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Do patients who smoke tobacco have success with primary arthroscopic rotator cuff repair? A comparison with nonsmokers

Keith M. Baumgarten, MD[a,b,*], Will E. Schweinle III, PhD[c], Peter S. Chang, MD[d]

[a]*Orthopedic Institute, Sioux Falls, SD, USA*
[b]*University of South Dakota Sanford School of Medicine, Sioux Falls, SD, USA*
[c]*University of South Dakota, Vermillion, SD, USA*
[d]*Department of Orthopaedics, Washington University, St. Louis, MO, USA*

Background: It is recommended that patients cease smoking before rotator cuff repair. However, not all patients want to or are able to successfully cease smoking. This raises the question if these patients should be advised to pursue surgical intervention or if surgery should be contraindicated until patients successfully cease smoking.

Methods: A retrospective analysis of patients undergoing rotator cuff repair was performed to examine the effects of smoking tobacco on patient-determined outcomes (Western Ontario Rotator Cuff Index [WORC], American Shoulder and Elbow Surgeons score [ASES], Simple Shoulder Test [SST], and Single Assessment Numeric Evaluation [SANE]). Patients who smoked tobacco at the time of surgery were compared with patients who were not smoking to determine if differences in (1) severity of preoperative and postoperative symptoms and (2) the postoperative improvements were statistically significant.

Results: Thirty-one patients were smokers and 205 were nonsmokers. Preoperative scores were worse for smokers compared with nonsmokers: WORC (32 vs. 43; $P = .0002$), ASES (32 vs. 43; $P = .001$), SST (3.5 vs. 4.6; $P = .04$), and SANE (34 vs. 38; $P = .35$). Postoperative scores were worse for smokers compared with nonsmokers: WORC (79 vs. 89; $P = .001$), ASES (82 vs. 89; $P = .04$), SST (9.0 vs. 10.2; $P = .02$), and SANE (84 vs. 89; $P = .09$). There were no significant differences in change in scores over time or percentage of patients achieving the minimal clinically important difference of the score between groups.

Conclusions: From examining the patients' subjective patient-determined outcome scores, it does not appear that rotator cuff repair should be strictly contraindicated in active smokers. Postoperative improvements in smokers were similar to nonsmokers. Smokers have lower baseline preoperative and postoperative outcome scores compared with nonsmokers.

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Rotator cuff repair; smoking; tobacco; patient-determined outcomes

According to census data, approximately 15.5% (37.8 million people) of the US population smokes tobacco.[8] Smoking has been associated with an increased incidence of rotator tears and severity of rotator cuff tears.[3,9,16] Although smoking tobacco has been shown to have a detrimental influence on successful rotator cuff tendon healing after attempts at surgical repair,[4,5,17,18,22] there are both insufficient and conflicting evidence regarding the relationship of smoking and clinical outcomes.[11,24] It is universally recommended that patients cease smoking before rotator cuff repair surgery.[6,12,17,22] However, not all patients want to or are

This study had institutional review board approval from the University of South Dakota (2014:115).

*Reprint requests: Keith M. Baumgarten, MD, Orthopedic Institute, 810 E 23rd Street, Sioux Falls, SD 57117, USA.

E-mail address: Kbaumga@yahoo.com (K.M. Baumgarten).

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able to successfully cease smoking. This raises the question if these patients should be advised to pursue surgical intervention or if surgery should be strictly contraindicated until the patients successfully cease smoking. The hypothesis of this study was that patients who smoke would have inferior improvements in patient-determined outcome scores after rotator cuff repair compared with nonsmokers. The aim of this study was to help guide the clinician on how to proceed with patients with a symptomatic, full thickness rotator cuff tear who refuse or are unable to cease smoking.

Methods

Prospective collection of preoperative patient-determined outcome scores on patients undergoing arthroscopic rotator cuff repair by a single surgeon (KMB) was begun in December 2008. Patient-determined outcome scores that were collected include the Western Ontario Rotator Cuff Index (WORC)[10] (a disease-specific outcome score that has been recommended for assessing the results of rotator cuff repair treatment[27]), the American Shoulder and Elbow Surgeons score (ASES),[21] the Simple Shoulder Test (SST)[14] (joint-specific outcome scores), and the Single Assessment Numeric Evaluation (SANE)[26] (a general health measure). After institutional review board approval was obtained, postoperatively, patients were mailed the follow-up outcome measures by US mail and asked to complete the identical outcome scores that were taken preoperatively to determine the effect of smoking on clinical outcomes after arthroscopic rotator cuff repair.

In our practice, it is routine to prospectively collect demographic data including smoking behaviors before pursing arthroscopic rotator cuff repair. These data are self-reported by the patient and include if they currently smoke or have smoked in the past. Those who were active smokers were then asked to report the number of packs/day that they smoked and the duration of smoking. Those who previously smoked but have quit were asked the duration of smoking, packs/day of smoking, and the date of final cessation of smoking. Patients who were active smokers were encouraged to cease smoking and were advised of the risks associated with smoking both specific to the treatment of their rotator cuff and also general health risks of smoking.

Patients who underwent primary arthroscopic rotator cuff repair with a concomitant subacromial decompression and had completed preoperative patient outcome forms had the potential for inclusion in this study. Patients who underwent concomitant acromioclavicular joint resection, biceps tenodesis, and/or labral repair were included to increase the generalizability of the study because they are often performed clinically along with rotator cuff repairs. Exclusion criteria were patients with radiographically apparent osteoarthritis, patients with less than 2-year follow-up, patients undergoing revision rotator cuff repair, patients with rotator cuff arthropathy or irreparable rotator cuff tears, patients who were deceased before postoperative outcome measures could be obtained, non–English-speaking patients, and patients with concomitant cervical radiculopathy, adhesive capsulitis, proximal humerus fracture, or a diagnosis of inflammatory arthritis.

To determine clinically meaningful improvements from arthroscopic rotator cuff repair, the percentage of shoulders who had improvements equal to or greater than the minimal clinically important difference (MCID) of the WORC, the ASES, and the SANE was reported.[15,23,25,27] These studies suggested that the MCID of the WORC was 11.7%, the MCID of the SANE was 15%, and the MCID of the ASES ranged from 6.4 to 17.

To determine if a dose-dependent relationship existed between the smoking and outcome scores, the cohort was stratified into 3 groups: current nonsmokers, low-dose smokers, and high-dose smokers. Low-dose smokers were defined as current smokers who smoked less than the median pack-years of the entire active smoking cohort. High-dose smokers were current smokers who smoked greater than the median pack-year amount of the entire active smoking cohort.

Statistical analysis was performed using Microsoft Excel 2010 and SAS 9.4 (SAS Institute, Cary, NC, USA, 2018). Dependent *t*-tests on pre- and post-test scores were used to determine statistically significant improvements in the patient-determined outcome scores. Comparisons of more than 2 means were analyzed using an analysis of variance (ANOVA) followed by Tukey's post hoc *t*-tests if the ANOVA determined statistical significance. Chi-square testing was used to analyze discrete variables. When multiple variables could lead to the statistical finding, mixed ANOVA models were used to identify which variables best explained the findings. The level of significance was set at .05.

Results

Two hundred sixty-three patients met inclusion and exclusion criteria for this study. Two hundred thirty-six patients returned their postoperative surveys (89.8%). Of the 27 patients who did not participate in this study, 6 (22%) were current smokers. Of the 236 patients participating in this study, 31 patients were current smokers (13%), 89 patients reported a past history of smoking, and 116 patients never smoked. Seventy-nine of the patients who reported a past history of smoking (89%) reported a date of cessation that averaged 20.7 $\pm$ 12.5 years before surgery (range: 0.25-46 years). The patients with a past history of smoking reported fewer years of smoking compared with current smokers (17.3 $\pm$ 12.6 vs. 30.9 $\pm$ 11.6 years; $P < .0001$), with 72% of patients with a past history of smoking and 90% of current smokers self-reporting these data. There were no statistically significant differences in any outcomes between the group that never smoked and past smokers ($.13 \leq P \leq .99$). Thus, these groups were combined to create a nonsmokers' group of 205 patients for outcomes analysis.

There was no difference in length of follow-up between smokers and nonsmokers (3.6 vs. 3.7 years; $P = .74$). The smokers trended to be younger than the nonsmokers (56.2 vs. 59.2 years; $P = .07$). Smokers were more likely involved in a worker's compensation claim compared with nonsmokers (48.4% vs. 21.2%; $P = .02$), but there were no significant differences in percentages of patients who were on disability (12.9% vs. 8.9%; $P = .60$), who self-reported concomitant neck pain (20.7% vs. 17.6%; $P = .93$), or who

Table I Size of rotator cuff tears

	Coronal size (mm)	Sagittal size (mm)	Area (mm^2)
Nonsmokers	23 ± 11	20 ± 9	531 ± 458
Smokers	20 ± 11	19 ± 9	452 ± 470
P value	.28	.50	.39
Effect size	0.2	0.1	0.2
95% confidence intervals	[−2, 6]	[−2, 4]	[−66, 223]

self-reported concomitant depression (12.9% vs. 12.2%; $P = .88$).

Smokers were more likely to undergo supraspinatus repair (100% vs. 88.8; $P = .05$) than nonsmokers but were less likely to require subscapularis repair (22.6 vs. 40.5%; $P = .06$) or infraspinatus repair (6.5% vs. 14.1%; $P = .24$) compared with nonsmokers. There was no difference in the size of the rotator cuff tears between smokers and nonsmokers (Table I). In addition, there was no difference in the percentage of smokers who had atrophy of the supraspinatus, infraspinatus, and/or the subscapularis compared with nonsmokers (35% vs. 34%; $P = .90$).

There was no significant difference between smokers and nonsmokers in the percentage of patients requiring concomitant procedures: biceps tenodesis (42.0% vs. 51.7%; $P = .31$), acromioclavicular joint resection (64.5% vs. 56.1%; $P = .38$), or labral repair (6.5% vs. 10.7%; $P = .46$).

Preoperative patient-reported outcome scores were worse for smokers compared with nonsmokers: WORC (32 ± 9 vs. 43 ± 16; $P = .0002$), ASES (32 ± 13 vs. 43 ± 17; $P = .001$), SST (3.5 ± 2.4 vs. 4.6 ± 2.9; $P = .04$), and SANE (34 ± 22 vs. 38 ± 22; $P = .35$). Likewise, postoperative patient-reported outcome scores were worse for smokers compared with nonsmokers: WORC (79 ± 22 vs. 89 ± 16; $P = .001$), ASES (82 ± 22 vs. 89 ± 17; $P = .04$), SST (9.0 ± 3.8 vs. 10.2 ± 2.5; $P = .02$), and SANE (84 ± 16 vs. 89 ± 16; $P = .09$). However, there were no significant differences in change in scores over time or percentage of patients achieving the MCID of the score between groups (Table II).

There was 1 complication in the nonsmoking group (1 of 205; 0.5%) and 1 complication in the smoking group (1 of 31; 3.2%) ($P = .12$) that required revision surgery. The nonsmoker was found to have a recurrent/persistent supraspinatus tear 5.5 months after supraspinatus repair and underwent revision rotator cuff repair. Her final follow-up scores were: WORC = 94; ASES = 86.7; SST = 7; SANE = 75. The smoker (48 pack-years) who also had a worker's compensation claim had persistent pain and stiffness 8 months after supraspinatus repair and underwent a revision arthroscopy with lysis of adhesions. His rotator cuff was healed at the time of second look surgery. His final follow-up scores were: WORC = 46; ASES = 55; SST = 6; SANE = 50.

Because there were significantly more patients with worker's compensation claims in the smoking cohort, it was possible that the worker's compensation claim was the factor that accounted for the inferior postoperative scores. To examine this concern, a mixed model ANOVA determined that it was reasonable to conclude that postoperative inferior scores of the ASES, WORC, and SST were attributable to smoking and not to workers' compensation nor to an interaction between smoking and workers' compensation (Table III).

A dose-dependent relationship was found between smoking and the preoperative and postoperative patient-determined outcome scores but not for the degree of improvement that occurred postoperatively (Table IV), which paralleled the main findings of this study. Specifically, high-dose smokers (41 ± 8 mean pack-years) had significantly inferior preoperative and postoperative WORC and ASES scores and significantly inferior postoperative SST scores compared with the nonsmoking group. The low-dose smokers (14 ± 7 mean pack-years) had significantly inferior preoperative WORC scores compared with the nonsmoking group. However, there were no statistically significant differences in patient-determined outcome scores between the low-dose and the high-dose smokers.

Discussion

Although the hypothesis of this study was that patients who smoke would have inferior clinical improvements as determined by patient-determined outcome scores after rotator cuff repair compared with nonsmokers, the results of this research endeavor did not support the hypothesis. Smokers had similar improvements in patient-reported outcomes after arthroscopic rotator cuff repair compared with nonsmokers. However, this study did demonstrate that both preoperative and postoperative patient-reported outcome scores were inferior in smokers compared with nonsmokers. This suggests that although smokers had equivalent benefit from the surgical intervention, their perception of their symptoms and their quality of life was worse both before and after surgery compared with nonsmokers.

Prior systematic reviews have differed on their interpretation of the effect of smoking on clinical outcomes after rotator cuff repair. Lambers Heerspink et al[11] concluded that there is insufficient evidence that smoking has an influence on functional outcomes, whereas Santiago-Torres et al[22] reported that smoking had a negative influence on rotator cuff repair clinical outcomes and was associated with decreased healing of small-to-medium rotator cuff tears after repair. We demonstrated that both smokers and nonsmokers had statistically significant improvements in their patient-reported outcome scores with the majority of improvements in both groups superseding the MCID of the

Table II The change in patient-determined outcome scores after surgery and the percentage of patients achieving the minimal clinically important difference (MCID)

	Change in score (smokers vs. nonsmokers)	*P* value	Effect size	95% confidence intervals	Percentage achieving MCID (smokers vs. nonsmokers)	*P* value
WORC	47 ± 20 vs. 46 ± 16	.76	0.07	[−5.5, 7.9]	93% vs. 95%	.68
ASES	49 ± 23 vs. 45 ± 20	.37	0.17	[−4.1, 11.7]	95% vs. 100%	.20
SST	5.7 ± 3.6 vs. 5.6 ± 3.5	.91	0.02	[−1.3, 1.4]	No MCID established	
SANE	51 ± 27 vs. 51 ± 20	.94	0.02	[−7.9, 8.7]	90% vs. 90%	.99

WORC, Western Ontario Rotator Cuff Index; *ASES*, American Shoulder and Elbow Surgeons score; *SST*, Simple Shoulder Test; *SANE*, Single Assessment Numeric Evaluation.

Table III Mixed effects *P* value for change in scores over time

Measure	Smoking	Workers' compensation	Smoking × workers' compensation
ASES	.001	.262	.466
WORC	<.0001	.056	.259
SANE	.249	.100	.663
SST	.015	.872	.966

ASES, American Shoulder and Elbow Surgeons score; *WORC*, Western Ontario Rotator Cuff Index; *SANE*, Single Assessment Numeric Evaluation; *SST*, Simple Shoulder Test.

scores. This finding was comparable with that of another study.[16]

The results of our study demonstrated similar degrees of postoperative improvements with arthroscopic rotator cuff repair in smokers and nonsmokers. This differed from the results of 2 prior studies.[13,16] Mallon et al[13] reported on 224 patients who underwent open rotator cuff repair, which revealed that the degree of improvement postoperatively of both pain and University of California, Los Angeles (UCLA) scores was significantly inferior in smokers compared with nonsmokers. Naimark et al[16] found that smokers had lower functional improvement in response to surgery compared with nonsmokers as determined by ASES scores.

Although the improvements between smokers and nonsmokers were equivalent, we determined that smokers had statistically significantly inferior outcome scores at final follow-up compared with nonsmokers. There are discordant findings in prior studies that sought answer to the question if smoking affected postoperative patient-determined outcome scores. Studies by Baettig et al,[1] Balyk et al,[2] and Mallon et al[13] reported that smokers had lower postoperative patient satisfaction, whereas studies by Inderhaug et al[7] and Prasad et al[19] concluded that smokers did not have inferior outcomes at final follow-up.

At this point, it is not clear if the physical act of smoking is the cause of the inferior preoperative and postoperative outcome scores found in smokers in this study or if the inferior outcome scores are inherent to the psychosocial make-up of a person who chooses to actively smoke. Ravindra et al[20] showed that the factors most predictive of persistent pain after arthroscopic rotator cuff repair are psychosocial characteristics, including poor performance on validated measures of emotional well-being. It is also unclear if a patient does choose to cease smoking immediately before arthroscopic rotator cuff repair that it will even further positively affect postoperative improvements in outcome compared with patients who continued to actively smoke.

We found that the smokers in our study group statistically trended ($P = .07$) younger than patients without a rotator cuff tear that was akin to the findings of Naimark et al.[16] Although this study was not designed to determine the effect of smoking on the age of presentation of patients with rotator cuff tears, the findings of this study might suggest that smoking may cause either (1) an earlier onset of a full-thickness tear of the rotator cuff tear or (2) the earlier development of symptoms of a rotator cuff tear that required a physician's attention. Further population-based studies would be required to further explore these possibilities.

We did not find any statistically significant differences in tear size between smokers and nonsmokers. This differed from the results of Naimark et al[16] that found a trend toward larger tear size in the smoking group that did not reach statistical significance.

Concomitant workers' compensation claims were significantly more likely in smokers than nonsmokers in our study. Balyk et al[2] demonstrated that patients with a workers' compensation claim were more likely to be smokers than patients without a workers' compensation claim in their cohort. In their study 6 months after rotator cuff repair, patients with workers' compensation claims had inferior outcomes compared with patients without claims. However, when they controlled for other preoperative factors including smoking, the effect of workers' compensation on outcomes was largely mitigated. They suggested that future research should evaluate smoking exposure levels between workers' compensation respondents and nonrespondents to determine the impact of these factors on postoperative recovery.[2] Subgroup analysis in our study implicated smoking as the cause of inferior postoperative

Table IV Dose of tobacco use compared with patient-determined outcome scores

	WORC			ASES			SST			SANE		
	Preop	Postop	Δ	Preop	Postop	Δ	Preop	Postop	Δ	Preop	Postop	Δ
Nonsmoker	43 ± 16*,†	89 ± 16†	46 ± 16	43 ± 17*	89 ± 17*	45 ± 20	4.6 ± 2.9	10.2 ± 2.5*	5.6 ± 3.5	38 ± 22	89 ± 16	51 ± 20
Low-dose smoker	29 ± 6†	82 ± 16	51 ± 16	33 ± 14	88 ± 17	55 ± 20	3.4 ± 2.1	9.7 ± 3.0	6.3 ± 3.5	25 ± 19	85 ± 12	60 ± 20
High-dose smoker	32 ± 11*	69 ± 25†	39 ± 22	31 ± 14*	70 ± 24*	39 ± 24	3.8 ± 2.7	7.6 ± 4.5*	4.0 ± 3.6	40 ± 27	77 ± 18	39 ± 34
ANOVA	**<.001**	**.004**	.59	**.004**	**.03**	.29	.11	**.04**	.62	.13	.22	.28

WORC, Western Ontario Rotator Cuff Index; *ASES*, American Shoulder and Elbow Surgeons score; *SST*, Simple Shoulder Test; *SANE*, Single Assessment Numeric Evaluation; *ANOVA*, analysis of variance.
Tukey's post hoc test: *$P < .05$; †$P < .01$.
Bold indicates values with statistically significant difference.

outcomes rather than the presence of a workers' compensation claim.

The strengths of our study include the comparative design of the study with a reasonable follow-up period (mean, 3.6 years) and a large sample size that was either equivalent to or bigger than that of other studies.[2,7,13,19] Limitations of this study included its retrospective nature and the fact that imaging of the integrity of the rotator cuff repair was not performed at final follow-up. In addition, other clinically important properties such as differences in strength and range of motion were not assessed. Whereas follow-up imaging and range of motion and strength assessments would have made this study more comprehensive, they did not affect the ability of this study to test the initial hypothesis that patients who smoke would have inferior improvements in patient-determined outcome scores after rotator cuff repair compared with nonsmokers. Another limitation of this study design was that we were unable to determine if smoking cessation immediately before proceeding with arthroscopic rotator cuff repair would further improve postoperative outcomes compared with smokers who refused to cease smoking. Lastly, smoking was self-reported by patients and not tested objectively with laboratory testing to determine the veracity of the patient's report. We believe that it is likely that categorizing patients into current smokers, past smokers, and nonsmokers is accurate. However, determination of (1) duration of smoking, (2) amount of packs/day smoking, and (3) pack-year history of smoking may be less accurate secondary to recall bias or a patient's hesitancy to accurately characterize his or her degree of smoking. This limitation in our methodology may affect the findings and conclusions of the dose-dependency relationship that we found but less likely to affect the examination of the primary hypothesis of this study.

Conclusions

Although we universally recommend to all smokers that they cease smoking regardless of nonoperative or operative treatments of rotator cuff tears, refusal to cease smoking does not appear to be a strict contraindication to arthroscopic rotator cuff repair because smokers have equivalent postoperative improvements in patient-reported outcome scores compared with nonsmokers. However, patients who smoke should expect to have inferior preoperative and postoperative patient-determined outcome scores compared with nonsmokers.

Disclaimer

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