Orthopaedics & Traumatology: Surgery & Research 101 (2015) S269–S273

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Original article

Impact of cardiovascular risk factor on the prevalence and severity of symptomatic full-thickness rotator cuff tears

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ARTICLE INFO

Article history:
Received 16 May 2015
Accepted 16 June 2015

Keywords:
Cardiovascular risk factors
Rotator cuff tear
Smoker
High blood pressure
Dyslipidemia
Case-control study

ABSTRACT

Introduction: The natural history of rotator cuff (RC) tears is likely multifactorial. Two theories have been put forward to explain them: extrinsic and intrinsic. Cardiovascular (CV) risk factors may be important in the context of the intrinsic theory.

Objectives: The objectives of this study were to demonstrate the influence of CV risk factors and their cumulative effect on the prevalence of symptomatic full-thickness RC tears and on the severity of these lesions.

Material and methods: A prospective observational case-control study was carried out with 206 consecutive patients undergoing arthroscopic rotator cuff repair. The control population consisted of 100 consecutive patients of the same age who had asymptomatic unoperated shoulders and were being operated in the orthopedics unit. The full-thickness RC tears were classified intraoperatively using the Southern California Orthopaedic Institute (SCOI) classification described by Snyder. CV risk factors were rated as either present or absent: smoking, high blood pressure (HBP), diabetes, alcoholism, dyslipidemia, obesity and CV history.

Results: Using a multivariate analysis, two factors were identified as having a significant influence on the prevalence of RC tears: smoking (OR = 8.715, 95%CI = 4.192–18.118, $P < 0.0001$) and dyslipidemia (OR = 4.920, 95%CI = 2.046–11.834, $P = 0.0004$). The following factors had a significant effect on the severity of RC tears: smoking (OR = 1.98, $P = 0.0341$, 95%CI = 1.05–3.74), HBP (OR = 3.215, $P = 0.0005$, 95%CI = 1.67–6.19) and history of CV disease (OR = 6.17, $P < 0.0001$, 95%CI = 2.5–14.78). The case patients had an average of 2.09 CV risk factors while the control patients had an average of 0.74 (OR = 3.56, 95%CI = 2.18–6.33, $P = 0.0012$). The average number of CV risk factors increased as the severity of the tear increased: 0.19 for stage 1, 1.75 for stage 2, 2.75 for stage 3 and 2.90 for stage 4.

Discussion: Modification of the vascular background appears to influence the severity and prevalence of tears. This corroborates anatomical studies in which a hypovascular area was identified in the tendon, 10–15 mm from the lesser trochanter attachment. Smoking, high blood pressure and obesity have been identified in other published studies as risks factors for the severity and prevalence of RC tears. However, it will be important to dissociate prevalence issues from that of RC healing in patients with compromised vascularity.

Conclusion: Cardiovascular risk factors have a significant role in the pathology of RC tears. The prevalence of RC tears is greater in patients who smoke or have dyslipidemia. Their severity is greater in patients who smoke, have high blood pressure or have experienced at least one CV event. The next step will be to study how these factors affect tendon healing, as this information could change our indications for cuff repair.

Level of evidence: Prospective cohort study level 2.

1. Introduction

The prevalence of rotator cuff (RC) tears makes this condition a public health problem. This brings up questions about their pathogenesis, ability of practitioners to prevent or stop progression to

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http://dx.doi.org/10.1016/j.otsr.2015.06.011
1877-0568/

rupture and how to optimize RC repair indications. Classically, two theories have been put forward: extrinsic theory of mechanical causes according to Neer and Bigliani [1–3], and the intrinsic theory of degenerative causes first suggested by Codman [4].

Cardiovascular (CV) risk factors may be important in the context of the intrinsic theory. Although the relationship of blood pressure and smoking with RC tears has been demonstrated by Gumina et al. [5,6], no study up to now has looked at the cumulative effects of CV risk factors on the occurrence and severity of RC tears.

The objectives of this study were to demonstrate the influence of CV risk factors and their cumulative effect on the prevalence of symptomatic full-thickness RC tears and on the severity of these lesions.

2. Materials and methods

2.1. Study population

This was a prospective observational case-control study of 206 consecutive patients undergoing arthroscopic RC repair carried out between January and December 2013. A control group of 100 consecutive patients of the same age with asymptomatic, unoperated shoulders who were operated in the same orthopaedic unit was put together. The two populations had similar average ages (57.8 ± 8.6 years for the cases and 59.4 ± 12.3 years for the controls), sex ratio (60% men in the case group and 55% in the control group), and the proportion performing manual labor (42% versus 38% in the control population) (Table 1).

Table 1
Exposure of case and control populations to the various risk factors; univariate analysis with Chi² test of the risk factors assumed to be involved in occurrence of rotator cuff tears.

	RC tear	Control	OR	95% CI	P (Chi²)
Sex M (%)	60	55	1.263	0.78–2.04	0.3441
Age (years)	57.8	59.4	1.546	0.96–2.5	0.0756
BMI	27.34	26.35	2.554	1.4–4.58	0.0017
Smoker (%)	54	10	10.516	5.18–21.35	<0.0001
Alcoholism (%)	13	8	1.735	0.76–3.97	0.192
HBP (%)	38	23	2.040	1.18–3.52	0.0102
Dyslipidemia (%)	36	7	7.606	3.35–17.25	<0.0001
CV history (%)	21	4	6.518	2.27–18.71	0.0005
Diabetes (%)	14	9	1.420	0.64–3.17	0.3919
No. of CV risk factors	2.09	0.74	3.56	2.18–6.33	0.0012

2.2. Study overview

The primary objective was to evaluate the effect of CV risk factors on the prevalence of RC tears. The exposure of the case and control groups to various risk factors was compared. The secondary objective was to evaluate the effect of CV risk factors on the severity of RC tears. In view of this objective, the case group was divided into two subgroups: one of 116 patients with "moderate tears" (SCOI stage 1, 2, 3) and one of 90 patients with "severe tears" (SCOI stage 4) (Fig. 1).

2.3. Outcome measures

2.3.1. Outcome measures for RC tears

All patients underwent a preoperative assessment consisting of a full clinical examination, standard A/P and lateral (Lamy) X-ray views of the shoulder and CT arthrography. The RC injuries were evaluated intraoperatively based on quantitative objective criteria. Only full-thickness tears were included; they were classified using the Southern California Orthopaedic Institute (SCOI) classification system developed by Snyder [7].

2.3.2. Evaluation of CV risk factors

Cardiovascular risk factors were analyzed as a binary event (present or absent) in a prospective manner during preoperative consultations:

- a patient was considered as hypertensive if he/she was being treated for high blood pressure (HBP) or was previously diagnosed with HBP by a generalist or specialist

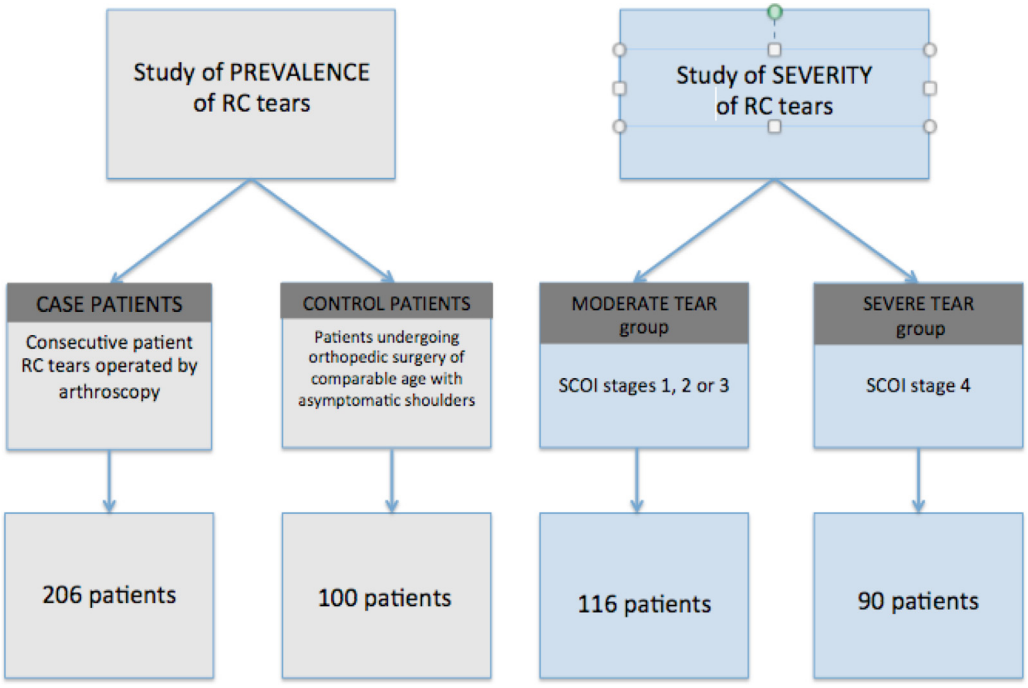

Fig. 1. Study design.

physician because of systolic BP > 140 mmHg and/or diastolic BP > 90 mmHg;
- obesity was defined as BMI > 30;
- diabetes was present if fasting blood glucose levels during the preoperative assessment were greater than 1.26 g/L or if the patient was being monitored or treated for Type I or II diabetes;
- dyslipidemia such as hypercholesterolemia was defined as the patient having values of LDLc > 1.60 g/L, TG > 1.50 g/L, HDLc > 0.40 g/L, or if the patient was currently taking cholesterol-lowering drugs;
- an active smoker was defined as a patient who smoked more than 10 cigarettes per day. Patients who had quit smoking more than 6 months before were considered non-smokers;
- presence of at least one CV event (myocardial infarction, peripheral arterial disease, vascular surgery, stents, etc.);
- chronic alcoholism was defined according to WHO values as consumption of more than 3 glasses of alcohol per day for women and 4 glasses per day for men.

2.4. Statistical analysis

The statistical analysis was performed by the medical statistics unit at our healthcare facility. The average values for the two groups were compared using either Student's *t*-test or Wilcoxon's test (depending whether the data was normally distributed) for quantitative variables or a Chi^2 test for qualitative variables. If the conditions for a Chi^2 test were not satisfied, Fisher's exact test was used instead. The significance threshold was set at 5% bilaterally for all tests.

A univariate analysis was performed to compare the exposure of the case group and control group to various CV risk factors using the odds ratio (OR). A univariate and then a multivariate analysis through a multinomial logistic regression was applied to look for risk factors for the occurrence of RC tears while taking into account any existing data on confounding factors. To study the effect of risk factors on the severity of RC tears, a univariate and then multivariate analysis was performed to compare the exposure of the two subgroups, "moderate tears" and "severe tears".

Table 2
Multivariate analysis of the risk factors assumed to be involved in occurrence of rotator cuff tear: dyslipidemia and smoking were the only significant risk factors in this model.

Factor evaluated	OR	*P*	95% Wald	
			Confidence	Limits
BMI	1.686	0.1407	0.842	3.377
Smoker	8.715	< 0.0001	4.192	18.118
Dyslipidemia	4.920	0.0004	2.046	11.834
CV history	2.390	0.1495	0.731	7.813

3. Results

3.1. Prevalence of RC tears

Comparison of the exposure of the case and control groups to the risk factors using a univariate analysis revealed greater exposure of RC tear patients to smoking (OR = 10.52, 95%CI = 5.18–21.35, $P < 0.0001$), obesity (OR = 2.55, 95%CI = 1.4–4.58, $P = 0.0017$), HBP (OR = 2.04, 95%CI = 1.18–3.52, $P = 0.0102$), dyslipidemia (OR = 7.69, 95%CI = 3.35–17.25, $P < 0.0001$) and to the presence of at least one historical CV event (OR = 6.52, 95%CI = 2.27–18.71, $P = 0.0005$) (Table 1).

Using a multivariate analysis, the only two factors that still had a significant effect on the prevalence of RC tears were smoking (OR = 8.715, 95%CI = 4.192–18.118, $P < 0.0001$) and dyslipidemia (OR = 4.920, 95%CI = 2.046–11.834, $P = 0.0004$) (Table 2, Fig. 2). The following factors were not significantly related to the occurrence of RC tears: sex ($P = 0.3441$), age ($P = 0.0756$), alcohol consumption ($P = 0.192$) and diabetes ($P = 0.3919$).

3.2. Severity of RC tears

According to the SCOI classification of full-thickness RC tears, the patient population was distributed as follows: 14.6% (30 patients) at stage 1, 25.2% (52 patients) at stage 2, 16.5% (34 patients) at stage 3 and 44.7% (90 patients) at stage 4 (Fig. 3).

Based on a univariate analysis, the following factors were significantly associated with SCOI stage 4 tears: obesity (OR = 2.105,

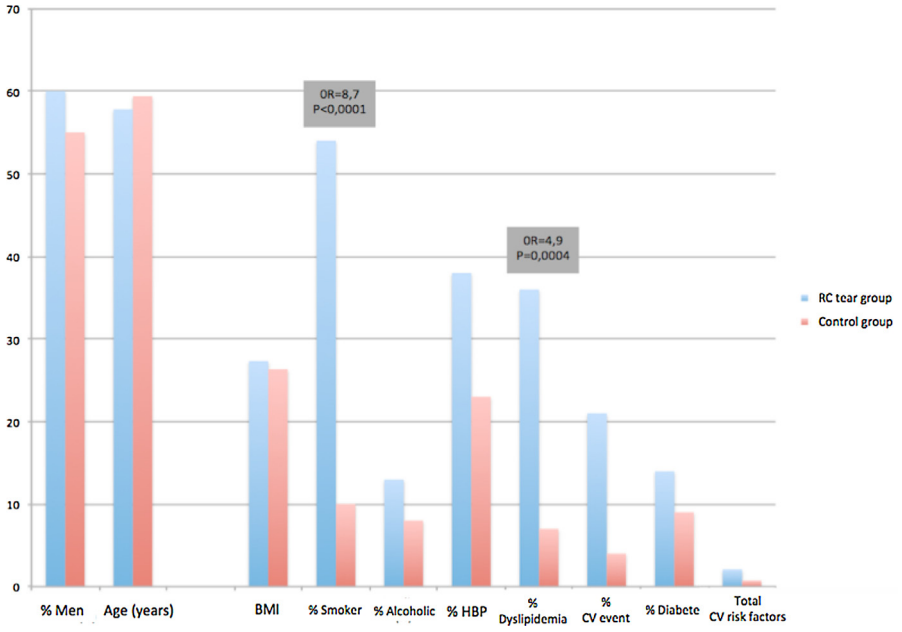

Fig. 2. Comparison of exposure to cardiovascular risk factors of the cases and controls; listed odds ratios were significant in a multivariate analysis.

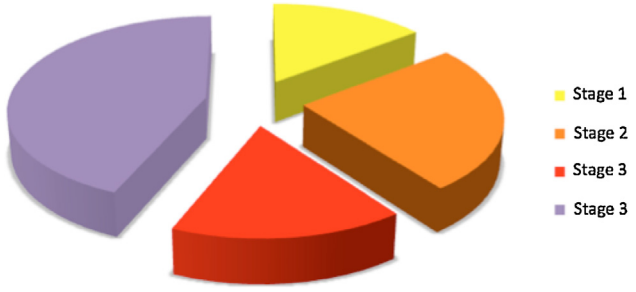

Fig. 3. Distribution of full-thickness rotator cuff tears according to the Southern California Orthopedic Institute (SCOI) classification system.

Table 3
Univariate analysis of the impact of various risk factors on the severity of rotator cuff tears; odds ratio for stage 4 full-thickness tears.

Factor evaluated	Odds ratio	P (Chi^2)
Sex M	1.326	0.3303
BMI > 30	2.105	0.0117
Age > 60	1.851	0.0320
Smoker	2.154	0.0078
Alcoholism	1.460	0.3608
HBP	4.311	< 0.0001
Dyslipidemia	2.867	0.0004
CV history	9.000	< 0.0001
Diabetes	2.208	0.0691

$P = 0.0117$), age above 60 years (OR = 1.851, $P = 0.032$), smoking (OR = 2.154, $P = 0.0078$), HBP (OR = 4.311, $P < 0.0001$), dyslipidemia (OR = 2.867, $P = 0.0004$) and cardiovascular history (OR = 9, $P < 0.0001$) (Table 3). The following factors were not significantly related to the severity of RC tears: sex ($P = 0.33$), alcoholism ($P = 0.36$), diabetes ($P = 0.0691$).

Based on a multivariate model, the following factors still had a significant effect on the severity of RC tears: smoking (OR = 1.98, $P = 0.0341$, 95%CI = 1.05–3.74), HBP (OR = 3.215, $P = 0.0005$, 95%CI = 1.67–6.19) and history of CV disease (OR = 6.17, $P < 0.0001$, 95%CI = 2.58–14.78).

3.3. Cumulative effect of risk factors

The case patients had an average of 2.09 CV risk factors while the control patients had an average of 0.74 (OR = 3.56, 95%CI = 2.18–6.33, $P = 0.0012$) (Table 1). The average number of CV risk factors increased as the severity of the tear increased: 0.19 for stage 1, 1.75 for stage 2, 2.75 for stage 3 and 2.90 for stage 4 (Fig. 4).

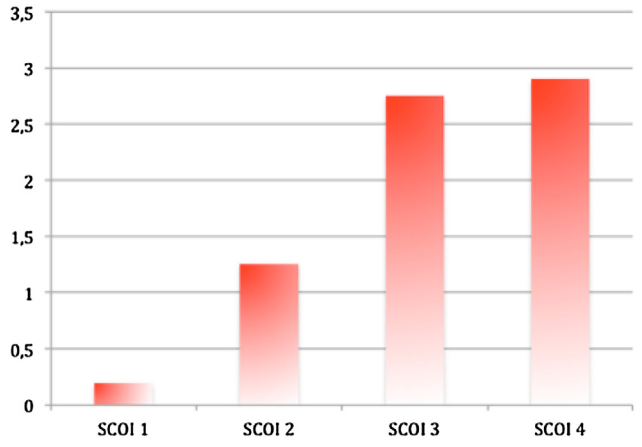

Fig. 4. Average number of cardiovascular risk factors as a function of the SCOI rotator cuff tear stage.

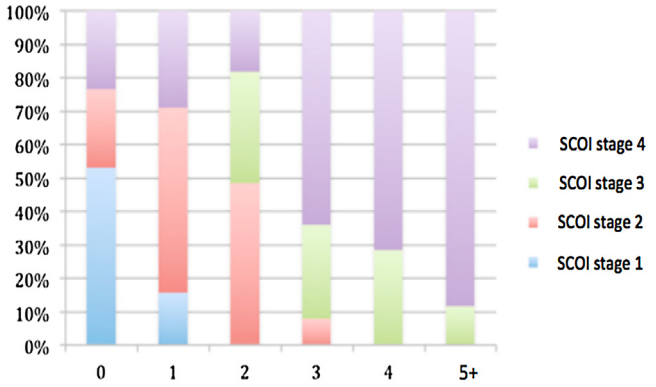

Fig. 5. Number of cardiovascular risk factors for each type of rotator cuff tear; there are no stage 3 or 4 tears in patients with 0 or 1 risk factors, while most of the patients with 5 or more risk factors had stage 4 tears.

The proportion of severe stage 4 tears increased with the number of CV risk factors. It was 23% of tears in patients without any risk factors; 29% in those with 1 CV risk factor, 18% in those with 2 risk factors, 64% in those with 3 risk factors, 71% in those with 4 risk factors and 88% of those with at least 5 risk factors (Fig. 5).

4. Discussion

This study has certain limitations. Treating the CV risk factors as binary events may have introduced a potential measurement bias. This approach was chosen to simplify the statistical analysis and to bring out significant results, but could have overestimated certain odds ratios.

There is inherent bias in any study of risk factors because the concept of penetration or exposure to each CV risk factor is difficult to evaluate. Several criteria must be taken into account: duration and intensity of exposure, treatment compliance and the impact of each risk factor on the overall CV risk.

In this study, a multivariate analysis revealed a significant effect of certain CV risk factors on the prevalence and severity of the RC tears. A comparison of these results to published ones seems relevant. Smoking increased the prevalence of RC tears eight-fold and the severity of the lesions (SCOI stage 4) by two-fold. In a study of smoking habits of 408 patients who underwent arthroscopic repair of RC tears, Gumina found a significant relationship between the number of cigarettes smoked daily and the severity of the lesion [6].

The risk of stage 4 RC tears is three times greater in the presence of HBP. The Gumina study also found that HBP was associated with two-fold higher risk of having a complete rotator cuff tear, two-fold higher risk of having a large tendon tear and four-fold higher risk of having a massive rotator cuff tear involving more than one tendon. A significant linear relationship has been observed between the duration of exposure (treatment duration) and the severity of lesions [5].

As for the role of obesity, the slight difference in BMI between the case and control populations (27.3 versus 26.4) was not significant. There is an interesting published case-control study of 381 patients with RC tears treated by arthroscopy and 220 control patients. The BMI increased with the size of the RC tear; obese patients (BMI > 30) had more than twice the number of RC tears than non-obese patients [8].

In addition, tears were five times more common in the presence of dyslipidemia; severe ruptures (SCOI stage 4) were six times more common in the presence of at least one previous CV event. This suggests a correlation between altered vascular background and the pathology of RC tears. The highly significant effect of certain

factors such as smoking, dyslipidemia and HBP on the prevalence and severity of RC tears cannot be ignored. Conversely, alcoholism, age, gender and diabetes were found to have no significant effect on the prevalence and severity of RC tears.

In another case-control study of 5000 subjects, a multivariate analysis found a certain number of comorbidities and factors associated with RC tears but the results partially contradicted other published data. Oral corticosteroid therapy, oral and insulin diabetes therapy, and excess weight (BMI between 25 and 30) appear to be important [9].

Alteration of the vascular background has also been studied anatomically using cadavers. Modifications in the microcirculation of the supraspinatus and infraspinatus tendon insertions were described. These studies found a hypovascular area in the tendon, 10–15 mm from the lesser trochanter insertion [10–13]. This is an area of vascular anastomosis, plagued by microcirculatory disturbances and tissue hypoxia [14]. The oxidative stress due to production of reactive oxygen species and cellular apoptosis could be the cause of the degeneration, tendon ruptures and reduced number of tenocytes in patients who smoke [15].

A recent immunohistochemistry study identified a bone microvascular alteration at the lesser trochanter and footprint due to infiltration of cortisone derivatives, without an effect of smoking, age and gender [16]. This is fairly consistent with intratendinous localization of the critical vascular area.

However, it will be important to dissociate the prevalence issues from that of RC healing in patients with compromised vascularity. Strictly speaking, RC healing may not involve tendon revascularization but instead, postoperative fibrosis around the reattached area. Cadet [17] studied the early vascularization of the RC after 3 months using high performance Doppler ultrasonography and found avascular conditions in every case after tendon reattachment.

A study of RC healing in patients exposed to CV risk factors could have a significant impact on our surgical practices. The correlation between healing and postoperative clinical results must still be demonstrated. For example, Namdari [18] found no significant difference in the early postoperative clinical results (DASH, SSH) between obese and non-obese patients (BMI < 30) who underwent arthroscopic RC repair; however they did not look at healing.

5. Conclusion

The natural history of rotator cuff (RC) tears is likely multifactorial. Cardiovascular risk factors have a significant role in the pathology of RC tears. The prevalence of RC tears is greater in patients who smoke or have dyslipidemia. Their severity is greater in patients who smoke, have high blood pressure or have a history of at least one CV event. Conversely, alcoholism, age, gender and diabetes were found to have no significant effect on the prevalence and severity of RC tears. The next step will be to study how these factors affect tendon healing, as this information could change our indications for RC repair.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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