Impact of smoking on pain and function in rotator cuff repair: a prospective 5-year cohort follow-up of 1383 patients

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Abstract

Background: This multicentre cohort study investigates the effect of smoking on the outcome of rotator cuff repair (RCR), with attention to age at presentation for surgery, pre-operative and post-operative pain and function and intra-operative findings.

Methods: Patient information was collected pre-operatively, including Flex Shoulder Function (Flex SF) and visual analogue scale pain, then at 6 months, 1, 2 and 5 years post-operatively. Intra-operative technical data were collected by the operating surgeon. Current smokers were classified by daily cigarette consumption.

Results: A total of 1383 RCRs in as many patients were included with an 84% 5-year follow-up. Smokers were on average 6.7 years younger than non-smokers (51.8 vs. 58.5, $P < 0.001$). There was no difference in intra-operatively assessed tear size both in anteroposterior dimension ($P = 0.5$) and retraction ($P = 0.9$). Pre-operative Flex SF score in smokers was below that of non-smokers (23.0 vs. 24.5, $P = 0.002$) and at 6 months ($P = 0.02$) but no different at 5 years ($P = 0.7$). Pain scores were higher in smokers than non-smokers both pre-operatively (5.34 vs. 4.67, $P < 0.001$) and up to 2 years ($P < 0.001$) but not at 5 years ($P = 0.073$).

Conclusion: Smokers undergoing RCR were younger than non-smokers, and had worse pre-operative pain scores and shoulder function. Poorer post-operative function persisted to 6 months, and with higher reported pain to 2 years in smokers. However, at 5-year follow-up, patient-reported outcomes were not affected by smoking status.

Introduction

Rotator cuff pathology is the most common cause of shoulder pain.[1,2] Population studies estimate rotator cuff tears to be present in 20%–22% of individuals in the adult population.[3,4] There are a number of factors that influence the outcome of rotator cuff repair (RCR), including age, tear size, muscle quality, gender and fatty degeneration.[5–10] Tendon integrity is correlated with better strength and function; thus it is important to be aware of factors that affect healing.[11,12]

Smoking continues to be prevalent internationally, with the average adult smoking rate in Organisation for Economic Co-operation and Development countries 18%.[13] The detrimental effects of smoking on the musculoskeletal system are well established, ranging from increased risk of fractures and tendon injury, to impaired soft-tissue and wound-healing, and increased pain.[14–16]

Previous studies suggest smoking is a factor predisposing to rotator cuff pathology.[17] It has been associated with an increased incidence of rotator cuff tears,[18,19] larger tears,[20] higher levels of shoulder pain[17,21–25] and poorer post-operative function.[22,25–27] However, there is significant variation in factors such as age at presentation, size of rotator cuff tears and degree of improvement post-operatively between smokers and non-smokers.

We compared smokers with non-smokers aiming to determine the difference in age at presentation for surgery, differences in intra-operative findings and to compare pre-operative and post-operative pain and function, with follow-up to 5 years post repair. We hypothesise that smokers have worse pre-operative and post-operative pain and function compared with non-smokers.

Table 1 Comparison of factors seen at presentation for surgery between smokers and non-smokers

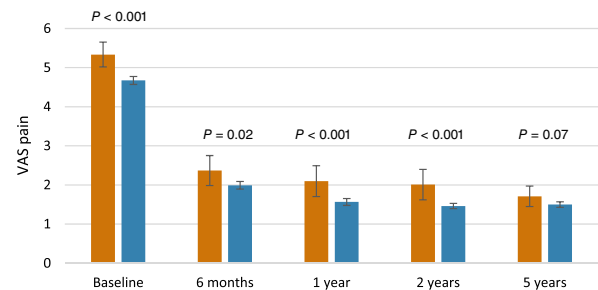|	Smoker	Non-smoker	*P*-value
Age	51.8 (CI 50.3–53.3)	58.5 (CI 57.9–59.0)	<0.001
Anteroposterior tear size (cm)	2.21	2.28	0.5
Tear retraction (cm)	1.79	1.80	0.9
Labral tear number	18 (13.4%)	130 (11.2%)	0.4
Thin/poor tendon quality number	25 (16.4%)	240 (20.4%)	0.3

CI, confidence interval.
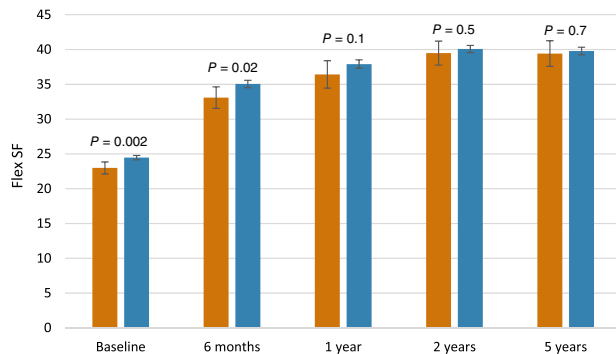
Fig. 1. Pre-operative and post-operative Flex Shoulder Function (Flex SF) scores in smokers (■) and non-smokers (■). Error bars represent 95% confidence intervals.

Fig. 2. Pre-operative and post-operative pain scores in smokers (■) and non-smokers (■). VAS, visual analogue scale. Error bars represent 95% confidence intervals.

Methods

Individual patient cohort data were collected prospectively from 92 surgeons between 1 March 2009 and 31 December 2010. Patients were recruited and consent obtained at the time of booking for surgery. Approval was obtained from the National Ethics Committee NTX/07/04/034/AM04. Approach to RCR was surgeon dependent and included arthroscopic, mini-open or open approaches. Post-operative care was as per the surgeon's preferences, with either formal physiotherapy, or a surgeon-directed exercise programme. Inclusion criteria were those undergoing RCR, with pre-operative and operating day questionnaires completed, who were consented to the study and post-operative follow-up.

Pre-operative patient data were collected during routine preadmission clinic or at booking for surgery. Patient factors recorded included age, gender, ethnicity, whether the tear was related to trauma, work and recreational activity and hand dominance. Smoking status was reported as smoker or non-smoker. Smokers were divided into four categories for analysis based on daily cigarette consumption: 1 to 10, 11 to 20, 21 to 30 or 31 or greater. The Flex Shoulder Function (Flex SF) score was used, a validated shoulder specific functional assessment score that is highly rated when compared to other shoulder scores.[28–30] A greater score reflects better function. A visual analogue scale (VAS) comprising four questions was used to assess pain experienced over the previous month.

A standardised questionnaire was completed by the primary operating surgeon on the day of surgery. Technical data including approach (open, mini-open and arthroscopic) and presence of labral tear were recorded. Tendon quality was graded as poor, thin, good (some deterioration) or very good (normal thickness).

Tear size was assessed by comparing to an instrument of known diameter (e.g., a probe), recording both retraction and the anteroposterior (AP) tear size.

Follow-up questionnaires including Flex SF and VAS pain scores were completed at 6 months, and subsequently at 1, 2 and minimum 5 years post-operatively. Patients lost to follow up were unable to be contacted to fill in questionnaires, primarily due to changes to contact details over the study duration.

Statistical analysis

Data were analysed with use of SOFA Statistics 1.4.6 (Patson-Simpson & Associates Ltd., Auckland, New Zealand). Paired *t*-testing, Pearson's chi-squared and analysis of variance methods were used to interpret data, with the assistance of a professional statistician (Cameron G. Walker). Improvement in pain and function was the difference between the pre-operative scores, and those at 5 years. R software package (2017, R Foundation for Statistical Computing, Vienna, Austria) was then used to perform univariate analysis, then logistic regression adjusting for age was undertaken. *P*-values less than 0.05 were considered significant.

Results

A total of 1383 patients who completed pre-operative questionnaires were included in the study. Five-year follow-up for the cohort was 84%, which included 32 patients who passed away over the study duration. A total of 11.4% of study participants were smokers, and patients were analysed in groups according to their smoking status at the time of surgery. Seventy percent of the study population were male, and they had a smoking rate of 12.6%,

Table 2 Number of smokers in each group, and comparison of improvement scores from pre-operatively to 5 years

Cigarettes/ day	No. of patients	Flex SF improvement	Pain improvement
1–10	64	16.7	3.78
11–20	61	14.7	3.40
21+	33	18.4	3.63
Non- smoker	1225	15.2	3.14

Flex SF, Flex Shoulder Function.

Table 3 Comparison of smoking groups by daily cigarette consumption, comparing improvement in Flex Shoulder Function (Flex SF) and pain scores from pre-operatively to 5 years post-operatively

	Cigarettes/day	Cigarettes/day	P-value
Flex SF	1–10	11–20	0.3
	1–10	21+	0.6
	11–20	21+	0.2
Pain	1–10	11–20	0.5
	1–10	21+	0.8
	11–20	21+	0.7

Table 5 Univariate analysis for improvement in Flex Shoulder Function (Flex SF) and pain pre-operatively to 5 years post-operatively

	Flex SF (P-value)	Pain (P-value)
Age	0.2	0.2
Ethnicity	0.2	0.1
Surgical approach	0.8	0.1
Work: nil use/low demand	0.5	0.4
Recreation: nil use/low demand	0.01	0.002
Male gender	0.8	<0.001
Smoking	0.3	0.03

Table 6 Improvement in function and pain from baseline to 5 years post-operatively controlling for age

	Flex SF	P-value	Pain	P-value
Smoker	16.1 (14.3–18.0)	0.5	3.68 (3.30–4.06)	0.01
Non-smoker	15.4 (14.8–16.0)		2.99 (3.12–3.24)	

Flex SF, Flex Shoulder Function.

which was higher than the smoking rate in the females at 8.6% ($P = 0.03$). A total of 21.5% of procedures were arthroscopic (19.7% smokers vs. 21.7% non-smokers), 40.7% mini-open (40.6% smokers vs. 42.0% non-smokers) and 37.8% open (38.2% smokers vs. 37.7% non-smokers), without significant difference in frequency of smokers and non-smokers ($P = 0.85$).

The smokers underwent surgery at a younger age; on average 6.7 (95% confidence interval [CI] 5.0–8.3, $P < 0.001$) years younger than the non-smokers. There was no difference between the smokers and non-smokers in size of tear, both in retraction and AP dimensions (Table 1). There was no difference in the proportion of labral tears, or frequency of thin or poor quality tendon encountered between these two groups (Table 1).

Improvement over time was seen in both function ($P < 0.001$) and pain ($P < 0.001$) for both smokers and non-smokers.

Smokers had lower Flex SF scores at presentation to surgery (23.0 [22.1–23.8] vs. 24.5 [24.1–24.7, $P = 0.002$]. This difference persisted at 6 months post-operatively (33.1 [31.5–34.6] vs. 35.0 [34.5–35.6], $P = 0.02$); however at 1 year (36.4 vs. 37.9, $P = 0.1$), 2 years (39.5 vs. 40.0, $P = 0.5$) and 5 years (39.4 vs. 39.8, $P = 0.7$) onwards there was no difference seen in Flex SF between these two groups (Fig. 1). At presentation to surgery pain scores were higher in the smoking group (5.3 [5.0–5.7] vs. 4.7 [4.6–4.8], $P < 0.001$), at 6 months (2.4 [2.0–2.8] vs. 2.0 [1.9–2.1], $P = 0.02$), 1 year (2.1 [1.7–2.5] vs. 1.6 [1.5–1.7], $P < 0.001$) and 2 years (2.0

[1.6–2.4] vs. 1.5 [1.4–1.5], $P < 0.001$) post-operatively. This trend persisted at 5 years (3.6 vs. 3.1); however this only approached significance ($P = 0.07$) (Fig. 2).

Dose response was tested based on number of cigarettes smoked per day. Given only six patients reported smoking 31 or more cigarettes per day, these results were grouped with the 21–30 per day group, to make the 21+ group for analysis (Table 2). There was no significant difference in function or pain between the different groups based on number of cigarettes smoked per day (Table 3).

There were no significant differences in the self-reported rate of stiffness or frozen shoulder (smokers 36.2% vs. non-smokers 30.6%, $P = 0.4$), infection (smokers 3.5% vs. non-smokers 2.2%, $P = 0.3$) or re-tear rate (smokers 6.5% vs. non-smokers 7.6%, $P = 0.7$) (Table 4). Logistic regression analysis demonstrated re-tear rate was not influenced by age in our study population ($P = 0.1$).

Univariate analysis to determine factors affecting improvement in pain and Flex SF from pre-operatively to 5 years post-operatively showed low or nil recreation was associated with better improvement in pain and function (Table 5). Women had a significantly better improvement in pain than men ($P < 0.001$). Smoking did not affect the improvement in Flex SF ($P = 0.3$); however, smokers had a higher improvement in pain at 5 years from pre-operatively than non-smokers ($P = 0.03$).

Regression analysis adjusting for age demonstrated no significant impact of smoking on the functional improvement at 5 years from

Table 4 Self-reported post-operative complication rate at any time out to 5 years

	Smoker	Non-smoker	Relative risk	P-value
Stiffness or frozen shoulder	50 (36.2%)	358 (30.6%)	1.19	0.4
Infection	5 (3.5%)	26 (2.2%)	1.61	0.3
Re-tear	9 (6.5%)	89 (7.6%)	0.86	0.7

pre-operatively (smokers 16.1 [14.3–18.0] vs. non-smokers 15.4 [14.8–16.0], $P = 0.5$) (Table 6). Smokers experienced a significantly better improvement in pain than non-smokers (3.68 [3.30–4.06] vs. 2.99 [3.12–3.24], respectively, $P = 0.01$).

Discussion

This study provides comprehensive follow-up (84%) of a large (1383 patients) prospectively analysed group of patients undergoing RCR, with medium term (5-year) follow-up with a focus on patient reported outcomes. We found smokers were on average 6.7 years younger than non-smokers at the time of surgery, with higher pain and lower function scores. Higher pain scores were experienced in the smoking group out to 6 months post-operatively, and poorer function to 2 years post-operatively. There was no difference in pain or functional outcomes between the smokers and non-smokers at 5 years following surgery.

Previous literature indicates smoking negatively impacts rotator cuff tears in multiple ways, including tear development, progression and the outcome of RCR.[17,18,22,27,31–33] Regarding age of presentation to RCR surgery, Mallon et al. found no difference in their study population.[22] Studies since then, however, have found a presenting age of 6–7.2 years earlier in smokers than non-smokers[25,27,32] in keeping with our results.

Whether size of cuff tear is influenced by smoking is unclear. Intra-operative evaluation of cuff tear size has demonstrated higher frequency of larger cuff tears with increasing cigarette consumption in 408 patients.[20] Whereas, Kukkonen et al. found no difference in tear size between the smokers and non-smokers at the time of repair in a cohort of 576 shoulders, in keeping with our results. We also found no difference in rates of labral tears, or frequency of thin or poor tendon quality encountered between smokers and non-smokers.

Prior research has demonstrated no difference in function between smokers and non-smokers pre-operatively.[27] However, other groups have demonstrated poorer pre-operative function and higher pain in smokers,[22,34,35] which is in keeping with our results.

Post-operative pain and function had predominantly been worse in smokers compared to non-smokers in American Shoulder and Elbow Surgeons (ASES) scores, Constant scores and University of California, Los Angeles (UCLA) scores as well as others, with 6-month,[26] 1-year[22,27] and minimum 2-year follow-up.[34] This is consistent with our findings of worse post-operative pain to 6 months post-operatively, and function to 2 years post-operatively. Smoking restricts blood supply in an area that is already relatively hypovascular,[20] and is associated with decreased cellular proliferation[36] and increased rates of cellular degeneration and inflammation.[32,36] These effects could contribute to decreased healing[31] and account for increased pain and poorer function. However, longer-term effects have not been reported in large studies; we found by 5 years post-operatively, there is no difference between the smoking and non-smoking groups.

A lack of difference in outcomes has been reported in a review of 627 RCRs,[37] with no difference between smokers and non-smokers across Patient Reported Outcome Measures (PROMs) in their study out to 1 year post-operatively. Baumgarten et al.[34] prospectively found no difference in improvement in 236 patients between smokers and non-smokers, again across multiple PROMs, in minimum 2-year follow-up. We found no difference at final follow-up in functional improvement between the two groups, and in fact, smokers had a better improvement in pain from pre-operatively to 5 years than non-smokers, which persisted following multivariate analysis. This is likely due to the worse pain scores pre-operatively, and the improvement is consistent with the findings of Chalmers et al.[38]

We found no dose response relationship between number of cigarettes smoked per day and tear size, or the improvement in pain or function at 5 years post-operatively. The absence of dose–response relationship to smoking was also reported by Kukkonen et al., who used dose as number of pack years.[27] Smoking is associated with increased infection rates in a number of surgical procedures, including superior labrum from anterior to posterior (SLAP) repair[39] and shoulder arthroplasty.[40] We found infection rate not significantly different between smokers and non-smokers for RCR, which is in agreement with a large retrospective series of 1824 RCRs by Vopat et al.[41] They reported no difference in infection rate for this surgery between the two groups ($P = 0.701$), with a low infection rate in the series (0.77%) a potential cause for this.

Smokers have been found to have lower healing rates in arthroscopically repaired small to medium sized supraspinatus tears than non-smokers.[42] Though a higher re-tear rate may be expected in the smoking group, given smoking accelerates tear progression[33] we found no difference, which is possibly explained in part by the smoking group presenting younger, and re-tear rates increase with increasing age.[1]

Limitations

This study has several limitations. Changes in smoking status through the study were not recorded, and could potentially influence outcome. However, previously a registry study recorded changes in smoking status during follow-up, and this was not found to significantly influence outcomes at 1 year.[27] Routine follow-up imaging would have demonstrated whether healing rates differed between smokers and non-smokers, but is impractical with such a large cohort. As our complication data were self-reported, results should be interpreted with caution. Self-reporting is likely to capture most clinically significant re-tears that have been imaged, but will miss silent re-tears and patients who have not been reimaged. There was no separation into superficial or deep infection.

Conclusion

We found that at presentation for RCR, smokers were younger, with higher pre-operative pain and lower function scores than non-smokers. Smokers had poorer function at 6 months post-operatively, and worse pain at 6 months, 1 year and 2 years, with no difference seen past this point. We demonstrated, however, that RCR resulted in excellent outcomes regardless of smoking status, with smokers experiencing the same improvement function, and better pain improvement than non-smokers by 5 years post-operatively. Thus, while we would advise counselling patients against smoking,

based on this data, smokers should not be excluded from undergoing RCR.

Author contributions

William Caughey: Data curation; formal analysis; investigation; methodology; project administration; supervision; visualization; writing - original draft; writing-review & editing. **Anthony Maher:** Data curation; investigation; methodology; project administration; resources; supervision. **Warren Leigh:** Conceptualization; funding acquisition; investigation; methodology; project administration; supervision; writing-review & editing. **Matt Brick:** Conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; writing-review & editing. **Simon Young:** Conceptualization; formal analysis; investigation; methodology; project administration; supervision; writing-review & editing. **Cameron Walker:** Data curation; formal analysis; investigation; methodology; writing-review & editing. **Michael Caughey:** Conceptualization; data curation; funding acquisition; investigation; methodology; project administration; resources; supervision; visualization; writing-review & editing.

Conflict of interest

None declared.

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