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Smoking as a risk factor for complications following arthroscopic rotator cuff repair

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Background: The purpose of this study was to investigate the association between smoking status and postoperative complications within 30 days of arthroscopic rotator cuff repair (ARCR).
Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried to identify all patients who underwent ARCR from 2015 to 2017. Smokers were defined as patients who reported smoking cigarettes in the year prior to rotator cuff repair. Patients who used chewing tobacco, cigars, or electronic cigarettes were not included in the smoking cohort. Postoperative complications were reported within 30 days of the procedure. Multivariate logistic regression was performed to investigate the relationship between smoking status and postoperative complications.
Results: There were 18,594 patients included in this study. Of these patients, 2834 (15.2%) were current smokers. Smokers were more likely to be men, to be aged < 65 years, and to have a body mass index < 30. Smokers were also more likely to have chronic obstructive pulmonary disease, to be functionally dependent, and to have an American Society of Anesthesiologists (ASA) class ≥ 3. After adjustment for all significantly associated patient demographic characteristics and comorbidities, smoking was identified as a significant predictor of surgical complications (odds ratio [OR], 1.955; $P = .022$), return to the operating room (OR, 2.547; $P = .003$), readmission (OR, 1.570; $P = .014$), and sepsis or septic shock (OR, 4.737; $P = .021$). Smoking was not a significant predictor of medical complications (OR, 1.105; $P = .687$) or surgical-site infections (OR, 1.216; $P = .713$).
Conclusion: Smoking may be a risk factor for surgical complications, readmission, and sepsis or septic shock within 30 days of ARCR.

A recent analysis of the 2016 National Health Interview Survey has identified 37.8 million adults in the United States as tobacco smokers.[22] Smoking tobacco has previously been identified as a patient-related risk factor for complications following many different orthopedic procedures. These complications include wound and periprosthetic joint infections, impaired bone union, poor wound healing, and reoperation.[1,6,7,14,16,32,38,44] Cigarette smoking is a common comorbidity afflicting patients with rotator cuff disease. Previous studies have identified between 15% and 18% of patients to be current cigarette smokers at the time of rotator cuff repair.[13,41] Smoking tobacco has also been associated with an increased risk of the development of rotator cuff tears[5,25,33] and inferior outcomes after rotator cuff repair.[15,28,33,34,37,40]

Previous studies have identified smoking as a risk factor for complications following open repair of rotator cuff tears, a procedure associated with higher rates of complications in comparison to arthroscopic rotator cuff repair (ARCR).[13,35] However, there is a paucity of literature regarding the impact of smoking status on the development of postoperative complications after ARCR.[9,29] The purpose of this study was to use a large national database to investigate the association between smoking status and postoperative complications within 30 days of ARCR. A secondary objective of this study was to identify patient demographic characteristics and comorbidities that are associated with preoperative smoking status.

Materials and methods

The American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database was queried to identify all

The retrospective data included in this analysis were fully deidentified, rendering the study exempt from approval by our university's institutional review board.

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patients who underwent ARCR from 2015 to 2017. The NSQIP database includes patient data from >600 community and academic hospitals. Data in the NSQIP database are collected by certified surgical clinical reviewers, and the database is episodically audited for accuracy.[42] Variables collected in this study included cigarette smoking status, patient demographic characteristics, comorbidities, postoperative complications, readmission rates, reoperation rates, and discharge information.

Patients who underwent ARCR were identified by Current Procedural Terminology code 29827. Patients were grouped into 2 cohorts based on their preoperative smoking status. Smokers were defined as patients who reported smoking cigarettes in the year prior to rotator cuff repair. Patients who used chewing tobacco, cigars, or electronic cigarettes were included in the nonsmoking cohort as the use of these alternative forms of tobacco is not a variable collected in the NSQIP database. Patient demographic characteristics including age, sex, body mass index, and American Society of Anesthesiologists (ASA) physical status classification were collected. Patient comorbidities including congestive heart failure, diabetes mellitus, hypertension (HTN), and chronic obstructive pulmonary disease (COPD) were also collected. Moreover, patients' functional status and preoperative use of steroids for a chronic condition were included in the analysis. Cases were excluded if any of the following variables had missing information: age, height, weight, functional health status, ASA class, or discharge destination.

Postoperative complications were reported within 30 days of the procedure. Surgical complications included wound dehiscence, deep surgical-site infection (SSI), superficial SSI, organ/space SSI, and return to the operating room. Medical complications included cardiac arrest or myocardial infarction, pulmonary complications, renal complications, urinary tract infection (UTI), deep vein thrombosis or pulmonary embolism, and sepsis or septic shock. Pulmonary complications included postoperative pneumonia, unplanned reintubation, and requirement of mechanical ventilation for >48 hours. Renal complications included acute renal failure and progressive renal insufficiency. Readmissions and reoperations within 30 days after ARCR were also reported.

All statistical analyses were conducted using SPSS Software (version 26.0; IBM, Armonk, NY, USA). Patient demographic characteristics, comorbidities, and procedural characteristics were compared between cohorts using bivariate analysis. Multivariate logistic regression, adjusted for all significantly associated patient demographic characteristics and comorbidities, was performed to investigate the relationship between preoperative smoking status and postoperative complications. Odds ratios (ORs) were reported in relation to 95% confidence intervals. The level of significance was set at $P < .05$.

Results

After application of the exclusion criteria, 18,594 patients were included in this study. Of these patients, 2834 (15.2%) were identified as current smokers (within 1 year of surgery) and 15,760 (84.8%) were identified as nonsmokers (Table I). In comparison to nonsmokers, smokers undergoing ARCR were more likely to be men (63.2% vs. 57.8%, $P < .001$), to be aged < 65 years, and to have a body mass index < 30 (Table I). Smokers were also more likely to have COPD (7.7% vs. 2.1%, $P < .001$), to be functionally dependent (0.6% vs. 0.3%, $P = .036$), and to have an ASA class ≥ 3 (38.4% vs. 32.3%, $P < .001$) (Table I). In comparison to smokers, nonsmokers were more likely to have diabetes (16.9% vs. 15.1%, $P = .025$), to have a diagnosis of HTN (46.0% vs. 42.3%, $P < .001$), and to use steroids preoperatively (2.1% vs. 1.5%, $P = .039$) (Table I). Smoking status was not associated with a diagnosis of congestive heart failure (0.2% vs. 0.2%, $P = .414$; Table I).

The overall rate of complications in our study was 1.1%. In comparison to nonsmokers, smokers had higher rates of surgical complications (0.6% vs. 0.3%, $P = .009$), return to the operating room (0.6% vs. 0.2%, $P = .001$), and readmission (1.5% vs. 1.0%, $P = .027$) (Table II). There was no significant difference in the rate of overall medical complications (0.7% vs. 0.8%, $P = .897$) or SSIs (Table II).

Table I
Comparison of patient demographic characteristics and comorbidities between smokers and nonsmokers

	Nonsmoker	Smoker	*P* value
	n (%)	n (%)	
Overall	15,760	2834	
Sex			<.001*
Male	9109 (57.8)	1791 (63.2)	
Female	6651 (42.2)	1043 (36.8)	
Age			
18-39 yr	743 (4.7)	245 (8.6)	<.001*
40-64 yr	10,023 (63.6)	2193 (77.4)	<.001*
65-74 yr	4030 (25.6)	357 (12.6)	<.001*
≥75 yr	964 (6.1)	39 (1.4)	<.001*
BMI			
<18.5	41 (0.3)	32 (1.1)	<.001*
18.5-29.9	7996 (50.7)	1552 (54.8)	<.001*
30-34.9	4312 (27.4)	732 (25.8)	.094
35-39.9	2085 (13.2)	309 (10.9)	.001*
≥40	1326 (8.4)	209 (7.4)	.071
Comorbidities			
CHF	24 (0.2)	2 (0.2)	.414
Diabetes mellitus	2656 (16.9)	429 (15.1)	.025*
HTN	7256 (46.0)	1199 (42.3)	<.001*
COPD	334 (2.1)	217 (7.7)	<.001*
Functional status			.036*
Dependent	48 (0.3)	16 (0.6)	
Independent	15,712 (99.7)	2818 (99.4)	
Steroid use			.039*
Yes	336 (2.1)	43 (1.5)	
No	15,424 (97.9)	2791 (98.5)	
ASA class			<.001*
≤2	10,664 (67.7)	1747 (61.6)	
≥3	5096 (32.3)	1087 (38.4)	

BMI, body mass index; *CHF*, congestive heart failure; *HTN*, hypertension; *COPD*, chronic obstructive pulmonary disease; *ASA*, American Society of Anesthesiologists.
* Statistically significant ($P < .05$).

Table II
Comparison of postoperative complication rates between smokers and nonsmokers

	Nonsmoker	Smoker	*P* value
	n (%)	n (%)	
Medical complication	124 (0.8)	21 (0.7)	.897
Cardiac arrest or MI	20 (0.1)	2 (0.1)	.563
Pulmonary complication	30 (0.2)	6 (0.2)	.816
Renal complication	5 (0.0)	2 (0.1)	.290
UTI	28 (0.2)	5 (0.2)	>.999
DVT or PE	51 (0.3)	7 (0.2)	.587
Sepsis or septic shock	8 (0.1)	4 (0.1)	.097
Surgical complication	47 (0.3)	18 (0.6)	.009*
Wound dehiscence	2 (0.0)	0 (0.0)	>.999
Superficial SSI	9 (0.1)	2 (0.1)	.679
Deep SSI	6 (0.0)	2 (0.1)	.350
Organ/space SSI	4 (0.0)	2 (0.1)	.229
Return to operating room	34 (0.2)	17 (0.6)	.001*
Any complication	164 (1.0)	36 (1.3)	.277
Readmission	159 (1.0)	42 (1.5)	.027*
Non-home discharge	89 (0.6)	9 (0.3)	.126

MI, myocardial infarction; *UTI*, urinary tract infection; *DVT*, deep vein thrombosis; *PE*, pulmonary embolism; *SSI*, surgical-site infection.
* Statistically significant ($P < .05$).

Table III
Univariate analysis of impact of smoking status on complications following arthroscopic rotator cuff repair

	Smoking unadjusted OR (95% CI)	*P* value
Medical complication	0.941 (0.592-1.498)	.799
Cardiac arrest or MI	0.556 (0.130-2.379)	.429
Pulmonary complication	1.112 (0.463-2.675)	.812
Renal complication	2.225 (0.432-11.475)	.339
UTI	0.993 (0.383-2.574)	.989
DVT or PE	0.763 (0.346-1.682)	.502
Sepsis or septic shock	2.783 (0.837-9.248)	.095
Surgical complication	2.137 (1.239-3.685)	.006*
Wound dehiscence	—	—
Superficial SSI	1.236 (0.267-5.723)	.786
Deep SSI	1.854 (0.374-9.192)	.450
Organ/space SSI	2.782 (0.509-15.195)	.238
Return to operating room	2.791 (1.557-5.003)	.001*
Any complication	1.224 (0.851-1.759)	.276
Readmission	1.476 (1.048-2.079)	.026*
Non-home discharge	0.561 (0.282-1.115)	.099

OR, odds ratio; *CI*, confidence interval; *MI*, myocardial infarction; *UTI*, urinary tract infection; *DVT*, deep vein thrombosis; *PE*, pulmonary embolism; *SSI*, surgical-site infection.
* Statistically significant ($P < .05$).

Unadjusted bivariate logistic regression identified smoking as a significant predictor of surgical complications (OR, 2.137; $P = .006$), return to the operating room (OR, 2.791; $P = .001$), and readmission (OR, 1.476; $P = .026$) (Table III). After adjustment for all significantly associated patient demographic characteristics and comorbidities, smoking was identified as a significant predictor of surgical complications (OR, 1.955; $P = .022$), return to the operating room (OR, 2.547; $P = .003$), readmission (OR, 1.570; $P = .014$), and sepsis or septic shock (OR, 4.737; $P = .021$) (Table IV). Smoking was not a significant predictor of medical complications (OR, 1.105; $P = .687$) or SSIs (OR, 1.216; $P = .713$).

Discussion

In this study, we used a large national database to identify smoking as an independent predictor of readmission, surgical complications, return to the operating room, and sepsis or septic shock following ARCR. Furthermore, smokers undergoing ARCR were more likely to have COPD, be functionally dependent, and be aged < 65 years.

Many patient- and procedure-specific variables, including male sex, older age, HTN, COPD, diabetes, dialysis, steroid use, ASA class 3 or 4, and increased operative time, have been identified as risk factors for complications after ARCR.[2,10,18,27,36] Previous studies have identified smoking as a risk factor for complications following total shoulder arthroplasty, shoulder arthroscopy, and open rotator cuff repair.[4,9,23,30,41,43] Many studies have also suggested that in comparison to nonsmokers, smokers may have decreased functional improvements, earlier recovery plateau points, lower postoperative outcome scores, and lower postoperative patient satisfaction scores after rotator cuff repair.[6,8,29,33,40] However, to our knowledge, no study has identified an association between preoperative smoking status and readmission rates, individual postoperative complications, and reoperation rates specifically after ARCR.

Previous studies have identified numerous risk factors for readmission following arthroscopic shoulder surgery and rotator cuff repair; however, our study is the first to identify smoking as a risk factor for readmission after ARCR. Kosinski et al[27] identified older age, COPD, HTN, dialysis, and ASA class 3 or 4 as predictors of readmission following outpatient rotator cuff repair. Hill et al[19] identified operative time > 1.5 hours, age > 40 years, ASA class 3 or 4, COPD, and chronic steroid use as independent predictors of readmission after elective arthroscopic shoulder surgery. Smoking has also been identified as a risk factor for readmission following all-arthroscopic surgery including knee, shoulder, and hip procedures.[23] Our study identified preoperative smoking status as a significant predictor of short-term readmission, further expanding our understanding of risk factors for readmission after ARCR. Our findings reiterate the importance of counseling patients to stop smoking preoperatively as this may reduce their likelihood of readmission following ARCR.

Table IV
Multivariate analysis of impact of smoking status on complications following arthroscopic rotator cuff repair

	Smoking adjusted OR (95% CI)	*P* value
Surgical complication	1.955 (1.104-3.462)	.022*
Return to operating room	2.547 (1.386-4.678)	.003*
Readmission	1.570 (1.095-2.253)	.014*
Sepsis or septic shock	4.737 (1.262-17.782)	.021*

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

This study also identified smoking as a risk factor for overall surgical complications after ARCR. Surgical complications included wound dehiscence, SSI, and return to the operating room within 30 days. Regarding the individual surgical complications, we found the greatest association between smoking status and the likelihood of reoperation. Our results suggest that in comparison to nonsmokers, smokers are more than 2 times as likely to undergo a reoperation within 30 days of ARCR. Previous studies have identified an association between smoking and impaired wound healing and tissue regeneration. These studies have suggested that smoking hinders the synthesis of collagen and modifies the balance of extracellular matrix turnover, leading to a detriment in wound healing.[24,26] Although our study identified smoking as a significant risk factor for overall surgical complications, we did not find an association between smoking and rates of wound dehiscence or SSI. Our results suggest that smoking status may not play a role in predicting individual wound disruptions or SSIs after ARCR. As smoking has been associated with an increased risk of SSIs and wound disruptions after other open procedures on the shoulder, such as total shoulder arthroplasty,[4,17] this difference may be explained by the minimally invasive nature of arthroscopic shoulder surgery. These findings may also be ascribed to the relatively low infection rate of ARCR. A cohort study of 903 patients comparing infection rates between open rotator cuff repair and ARCR found that a postoperative infection was 5.6 times more likely to develop in the open group than in the arthroscopic group.[20] Nonetheless, the results of our study demonstrate that smoking status is a significant predictor of overall surgical complications following ARCR.

In this study, we found smokers and nonsmokers to have similar rates of overall medical complications. Our analysis did not identify smoking status as a significant predictor of overall medical complications after ARCR. Padaki et al[36] suggested that patients aged > 65 years have an increased likelihood of postoperative respiratory complications and UTIs developing after ARCR. Agarwalla et al[2] identified that an increased operative time is associated with increased rates of postoperative anemia requiring transfusion, venous thromboembolism, SSI, and an extended length of hospital stay following ARCR. In particular, smoking has been identified as an independent risk factor for venous thromboembolic events after open rotator cuff repair.[9] The results of our study suggest that preoperative smoking status may not increase the risk of thromboembolic events, UTIs, pulmonary complications, or overall medical complications after ARCR. However, this lack of association

may also be attributed to the low rates of these complications in our study population. Nonetheless, our results identify an association between smoking and an increased likelihood of postoperative sepsis or septic shock, a finding consistent with the results of a meta-analysis of large cohort studies and systematic reviews.[39]

Current trends in the operative management of rotator cuff tears include a continuing shift toward arthroscopy, which allows for preservation of the deltoid muscle, improved visualization of intra-articular pathology, and decreased early postoperative pain. In addition, open arthroscopic repair has been associated with deltoid detachment or atrophy and increased immediate postoperative pain and stiffness.[11,12] Complications following ARCR are relatively infrequent. Current estimates of complication rates after ARCR fall between 0.88% and 2%.[2,13,19,23,36,41,43] Our study demonstrated an overall complication rate of 1.1%, which is consistent with these literature reports. Although rare, these complications may increase patient morbidity and health care expenditures. Recognizing modifiable risk factors such as smoking is important to improve surgical outcomes and reduce complication rates. Additionally, an increasing number of arthroscopic procedures are being performed at many physician-owned outpatient surgical centers,[21,31] thereby increasing orthopedic surgeons' accountability for complications after these procedures.[2] Therefore, knowledge of modifiable risk factors for readmissions, complications, and reoperations following ARCR is becoming increasingly valuable. Our findings emphasize the importance of counseling patients to stop smoking prior to ARCR, a recommendation that has been supported by many studies.[15,24,28,34,40] Additionally, orthopedic surgeons may use patients' smoking status for preoperative risk stratification prior to ARCR.

Although this study identified an association between smoking status and specific postoperative complications following ARCR, there are several limitations that warrant further discussion. Patients were placed in the smoking cohort if they had reported smoking cigarettes within 1 year prior to ARCR. This introduces an aspect of reporting bias as patients may not accurately report their smoking history. Moreover, the duration and extent of a patient's smoking history are unavailable in the NSQIP database. Additional studies are needed to evaluate whether there is a relationship between the extent of patients' smoking history and complication rates after ARCR. This study found significant differences in demographic characteristics between smokers and nonsmokers; this represents a limitation that is likely unavoidable owing to underlying differences between smokers and the general population. Furthermore, patients who used electronic cigarettes, cigars, or chewing tobacco were included in the nonsmoking cohort as the use of these alternative forms of tobacco is not a variable collected in the NSQIP database. Rates of electronic cigarette use in the United States have seen considerable growth in the past decade.[3] A recent analysis has suggested that approximately 14% of current cigarette smokers in the United States concurrently use electronic cigarettes[3]; thus, an association between electronic cigarette use and adverse outcomes following ARCR has yet to be elucidated. Additional studies with the ability to identify electronic cigarette users, chewing tobacco users, and cigar smokers are also needed to investigate whether these alternative forms of tobacco are risk factors for complications after ARCR. This study identified smoking as an independent risk factor for complications following ARCR. However, smoking may potentiate other patient comorbidities to increase patients' risk of complications. Future research is needed to identify how patients' smoking status modifies concomitant comorbidities as risk factors for complications after ARCR. Additionally, future research identifying risk factors specific to smokers undergoing ARCR would improve physicians' ability to stratify smokers' preoperative risk. Finally, the American College of Surgeons NSQIP database only records complications occurring within 30 days of the principal procedure. As intended, the findings of this study are limited to the immediate 30-day postoperative period.

Conclusion

Complications following ARCR are relatively infrequent. Smoking was identified as an independent predictor of readmission, surgical complications, return to the operating room, and sepsis or septic shock within 30 days of ARCR. Smokers undergoing ARCR were more likely to have COPD, to be functionally dependent, and to be aged < 65 years. Patients undergoing ARCR should be counseled to stop smoking preoperatively as smoking cessation may reduce their likelihood of surgical complications, readmission, reoperation, and sepsis or septic shock. Additionally, knowledge of smoking as a risk factor for complications following ARCR may assist orthopedic surgeons in preoperative risk stratification.

Disclaimer

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