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The effect of age on risk of retear after rotator cuff repair: a systematic review and meta-analysis

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Hypothesis: The purpose of this study was to perform a systematic review and meta-analysis to determine the effect of age on rotator cuff repair failure. The hypothesis of this study was that increased patient age would lead to a higher rate of retears and/or repair failures after rotator cuff repair.
Methods: We conducted a systematic review and meta-analysis of level I and II studies evaluating patients undergoing rotator cuff repair that also included an imaging assessment of the structural integrity of the repair. Univariate and multivariate meta-regression was performed to assess the dependence of the retear rate on the mean age of the cohort, imaging modality, time to imaging, and publication year.
Results: The meta-regression included 38 studies with a total of 3072 patients. Significant heterogeneity in retear rates was found among the studies ($Q = 209.53$, $I^2 = 82.34$, $P < .001$). By use of a random-effects model, the retear rate point estimate was 22.1% (95% confidence interval [CI], 18.6%-26.0%). On univariate analysis, type of imaging modality did not significantly influence the retear rate ($P = .188$). On univariate analysis, mean age (odds ratio [OR], 1.05 [95% CI, 1.01-1.09]; $P = .027$) and mean time to imaging (OR, 1.04 [95% CI, 1.01-1.08]; $P = .006$) were associated with the retear rate. Publication year (OR, 0.94 [95% CI, 0.88-1.01]; $P = .083$) demonstrated a trend toward significance. On multivariate analysis, increased age was associated with a 5%/yr increased odds of retear (OR, 1.05 [95% CI, 1.01-1.08]; $P = .025$). The risk of retear doubled from 15% at age 50 years to >30% at age 70 years. Time to imaging demonstrated a trend toward increased odds of retear (OR, 1.03 [95% CI, 1.00-1.07]; $P = .056$). Publication year was not associated with the retear rate on multivariate analysis (OR, 0.96 [95% CI, 0.90-1.02]; $P = .195$).
Conclusion: The risk of retear after rotator cuff repair is associated with increased age and doubles between the ages of 50 and 70 years.

Rotator cuff tears are common and can be a significant source of pain and disability in the adult population. The incidence of full-thickness rotator cuff tears increases with age regardless whether symptomatic or asymptomatic.[49,61,62] Rotator cuff repair surgery has demonstrated improvement in pain and shoulder functional outcome scores regardless of the integrity of the repair.[35,45] Despite the good clinical outcomes observed in these patients, the rate of unhealed rotator cuffs or rotator cuff repair failure has been reported to be as high as 94% in patients following massive rotator cuff repair.[3,24,59] Although the etiology of these failures is still not completely understood biologically, several causes have been hypothesized to explain the high rate of repair failure, including age, associated medical comorbidities (eg, diabetes mellitus), smoking, tear size, muscle fatty infiltration, muscle atrophy, and repair technique.[2,9,18,24,51,60]

A number of case series (level of evidence [LOE] IV) examining the impact of age on rotator cuff healing have been performed.[7,26,60] Tashjian et al[60] described a case series of 49 shoulders in which age ($P = .01$; odds ratio [OR], 0.43 [95% confidence interval (CI), 0.23-0.82]) was shown to be a significant factor associated with lower healing rates (mean age of 63.3 ± 10 years for the 24 patients without healing vs. 55.1 years for the 25 patients with healing). Charousset et al[7] found a retear rate > 40% in 88 patients aged > 65 years. Despite these small case series, to our knowledge, no studies have analyzed the effect of age on retear rates after rotator cuff repair. Fermont et al[19] performed a systematic review of successful recovery following rotator cuff repair. They found that younger age, male sex, absence of diabetes, high activity level, smaller sagittal tear size, and less fatty infiltration were all predictors of successful structural tendon-to-bone healing after rotator cuff repair. Specifically, this study found that, on average, patients with healed rotator cuff repairs were 10 years younger (mean, 57.8 ± 9.4 years) than those without healed repairs (mean, 68 ± 7.6 years).

Institutional review board approval was not required for this systematic review.

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The purpose of this study was to perform a systematic review and meta-analysis to determine the effect of age on rotator cuff repair failure. The hypothesis of this study was that increased patient age would lead to a higher rate of retears and/or repair failures following rotator cuff repair.

Methods

We performed a systematic review of the literature using the Cochrane Central Register of Controlled Trials, EMBASE, PubMed, and Web of Science databases to identify articles reporting both structural integrity and age in patients undergoing rotator cuff repair. The following search (MeSH [Medical Subject Headings]) terms were used: "rotator cuff tear AND age," "rotator cuff AND age AND repair," "rotator cuff AND repair AND healing AND age," and "rotator cuff AND repair AND imaging AND age."

The inclusion criteria included peer-reviewed articles published in the English language prior to August 2017. To be included, a study had to report an assessment of the structural integrity of the rotator cuff after repair using computed tomographic arthrography, magnetic resonance imaging, or ultrasound and had to present the mean age of the patients. The minimum time requirement between rotator cuff repair and subsequent imaging was 6 months; Iannotti et al[27] showed that the majority of retears occur between 6 and 26 weeks after rotator cuff repair surgery and few retears happen after 26 weeks. Only level I and II studies were included in this study. The LOEs of the included studies were determined by 2 reviewers (S.W.B. and a non-author). Any disputes regarding the LOE were resolved by a third reviewer (M.K.). The exclusion criteria were studies with LOE III or lower, studies with a time to repeated imaging < 6 months, or studies that did not include the mean age of the study population.

After initial review, the article titles were reviewed by the 2 independent reviewers, and any article deemed inappropriate for inclusion in this study was excluded. After this exclusionary period, the abstracts of all remaining studies were reviewed to assess inclusion via the aforementioned criteria. On review of the abstract, if it was unclear whether the criteria were met, the methods section of the article was reviewed. The complete article was reviewed for all remaining studies.

For all included studies, the data extracted from the articles included age, retear rate, timing of repeated imaging, and modality of repeated imaging. In addition, the authors from each included study were contacted, and the raw data, including deidentified, individual patient data, were requested to further analyze the relationship between age and the incidence of retear after rotator cuff repair. If the authors did not respond or did not have the necessary information, their study was excluded from this subgroup analysis (Fig. 1).

A meta-analysis was performed to compare the mean age with the mean retear rates from the included studies. A retear was defined as any full- or partial-thickness tear after rotator cuff repair. Any abnormal signal without a tear was deemed to indicate an intact repair. Statistical analysis was then performed to evaluate for any effect of age on the retear rate after rotator cuff repair.

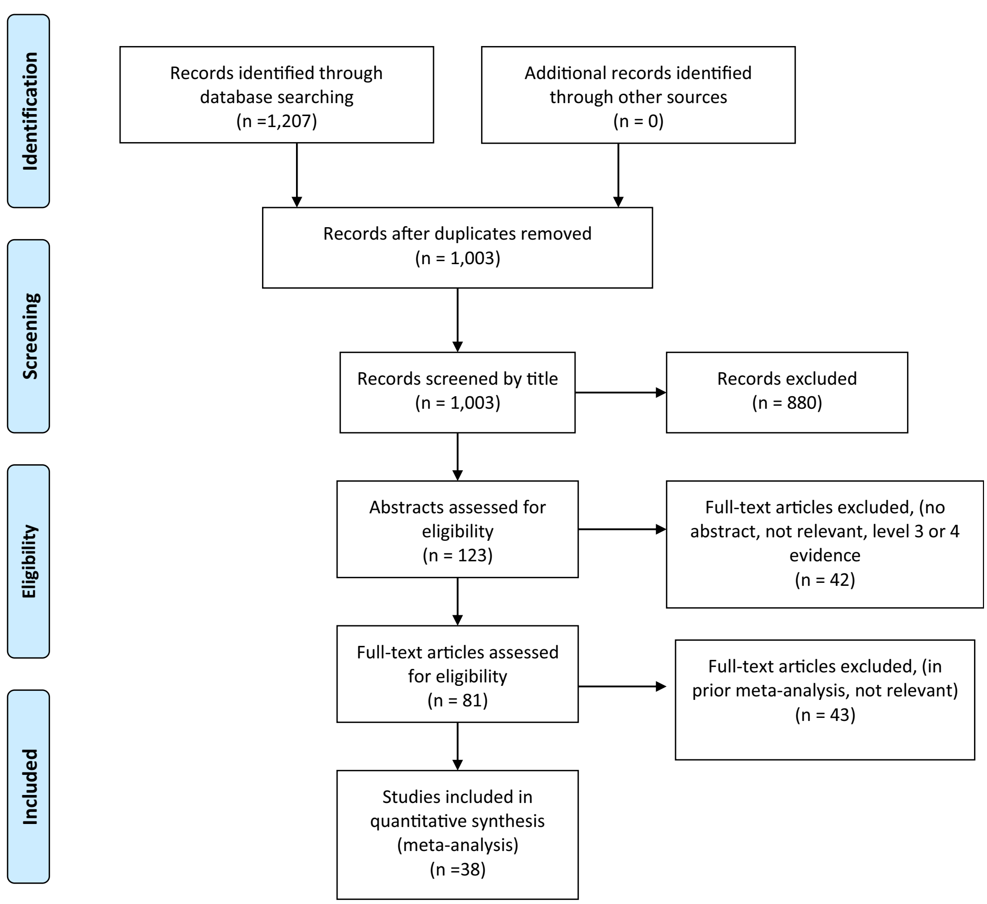


Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flowchart of search process.

Statistical analysis

Retear rate heterogeneity was characterized with the Cochran Q and I^2 statistics. Univariate random-effects logistic meta-regression was performed to evaluate the influence of the covariates mean age, timing of repeated imaging (in months), modality of repeated imaging, and publication year on retear rate heterogeneity among the included studies. If the covariate demonstrated a trend toward significance, defined as $P < .10$, then the covariate was included in the random-effects multivariate logistic meta-regression. Statistical significance was defined as $P < .05$. Comprehensive Meta-Analysis software (version 3.3.070; Biostat, Englewood, NJ, USA) was used for analysis.

Results

We included 38 studies with 3072 patients for full-text review, as well as in the meta-analysis, as they met the final inclusion criteria.[1,4-6,8,10-15,20-23,25,28,29,31-34,36,37-44,46,50,52-54,56,57] The study characteristics of each included cohort are shown in Table I. A forest plot of retear rates is shown in Figure 2. The random-effects pooled retear rate was 22.1% (95% CI, 18.6%-26.0%; $P < .001$). Significant retear rate heterogeneity was found among the cohorts (Q = 209.532, $P < .001$, $I^2 = 82.342$), with retear rates ranging from 3.3% to 50%. All studies were published between 2004 and 2017. Of the studies, 15 had LOE I and 23 had LOE II. The average patient age for all the included studies was 60.2 years. The average time from rotator cuff repair to imaging was 12 months (range, 6-27 months) postoperatively.

On univariate analysis (Table II), mean age (OR, 1.05 [95% CI, 1.01-1.09]; $P = .027$) and time to imaging (OR, 1.04 [95% CI, 1.01-1.08]; $P = .006$) were associated with an increased retear rate. Publication year demonstrated a trend toward a decreased retear rate (OR, 0.94 [95% CI, 0.88-1.01]; $P = .083$). Type of imaging modality did not significantly influence the retear rate ($P = .1881$).

On multivariate analysis (Table III), increased age was associated with a 5%/yr increased odds of retear (OR, 1.05 [95% CI 1.01-1.08]; $P = .025$). Time to imaging demonstrated a trend toward increased odds of retear (OR, 1.03 [95% CI, 1.00-1.07]; $P = .056$). Publication year was not associated with the retear rate on multivariate analysis (OR, 0.96 [95% CI, 0.90-1.02]; $P = .195$). A bubble plot of the log transformation of the retear rate and cohort mean age is shown in Figure 3, *A*, with the trend line and 95% CIs. The bubble area is proportional to the inverse variance of the cohort retear rate. As shown in Figure 3, *B*, the risk of retear doubled from 15% at age 50 years to >30% at age 70 years.

Discussion

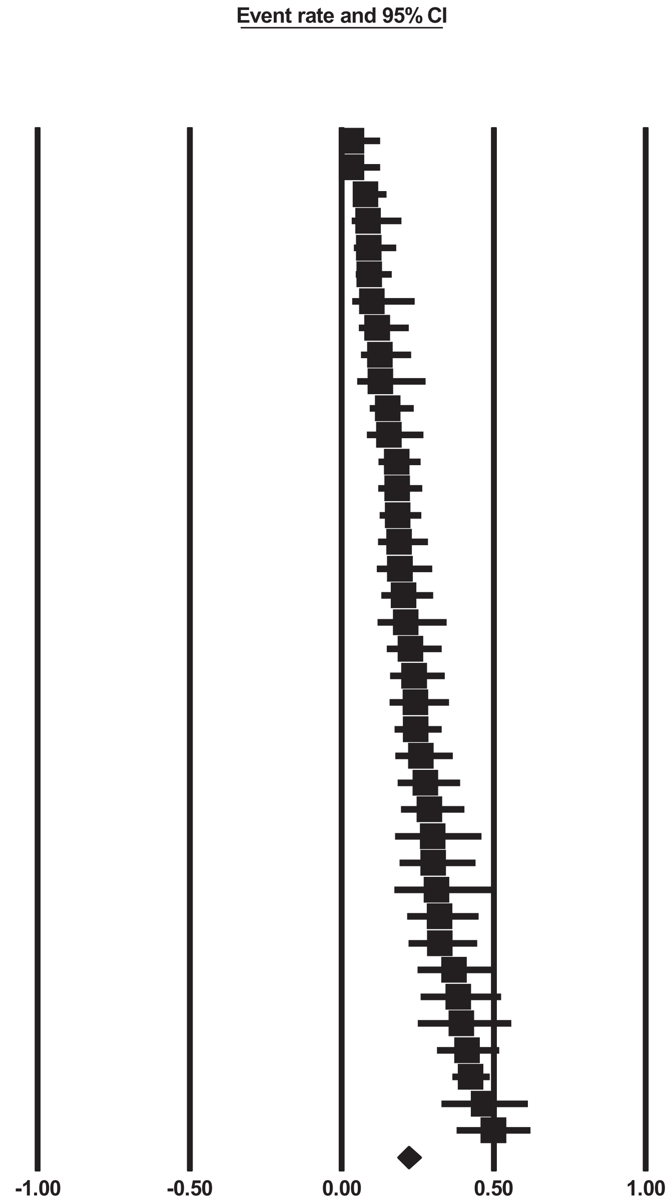
The purpose of this study was to establish the relationship between increased age and rotator cuff repair failure. We performed a systematic review and meta-analysis of LOE I and II studies, the findings of which revealed that the risk of retear after rotator cuff

Table I
Study characteristics

Cohort	Retear rate, %	Publication year	Mean age, yr	Imaging modality	Time to imaging, mo	LOE
Klepps et al[38]	31.3	2004	64	MRI	12	II
Boehm et al[4]	20.4	2005	56.5	US	27	I
Charousset et al[7]	50.0	2007	58.9	CTA	6	II
Franceschi et al[23]	38.5	2007	61.5	MRI	24	I
Gladstone et al[25]	39.5	2007	62	MRI	12	II
Deutsch et al[14]	12.8	2008	54	MRI	12	II
Ko et al[39]	19.2	2008	53.4	MRI	6	II
Burks et al[5]	10.0	2009	56.5	MRI	12	I
Nho et al[50]	24.4	2009	58.6	US	24	II
Cuff and Pupello[12]	11.8	2012	63.2	US	9	I
Dezaly et al[15]	32.4	2011	67.5	US	12	II
Koh et al[40]	46.8	2011	61.4	MRI	27	I
Arndt et al[1]	41.3	2012	55	CTA	14	I
Cuff and Pupello[13]	23.9	2012	57.65	US	9	II
Kim et al	21.2	2012	58.2	Combined	12	I
Kim et al	15.2	2012	60	Combined	12	I
Lapner et al[43]	27.6	2012	56.8	Combined	12	I
Lee et al[44]	15.6	2012	54.9	MRI	6	II
Ma et al[46]	30.2	2012	61.2	MRI	24	II
Shin et al[57]	18.3	2012	56.8	Combined	6	II
Flurin et al	18.5	2013	73.9	US	12	II
Franceschi et al[22]	3.3	2013	56.5	MRI	12	II
Jo and Shin[29]	22.7	2013	60	MRI	12	II
Osti et al[52]	8.8	2010	60.5	MRI	6	I
Robinson et al[54]	32.3	2013	77	US	14	II
Jacquot et al[28]	37.0	2014	67	US	12	II
Keener et al[31]	7.9	2014	55	US	12	I
Koh et al[41]	26.1	2014	59.9	MRI	6	I
Oh et al[51]	24.4	2010	63.8	Combined	6	I
Kim et al	28.9	2015	63.4	MRI	12	II
Lam et al[42]	9.2	2015	57.5	US	6	I
Pauly et al[53]	30.0	2015	60.3	MRI	24	II
Ryu et al[56]	12.7	2015	57.3	MRI	3	II
Collin et al[10]	9.0	2016	57	US	6	II
Colliver et al[11]	3.3	2016	58.8	MRI	4	II
Kim et al[33]	18.2	2016	60.8	MRI	12	II
Carr et al[17]	42.5	2017	62.9	Combined	12	I
Kim et al[32]	18.9	2017	58.3	CTA	6	II

LOE, level of evidence; *MRI*, magnetic resonance imaging; *US*, ultrasound; *CTA*, computed tomographic arthrography.

Study name	Statistics for each study				
	Event rate	Lower limit	Upper limit	Z-Value	p-Value
Colliver 2016	0.033	0.008	0.124	-4.682	0.000
Franceschi 2013	0.033	0.008	0.124	-4.682	0.000
Keener 2014	0.079	0.042	0.145	-7.073	0.000
Osti 2013	0.088	0.037	0.194	-5.001	0.000
Collin 2016	0.090	0.043	0.176	-5.848	0.000
Lam 2015	0.092	0.050	0.162	-6.909	0.000
Burks 2009	0.100	0.038	0.238	-4.169	0.000
Cuff 2011	0.118	0.060	0.218	-5.353	0.000
Ryu 2015	0.127	0.067	0.226	-5.410	0.000
Deutsch 2008	0.128	0.054	0.273	-4.002	0.000
Kim 2012 (2)	0.152	0.095	0.234	-6.320	0.000
Lee 2012	0.156	0.086	0.267	-4.899	0.000
Kim 2016	0.182	0.125	0.257	-6.665	0.000
Shin 2012	0.183	0.124	0.263	-6.332	0.000
Flurin 2013	0.185	0.128	0.260	-6.687	0.000
Kim 2017	0.189	0.123	0.281	-5.552	0.000
Ko 2008	0.192	0.119	0.295	-4.995	0.000
Boehm 2005	0.204	0.134	0.298	-5.287	0.000
Kim 2012 (1)	0.212	0.121	0.343	-3.875	0.000
Jo 2013	0.227	0.152	0.326	-4.811	0.000
Cuff 2012	0.239	0.163	0.337	-4.736	0.000
Oh 2014	0.244	0.161	0.351	-4.296	0.000
Nho 2009	0.244	0.177	0.326	-5.472	0.000
Koh 2014	0.261	0.180	0.363	-4.282	0.000
Lapner 2012	0.276	0.188	0.387	-3.753	0.000
Kim 2015	0.289	0.199	0.401	-3.550	0.000
Pauly 2015	0.300	0.179	0.457	-2.456	0.014
Ma 2012	0.302	0.194	0.437	-2.802	0.005
Klepps 2004	0.313	0.177	0.490	-2.067	0.039
Robinson 2013	0.323	0.219	0.448	-2.731	0.006
Dezaly 2011	0.324	0.223	0.443	-2.845	0.004
Jacquot 2014	0.370	0.253	0.505	-1.883	0.060
Franceschi 2007	0.385	0.263	0.522	-1.649	0.099
Gladstone 2007	0.395	0.254	0.556	-1.288	0.198
Arndt 2012	0.413	0.317	0.516	-1.660	0.097
Carr 2017	0.425	0.368	0.484	-2.472	0.013
Koh 2011	0.468	0.332	0.609	-0.437	0.662
Charousset 2007	0.500	0.382	0.618	0.000	1.000
	0.221	0.186	0.260	-11.495	0.000



Meta Analysis

Figure 2 Forest plot. *CI*, confidence interval.

repair is associated with increased age and doubles from 15% at age 50 years to 31% at age 70 years, with an increased OR of 1.05/yr.

This analysis has several limitations. First, each of the 38 included studies has its own limitations and biases. We included only level I and II publications and carefully reviewed each study to include only the highest quality of evidence. At the time of writing, our study is the largest level II systematic review of the literature evaluating the impact of increased patient age on rotator cuff repair failure. Second, the studies included a heterogeneous mix of patients, study aims, repair techniques, reported outcomes, and imaging modalities with multiple different surgeons, and although this increases the results' generalizability, it makes analysis of these pooled data difficult to interpret accurately. Third, we included studies with postoperative magnetic resonance imaging, computed tomographic arthrography, or ultrasound. Although each of these modalities has been validated in the postoperative setting to assess rotator cuff integrity,[17,30,47] it is unclear whether they have similar sensitivities and specificities in this setting, which yields the potential for detection bias. We did attempt to control for this and found no significant differences between the imaging modalities

Table II
Univariate analysis

Variable	OR	95% CI		*P* value
		Lower	Upper	
Publication year	0.94	0.88	1.01	.083
Mean age	1.05	1.01	1.09	.027
Imaging modality				.188
CTA	1.00	—	—	
US	0.43	0.20	0.95	
MRI	0.49	0.23	1.04	
Combined	0.58	0.25	1.37	
Time to imaging	1.04	1.01	1.08	.006

OR, odds ratio; *CI*, confidence interval; *CTA*, computed tomography arthrography; *US*, ultrasound; *MRI*, magnetic resonance imaging.

Table III
Multivariate analysis

Variable	OR	95% CI		*P* value
		Lower	Upper	
Publication year	0.96	0.90	1.02	.195
Mean age	1.05	1.01	1.09	.025
Time to imaging	1.03	1.00	1.07	.056

OR, odds ratio; *CI*, confidence interval.

used in each study to evaluate the final status of the rotator cuff repair. Fourth, there are significant confounding preoperative risk factors that were unable to be obtained from the data, including the patients' sex, hand dominance, medical comorbidities, degree of fatty infiltration, degree of atrophy, and severity of tendon retraction, as well as tear acuity. These are known variables that have been proved to correlate with healing rates after rotator cuff repair. Finally, 2 studies in our analysis only included patients aged < 65 years who underwent rotator cuff repair.[31,56] This could potentially skew the results given that, collectively, these 2 studies contributed 197 patients, leading to the group aged > 65 years having a smaller sample size and potentially being underpowered. Further studies could be performed to evaluate the impact of each of the aforementioned factors on rotator cuff repair success.

The year of publication was an important variable in our evaluation because the chronology of when the article was published may reflect the surgical technique used for rotator cuff repair.

McElvany et al[48] performed a systematic review and meta-analysis (LOE IV) of 11 studies and found increased age to be a risk factor for retears, with an OR of 1.67 (95% CI, 1.49-1.87) for each increase of 10 years. (Their review had 108 studies in total, with LOEs I-IV; Table I shows only the 11 studies used for age analysis.) Our finding of an increased OR of 1.05/yr, when extrapolated, reveals a similar OR of 1.63 per 10 years. Our study also found that the time from repair to imaging was significant on univariate analysis and trended toward significance on multivariate analysis. This supports the notion that the repair is more likely to be torn at longer-term follow-up regardless of age. Diebold et al[16] performed a retrospective cohort study of 1600 patients following rotator cuff repair who were evaluated by ultrasound to assess the structural integrity of the repair at a minimum of 6 months postoperatively. They found that the retear rate was low in patients aged < 50 years and observed a linear relationship between age and retear rate, with an increase of 10% in those aged 50-59 years, 15% in those aged 60-69 years, 25% in those aged 70-79 years, and 34% in those aged ≥80 years of age. In addition, they found patient age to be an independent factor strongly associated with retears on multiple logistic regression analysis. The findings of our meta-analysis support these results with a >30% failure rate in patients aged > 70 years.

Several studies have demonstrated equivalent outcome scores regardless of the integrity of the repair on follow-up imaging.[19,55,58] Russell et al[55] performed a meta-analysis (LOE II) of 861 patients in 14 studies (average age, 58.5 years) and found that patients with intact rotator cuffs after rotator cuff repair had increased strength in forward elevation compared with patients with retears. However, no clinically significant difference was found in their validated outcome measure scores, including the American Shoulder and Elbow Surgeons score, University of California, Los Angeles shoulder scoring scale, and visual analog pain scale. The average follow-up period for these patients was 30.1 months. The only factors found to be significantly different in patients with structural healing vs. those who had rotator cuff retears were the Constant score and forward elevation and external rotation strength measurements. The Constant score is likely the only patient-reported

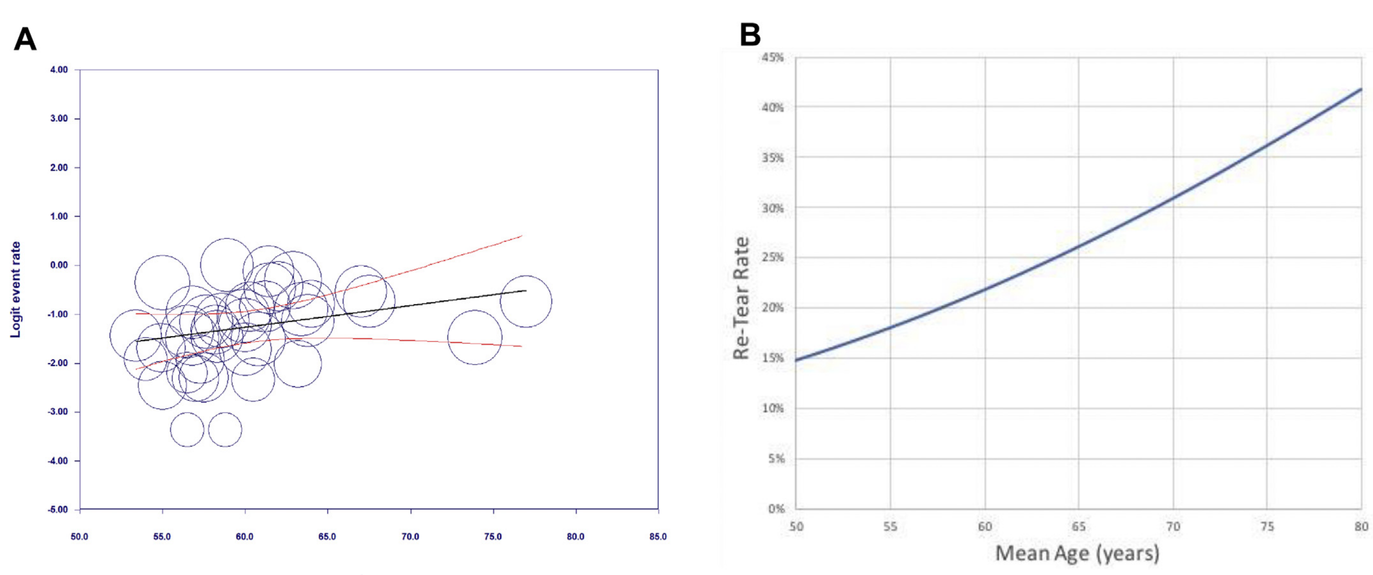


Figure 3 **(A)** Bubble plot with trend line (*black line*) and 95% confidence intervals (*red lines*). The bubble area is proportional to the inverse variance of the cohort retear rate. **(B)** Graph of age vs. retear rate. The risk of retear doubled from 15% at age 50 years to >30% at age 70 years.

outcome measure found to demonstrate a significant difference between groups because of its strength component. Slabaugh et al[58] performed a systematic review (LOE IV) and correlated rotator cuff structural integrity to patient outcomes. Intact repairs were found to have increased strength and motion in forward elevation, but no difference was observed between groups overall regarding outcome measures. Given that an intact rotator cuff repair is protective against proximal humeral head migration, eccentric superior wear of the glenoid, and progression of glenohumeral rotator cuff tear arthropathy, longer follow-up is needed to determine whether there are clinically significant differences between these groups over time.

Conclusion

The risk of retear after rotator cuff repair is associated with increased age and doubles between the ages of 50 and 70 years.

Disclaimer

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