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Effect of smoking on complications following primary shoulder arthroplasty

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Background: The purpose of this study was to examine the effect of smoking on the incidence of complications after primary anatomic total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA).
Methods: All patients who underwent primary TSA or RSA at our institution between 2002 and 2011 and had a minimum 2-year follow-up were included. Smoking status was assessed at the time of surgery. Current smokers, former smokers, and nonsmokers were compared for periprosthetic infection, fractures (intraoperative and postoperative), and loosening after surgery.
Results: The cohort included 1834 shoulders in 1614 patients (814 in smokers and 1020 in nonsmokers). Complications occurred in 73 patients (75 shoulders; 44 in smokers and 31 in nonsmokers). There were 20 periprosthetic infections (16 in smokers and 4 in nonsmokers), 27 periprosthetic fractures (14 in smokers and 13 in nonsmokers), and 28 loosenings (14 in smokers and 14 in nonsmokers). Smokers had lower periprosthetic infection-free survival rates (95.3%-99.4% at 10 years; $P = .001$) and overall complication-free survival rates (78.4%-90.2%; $P = .012$) than nonsmokers. Multivariable analyses showed that both current and former smokers had significantly higher risk of periprosthetic infection in comparison with nonsmokers (hazard ratio [HR], 7.27 and 4.56, respectively). In addition, current smokers showed a higher risk of postoperative fractures than both former smokers (HR, 3.63) and nonsmokers (HR, 6.99).
Conclusions: This study demonstrates that smoking is a significant risk factor of complications after TSA and RSA. These findings emphasize the need for preoperative collaborative interventions, including smoking cessation programs.
Level of evidence: Level II; Retrospective Design; Prognosis Study

Keywords: Total shoulder arthroplasty; reverse shoulder arthroplasty; smoking; complications; periprosthetic infection; periprosthetic fracture

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Shoulder arthroplasty has been established as a successful procedure that leads to marked improvements in shoulder pain, function, and quality of life in patients with end-stage joint arthritis.[2,5] Despite its success, shoulder arthroplasty has been associated with various complications, including postoperative periprosthetic infection (0.4%-2.9%)[4,30,35] and

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fractures (2.3%-3.0%).[3,29,37] Furthermore, humerus or glenoid loosening rates approach approximately 30% at 15 to 20 years of follow-up.[24] Patient-specific factors that have been demonstrated to increase the rates of these common complications include younger age, higher body mass index (BMI), rheumatoid arthritis, and diabetes mellitus.[7,11,13,17,23]

Smoking habit has been suggested as a deleterious factor of postoperative outcomes in various surgeries.[34] Recent studies for total hip and knee arthroplasties showed that preoperative smoking status could affect the incidence of complications, such as periprosthetic infection, fractures, and systemic pathologic changes.[15,20,21,27,28] On the other hand, there is a paucity of studies examining the effects of smoking on shoulder arthroplasty as well as the potential benefits of smoking cessation before or after the procedure.

The purpose of this study was to examine the effect of smoking on the incidence of common complications after primary total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA).

Materials and methods

Study cohort

This is a retrospective case-control study regarding the effect of smoking on the incidence of complications after shoulder prosthesis using the prospectively collected data from our institution's Total Joint Registry.[1] Our study cohort consisted of every patient who was 18 years or older, underwent shoulder arthroplasty (TSA or RSA) from 2002 to 2011, and had a minimum of 2-year follow-up or follow-up to revision surgery.

In this registry, patients' information is prospectively captured through in-person examinations and interviews, trained abstractor chart review, and questionnaires.[31] Systematic follow-up intervals include 1 year, 2 years, and 5 years postoperatively and every 5 years thereafter. In addition to the data collected through the registry (demographics, comorbidities, indications, operative factors, outcomes, complications), our study required detailed data from the electronic medical record on both current smoking status and former history of smoking. These databases report smoking status as being current, quit (including the period), or never.

Outcomes

Complication rates after primary TSA or RSA were measured. Previous studies have showed that periprosthetic infection, intraoperative and postoperative periprosthetic fracture, and loosening are possibly associated with smoking in lower extremity arthroplasty.[15,20,21,27,28] Periprosthetic infection was defined by the presence of positive joint fluid culture, positive synovial or bone tissue culture, intraoperative findings, or positive blood culture associated with a clinical presentation consistent with periprosthetic infection. Superficial infections (suture infections or stitch abscesses) were not analyzed. Loosening was defined at the time of revision surgery as an intraoperatively loose glenoid or humeral components.

Effect of smoking

Patients were separated into 2 groups based on their smoking status (smoker or nonsmoker). Smoker was defined as a patient who had a documented history of tobacco use, in the form of cigarettes, cigars, or chewing tobacco, during his or her lifetime.[12] Stratified factors in smoking status were also analyzed. These focused on the effect of smoking cessation. Using the clinical databases, all smokers were stratified successfully into 2 categories: current smoker, who had smoked within 1 month before surgery; and former smoker, who had not.[12] Quantitative stratification in pack-years was not performed because this information was poorly documented.

Predictors of interest

Covariates were identified in the Total Joint Registry and included sex, age, BMI, type of surgery (TSA or RSA), rheumatoid arthritis, and diabetes mellitus on the basis of previous studies.[7,11,13,17,23]

Statistical analyses

Statistical analyses were performed using JMP Pro 10 (SAS Institute Inc., Cary, NC, USA). Survival free of periprosthetic infection, fractures, loosening, and overall complications was estimated using Kaplan-Meier survival analysis. Univariate and multivariable-adjusted analyses for each event were examined using Cox regression, excepting the analyses of intraoperative fractures with the use of logistic regression. Variables including smoking status, sex, age (per 10 years), BMI (per unit), type of surgery (TSA or RSA), rheumatoid arthritis, and diabetes mellitus were assessed for association with each event. The level of significance was set at $P = .05$.

Results

Clinical and demographic characteristics

A total of 1614 patients underwent 1834 shoulder arthroplasties during 2002 to 2011, including 1332 TSAs and 502 RSAs (Table I). The mean age at the time of surgery was 69 years (range, 19-92), and 52% of patients were female. Overall, 814 shoulders in 716 patients had a smoking history at the time of surgery; 140 (17%) shoulders were current smokers, and 674 (83%) were former smokers who had quit smoking at least 1 month before surgery.

Frequency of complications after shoulder arthroplasty

Of the 1834 shoulders that underwent TSA or RSA, 20 (1.1%) periprosthetic infections (16 in smokers and 4 in nonsmokers), 27 (1.5%) periprosthetic fractures (14 in smokers and 13 in nonsmokers), and 28 (1.5%) loosenings (14 in smokers and 14 in nonsmokers) were identified (Table II). Survivorship analyses showed that smokers had significantly lower survival rates compared with nonsmokers for 10-year survival free of periprosthetic infection (95.3% [95% confidence interval (CI), 89.7-97.9] to 99.4% [95% CI, 98.5-99.8];

Table I Characteristics of study population

	Smoker	Nonsmoker
No. of shoulders (No. of patients)	814 (716)	1020 (898)
Male/female	59%/41%	40%/60%
Age at surgery, mean ± SD (years)	68 ± 10	70 ± 11
BMI, mean ± SD	30.8 ± 6.4	30.2 ± 6.4
Type of implant*		
TSA	586	746
RSA	228	274
Mean follow-up duration (years)	3.5	3.7
Smoking status at surgery*		
Current	140	*NA*
Former	674	
Rheumatoid arthritis*	59	66
Diabetes mellitus*	124	122

BMI, body mass index; *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty; *SD*, standard deviation.
* Each value represents the number of shoulders.

Table II Complications after primary shoulder arthroplasty

	Smoker	Nonsmoker
Periprosthetic infection	16	4
Periprosthetic fracture	14	13
Intraoperative	8	11
Postoperative	6	2
Loosening	14	14
Overall complications	44	31

Each value represents the number of shoulders.

$P = .001$) and for overall 10-year survival free of complications (78.4% [95% CI, 64.3-88.0] to 90.2% [95% CI, 80.7-95.3]; $P = .012$). On the other hand, no significant differences were found between smokers and nonsmokers for survival free of periprosthetic fractures (94.9% [95% CI, 86.3-98.2] to 98.5% [95% CI, 97.6-99.1]; $P = .167$) or revision for component loosening (86.3% [95% CI, 69.9-94.4] to 92.2% [95% CI, 81.5-96.9]; $P = .450$) at 10 years.

Effect of smoking status on complications

Univariate analyses showed that smoking was significantly associated with higher risks of periprosthetic infection ($P < .001$), postoperative periprosthetic fractures ($P = .037$), and overall complications ($P = .013$) (Table III). This also held true in the multivariable analyses for infection and overall complications ($P < .001$, $P = .011$, respectively) but was not significant for postoperative fractures ($P = .068$). In contrast, intraoperative fractures and revision for periprosthetic loosening were not significantly affected by smoking status.

As for other predictors of risks, younger age at surgery was found to be significantly associated with periprosthetic infection ($P < .001$). This predictor also showed significant association with overall complications in multivariable

Table III Factors associated with periprosthetic infection, postoperative fractures, and overall complications

	Periprosthetic infection				Postoperative fractures				Overall complications			
	Univariate		Multivariable		Univariate		Multivariable		Univariate		Multivariable	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Smoking status (nonsmoker to smoker)	5.22 (1.92-18.23)	**<.001**	5.36 (1.91-19.11)	**<.001**	4.50 (1.09-30.21)	**.037**	3.87 (0.91-26.41)	.068	1.75 (1.28-2.75)	**.013**	1.87 (1.21-2.93)	**.011**
Sex (male to female)	0.63 (0.25-1.51)	.300	0.83 (0.32-2.05)	.691	0.49 (0.10-1.88)	.304	0.60 (0.12-2.34)	.466	1.13 (0.73-1.77)	.583	1.23 (0.79-1.91)	.299
Age at surgery	0.58 (0.44-0.80)	**.002**	0.50 (0.36-0.72)	**<.001**	0.78 (0.48-1.44)	.404	0.75 (0.43-1.46)	.367	0.82 (0.68-1.00)	.051	0.80 (0.66-0.98)	**.031**
BMI	1.00 (0.93-1.06)	.903	0.99 (0.92-1.06)	.852	1.03 (0.93-1.12)	.589	1.01 (0.91-1.11)	.852	0.99 (0.96-1.03)	.656	0.99 (0.95-1.02)	.438
Type of surgery (TSA to RSA)	1.55 (0.54-3.99)	.392	2.40 (0.81-6.42)	.108	1.80 (0.37-7.49)	.438	2.21 (0.43-9.93)	.320	1.15 (0.66-1.92)	.605	1.25 (0.81-2.01)	.436
Rheumatoid arthritis	1.16 (0.14-3.94)	.855	0.95 (0.13-3.30)	.941	1.77 (0.09-9.64)	.619	1.91 (0.10-11.46)	.582	1.09 (0.42-2.31)	.834	1.07 (0.50-2.82)	.861
Diabetes mellitus	0.95 (0.24-2.67)	.922	0.87 (0.23-2.65)	.821	2.04 (0.30-8.47)	.410	1.77 (0.24-8.25)	.523	1.23 (0.63-2.19)	.520	1.27 (0.43-1.56)	.475

HR, hazard ratio; *CI*, confidence interval; *BMI*, body mass index; *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.
Univariate and multivariable Cox regression analyses were used. Values in **bold** indicate statistical significance.

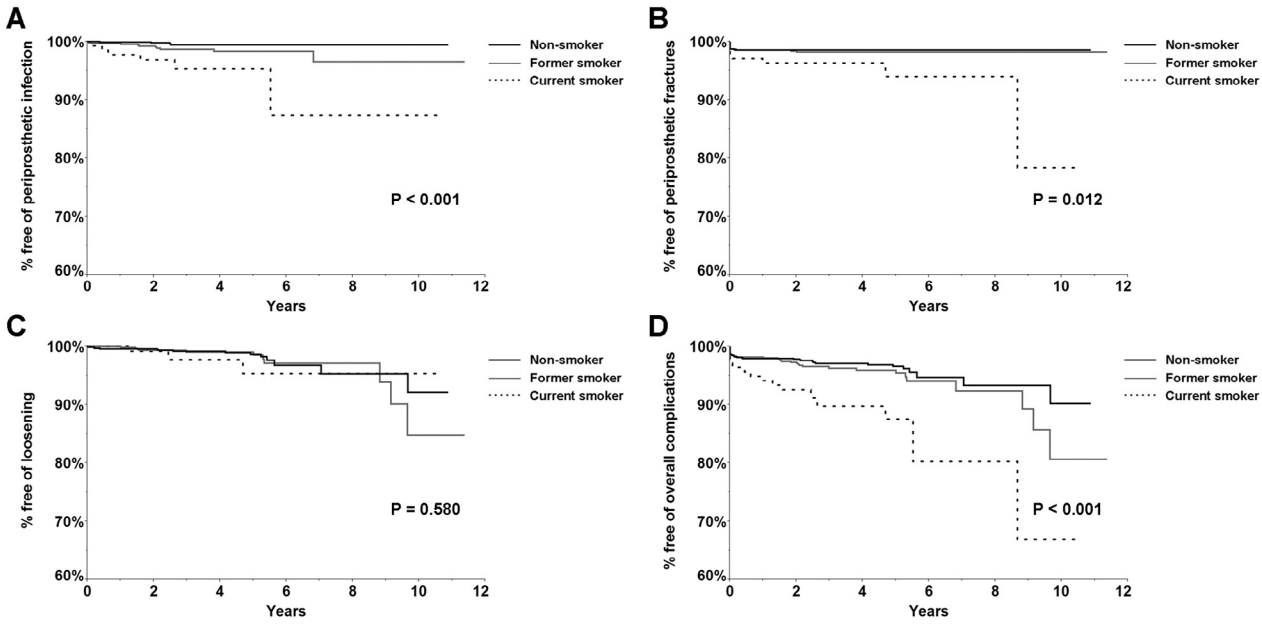

Figure 1 Survival free of periprosthetic infection (**A**), fractures (**B**), loosening (**C**), and overall complications (**D**) in current smokers, former smokers, and nonsmokers at the time of surgery. The *P* values in (**A**), (**B**), (**C**), and (**D**) represent the overall *P* values for the difference in survival rates among the categories of the smoking status.

Table IV Multivariable-adjusted analyses for factors of smoking status

Smoking status at the time of surgery	Periprosthetic infection		Intraoperative fractures		Postoperative fractures		Overall complications	
	HR (95% CI)	*P* value	OR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Nonsmoker	1.0 (ref)		1.0 (ref)		1.0 (ref)		1.0 (ref)	
Former smoker	4.56 (1.47-17.15)	**.008**	1.32 (0.53-3.13)	.534	1.93 (0.80-4.67)	.423	1.49 (0.90-2.44)	.117
Current smoker	7.27 (1.97-29.85)	**.003**	3.21 (0.68-11.44)	.128	6.99 (2.18-20.95)	**.004**	3.37 (1.71-6.39)	**.001**
Former to current	*1.60 (0.48-4.84)*	*.428*	*2.43 (0.50-9.01)*	*.240*	*3.63 (1.16-10.46)*	***.025***	*2.27 (1.15-4.32)*	***.020***

HR, hazard ratio; *OR*, odds ratio; *CI*, confidence interval.
Values in **bold** indicate statistical significance.

analyses ($P = .031$). In contrast, predictors including sex, type of implant (RSA or TSA), rheumatoid arthritis, and diabetes mellitus were not significantly associated with risks of complications in this study.

Risk analyses of complications related to smoking cessation

Figure 1 demonstrates the Kaplan-Meier curves for nonsmokers, former smokers, and current smokers for survival free of periprosthetic infection, fractures, loosening, and overall complications. There were significantly increased risks in the smokers for periprosthetic infection ($P < .001$), periprosthetic fractures ($P = .012$), and overall complications ($P < .001$).

Influence of smoking status (stratified into current smoker, former smoker, or nonsmoker) on complications was adjusted with sex, age, type of implant (TSA or RSA), rheumatoid arthritis, and diabetes mellitus in a multivariate analysis. This analysis demonstrated an increased risk of overall complications in both current and former smokers compared with nonsmokers (Table IV). When each complication was analyzed independently, periprosthetic infection showed that both current and former smokers had significantly higher risk in comparison with nonsmokers (hazard ratio [HR], 7.27 [95% CI, 1.97-29.85], $P = .003$; HR, 4.56 [95% CI, 1.47-17.15], $P = .008$, respectively). In addition, current smokers showed a significantly higher risk of postoperative fractures than both former smokers (HR, 3.63 [95% CI, 1.16-10.46]; $P = .025$) and nonsmokers (HR, 6.99 [95% CI, 2.18-20.95]; $P = .004$).

Discussion

In this study of 1834 arthroplasties, preoperative smoking status was found to be associated with a higher risk of complications following primary TSA and RSA. Smoking was found to be a significant risk factor of periprosthetic infection, postoperative periprosthetic fractures, and overall complications.

To our knowledge, this is the first study to demonstrate a correlation between smoking and complications after shoulder arthroplasties. In one series of 301 patients (38 smokers) who underwent RSA, smoking did not affect the incidence of periprosthetic infection.[17] In another smaller study of 22 patients who underwent hemiarthroplasty for post-traumatic arthritis, there were no early differences in clinical outcomes between smokers and nonsmokers.[33] In contrast to these results, several large-scale studies on total hip and knee arthroplasties have demonstrated that smoking was a risk factor for postoperative complications.[15,21,26,28] The correlation found in our study between smoking and complications is likely due in part to the large number of arthroplasties analyzed compared with the 2 other smaller prior series.

Regarding periprosthetic infection, we found that patients with smoking history had an approximately 5-fold higher risk compared with nonsmokers. Postoperative infections after orthopedic procedures have a well-documented association with smoking in numerous clinical studies.[14,18,21,28] For example, in ankle fractures, Nåsell et al[18] found a risk of postoperative infection similar to ours, with a risk 6 times greater for smokers compared with nonsmokers. The deleterious effect of tobacco components (eg, nicotine) on tissue healing is thought to involve a combination of vasoconstriction-induced hypoxia, decreased neutrophil and monocyte oxidative burst activity, and altered enzyme activities for the extracellular matrices.[9,32,36] Therefore, when a foreign body such as the shoulder arthroplasty is introduced into the body, these effects could be magnified.

Smoking has been shown to increase incidence of fracture independently in population-based studies in England and Brazil and in military veterans.[6,10,19,22] Furthermore, multiple components in cigarette smoke have been found to deteriorate bone quality.[8,25,38] In our study, postoperative periprosthetic fractures occurred more frequently in smokers than in nonsmokers. Although there are likely multiple factors that contributed to these fractures, it does appear that the effect of smoking on the patient's bone quality increases the risk for periprosthetic fractures.

An important finding of this study is the analysis between patients who currently smoke and those who had a history of smoking but quit, demonstrating improved outcomes in those who quit. To date, the effect of smoking cessation remains unclear because previous studies have shown controversial results.[16,26,27] In this study, on the other hand, the most pronounced effect was seen in the reduction of periprosthetic fractures in the former smokers. This emphasizes the importance of collaborative efforts in smoking cessation programs before shoulder arthroplasty.

There were several limitations in our study. First, our cohort consisted of patients seen in a single institution, limiting the generalizability of our results. This also helps reduce confounding variables seen in multicenter studies. Second, pack-year history was not analyzed because this was poorly documented in our database and accuracy of pack-year history may be subject to recall bias in long-time smokers. In addition, detailed analysis within the former smokers to determine the effective duration of smoking cessation before the prosthesis could not be accomplished because of limited numbers. Third, we classified smokers into current and former smokers at the period of 1 month before surgery. Although this period was referred from the previous study,[12] further studies focused on the quitted timing of tobacco. The strengths of this study are its large cohort and the long duration of prospective follow-up of all the patients included in a single-institution total joints registry. Furthermore, smoking status and complications were prospectively collected in our institution's registry.

Conclusion

Smoking is a significant risk factor of complications after primary shoulder arthroplasty. To decrease the risk of postoperative complications, it is critical to engage patients in a discussion about these risks and to work with other providers in smoking cessation programs.

Disclaimer

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