Risk Factors for High Repair Tension During Rotator Cuff Repair

Satoshi Miyake,*† MD, PhD, Terufumi Shibata,† MD, PhD, Shunsuke Kobayashi,† MD, Kei Matsunaga,† MD, Naofumi Hata,† MD, Yozo Shibata,‡ MD, PhD, Teruaki Izaki,‡ MD, PhD, and Takuaki Yamamoto,† MD, PhD
Investigation performed at the Department of Orthopedic Surgery, Faculty of Medicine, Fukuoka University, Fukuoka, Japan

Background: Excessively high repair tension, especially tension ≥10 N, can lead to unsuccessful rotator cuff repair.

Purpose/Hypothesis: The purpose of this study was to identify the preoperative risk factors for high repair tension in rotator cuff repair. It was hypothesized was that older age, longer symptom duration, nontraumatic (ie, degenerative) tear onset, progressive fatty degeneration, and larger tear size would be among the risk factors.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: This retrospective study involved 80 patients (80 shoulders) diagnosed with rotator cuff tears by magnetic resonance imaging between July 2018 and August 2020. Repair tension was measured intraoperatively using a digital tension meter. Risk factors for high repair tension (≥10 N) were evaluated. The *t* test was used to assess the relationship of repair tension with patient characteristics and surgical parameters. Parameters with a *P* value of <.05 in the univariate analysis were entered into a multivariate logistic regression model to determine their relationship with repair tension ≥10 N.

Results: Symptom duration of ≥4 months, nontraumatic tear onset, large/massive tears, mediolateral (ML) tear length of ≥20 mm, and anteroposterior (AP) tear length of ≥18 mm were associated with high odds of repair tension ≥10 N (*P* ≤ .013 for all). Multivariate analysis showed that nontraumatic onset, ML tear length of ≥20 mm, and AP tear length of ≥18 mm were independent risk factors for repair tension ≥10 N (*P* ≤ .035 for all).

Conclusion: The independent risk factors for high repair tension (≥10 N) during rotator cuff repair were nontraumatic tear onset, ML tear length of ≥20 mm, and AP tear length of ≥18 mm. Symptom duration of ≥4 months and large/massive tears were associated with high odds of repair tension ≥10 N, although they were not considered independent risk factors. Prospective cohort studies with larger sample sizes are needed to confirm the clinical value of the risk factors identified in this study.

Keywords: repair tension; rotator cuff tear; risk factor; univariate analysis; multivariate analysis

Excessively high repair tension is a key factor in unsuccessful rotator cuff repair. Burkhart et al[2] showed an association between high repair tension and increased pain. Davidson and Rivenburgh[3] reported that high-tension rotator cuff repairs were associated with poor clinical outcomes (clinical scores, muscle strength, and visual analog scale score). Recent investigators have also shown an association between repair tension and cuff integrity,[12,17,23,26] concluding that the cutoff value of repair tension for retears was 26.0 to 35.6 N. Uno et al[24] identified an even lower cutoff value of 10 N for repair tension of rotator cuff retears. Miyake et al[15] reported that a repair tension of ≥10 N during rotator cuff repair significantly decreased microvascular blood flow within the rotator cuff. Furthermore, the mean repair tension for acute (traumatic) rotator cuff tears has been found to be approximately 10 N in previous studies.[10,21] These findings highlight the importance of low repair tension, especially tension values of <10 N.[15,24] Footprint medialization during rotator cuff repair can reduce repair tension, and recently, several good clinical reports of medialized arthroscopic rotator cuff repair have been published.[5,16,25]

Several factors are associated with high repair tension, including age,[1,24] tear size,[12,23,24] fatty degeneration of the rotator cuff,[11,12,23,24] trauma history,[21] and symptom duration.[7,8,10,20] However, Takeda et al[23] reported no association between high repair tension and trauma history or

The Orthopaedic Journal of Sports Medicine, 12(10), 23259671241276445
DOI: 10.1177/23259671241276445

symptom duration in a 2021 study. Thus, the preoperative predictors of repair tension remain unclear. Additionally, the devices used to measure repair tension vary between studies. Spring tension meters have been used in many studies; however, digital tension meters are preferred for measuring repair tension,[15,21] as they can provide more precise data.

The aim of this study was to identify the preoperative risk factors for high repair tension using a digital tension meter. The hypothesis was that the preoperative risk factors would include older age, longer symptom duration, nontraumatic (ie, degenerative) tear onset, progressive fatty degeneration, and larger tear size.

METHODS

The protocol for this study was approved by the ethics committee of our university's school of medicine. The data were collected from July 2018 to August 2020. The study involved 80 patients (80 shoulders) diagnosed with rotator cuff tear by magnetic resonance imaging (MRI) at our university's orthopaedic surgery department. Patients with partial-thickness rotator cuff tears, longitudinal-pattern rotator cuff tears, isolated subscapularis tears, and rotator cuff retears were excluded.

Intraoperative Assessment

All patients underwent general anesthesia with an oblique interscalene block, and the operations were performed with the patient in the beach-chair position. First, the intra-articular and subacromial bursas were evaluated, and bursectomy and subacromial decompression were performed. When necessary, the rotator cuff was mobilized from any surrounding scar tissue. Next, the rotator cuff tear size and pattern were assessed. The tear size was measured with a device that recorded in 1-mm increments and was categorized as small (0-0.9 cm), medium (1-2.9 cm), or large (3-5 cm).[4] Measurements of repair tension were obtained after mobilization, and rotator cuff repair was performed after the measurements. No patients in the study underwent margin convergence.

Tension was measured using a digital tension meter with a measurement range of 0 to 50 N (DSV-50N digital force gauge; Imada). First, a nonstretching, nonabsorbable suture (Ultrabraid; Smith+Nephew) was passed through the torn supraspinatus tendon. The suture was then connected to a digital tension meter, and the repair tension was measured for 10 seconds (Figure 1). The upper limb was at 0° of abduction during measurement of the repair tension. The measurements were performed by 1 of 3 surgeons (S.M., Y.S. and T.I.) who were specialists in shoulder surgery.

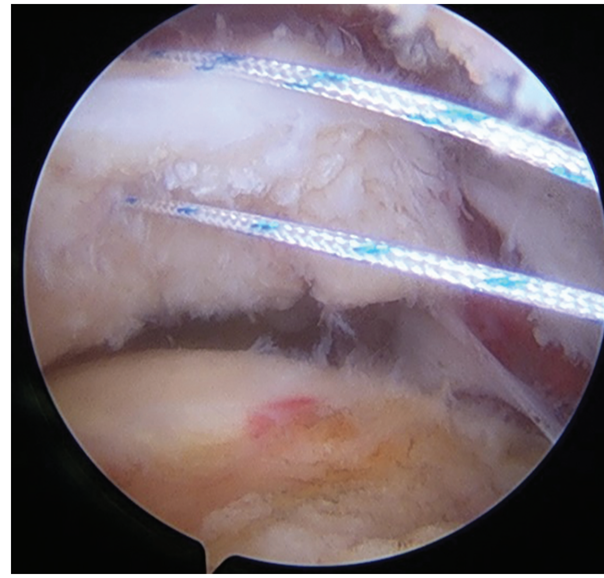

Figure 1. A nonstretching, nonabsorbable thread was passed through the supraspinatus tendon and then pulled out to its anatomic location. Tension was measured using a digital tensiometer.

Data Collection

Preoperative risk factors for high repair tension that were considered included patient age, sex, diabetes mellitus, current nicotine use, symptom duration, tear onset (traumatic vs nontraumatic [ie, degenerative]), fatty degeneration of the supraspinatus, tear size, mediolateral (ML) tear length, and anteroposterior (AP) tear length. Patient characteristics and symptom duration were obtained from the medical records. Age was dichotomized to <65 versus ≥65 years. Symptom duration was dichotomized into <4 and ≥4 months in accordance with the results of a clinical study by Petersen and Murphy.[18] The criteria for traumatic tears were in accordance with those established by Shibata et al[21]: (1) sudden onset, (2) unexpected traumatic event on a specific date and place, (3) falling onto the outstretched arm from a standing height or a traffic accident resulting in injury, and (4) no previous shoulder symptoms. Fatty degeneration of the supraspinatus

*Address correspondence to Satoshi Miyake, MD, PhD, Department of Orthopedic Surgery, Faculty of Medicine, Fukuoka University, 7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan (email: satoshimiyake@adm.fukuoka-u.ac.jp).
†Department of Orthopedic Surgery, Faculty of Medicine, Fukuoka University, Fukuoka, Japan.
‡Department of Orthopedic Surgery, Fukuoka University, Chukushi Hospital, Fukuoka, Japan.
Final revision submitted February 16, 2024; accepted March 7, 2024.
The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Fukuoka University (ref No. H23-04-005).

TABLE 1
Patient Characteristics (N = 80)[a]

Characteristic	Value
Sex, male/female, n	53/27
Age, y	69.1 (42-86)
Side affected, dominant/nondominant, n	69/11
Diabetes mellitus	17 (21.3)
Current nicotine use	17 (21.3)
Symptom duration, mo	18.0 (1-720)
Traumatic onset	34 (42.5)
SSP fatty degeneration, Goutallier stage[b]	1.9 (1-3)
Tear size, mm^2	570.1 (56-1600)
AP tear length, mm	22.5 (7-50)
ML tear length, mm	22.9 (8-40)

[a]Data are reported as mean (range) or n (%) unless otherwise indicated. AP, anterolateral; ML, mediolateral; SSP, supraspinatus.

[b]Fatty degeneration of the supraspinatus was evaluated on magnetic resonance imaging in accordance with the 5-stage grading system developed by Goutallier et al.[9]

was evaluated on MRI by 2 shoulder specialists (S.M. and T.S.) in accordance with the 5-stage Goutallier classification.[9] We compared shoulders with Goutallier stages <3 versus ≥3. Finally, we compared the ML tear lengths of <18 versus ≥18 mm and the AP tear lengths of <20 versus ≥20 mm, in accordance with the study by Uno et al.[24]

Statistical Analysis

The *t* test was used to compare the repair tension within the dichotomized preoperative factors. The chi-square test was used to compare potentially relevant factors between shoulders with repair tension of ≥10 N. Parameters with a *P* value of <.05 in the univariate analysis were entered into the multivariate logistic regression model to determine their relationships with repair tension of ≥10 N. All statistical analyses were performed using SPSS Statistics (Version 23.0.0; IBM). Statistical significance was set at $P < .05$.

RESULTS

The characteristics of the 80 included patients are shown in Table 1. The repair tension values according to the study parameters are shown in Table 2. Symptom duration of ≥4 months, nontraumatic, Goutallier stage ≥3, large and massive tears, ML length of ≥20 mm, and AP length of ≥18 mm were significantly associated with repair tension. The parameters tested against repair tension of ≥10 N in the univariate analysis are summarized in Table 3. Symptom duration of ≥4 months, nontraumatic tear onset, large and massive tears, ML tear length of ≥20 mm, and AP tear length of ≥18 mm were associated with high odds of repair tension of ≥10 N.

Repair tension was significantly higher in patients with a symptom duration of ≥4 versus <4 months ($P = .002$) (Table 2). The odds ratio (OR) for repair tension of ≥10 N in patients with a symptom duration of ≥4 months was 4.06 times higher than that in patients with a symptom duration of <4 months ($P = .006$) (Table 3).

Repair tension was significantly higher in patients with a nontraumatic versus traumatic tear onset ($P < .001$) (Table 2). The OR for repair tension of ≥10 N in patients with nontraumatic tears was 6.67 times higher than that in patients with traumatic tears ($P < .001$) (Table 3).

Repair tension was significantly higher in patients with large or massive rotator cuff tears than in patients with small or medium rotator cuff tears ($P = .009$) (Table 2). The OR for repair tension of ≥10 N in patients with large or massive rotator cuff tears was 4.85 times higher than that in patients with small or medium rotator cuff tears ($P = .013$) (Table 3).

Repair tension was significantly higher in patients with an ML tear length of ≥20 vs <20 mm ($P < .001$) (Table 2). The OR for repair tension of ≥10 N in patients with an ML tear length of ≥20 mm was 14.0 times higher than that in patients with an ML tear length of <20 mm ($P < .001$) (Table 3). Similarly, repair tension was significantly higher in patients with an AP tear length of ≥18 versus <18 mm ($P < .019$) (Table 2). The OR for repair tension of ≥10 N in patients with an AP tear length of ≥18 mm was 7.31 times higher than that in patients with an AP tear length of <18 mm ($P < .001$) (Table 3).

The associations between repair tension and age (<65 vs ≥65 years), sex (male vs female), presence of diabetes mellitus, and nicotine use were not significantly different between the groups (Table 2).

Multivariate analysis revealed that nontraumatic tear onset (OR, 6.53 [95% CI, 1.35-31.45]; $P = .02$), ML tear length of ≥20 mm (OR = 13.91 [95% CI, 2.32-83.37]; $P = .004$), and AP tear length of ≥18 mm (OR = 6.57 [95% CI, 1.15-37.7]; $P = .035$) were independent predictors of repair tension of ≥10 N (Table 4).

DISCUSSION

Symptom duration of ≥4 months, nontraumatic tear onset, large/massive tears, ML tear length of ≥20 mm, and AP tear length of ≥18 mm were associated with high odds of repair tension of ≥10 N in this study. Multivariate analysis revealed that nontraumatic tears, MP tear length of ≥20 mm, and AP tear length of ≥18 mm were independent risk factors for repair tension of ≥10 N.

The first potentially relevant risk factor to consider is nontraumatic tear onset. Shibata et al[21] measured repair tension during rotator cuff repair with a digital tension meter and reported significantly higher values in tears with nontraumatic onset (n = 23) versus traumatic onset (n = 19) (23.6 vs 11.6 N, respectively; $P < .01$). The results of our study revealed that nontraumatic tears were associated with high odds of repair tension ≥10 N, and multivariate analysis indicated nontraumatic tears to be an

TABLE 2
Relationship Between Repair Tension and Preoperative Factors[a]

	Repair Tension, N, Mean ± SD	MD (95% CI)	*P*
Age, y			.56
<65 (n = 14)	21.1 ± 17.3	Reference	
≥65 (n = 66)	23.8 ± 15.6	2.7 (–12.0 to 6.6)	
Sex			.58
Male (n = 53)	24.0 ± 15.2	Reference	
Female (n = 27)	21.9 ± 17.1	2.1 (–5.4 to −9.6)	
Diabetes mellitus			.52
No (n = 63)	22.7 ± 16.4	Reference	
Yes (n = 17)	25.5 ± 13.7	–2.9 (–11.4 to 5.8)	
Nicotine use			.53
No (n = 63)	23.9 ± 16.0	Reference	
Yes (n = 17)	21.1 ± 15.3	2.7 (–5.9 to 11.4)	
Symptom duration, mo			**.002**
<4 (n = 33)	16.8 ± 14.2	Reference	
≥4 (n = 47)	27.6 ± 15.4	−10.8 (–17.6 to −4.0)	
Traumatic onset			**<.001**
No (n = 46)	28.6 ± 15.0	Reference	
Yes (n = 34)	16.0 ± 14.0	−12.6 (–19.2 to −6.0)	
Goutallier stage			**<.001**
1-2 (n = 69)	20.4 ± 13.8	Reference	
3-4 (n = 11)	43.3 ± 14.7	−23.5 (–32.5 to −14.5)	
Tear size[b]			**.009**
Small, medium (n = 2, n = 51)	19.8 ± 14.6	Reference	
Large, massive (n = 26, n = 1)	29.3 ± 16.1	–9.5 (–16.9 to −2.5)	
ML tear length, mm			**<.001**
<20 (n = 24)	16.4 ± 12.9	Reference	
≥20 (n = 56)	28.6 ± 15.9	−12.2 (–18.7 to −5.6)	
AP tear length (mm)			**.019**
<18 (n = 24)	16.6 ± 11.1	Reference	
≥18 (n = 56)	25.8 ± 16.6	−12.4 (–19.8 to −5.0)	

[a]Boldface *P* values indicate statistically significant difference between groups compared ($P < .05$). AP, anteroposterior; MD, mean difference; ML, mediolateral.
[b]Tear size was categorized as small (0-0.9 cm), medium (1-2.9 cm), or large (3-5 cm) in accordance with the classification of DeOrio and Cofield.[4]

independent risk factor for repair tension ≥10 N. Conversely, Takeda et al[23] reported no association between traumatic-onset rotator cuff tears and repair tension. The strict inclusion criteria for traumatic rotator cuff tears might have contributed to the difference in results between our study and that of Takeda et al. As mentioned, differences in measurement devices, upper limb positions during repair tension measurement, and definitions of repair tension may have also contributed to the discrepancy in the results. Repair tension during repair of nontraumatic tears should receive more attention.

A second potentially relevant risk factor is tear size. Takeda et al[23] showed that both the AP and ML tear lengths were associated with repair tension in a univariate analysis; however, their multivariate analysis showed that only the ML tear length was an independent risk factor associated with repair tension. In their univariate analysis, Uno et al[24] showed that the predictors of repair tension ≥10 N were AP tear length ≥18 mm and ML tear length ≥20 mm, with multivariate analysis showing that only ML tear length ≥20 mm was an independent risk factor associated with repair tension. The results of our study revealed that a large/massive tear, ML tear length ≥20 mm, and AP tear length ≥18 mm were associated with high odds of repair tension of ≥10 N, and our multivariate analysis revealed that both ML tear length ≥20 mm and AP tear length ≥18 mm were independent risk factors for repair tension of ≥10 N. Repair tension during rotator cuff repair in patients with an ML tear length ≥20 mm or AP tear length ≥18 mm should receive more attention.

Although our multivariate analysis revealed that symptom duration was not an independent risk factor for repair tension of ≥10 N, symptom duration may be another potentially relevant risk factor. Hersche and Gerber[10] measured rotator cuff tension in patients with acute and chronic rotator cuff tears and reported that the tension in the former (10 N) was lower than that in the latter (28 N). The authors reported that when the rotator cuff was retracted 10 mm, the repair tension in acute rotator cuff tears increased from 10 to 13 N but that in chronic cuff tears increased from 28 to 60 N.[10] In a study using a sheep model of rotator cuff tear, Gerber et al[7] found that the stiffness (N/mm) of

TABLE 3
Relationship Between Repair Tension of ≥10 N and Preoperative Factors[a]

	Repair Tension ≥10 N, n/Total (%)	Odds Ratio (95% CI)	*P*
Age, y			.20
<65 (n = 14)	8/14 (57.1)	Reference	
≥65 (n = 66)	49/66 (74.2)	2.16 (0.66-7.13)	
Sex			.24
Male (n = 53)	13/53 (24.5)	Reference	
Female (n = 27)	10/27 (37.0)	0.55 (0.20-1.50)	
Diabetes mellitus			.08
No (n = 63)	42/63 (66.7)	Reference	
Yes (n = 17)	15/17 (88.2)	3.75 (0.78-17.9)	
Nicotine use			.20
No (n = 63)	47/63 (74.6)	Reference	
Yes (n = 17)	10/17 (58.8)	0.49 (0.16-1.49)	
Symptom duration, mo			**.006**
<4 (n = 33)	18/33 (54.5)	Reference	
≥4 (n = 47)	39/47 (83.0)	4.06 (1.46-11.31)	
Traumatic onset			**<.001**
No (n = 46)	40/46 (87.0)	Reference	
Yes (n = 34)	17/34 (50.0)	6.67 (2.24-19.83)	
Goutallier stage			.16
1-2 (n = 69)	48/69 (69.6)	Reference	
3-4 (n = 11)	10/11 (90.9)	4.21 (0.50-35.3)	
Tear size[b]			**.013**
Small, medium (n = 2, n = 51)	33/53 (62.3)	Reference	
Large, massive (n = 26, n = 1)	24/27 (88.9)	4.85 (1.29-18.20)	
ML tear length, mm			**<.001**
<20 (n = 24)	8/24 (33.3)	Reference	
≥20 (n = 56)	49/56 (87.5)	14.0 (4.39-44.70)	
AP tear length (mm)			**<.001**
<18 (n = 24)	10/24 (41.7)	Reference	
≥18 (n = 56)	47/56 (83.9)	7.31 (2.48-21.54)	

[a]Boldface *P* values indicate a statistically significant difference between groups compared ($P < .05$). AP, anteroposterior; ML, mediolateral.
[b]Tear size was categorized as small (0-0.9 cm), medium (1-2.9 cm), or large (3-5 cm) in accordance with the classification system of DeOrio and Cofield.[4]

TABLE 4
Results of Multivariate Analysis of Risk Factors for Repair Tension of ≥10 N[a]

Risk Factor	Odds Ratio (95% CI)	*P*
Nontraumatic tear onset	6.53 (1.35-31.45)	**.02**
Symptom duration ≥4 mo	3.19 (0.77-13.27)	.11
Large/massive tear	0.37 (0.04-3.44)	.38
ML tear length ≥20 mm	13.91 (2.32-83.37)	**.004**
AP tear length ≥18 mm	6.57 (1.15-37.7)	**.035**

[a]Boldface *P* values indicate statistical significance ($P < .05$). AP, anteroposterior; ML, mediolateral.

the muscle-tendon unit 40 weeks (approximately 9 months) after rotator cuff tear was 7 times that of an acute tear. In a study using a canine model of rotator cuff tear, Safran et al[20] stated that the stiffness (N/mm) of the rotator cuff muscle-tendon unit 12 weeks (approximately 3 months) after rotator cuff tear was notably higher than that in the control group. In a study using a rat model of rotator cuff tear, Gimbel et al[8] stated that tendon detachment initially resulted in a dramatic decrease in mechanical properties, followed by a progressive increase over time. These results suggest that symptom duration is associated with repair tension.[7,8,10,20] The results of our study revealed that symptom duration of ≥4 months was associated with high odds of repair tension of ≥10 N. Conversely, Takeda et al[23] reported no association between symptom duration and repair tension.

We speculate that there are 3 factors contributing to the differences between our study and that by Takeda et al[23]: (1) differences in the measurement device (digital tension meter vs spring tension meter[23]), (2) differences in the upper limb position for measuring repair tension (0° abduction vs 30° abduction[23]), and (3) differences in the definition of repair tension. We consider that the most significant difference between the 2 studies is the definition of repair tension. Takeda et al defined repair tension as the value at which the rotator cuff was able to be retracted to the lateral edge of the footprint. However, when tension was high, repair tension was defined as the value at which the rotator cuff was retracted to the most medial side of the footprint. By contrast, in all cases in our study, we defined repair tension as the value at which the rotator cuff was retracted to the lateral edge of the footprint. When the rotator cuff could not be retracted to the lateral edge of the footprint, repair tension was defined as 50 N, the maximum value measured by the digital tension meter. Although symptom duration of ≥4 months was not an independent risk factor for repair tension of ≥10 N, repair tension during rotator cuff repair for patients with symptom duration of ≥4 months should receive attention.

Several previous researchers have found that the Goutallier stage is associated with repair tension.[11,12,23,24] Itoigawa et al[11] found an association between fatty degeneration of the rotator cuff muscle and rotator cuff muscle stiffness (N/mm). Kim et al[12] and Takeda et al[23] also found an association between fatty degeneration and repair tension. Uno et al[24] reported that Goutallier stage ≥2 had an OR 3.6 times higher than that of Goutallier stage 1 for repair tension of ≥10 N. In our study, repair tension was significantly higher in patients with Goutallier stage ≥3 vs <3 (43.3 vs 20.4 N, respectively; P < .001). However, the results of the univariate analysis revealed that Goutallier stage ≥3 was not associated with repair tension of ≥10 N (P = .16). Very few patients in our series had Goutallier stage 1, whereas numerous patients had Goutallier stage ≥3. Therefore, we could not compare Goutallier stages <2 and ≥2 for comparison with the study by Uno et al. The low interobserver reliability of the Goutallier classification may have also contributed to the differences between study results.[22]

Repair tension was not significantly higher in patients aged ≥65 versus <65 years in our study. Uno et al[24] found a statistically significant association between age and repair tension using grasper tensioning attachments. The authors also reported that age ≥65 years was associated with repair tension of ≥10 N.[24] Notably, Takeda et al[23] stated that there was no association between age and repair tension. Itoigawa et al[11] found that there was no statistically significant difference in supraspinatus stiffness (N/mm) values between patients aged <70 years and ≥70 years using ultrasonographic elastography. Interestingly, all patients aged ≥75 years in our series had repair tension of ≥10 N. Therefore, we could not use a logistic model to compare the ages of <75 versus ≥75 years. Repair tension during rotator cuff repair for patients aged ≥75 years requires more attention.

Interestingly, no statistically significant associations were found between repair tension and other factors associated with retear, such as sex,[19] diabetes mellitus,[13] and current nicotine use.[6,14] These factors may be strongly associated with factors other than repair tension (eg, degenerative changes in the rotator cuff). Of course, we do not consider repair tension to be the only key factor in successful rotator cuff repair.

Strength and Limitations

The main strength of this study was that it is the first to our knowledge to use a digital tension meter to investigate the relationship between repair tension and risk factors for repair tension of ≥10 N. However, this study also had several limitations. The study design was retrospective, and the sample size was small. In addition, the association between histological factors and repair tension was not investigated. Regarding tension measurement, only a single suture was applied to the rotator cuff, and the tension measurement time was set at 10 seconds; thus, the tension over a longer measurement period is unknown. Also, repair tension of >50 N, which is the limit of measurement, could not be measured; however, the tension meters used in previous studies could not measure even 50 N. Another limitation is that symptom onset may differ from the time of rotator cuff rupture. Finally, we did not report the clinical results. The reason for this is because the present study included patients in whom arthroscopic rotator cuff repair was performed with a repair tension of <10 N as well as patients in whom arthroscopic rotator cuff repair was performed without considering the repair tension, as our repair concept was not established at that time. We now perform arthroscopic rotator cuff repair (single or triple row) with tension of <10 N in all cases of rotator cuff tear.

CONCLUSION

The independent risk factors for high repair tension (≥10 N) during rotator cuff repair were nontraumatic tear onset, MP tear length of ≥20 mm, and AP tear length of ≥18 mm. Symptom duration of ≥4 months and large/massive tears were associated with high odds of repair tension of ≥10 N, although they were not considered independent risk factors. Prospective cohort studies with larger sample sizes are needed to confirm the clinical value of the risk factors identified in this study.

ACKNOWLEDGMENT

The authors thank Dr Hisatomi Arima, professor in the Department of Preventive Medicine and Public Health, Faculty of Medicine, Fukuoka University, for his valuable guidance in the statistical analysis of the data; Angela Morben, DVM, ELS, from Edanz (https://jp.edanz.com/ac), for editing a draft of this paper; and Mikihito Tamai, MD, PhD, for his expertise and support in all aspects of the research and his help in manuscript preparation.

REFERENCES

1. Baumer TG, Dischler J, Davis L, et al. Effects of age and pathology on shear wave speed of the human rotator cuff. *J Orthop Res*. 2018;36(1):282-288.
2. Burkhart SS, Athanasiou KA, Wirth MA. Margin convergence: a method of reducing strain in massive rotator cuff tears. *Arthroscopy*. 1996;12(3):335-338.
3. Davidson PA, Rivenburgh DW. Rotator cuff repair tension as a determinant of functional outcome. *J Shoulder Elbow Surg*. 2000;9(6):502-506.
4. DeOrio JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. *J Bone Joint Surg Am*. 1984;66(4):563-537.

5. Dierckman BD, Frousiakis P, Burns JP, et al. Arthroscopic repair of medium to large rotator cuff tears with a triple-loaded medially based single-row technique augmented with marrow vents. *Arthroscopy*. 2021;37(1):28-37.
6. Fan N, Yuan S, Du P, et al. The effects of smoking on clinical and structural outcomes after rotator cuff repair: a systematic review and meta-analysis. *J Shoulder Elbow Surg*. 2022;31(3):656-667.
7. Gerber C, Meyer DC, Schneeberger AG, Hoppeler H, von Rechenberg B. Effect of tendon release and delayed repair on the structure of the muscles of the rotator cuff: an experimental study in sheep. *J Bone Joint Surg Am*. 2004;86:1973-1982.
8. Gimbel JA, Van Kleunen JP, Lake SP, Williams GR, Soslowsky LJ. The role of repair tension on tendon to bone healing in an animal model of chronic rotator cuff tears. *J Biomech*. 2007;40(3):561–568.
9. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78-83.
10. Hersche O, Gerber C. Passive tension in the supraspinatus musculotendinous unit after long-standing rupture of its tendon: a preliminary report. *J Shoulder Elbow Surg*. 1998;7(4):393-396.
11. Itoigawa Y, Maruyama Y, Kawasaki T, et al. Shear wave elastography can predict passive stiffness of supraspinatus musculotendinous unit during arthroscopic rotator cuff repair for presurgical planning. *Arthroscopy*. 2018;34(8):2276-2284.
12. Kim DH, Jang YH, Choi YE, Lee HR, Kim SH. Evaluation of repair tension in arthroscopic rotator cuff repair: does it really matter to the integrity of the rotator cuff? *Am J Sports Med*. 2016;44(11):2807-2812.
13. Kim MS, Rhee SM, Cho NS. Increased HbA1c levels in diabetics during the postoperative 3-6 months after rotator cuff repair correlated with increased retear rates. *Arthroscopy*. 2023;39(2):176-182.
14. Livesey MG, Bains SS, Weir TB, et al. Does timing matter? The effect of preoperative smoking cessation on the risk of infection or revision following rotator cuff repair. *J Shoulder Elbow Surg*. 2023;32(9):1937-1944.
15. Miyake S, Izaki T, Arashiro Y, et al. Excessively high repair tension decreases microvascular blood flow within the rotator cuff. *Am J Sports Med*. 2022;50(13):3643-3648.
16. Mizuki Y, Senjyu T, Ito T, Ueda K, Uchimura T. Extreme medialized repair for challenging large and massive rotator cuff tears reveals healing and significant functional improvement. *Arthroscopy*. 2023;39(10):2122-2130.
17. Park SG, Shim BJ, Seok HG. How much will high tension adversely affect rotator cuff repair integrity? *Arthroscopy*. 2019;35(11):2992-3000.
18. Petersen SA, Murphy TP. The timing of rotator cuff repair for the restoration of function. *J Shoulder Elbow Surg*. 2011;20(1):62-68.
19. Rudisill SS, Eberlin CT, Kucharik MP, et al. Sex differences in utilization and perioperative outcomes of arthroscopic rotator cuff repair. *JSES Int*. 2022;6(6):992-998.
20. Safran O, Derwin KA, Powell K, Iannotti JP. Changes in rotator cuff muscle volume, fat content, and passive mechanics after chronic detachment in a canine model. *J Bone Joint Surg Am*. 2005;87(12):2662-2670.
21. Shibata T, Izaki T, Nishio J, et al. Are there differences in arthroscopic and histological features between traumatic and degenerative rotator cuff tears in elderly patients? A prospective dual-center analysis. *J Orthop Surg Res*. 2022;17(1):206.
22. Slabaugh MA, Friel NA, Karas V, Romeo AA, Verma NN, Cole BJ. Interobserver and intraobserver reliability of the Goutallier classification using magnetic resonance imaging: proposal of a simplified classification system to increase reliability. *Am J Sports Med*. 2012;40(8):1728-1734.
23. Takeda Y, Fujii K, Suzue N, Miyatake K, Kawasaki Y, Yokoyama K. Repair tension during arthroscopic rotator cuff repair is correlated with preoperative tendon retraction and postoperative rotator cuff integrity. *Arthroscopy*. 2021;37(9):2735-2742.
24. Uno T, Mura N, Yuki I, Oishi R, Takagi M. Factors correlated with the optimal tension for arthroscopic rotator cuff repair using Grasper Tensioning Attachment. *J Shoulder Elbow Surg*. 2022;31(5):e213-e222.
25. Yamakado K. A prospective randomized trial comparing suture bridge and medially based single-row rotator cuff repair in medium-sized supraspinatus tears. *Arthroscopy*. 2019;35(10):2803-2813.
26. Yokoya S, Nakamura Y, Harada Y, et al. Effectiveness of measuring tension during arthroscopic rotator cuff repair. *J Exp Orthop*. 2021;8(1):21.