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

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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.15,16,21,43,44 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.15,44 Smoking tobacco has also been associated with an increased risk of the development of rotator cuff tears5,25,33 and inferior outcomes after rotator cuff repair.15,28,33,37,40

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).13,25 However, there is a paucity of literature regarding the impact of smoking status on the development of postoperative complications after ARCR.6,29 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
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. 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 \( \leq 30 \) (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 \( \geq 3 \) (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 11.1%. 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

| | Nonsmoker | Smoker | \( P \) value |
|---|---|---|---|
| **Overall** | | | |
| Sex | 15,760 (78.8%) | 2834 (78.8%) | \( P = .877 \) |
| Female | 9105 (57.8%) | 1791 (62.3%) | \( P = .036 \) |
| Male | 6651 (42.2%) | 1043 (37.7%) | \( P = .001 \) |
| **Age** | | | |
| \( \leq 18 \) yr | 741 (4.7%) | 245 (8.6%) | \( P = .001 \) |
| 18-34 yr | 10,023 (63.6%) | 2193 (77.4%) | \( P = .001 \) |
| 35-39 yr | 4030 (25.6%) | 357 (12.6%) | \( P = .001 \) |
| \( \geq 40 \) | 964 (6.1%) | 39 (1.4%) | \( P = .001 \) |
| **BMI** | | | |
| \( <18.5 \) | 41 (0.3%) | 32 (1.1%) | \( P = .001 \) |
| 18.5-29.9 | 7996 (50.7%) | 1552 (54.8%) | \( P = .001 \) |
| 30-34.9 | 4312 (27.4%) | 732 (25.8%) | \( P = .094 \) |
| 35-39.9 | 2085 (13.2%) | 309 (10.9%) | \( P = .001 \) |
| \( \geq 40 \) | 1326 (8.4%) | 209 (7.4%) | \( P = .071 \) |
| **Comorbidities** | | | |
| CHF | 24 (0.2%) | 2 (0.2%) | \( P = .414 \) |
| Diabetes mellitus | 2656 (16.9%) | 429 (15.1%) | \( P = .025 \) |
| HTN | 7256 (46.0%) | 1199 (42.3%) | \( P = .001 \) |
| COPD | 334 (2.1%) | 217 (7.7%) | \( P = .001 \) |
| **Functional status** | | | |
| Dependent | 48 (0.3%) | 16 (0.6%) | \( P = .001 \) |
| Independent | 15,712 (99.7%) | 2818 (99.4%) | \( P = .001 \) |
| **Steroid use** | | | |
| Yes | 336 (2.1%) | 43 (1.5%) | \( P = .036 \) |
| No | 15,424 (97.9%) | 2791 (98.5%) | \( P = .001 \) |
| **ASA class** | | | |
| \( \leq 2 \) | 10,664 (67.7%) | 1747 (61.6%) | \( P = .001 \) |
| \( \geq 3 \) | 5096 (32.3%) | 1087 (38.4%) | \( P = .001 \) |

**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

| | Nonsmoker | Smoker | \( P \) value |
|---|---|---|---|
| **Medical complication** | 124 (0.8%) | 21 (0.7%) | \( P = .891 \) |
| Cardiac arrest or MI | 20 (0.1%) | 2 (0.1%) | \( P = .563 \) |
| Pulmonary complication | 30 (0.2%) | 6 (0.2%) | \( P = .816 \) |
| Renal complication | 5 (0.0%) | 2 (0.1%) | \( P = .290 \) |
| UTI | 28 (0.2%) | 5 (0.2%) | \( P = .999 \) |
| DVT or PE | 51 (0.3%) | 7 (0.2%) | \( P = .587 \) |
| Sepsis or septic shock | 8 (0.1%) | 4 (0.1%) | \( P = .097 \) |
| **Surgical complication** | 47 (0.3%) | 18 (0.6%) | \( P = .099 \) |
| Wound dehiscence | 2 (0.0%) | 0 (0.0%) | \( P = .999 \) |
| Superficial SSI | 9 (0.1%) | 2 (0.1%) | \( P = .679 \) |
| Deep SSI | 6 (0.0%) | 2 (0.1%) | \( P = .350 \) |
| Organ/space SSI | 4 (0.0%) | 2 (0.1%) | \( P = .229 \) |
| Return to operating room | 34 (0.2%) | 17 (0.6%) | \( P = .001 \) |
| **Any complication** | 164 (1.0%) | 36 (1.3%) | \( P = .277 \) |
| Readmission | 159 (1.0%) | 42 (1.5%) | \( P = .027 \) |
| Non-home discharge | 89 (0.6%) | 9 (0.3%) | \( P = .126 \) |

*MI*, myocardial infarction; **UTI**, urinary tract infection; **DVT**, deep vein thrombosis; **PE**, pulmonary embolism; **SSI**, surgical-site infection.

*Statistically significant (\( P < .05 \)).
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 (0.851-1.799) | .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).

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.

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.4,17 Our study demonstrated that smoking status is a significant predictor of overall surgical complications following ARCR.

Readmission following ARCR. Furthermore, smoking was associated with an increased risk of SSIs and wound disruptions after open procedures on the shoulder, such as total shoulder arthroplasty.6,14 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.26 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 al16 suggested that patients aged > 65 years have an increased likelihood of postoperative respiratory complications and UTIs developing after ARCR. AGARWALLA et al1 identified 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 deltoit 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.1,4,5 Complications following ARCR are relatively infrequent. Current estimates of complication rates after ARCR fall between 0.8% and 2%.6,7,8,9,10,11,12 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,13,14 thereby increasing orthopedic surgeons’ accountability for complications after these procedures.15 Therefore, knowledge of modifiable risk factors for readmissions, complications, and reoperations following ARCR is becoming increasingly valuable. Our factors for readmissions, complications, and reoperations following ARCR. 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.2 A recent analysis has suggested that approximately 14% of current cigarette smokers in the United States concurrently use electronic cigarettes3; 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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