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SHOULDER

Older age and higher body mass index are independent risk factors for tendon healing in small- to medium-sized rotator cuff tears

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Abstract

Purpose Many previous research efforts have been made to identify prognostic factors for rotator cuff healing. However, majority of these studies were conducted with heterogeneous cohorts consisted of different tear characteristics. Healing properties of a rotator cuff tear may differ depending on tear characteristics such as tear size or fatty infiltration. Therefore, studies with subgroups confined by these variables may reflect more accurate results. This study aims to investigate predictive factors for rotator cuff healing in a subgroup with small- to medium-sized tears without significant fatty infiltration.

Methods This retrospective case–control study was conducted with 94 patients with small- to medium-sized rotator cuff tears. Mean age of patients was 56.0 ± 9.0 years and mean follow-up duration was 38.3 ± 8.1 months. Post-operative magnetic resonance imaging assessment showed that there were 75 (79.8%) successfully healed repairs and 19 (20.2%) healing failures. Age, gender, hand dominancy, body mass index (BMI), smoking habit, diabetes, corticosteroid injection, baseline clinical status, duration of surgery and biceps procedure were variables evaluated as predictive factors.

Results Both study groups showed significant improvement from baseline regarding clinical outcome measures ($p < 0.05$). However, successfully healed patients had significantly higher post-operative functional scores and lower pain scores ($p < 0.05$). The univariate analysis revealed that healing was significantly affected by age ($p = 0.004$), BMI ($p = 0.01$) and diabetes ($p = 0.03$). In the multivariate analysis, age ($p = 0.02$) and BMI ($p = 0.02$) were found to be significant independent factors for healing. Cutoff values for oldest age and highest BMI were 63 years and 28.1 kg/m^2, respectively, for a successful healing according to receiver-operating characteristic curve analysis.

Conclusion Healing failure after rotator cuff repair in small- to medium-sized tears is associated with poorer outcomes. Age and BMI are independent predictive factors for healing. A successful repair is more likely in patients younger than 63 years and with BMI less than 28.1 kg/m^2. Surgeons should consider this information during risk assessment, decision making and patient counselling.

Level of evidence Level III.

Keywords Rotator cuff tear · Rotator cuff healing · Healing failure · Retear · Prognostic factor · Small- to medium-sized tears

Introduction

In current practice, arthroscopic rotator cuff repair (ARCR) is the most preferred treatment method with good reported outcomes for rotator cuff tears (RCTs) for which conservative management failed [15]. Achieving an anatomic integrity of the repaired tendon is the essential objective of ARCR; however, repair failure is still a major complication of ARCR with variable reported structural failure rates [4, 16]. Therefore, it is essential to identify risk factors for tendon healing and to make meticulous pre-operative risk assessments of patients with RCT.

This study was conducted at Istanbul University Istanbul Faculty of Medicine Hospital.

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Numerous previous studies have attempted to identify predictive factors for rotator cuff healing. Several tear characteristics such as tear size, degree of fatty infiltration and degree of tendon retraction have been reported as the most important contributors for repair failure [5, 17, 23]. However, the majority of previous studies were conducted with heterogeneous cohorts consisting a mixture of tear size and fatty infiltration characteristics which led controversial results regarding some other prognostic factors. We believe that healing characteristics of RCTs could vary widely depending on tear size. In other words, effect of a factor on cuff healing might be different for a small-sized tear compared to a massive tear. Therefore, healing of RCTs should be evaluated separately on the basis of subgroups by tear size in order to make a more accurate analysis. There are several subgroup analyses in the current literature; but few studies were conducted regarding prognostic factors for healing of small-sized tears. The present study aims to evaluate retear rate and predictive factors for repair failure following ARCR in small- to medium-sized RCTs without significant fatty infiltration. The cohort of this study was confined in order to create a homogenous population for a more precise evaluation for this specific subgroup.

Materials and methods

This study was a retrospective case control study conducted with patients who underwent ARCR with full-thickness RCT diagnosis between April 2016 and September 2020. The study was conducted in a tertiary university hospital, which is a referral centre for shoulder disorders, and was approved from institutional review board of relevant hospital (Istanbul University Istanbul Faculty of Medicine/E-67690154-622.03-226564). Written inform consents were obtained from all the included patients.

Patient selection

Records of 389 patients who underwent ARCR surgery during study period by the first author (A.E.) at a single institution were reviewed. Indications of surgery were persistent pain or shoulder dysfunction despite adequate conservative treatment including medication with analgesic and non-steroidal anti-inflammatory agents, local corticosteroid injections or physical therapy programme for a minimum of 6 months and presence of a full-thickness RCT confirmed by pre-operative magnetic resonance imaging (MRI). Decision of surgery was made by the first author during pre-operative follow-up evaluations for all patients.

Inclusion criteria included (1) full-thickness small- to medium-sized RCT treated with double row suture-bridge ARCR technique and (2) ability to obtain a structural outcome measurement with post-operative MRI scans at least 9 months after surgery. Exclusion criteria were (1) age < 18 years, (2) partial-thickness RCTs, (3) any subscapularis tears confirmed during arthroscopy, (4) large or massive rotator cuff tears according to classification described by DeOrio and Cofield [12], (5) moderate or severe fatty infiltration (≥ grade II) of supraspinatus or infraspinatus muscles detected on pre-operative MRI scans according to Fuchs modification of Goutallier classification [13], (6) severe retraction of the torn tendon (grade III) detected on pre-operative MRI scans according to Patte classification [32], (7) history of previous surgery to affected shoulder or revision surgery and (8) any surgical technique other than double row suture-bridge ARCR.

Identified patients were reviewed for eligibility. Of the 389 patients; 63 patients had large or massive tears, 44 patients had moderate or severe fatty infiltration, 31 patients had severe tear retraction, 36 patients had partial-thickness tears, 41 patients had subscapularis tears, 29 patients underwent ARCR with different technique, 7 patients had previous surgery on the affected shoulder, 18 patients were lost-to follow-up or refused to be enrolled in the study and 26 patients were unable to undergo post-operative MRI. Finally, 94 patients who had small- to medium-sized full-thickness rotator cuff tear without evident fatty infiltration or tear retraction and who were treated with double row suture-bridge ARCR were included to this study. Mean age of the patients at the time of surgery was 56.0 ± 9.0 years and mean follow-up duration was 38.3 ± 8.1 months. There were 62 (66.0%) female and 32 (34.0%) male patients. 25 (26.6%) patients had small-sized and 69 (73.4%) patients had medium-sized tears.

Surgical procedure

All interventions were performed by the first author (A.E.) with patients under general anaesthesia and positioned in the beach-chair position. First, diagnostic arthroscopy of the glenohumeral joint was performed through posterior portal. In case of a pathologic long head of the biceps tendon (LHBT), tenotomy was performed by taking into consideration the age and activity level of the patient.

A routine subacromial decompression was performed with debridement of pathologic bursal tissue. Rotator cuff was assessed for tear size, retraction and mobility. Footprint preparation was performed using an arthroscopic burr in order to obtain a bleeding surface and to promote tendon-to-bone healing.

A knotless suture-bridge ARCR was then performed using a previously described technique [35]. The number of the medial row anchors (Healicoil Suture Anchor; Smith & Nephew) loaded with 1 no.2 braided-nonabsorbable suture (Ultrabraid; Smith & Nephew) and 1 nonabsorbable suture tape (Ultratape; Smith & Nephew) was decided by taking into consideration the tear size. 1 anchor was used for small tears and 2 anchors were used for medium-sized tears. 1 knotless lateral row anchor (Footprint PK; Smith & Nephew) was used to complete the repair.

Post-operative rehabilitation

Immobilisation with an abduction sling in 30° of abduction and neutral rotation was performed for all patients for 4 weeks. Immediate active hand, wrist and elbow motion and passive shoulder motion were allowed post-operatively. At 4th week post-operatively, active-assisted range of motion (ROM) exercises were initiated until full passive ROM was achieved. Active ROM, strengthening and proprioceptive exercises were introduced at 8th weeks post-operatively with gradually increasing intensity. Return to full physical activity and sports were allowed at 6th months post-operatively according to recovery of each individual.

Patient assessment and clinical variables

Pre-operative clinical assessments of all patients were performed by a single author (K.Ş.) 1 day before the surgery. Demographic and clinical variables which were recorded and included to analysis were age, sex, hand dominancy, BMI, smoking habit, history of diabetes mellitus, history of pre-operative corticosteroids injection and number of injections performed, pre-operative ROM, pre-operative pain score and pre-operative functional score. Intra-operative variables which were recorded and included to analysis were duration of surgery and biceps procedure (tenotomy of LHBT).

Post-operative clinical evaluations of the patients were performed by the same author at 2 weeks, 6 weeks, 3 months, 6 months, 12 months and each following year after surgery. Data from the most recent clinical evaluation were used for final analysis.

ROM measurements of the affected shoulder included abduction, forward flexion and external rotation at side with elbow at 90° of flexion which were performed using a goniometer. A visual analogue scale (VAS) was used in order to assess pre-operative and post-operative pain score in a 10 points scale with 0 point indicating no pain and 10 points indicating maximum pain. Pre-operative and post-operative functional outcomes were evaluated using the Constant–Murley score (CMS) [8].

Radiologic assessment

All patients had underwent pre-operative MRI in order to confirm the clinical diagnosis and to assess tear characteristics. Tear size was evaluated according to classification described by DeOrio and Cofield [12] on T2-weighted sagittal oblique images. Evaluation of tear retraction was performed on T2-weighted coronal oblique images using the Patte classification [32]. Fatty infiltration of the supraspinatus and infraspinatus muscles was classified according to the Fuchs modification of the Goutallier classification [13] on T1-weighted sagittal oblique images at the level where scapular body and spine form a “Y” shape.

All included patients underwent post-operative MRI scan at a mean of 13.2 ± 2.3 months after surgery. Structural integrity of the repaired tendon was evaluated on post-operative MRI scans using the classification described by Sugaya et al. [36], consisting of 5 grades, on T2-weighted coronal oblique and sagittal oblique images: grade I, homogenous low signal of the tendon with sufficient thickness; grade II, partial high-intensity signal in the tendon with sufficient thickness; grade III, preserved tendon continuity without sufficient thickness of the tendon; grade IV, minor discontinuity on more than 1 slice indicating a small retear; grade V, major discontinuity in the tendon suggesting a large retear (Table 1). While grade I–III were considered as successfully repaired tendons; grade IV and V were considered as failed repair.

All pre-operative and post-operative MRI scans were performed with a 1.5-T magnetic resonance unit (Magnetom Aera, Siemens) equipped with a dedicated shoulder coil and the upper extremity positioned in neutral position. T1- and T2-weighted images were obtained on axial, sagittal oblique and coronal oblique planes. Images were stored in DICOM (Digital Imaging and Communications in Medicine) format and radiologic assessments were performed using RadiAnt DICOM Viewer Software (Version 5.5.0; Medixant). A senior musculoskeletal radiologist with 12 years of experience in shoulder radiology who was blinded to study data performed all radiologic evaluations.

Statistical analysis

Mean, standard deviation, median, range, interquartile range, frequency and percentage were used as descriptive statistical methods in order to analyse study data. Assessment of normality distribution of continuous variables was performed using the Shapiro–Wilk test, Kolmogorov–Smirnov test and histograms. In the univariate analysis, comparisons of normally distributed continuous variables between study groups were performed using the unpaired *t* test. The Mann–Whitney *U* test was used in order to compare continuous variables which were not normally distributed. Analysis of categorical data were performed using the Chi-square test and the Fisher exact test. Intragroup comparisons of continuous variables were performed using paired *t* test for normally distributed data

Table 1 Pre-operative demographic, clinical and operative data of the study cohort

Demographic, clinical and operative variable ($n=94$)	Data
Gender	
Female	62 (66.0)
Male	32 (34.0)
Age, years	56.0 ± 9.0 (range: 24–75)
Hand dominancy	
Dominant	65 (69.1)
Non-dominant	29 (30.9)
BMI, kg/m^2	27.3 ± 4.4 (range: 18.2–43.0)
Smoking habit	
Yes	29 (30.9)
No	65 (69.1)
Diabetes	
Yes	26 (27.7)
No	68 (72.3)
Corticosteroid injections	
Yes	49 (52.1)
No	45 (47.9)
Number of corticosteroid injection	0.99 ± 1.4 (range: 0–6)
Pre-operative abduction, deg	106.8 ± 33.7 (range: 45–170)
Pre-operative forward flexion, deg	119.4 ± 34.0 (range: 40–180)
Pre-operative external rotation, deg	37.6 ± 13.8 (range: 0–60)
Pre-operative CMS	51.2 ± 15.3 (range: 21–83)
Pre-operative pain score	7.0 ± 1.8 (range: 2–10)
Duration of surgery, minutes	101 ± 28.2 (range: 45–160)
Biceps tenotomy	
Yes	62 (66.0)
No	32 (34.0)

Data are reported as mean ± standard deviation or n(%))

BMI Body mass index, deg: degrees, *CMS* Constant–Murley score

and Wilcoxon signed rank test otherwise. A multivariate logistic regression analysis was conducted in order to determine independent predictive factors for a repair failure and to estimate odds ratios (ORs) with statistically significant factors that were observed in the univariate analysis. In addition, a receiver-operating characteristic (ROC) curve was used to determine the predictive cutoff value for observed independent factors. The optimum cutoff point (c) estimation was performed using the Youden index (J) method. Highest value for J (sensitivity + specificity-1) was calculated using the ROC curve data and the corresponding c value was determined as the cutoff value for the mentioned independent factor. All statistical analyses were performed using GraphPad Prism Software for Windows (Version 9.3.0, San Diego, California, USA). Significance level was set at $p=0.05$ for all analyses.

Table 2 Results of radiological assessment. (Data are reported as n (%))

Group I (successfully healed, $n=75$)	Group II (repair failure, $n=19$)
Grade I, 36 (48.0)	Grade IV, 14 (73.7)
Grade II, 21 (28.0)	Grade V, 5 (26.3)
Grade III, 18 (24.0)	

Results

Pre-operative demographic, clinical and operative data of the study cohort are resumed in Table 1. Radiologic assessment of the patients revealed that there were 75 (79.8%) successfully healed repairs and 19 (20.2%) healing failure which constituted two study groups (Table 2). No other complication such as infection, wound problem, deltoid problem or neurovascular injury were observed during follow-up period. Comparison of baseline clinical data (ROM, functional score, pain score) did not show statistically significant difference between two study groups (n.s.). Both study groups showed significant improvement in terms of all clinical outcome measures compared to baseline values ($p<0.05$). Comparison of post-operative clinical outcome data between two study groups revealed that successfully healed repairs had significantly higher functional scores, significantly lower pain scores and significantly better improvement from baseline compared to repair failure group after surgery ($p<0.05$). However, no significant difference was observed between two study groups in terms of post-operative ROM values (n.s.) (Table 3).

The univariate analysis (Table 4) revealed that rotator cuff healing was significantly affected by age ($p=0.004$), BMI ($p=0.01$) and history of diabetes ($p=0.03$). No significant difference was observed between healed and failed repairs for other variables (n.s.). In the multivariate logistic regression analysis, age ($p=0.02$; OR 1.11; 95% CI 1.02–1.22) and BMI ($p=0.02$; OR 1.15; 95% CI 1.02–1.31) were found to be significant independent predictive factors for repair failure (Table 5).

ROC curve analyses of independent factors (age and BMI) were performed in order to determine the predictive cutoff values of the oldest age and highest BMI value for a successful rotator cuff healing. 63 years and 28.1 kg/m^2 values were determined as the critical age and BMI cutoff values, respectively, for a successful healing of the repaired rotator cuff (Fig. 1). A post hoc analysis confirmed that repair failure was significantly higher in patients with age ≥ 63 years ($p<0.001$) or BMI ≥ 28.1 kg/m^2 ($p=0.001$) (Table 6).

Table 3 Pre-operative and post-operative clinical outcome data of two study groups

	Group I (successfully healed, $n=75$)	Group II (repair failure, $n=19$)	P value	Mean or median difference (95% CI)
Abduction, deg				
Pre-operative	106.3 ± 33.6	108.4 ± 35.3	n.s.[b]	− 10.0[c] (− 20.0 to 20.0)
Post-operative	144.0 ± 21.9	134.5 ± 22.8	n.s.[b]	− 10.0[c] (− 20.0 to 0)
Δ	37.7 ± 35.4	26.1 ± 33.6	n.s.[b]	− 10.0[c] (− 30.0 to 5.0)
P value	**< 0.0001[a]**	**0.004[a]**		
Forward flexion, deg				
Pre-operative	119.5 ± 33.4	118.9 ± 37.1	n.s.[b]	− 10.0[c] (− 20.0 to 20.0)
Post-operative	159.3 ± 18.8	153.4 ± 20.8	n.s.[b]	− 10.0[c] (− 10.0 to 0)
Δ	39.8 ± 33.2	34.5 ± 40.1	n.s.[b]	15.0[c] (− 20.0 to 10.0)
P value	**< 0.0001[a]**	**0.005[a]**		
External rotation, deg				
Pre-operative	38.7 ± 13.8	32.9 ± 13.1	n.s.[b]	− 10.0[c] (− 15.0 to 0)
Post-operative	55.7 ± 10.0	51.8 ± 16.2	n.s.[b]	0[c] (− 10.0 to o)
Δ	16.9 ± 15.2	19.2 ± 20.2	n.s.[b]	5.0[c] (− 10.0 to 10.0)
P value	**< 0.0001[a]**	**0.0009[a]**		
Functional score, CMS				
Pre-operative	51.1 ± 14.3	51.8 ± 19.4	n.s.[d]	0.7[e] (− 7.2 to 8.6)
Post-operative	87.2 ± 12.5	79.1 ± 17.9	**0.02[d]**	− 8.1[e] (− 15.1 to − 1.0)
Δ	36.1 ± 15.2	27.3 ± 19.9	**0.04[d]**	− 8.7[e] (− 17.0 to − 0.5)
P value	**< 0.0001[f]**	**< 0.0001[f]**		
Pain score, VAS				
Pre-operative	7.1 ± 1.9	6.9 ± 1.6	n.s.[b]	− 1.0[c] (− 1.0 to 1.0)
Post-operative	1.1 ± 1.8	2.2 ± 2.3	**0.04[b]**	2.0[c] (0–2.0)
Δ	− 5.9 ± 2.3	− 4.7 ± 2.1	**0.02[b]**	1.0[c] (0–2.0)
P values	**< 0.0001[a]**	**< 0.0001[a]**		

Data are reported as mean ± standard deviation. Bolded P values indicate statistical significance as $P<0.05$

deg degrees, *CI* confidence interval, *VAS* visual analogue scale

[a]Wilcoxon matched-pairs signed ranks test

[b]Mann–Whitney U test

[c]Median

[d]Unpaired t test

[e]Mean

[f]Paired-samples t test

Discussion

The most important finding of the present study is that age and BMI are independent risk factors for rotator cuff healing in small- to medium-sized RCTs and that failed repairs are associated with poorer clinical outcomes. Failure of rotator cuff repair remains a major issue in the last decades despite advances in surgical techniques and implant technology. Extensive research efforts have been made in order to understand the healing process of the rotator cuff from molecular, cellular, biomechanical level and in various clinical scenarios. However, controversy still exists with regard to predictability of rotator cuff healing and influence of a failure on clinical outcomes. Most previous studies reported superior clinical outcomes and patient satisfaction with successfully healed rotator cuffs [16, 37]. However, others indicated that rotator cuff healing does not affect clinical outcomes and repairs with failure would still have satisfactory outcomes and high satisfaction [21, 24]. The failure rate of our study cohort was 20.2% which is consistent with previous data [15, 16, 18]. However, findings of our study suggest significant decrease in functional outcomes and pain relief in patients with repair failure which lay the emphasis on determination of predictive factors for failure after ARCR.

In this study, cohort characteristics were confined to a small subgroup of small- to medium-sized tears without significant fatty infiltration. The majority of the existing knowledge about the prognostic factors for rotator cuff healing relies on previous reports conducted with large, heterogeneous cohorts consisting a mixture of tear size and fatty

Table 4 Univariate analysis of demographic, clinical and operative factors affecting rotator cuff healing. (Data reported as mean ± standard deviation or *n* (%)

	Group I (successfully healed, *n* = 75)	Group II (repair failure, *n* = 19)	*P* value	Mean or median difference (95% CI)	Odds ratio (95% CI)
Gender	Female, 48 (64.0) Male, 27 (36.0)	Female, 14 (73.7) Male, 5 (26.3)	n.s.[a]	N/A	1.58 (0.50–4.30)
Age, years	54.7 ± 9.1	61.3 ± 6.9	**0.004[b]**	6.7[c] (2.24 to 11.1)	N/A
Hand dominancy	Dominant, 52 (69.3) Non-dominant, 23 (30.7)	Dominant, 13 (68.4) Non-dominant, 6 (31.6)	n.s.[a]	N/A	1.04 (0.34–2.94)
BMI, kg/m^2	26.7 ± 4.4	29.4 ± 3.6	**0.01[b]**	2.73 (0.55 to 4.92)	N/A
Smoking habit	Yes, 24 (32.0) No, 51 (68.0)	Yes, 5 (26.3) No, 14 (73.7)	n.s.[a]	N/A	1.32 (0.45–3.62)
Diabetes	Yes, 17 (22.7) No, 58 (77.3)	Yes, 9 (47.4) No, 10 (52.6)	**0.03[d]**	N/A	0.33 (0.12–0.93)
Corticosteroid injections	Yes, 39 (52.0) No, 36 (48.0)	Yes, 10 (52.6) No, 9 (47.4)	n.s.[a]	N/A	0.98 (0.37–2.50)
Number of corticosteroid injection	0.97 ± 1.4	1.1 ± 1.3	n.s.[e]	0[e] (0–1.00)	N/A
Pre-operative abduction, deg	106.3 ± 33.6	108.4 ± 35.3	n.s.[e]	– 10.0[f] (– 20.0 to 20.0)	N/A
Pre-operative forward flexion, deg	119.5 ± 33.4	118.9 ± 37.1	n.s.[e]	– 10.0[f] (– 20.0 to 20.0)	N/A
Pre-operative external rotation, deg	38.7 ± 13.8	32.9 ± 13.1	n.s.[e]	– 10.0[f] (– 15.0 to 0)	N/A
Pre-operative functional score, CMS	51.1 ± 14.3	51.8 ± 19.4	n.s.[b]	0.68[c] (– 7.18 to 8.55)	N/A
Pre-operative pain score, VAS	7.1 ± 1.9	6.9 ± 1.6	n.s.[e]	– 1.00[f] (– 1.00 to 1.00)	N/A
Duration of surgery, minutes	99.9 ± 27.0	105.3 ± 33.0	n.s.[b]	5.33[c] (– 9.1 to 19.8)	N/A
Biceps tenotomy	Yes, 47 (62.7) No, 28 (37.3)	Yes, 15 (78.9) No, 4 (21.1)	n.s.[a]	N/A	0.45 (0.15–1.53)

Bolded *p* values indicate statistical significance as < 0.05

CI Confidence interval, *BMI* Body mass index, *deg* degrees, *CMS* Constant–Murley score, *VAS* Visual analogue scale, *N/A* Not applicable

[a]Fisher's exact test

[b]Unpaired *t* test

[c]Mean

[d]Chi-square test

[d]Mann–Whitney *U* test

[f]Median

Table 5 Multivariate logistic regression analysis of predictive factors affecting rotator cuff healing

Variable	Odds ratio	95% CI	*P* value
Age	1.11	1.02–1.22	**0.02**
BMI	1.15	1.02–1.31	**0.02**
Diabetes	1.16	0.29–4.25	n.s

Bolded *P* values indicate statistical significance as *P* < 0.05

BMI Body mass index, *CI* Confidence interval

infiltration characteristics. Tear characteristics such as tear size, degree of fatty infiltration and tear retraction have been indicated to be the most significant contributors for healing failure [5, 17, 18, 23]. Therefore, healing characteristics of a rotator cuff may differ widely with regard to tear size and separate subgroup analyses should be performed in order to obtain more accurate results. There are numerous subgroup analyses for large to massive RCTs in the literature [11, 39]. However, few studies have limited their investigation to prognostic factors for only small- to medium-sized RCTs [1, 31]. Consistently to our findings, both studies reported age as a significant factor affecting rotator cuff healing in small- to medium-sized tears [1, 31]. The influence of age

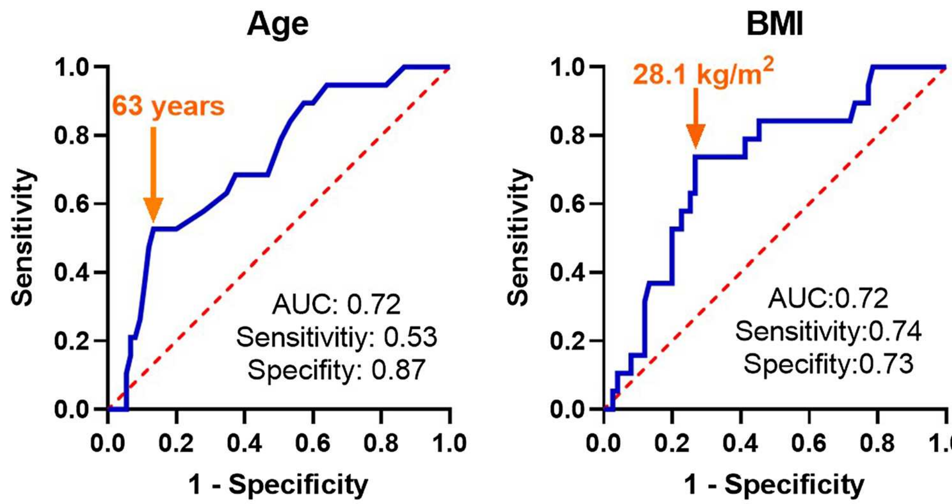

Fig. 1 Receiver-operating characteristics (ROC) curves for significant independent variables (age and body mass index). (*BMI* body mass index, *AUC* area under the curve)

Table 6 Analysis of repair integrity with regard to determined cutoff values for significant independent predictive factors (age and BMI)

Variable		*P* value	Odds ratio (95% CI)
Age, years		**< 0.001**[a]	7.22 (2.33–20.1)
Age ≥ 63 (*n* = 20)	Healed, 10 (50.0) Failed, 10 (50.0)		
Age < 63 (*n* = 74)	Healed, 65 (87.8) Failed, 9 (12.2)		
BMI, kg/m^2		**0.001**[a]	5.96 (1.90–18.4)
BMI ≥ 28.1 (*n* = 33)	Healed, 20 (60.6) Failed, 13 (39.4)		
BMI < 28.1 (*n* = 61)	Healed, 55 (90.2) Failed, 6 (9.8)		

Data reported as *n* (%). Bolded *p* values indicate statistical significance as $P < 0.05$

CI Confidence interval, *BMI* Body mass index

[a]Fisher's exact test

on rotator cuff healing has been a debated issue. Boileau et al. reported that mean age of the patients with successfully healed rotator cuffs were 10 years younger than patients with failed repair. They also indicated that the healing rate significantly decreased with increasing age [4]. Some previous meta-analyses with high evidence level also determined that advanced age was associated with rotator cuff retears [28, 34]. A recent study by Kwon et al. also reported age as an independent risk factor for rotator cuff healing. However, this study was conducted with a heterogeneous cohort in terms of tear characteristics and surgical techniques. Moreover, authors indicated that cutoff age limit for a successful rotator cuff repair was 70 years [22]. On the contrary, several reports suggested that age was not independently associated with healing failure [5, 17]. The influence of age may be obscured by other significant factors such as tear size or fatty infiltration in rotator cuff muscles in cohorts involving large and massive tears. However, the present study demonstrated that age itself is an independent predictive factor for small- to medium-sized RCTs with increasing odds of repair failure 1.11 times for every additional year and patients older than 63 years are significantly prone to a healing failure possibly due to diminished healing environment.

Another independent prognostic factor for rotator cuff healing which was suggested by our findings was BMI. Animal studies have demonstrated that obesity in mouse models is associated with poor tendon quality and high levels of pro-inflammatory cytokines and reactive oxygen species [9, 26]. Hereby, increased BMI diminishes tendon healing by promoting inflammation. One possible explanation is that obesity may increase mechanical load and pressure on the joint and concurrently on the healing tendon [20]. A recent systematic review conducted with 5,693 patients reported that higher BMI was associated with increased rate of retear after ARCR [38]. Another systematic review also indicated that obesity was associated with higher incidence of rotator cuff tendinopathy, tear and also with complications following surgery [27]. A recent clinical study also indicated that obesity was associated with poor clinical outcomes and high retear rates [2]. Consistently with previous data, our findings suggest that BMI is a significant independent prognostic factor for healing of small- to medium-sized RCTs. The critical cutoff value for successful healing was detected as 28.1 kg/m^2 and higher BMI values were found to be significantly associated with increased failure rates.

The univariate analysis showed that healing failure was significantly higher in diabetic patients. However, the multivariate analysis demonstrated that diabetes is not a significant independent prognostic factor for rotator cuff healing in small- to medium-sized tears. One explanation for this may be confounding effect of other independent factors (age and BMI) which are also highly associated with diabetes.

Severity of diabetes may be another contributor which was not evaluated in our study. Previous reports suggested diabetes as another contributor to poor outcomes and high failure rates following ARCR [6, 7]. Systematic review conducted by Zhao et al. also suggested diabetes as a risk factor for post-operative retear [38]. On the contrary, a recent report by Jeong et al. indicated that diabetes history was not associated with healing failure [19].

There are two other potential contributors to healing failure that needs to be mentioned which are tobacco use and pre-operative corticosteroid injection. There is paucity of evidence and current results are conflicting. Experimental studies have showed that nicotine is associated with poor type-I collagen expression and delay in tendon-bone healing with poor biomechanical tendon characteristics in a rat model [14]. Moreover, impaired blood flow may diminish rotator cuff healing since nicotine has been implicated as a major vasoconstrictor [29]. However, findings of clinical studies are controversial some suggesting negative influence of smoking on healing rates after ARCR [30] and other indicating no correlation between smoking and rotator cuff healing [28]. Results of the present study suggest that smoking does not affect healing of rotator cuff in patients with small- to medium-sized RCTs.

Pre-operative corticosteroid injection is a widely preferred component of conservative management of RCTs. Corticosteroids have some potential benefits such as alleviating symptoms and facilitating rehabilitation, preventing need for surgery and prepare shoulders to surgical intervention by decreasing inflammation in the subacromial bursa. However, there are concerns about their use due to potential excitotoxic damage to rotator cuff [10]. Literature lacks clinical evidence about their use with previous studies reporting conflicting results [3, 25]. No significant relation between pre-operative corticosteroid injection and rotator cuff healing was indicated by the results of our study. Similar findings about the effect of corticosteroid injection on rotator cuff healing have been reported in a recent randomised controlled trial [33].

This study has some limitations that should be noted. Retrospective nature of the study is its first limitation which may have cause selection bias and other unanticipated factors may have distorted the results. However, the fact that study results were retrieved from a prospectively collected data can minimise this risk. Second, all clinical evaluation were performed by a single author which may have caused evaluation bias. Another limitation is relatively small cohort size which may impair power of the study. However, a strict selection protocol was performed in order to create a homogeneous cohort including patients with a specific subgroup of RCTs of small- to medium-sized tears without evident fatty infiltration and tear retraction. This may be considered as a strength of our study rather than a limitation since a homogeneous subgroup was obtained and multivariate analysis with cutoff value determinations for rotator cuff healing using ROC curves was done. Moreover, compared to most of the previous reports, a considerably large population size was obtained. Another limitation is that type of diabetes and level of glycemic control was not assessed which is potentially important for its influence on rotator cuff healing. This variable was evaluated only relying on patient charts which may have distorted our results.

There are also strengths of this study which need to be mentioned. All patients were operated by a single author with a standardised surgical technique. Second, all structural evaluations were performed by a single imaging modality (MRI) at a considerably sufficient time after surgery which was not available for most previous studies. Another strength of our study is that use of multivariate logistic regression analysis for identification of independent factors and ROC curve analysis for cutoff estimations. Current data and existing knowledge about predictive factors affecting rotator cuff healing are mostly based on univariate analyses.

Conclusion

Healing failure rate after ARCR of small- to medium-sized RCTs is 20.2% which is considerably high and failed repairs are associated with poorer clinical outcomes. Age and BMI are significant independent predictive factors for rotator cuff healing in this specific group. Age of 63 years and BMI of 28.1 kg/m^2 were identified as reference cutoff values for rotator cuff healing. This information should be considered during risk assessment of the patients and decision making for a surgical indication. Surgeons should also use this information during pre-operative patient counselling regarding post-operative healing and functional improvement expectations.

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Declarations

Conflict of interest None.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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