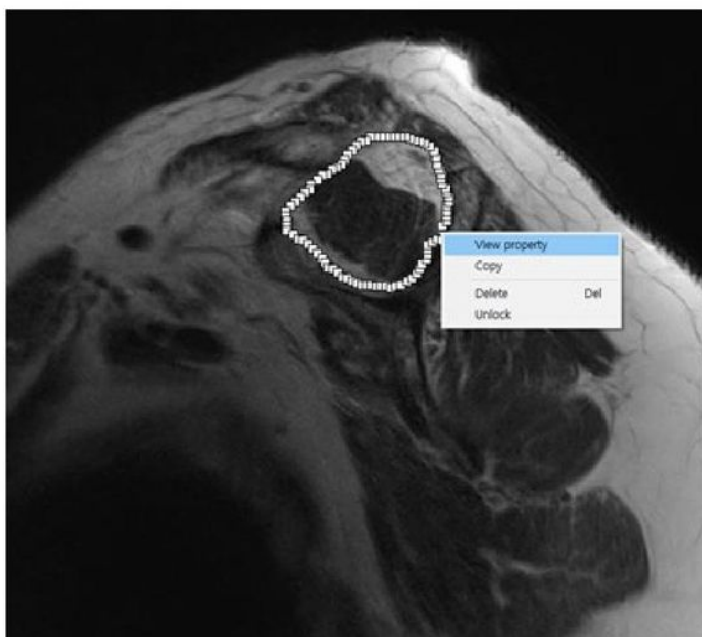
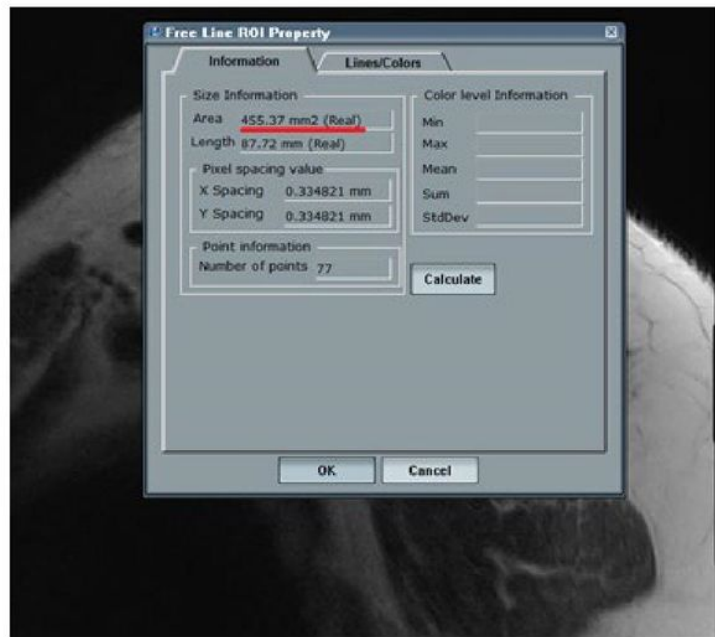
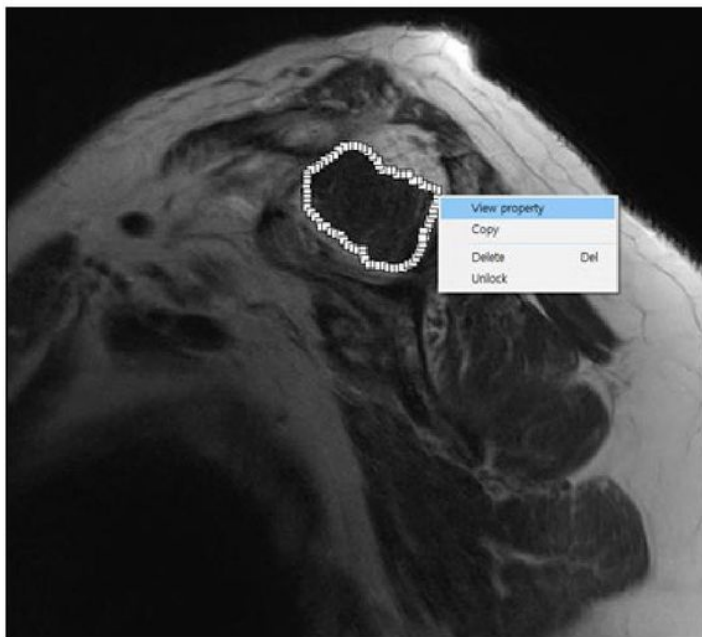


Figure 6

To quantify occupation ratio(%) and muscle area(㎡), draw the outline of estimated anatomical muscle occupying area, and actual occupied area. Then can get the value of each area(㎡) and ratio