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Is preoperative elevated glycated hemoglobin (HbA1c) a risk factor for postoperative shoulder stiffness after posterior-superior rotator cuff repair?

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Background: Postoperative shoulder stiffness (POSS) affects a large number of patients undergoing rotator cuff repair (RCR). Diabetes may increase the risk of POSS. Preoperative glycated hemoglobin (HbA1c) is a convenient measure of glucose control in this group. The aim of the present study was to determine a relationship between preoperative HbA1c and POSS in patients undergoing postero-superior RCR.

Methods: Two hundred fifty patients with full-thickness postero-superior rotator cuffs who underwent RCR were followed for 6 months. Pre- and post-operative external rotation with arm by the side at 3 and 6 months were measured. Patient demographics, tear characteristics, preoperative HbA1c level, and surgical details were recorded. Patients with subscapularis tears, concomitant instability, partial thickness tears, arthritis, and irreparable rotator cuff tears were excluded. Univariate and multivariate logistic regression were used to determine the association between patient characteristics and POSS at 6 months.

Results: At the end of 6 months, 16% (41/250) of patients had POSS. Multivariate analysis demonstrated an elevated preoperative HbA1c level was a statistically significant predictor of POSS at 6 months (odds ratio 7.04, $P < .01$) after posterior superior RCR. Lower preoperative external rotation ($P = .02$) and female sex ($P < .01$) were also risk factors associated with POSS. Age, hand dominance, worker's compensation claim status, etiology, and size of the tear, surgical technique, and additional treatments were not statistically significant predictors.

Conclusion: Elevated preoperative HbA1c level is associated with POSS after RCR. Measuring HbA1c preoperatively may assist clinicians to identify patients at risk of POSS. HbA1c is a modifiable parameter that could then be optimized preoperatively in order to improve outcomes.

Rotator cuff disease is the most common source of shoulder disability in individuals over the age of 50 years.[46] Rotator cuff disease occurs in up to one-quarter of the population.[31] This has resulted in more than a two-fold rise in rotator cuff repair (RCR) surgeries performed in the United States over a 10-year period[17] and a 55.1% rise for past two decades in Australia.[22,49]

Postoperative shoulder stiffness (POSS) can affect between 2.7% and 32.7%[2,35,50] of patients undergoing RCR. Postoperative stiffness may lead to patient distress and dissatisfaction.[25] Furthermore, it can affect everyday activities, leading to prolonged rehabilitation and, in severe cases, further surgical intervention such as manipulation or capsular release.

Diabetes is a known independent risk factor leading to altered bone and tendon healing[4,29,41] and adhesive capsulitis.[1,9,11] Specifically, it has been identified as a possible risk factor for POSS, but the relationship is not yet clearly established. Studies have observed that diabetic patients are more likely to have POSS,[5,6,12,15,21,28,43] whereas others have reported no increased risk.[13,24]

Glycosylated hemoglobin (HbA1c) is a blood test that can provide diagnostic and prognostic information in patients with diabetes mellitus. The test provides a numeric value that is not only highly diagnostic for diabetes when elevated but also represents a weighted mean glucose level over 8-12 weeks.[16,37,42] It is convenient test for patients as it can be performed at any time of the day and does not require fasting. Therefore, HbA1c has been utilized as a preoperative marker to help predict adverse outcomes in orthopedic surgery.[40,45] Its utility has more recently extended to predict

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adverse outcomes in shoulder surgery.[9,10] More specifically, its relationship has been investigated with regard to RCR retear rate[26] and outcomes.[32] Its relationship to POSS has not been elucidated in the literature. HbA1c is a measurable and modifiable marker. Various potential changes at the pre-, peri-, or post-operative stage could be implemented in order to modulate the potential effects of glycemic control on postoperative stiffness.

The ability to better assess the risk and prevent postoperative stiffness is crucial. Therefore, the aim of our study was to determine whether there is a relationship between preoperative HbA1c and POSS in patients undergoing RCR for posterosuperior tears. We hypothesized that a raised HbA1c would result in greater POSS.

Methods

Study design

The present study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[19]

Institutional ethical committee approval was obtained before the commencement of the study (Macquarie University Human Research Ethics Committee Medical Sciences MQCIAC2019010). Retrospective analysis of prospectively collected data was carried out on 250 consecutive patients who underwent RCR surgery by a single senior fellowship-trained shoulder surgeon (D.J.B.) between September 2016 and September 2018.

Data collection

The data review was done using the Medical Director Blue-Chip version 3.18.0.22 (Health Communication Ltd., Sydney, Australia) database and Medical Director Clinical version 3.16.16.10323 (Health Communication Ltd., Sydney, Australia) software.

Inclusion and exclusion criteria

All adult patients with magnetic resonance imaging and arthroscopically diagnosed, isolated full-thickness posterior superior rotator cuff tears were included in the study. Patients with associated subscapularis tears, concomitant instability, partial thickness tears, arthritis, previously operated patients for any shoulder pathology, and irreparable rotator cuff tears were excluded from the study.

Data collected

Demographic variables such as age, sex, hand dominance, worker's compensation claim status, etiology of the tear, known history of diabetes (or family history), preoperative stiffness, size of the tear, type of procedure (arthroscopic or arthroscopic combined with mini-open), and the technique used (single/double row/transosseous). Additional treatments such as long head of biceps (LHB) tenodesis or excision of outer end clavicle, range of motion at 3 and 6 months, and complications were reported.

Preoperative HbA1c, collected from a single lab within 1 month of surgery was recorded. As per the International Expert Committee and American Diabetes Association criteria, the cutoff values of HbA1c were defined as normal or low risk of diabetes (International Federation of Clinical Chemistry [IFCC] <40 nmol/mol and National Glycohaemoglobin Standardisation Program [NGSP] <5.8%), at-risk for diabetes or intermediate (IFCC 40-46 nmol/mol, NGSP 5.8%-6.4%), and diabetic or elevated (IFCC >46 nmol/mol, NGSP >6.4%).[16,48]

Surgical technique

All patients had surgery under general anesthesia with interscalene block. The procedures were conducted in a lateral decubitus position with the arm in 15 degrees of forward flexion and 30 degrees of abduction using a traction device weighing 10 pounds. Standard posterolateral, anterior mid-glenoid, lateral, and anterolateral portals were created in all arthroscopically operated patients. Following a standard examination of the glenohumeral joint, any pathology associated with the LHB tendon was treated, and tenotomy or tenodesis was performed, as discussed with the patient prior to surgery. After evaluating the rotator cuff injury, subacromial débridement and acromioplasty were performed. If the patient exhibited clinical (local tenderness to palpation over the acromioclavicular joint) and radiographic signs (large inferior osteophytes that protruded into the subacromial space) of acromioclavicular joint arthrosis before surgery, distal excision of the clavicle was performed. Depending on the magnitude of the tear, a single or double-row arthroscopic repair or a mini-open transosseous method was used.

All single-row repairs were performed with the over the top approach with biodegradable 4.75 mm Healicoil Regensorb suture anchors (Smith & Nephew Watford, Hertfordshire, UK). For the double row, a suture bridge arrangement was performed consisting of biodegradable 4.75 mm Healicoil Regensorb (Smith & Nephew Watford, Hertfordshire, UK) for the medial row and Magnum X Arthrocare anchors (Smith & Nephew Watford, Hertfordshire, UK) for the lateral row. After cuff repair, an open subpectoral LHB tenodesis employing a Versatile TenoLoc (ConMed, Largo, FL, USA) dual-expanding tenodesis anchor was done when indicated.

In patients receiving a mini-open repair, the lateral portal incision was lengthened, and the deltoid splitting technique was utilized between the anterior and middle fibers. The transosseous equivalent repair was performed using No. 2 FiberWire (Arthrex Inc., Naples, FL, USA). The LHB tenodesis was performed by suturing the stump of the LHB onto the transverse biceps ligament via the open incision.

Postoperative protocol

All patients were immobilized with an arm sling for six weeks following surgery. Immediate postoperative passive-aided external rotation (ER) to neutral and forward flexion to 90° were commenced. After six weeks, complete elevation and ER were encouraged.

All patients were followed up at 2 weeks, 6 weeks, 3 months, and 6 months, respectively.

Measurement of postoperative stiffness

Due to potential postoperative subacromial irritation, forward flexion was not deemed a suitable indicator for capsular stiffness. Clinical measurements were done in a standardized fashion by a single senior surgeon (D.J.B.) at the end of 3 and 6 months postoperatively.[12] Passive ER with arm by the side was therefore used as a criterion for postoperative stiffness. External rotation goniometer measurement was performed with arm resting by the side and elbow flexed at 90 degrees. The shoulder was externally rotated maximally, and the angle made between the line of the forearm and the trunk was measured.[34] POSS was defined as passive ER at side <30° according to the definition of Oh and Blonna et al.[5,34] Preoperative stiffness was defined similarly.

Table I
Patient-related summary statistics overall and by postoperative stiffness group and results of logistic regression for odds of stiffness at 6 months.

Characteristic	Overall (n = 250)	Nonstiff (n = 209)	Stiff (n = 41)	Univariate OR (95% CI), *P* value	Multivariate OR (95% CI), *P* value
Mean age (SD)	58 (10)	58 (11)	59 (9)	1.01 (0.98, 1.05), *P* = .44	
Sex, n (%)					
Female	58 (23)	42 (20)	16 (39)	reference	reference
Male	192 (77)	167 (80)	25 (61)	**0.39 (0.19, 0.81), *P* = .01**	**0.31 (0.14, 0.67), *P* < .01**
Diabetes mellitus (DM), n (%)					
No	220 (88)	191 (91)	12 (71)	reference	
Yes	30 (12)	18 (9)	12 (29)	**4.39 (1.89, 10.02), *P* < .01**	
Family history of DM, n (%)					
No	237 (95)	201 (96)	36 (88)	reference	
Yes	13 (5)	8 (4)	5 (12)	**3.49 (1.01, 11.07), *P* = .04**	
Mean time from injury to surgery in weeks (SD)	66 (88)	66 (87)	63 (93)	1.00 (1.00, 1.00), *P* = .81	
Etiology, n (%)					
Degenerative	104 (42)	87 (42)	17 (41)	reference	
Traumatic	146 (58)	122 (58)	24 (59)	1.01 (0.51, 2.01), *P* = .98	
Size of tear, n (%)					
Large	61 (24)	49 (23)	12 (29)	reference	
Medium	187 (75)	160 (77)	27 (66)	0.74 (0.36,1.61), *P* = .43*	
Small	2 (1)	0 (0)	2 (5)		
Injury on dominant side, n (%)					
No	180 (72)	151 (72)	29 (71)	reference	
Yes	70 (28)	58 (28)	12 (29)	1.08 (0.50, 2.21), *P* = .84	
Mean HbA1c (SD)	5.59 (0.82)	5.53 (0.80)	5.85 (0.91)	**1.43 (1.01, 2.04), *P* = .04**	
Mean HbA1c IFCC (SD)	37 (9)	37 (9)	40 (10)	**1.03 (1.00, 1.07), *P* = .04**	
HbA1c category, n (%)					
Normal	189 (76)	165 (79)	24 (59)	reference	reference
Intermediate	40 (16)	32 (15)	8 (20)	1.72 (0.67, 4.04), *P* = .23	1.81 (0.68, 4.46), *P* = .21
Elevated	21 (8)	12 (6)	9 (22)	**5.16 (1.92, 13.53), *P* < .01**	**7.04 (2.47, 20.08), *P* < .01**
Preoperative external rotation, mean (SD)	49 (12)	50 (12)	44 (13)	**0.97 (0.94, 0.99), *P* < .01**	**0.97 (0.94, 0.99), *P* = .02**
External rotation 3 months postoperatively, mean (SD)	24 (10)	26 (8)	13 (9)		
External rotation 6 months postoperatively, mean (SD)	38 (12)	42 (8)	19 (6)		
Preoperative stiffness, n (%)					
No	232 (93)	200 (96)	37 (90)	reference	
Yes	13 (5)	9 (4)	4 (10)	2.40 (0.63, 7.80), *P* = .16	
Surgery type, n (%)					
Open	76 (30)	63 (30)	13 (32)	reference	
Double	162 (65)	135 (65)	27 (66)	1.08 (0.51, 2.18), *P* = .84†	
Single	12 (5)	11 (5)	1 (2)		
Long head biceps tenodesis, n (%)					
No	133 (53)	107 (51)	26 (63)	reference	
Yes	117 (47)	102 (49)	15 (37)	0.61 (0.30, 1.20), *P* = .15	
Acromioplasty, n (%)					
No	16 (6)	16 (8)	0 (0)		
Yes	234 (94)	193 (92)	41 (100)		
Clavicle excision, n (%)					
No	144 (58)	121 (58)	23 (56)	reference	
Yes	106 (42)	88 (42)	18 (44)	1.08 (0.54, 2.11), *P* = .83	
Workers compensation, n (%)					
No	219 (88)	185 (89)	34 (83)	reference	
Yes	31 (12)	24 (11)	7 (17)	1.59 (0.59, 3.82), *P* = .32	

OR, odds ratio; *CI*, confidence interval; *SD*, standard deviation.
*Small and medium combined for analysis.
†Single and double combined for analysis.

Statistical analysis

All the categorical variables were summarized using counts with percentages. Numerical variables were summarized with mean and standard deviation. Univariate logistic regression was used to determine the association between patient factors and POSS at 6 months. Variables significant at the 10% level of significance (that were not related to each other, such as multiple variants of HbA1c) were entered into a multivariable model, and a backward elimination procedure was used to remove variables that did not contribute significantly to the model (ie, they did not explain variability between POSS groups). Results were presented as odds ratios (ORs) with 95% confidence interval and *P* value. In the final model, *P* values less than 5% were considered significant.

Results

Demographics

We included 250 consecutive patients; 41 (16%) individuals had POSS at the 6-month follow-up. Demographics are outlined in Table I. The mean age of the patients was 58 ± 10 years. There were 192 (77%) males in the present study. One hundred forty-six (58%) patients had rotator cuff tears that had a traumatic etiology. These occurred on average 66 ± 88 weeks prior to surgery. Thirty-one (12%) patients had worker compensation claims.

Thirty (12%) reported a history of diabetes preoperatively. However only 21 (8%) had biochemically elevated HbA1c (>6.4%) consistent with a diagnosis of diabetes. Forty (16%) patients had a

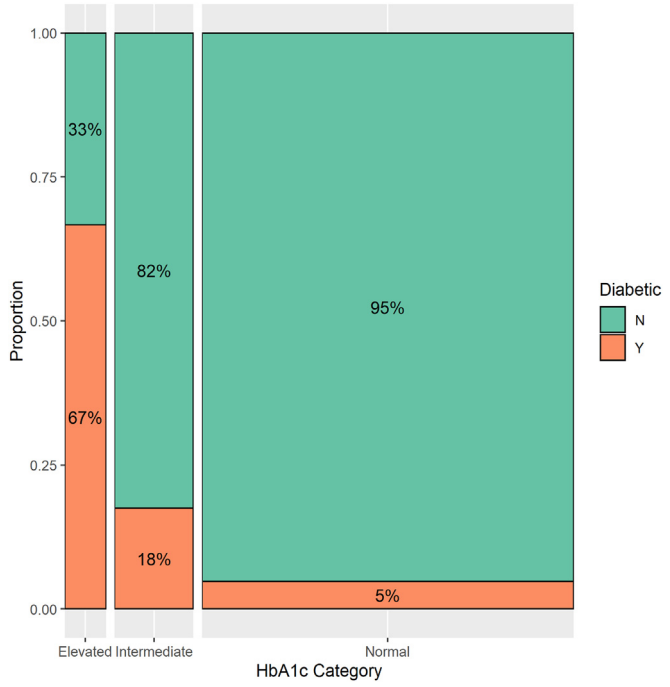

Figure 1 Mosaic plot of preoperative HbA1c level and diabetic status.

HbA1c in the intermediate range. Seven of the 21 (33%) patients with elevated HbA1c did not report a history of diabetes (Fig. 1).

Surgical details

Surgical information is also outlined in Table I. The vast majority (174, 70%) of patients underwent arthroscopic repair with 12 (5%) of these patients receiving a single row repair technique, and in the remainder (162, 65%), a double row suture bridge technique was used. The remaining patients (76, 30%) underwent a combined arthroscopic and mini-open transosseous repair. As per the DeOrio and Cofield classification system,[20] medium size tear was the most common and were seen in three-quarters of patients. Among the concomitant procedures, 117 (47%) patients had a subpectoral LHB tendon tenodesis, and 106 (42%) patients had excision of the outer end of the clavicle.

Risk factors for POSS

According to univariate logistic regression analysis (Table I), those who were in the elevated HbA1c category were substantially more likely to experience POSS at 6 months than those with normal HbA1c ($P < .01$). Furthermore, this relationship was also observed when HbA1c ($P = .04$) was analyzed as a numerical variable. The odds of POSS at 6 months were substantially lower for males ($P = .01$), significantly greater for diabetics ($P < .01$), and those with a family history of diabetes ($P = .04$). Odds of POSS were significantly lower for those with greater preoperative ER ($P < .01$).

In the multivariate logistic regression analysis, elevated HbA1c (OR: 7.04, $P < .01$), female sex ($P < .01$), and lower preoperative ER ($P = .02$) were risk factors for POSS.

Discussion

After 6 months of follow-up, 16% of our cohort had POSS. An elevated preoperative HbA1c (>6.4%) level was a statistically significant predictor of POSS after posterior superior RCR. Lower preoperative external rotation and female sex were also recognized as risk factors. Seven patients did not have a history of diabetes but had an elevated HbA1c consistent with diabetes.

After RCR, reported POSS varies greatly (2%-28.5%).[27,30,44,47] This vast range of variability is probably brought about by the absence of a consensus definition for POSS,[3] variation in follow-up, procedure type, and concomitant procedures. External rotation of less than 30 degrees has been utilized as POSS criteria in a number of studies.[8,12,36,44] Harris et al 2013[23] examination of the normal range of motion postoperatively supports this definition to an extent. They determined that all patients in their cohort had more than 30 degrees of external rotation at 3 months and had restored most of their range at 6 months. According to Brislin et al,[8] who used this criterion, 23 out of 263 patients (8.7%) exhibited shoulder stiffness three months following RCR. At their three-month follow-up visit, Tan et al[44] found that 32 of 290 patients (11%) had POSS. POSS was noted in 18.8% (54/288) of patients at 3 months following RCR, 2.8% (8/288) at 6 months, and 6.6% (19/288) at the end of follow-up (mean 13.5 months), according to Chung et al.[14] Cho et al[12] found that 39 of 274 patients (14.2%) who underwent RCR developed POSS at 3 months after surgery. In our study, POSS was present following RCR surgery in 35 of 250 patients (18%). This finding is in line with the published literature.

A history of diabetes has been demonstrated to be an independent risk factor for POSS. Koorevar et al[28] demonstrated an odds ratio of 4.13 and Cho et al[12] of 2.9 with regard to the development of POSS in patients with diabetes mellitus. In accordance with these studies, diabetics had a greater association with POSS (OR 4.4, $P < .01$) in univariate but not multivariate analysis.

Elevated HbA1c was a significant predictor of POSS in our study during both univariate and multivariate analyses ($P < .001$). Interestingly, seven patients in our study had biochemical evidence (elevated HbA1c) but denied a history of diabetes. HbA1c has very high specificity[39] for diagnosis of diabetes and is quantifiable. As such, it may be a more useful measure of patients with impaired glucose tolerance than history of diabetes alone. We are not aware of any other studies that have determined the relationship between preoperative HbA1c and POSS. However, Miyatake et al[32] looked at the outcomes of RCR in diabetics compared with nondiabetics. They used HbA1c levels preoperatively to stratify diabetic patients in those with poor (HbA1c >7%) and good (HbA1c <7%) control. They intensively treated those with poor control and found equal outcomes when this was done. While this approach may not be appropriate in all settings, further research about preoperative intervention in this cohort is warranted.

We demonstrated other predictors of POSS including female sex and preoperative ER. This finding is consistent with the literature. Studies have shown that females more commonly have relative POSS compared to males during the early postoperative period.[18,28] Preoperative stiffness has been shown to be a risk factor for early postoperative stiffness, as observed by many authors.[3,14,18,33,35] Only 13 of our patients had stiffness preoperatively; therefore, our study was not sufficiently powered to explore this relationship.

We did not find an association with the other variables we included. In particular, surgical approach (open vs. arthroscopic) was not identified as a predictor of POSS. This is concordant with the literature on the whole. A recent systematic review[38] demonstrated no statistically significant difference in their meta-analysis. Furthermore, there was no demonstrable difference between patients who received double or single row repairs. This finding is also comparable with literature. Bowen et al 2023[7] demonstrated in their review that there were only differences in single and double row repair in large to massive tears. This

suggests that more important than the technique of the repair is that the correct technique is applied in order to address the type of tear present. In our study, the surgical technique was adapted in order to achieve the most robust repair. In light of this, it is unsurprising that we did not find a difference in stiffness between the open and arthroscopic techniques applied, and we had too few single-row repairs to enable the single and double arthroscopic repairs to be compared.

Strengths and limitations

This study has a number of limitations. The number of patients with POSS was relatively low compared with the overall cohort size, which may affect the statistical power. We did not use imaging evaluation postoperatively to assess structural integrity of the repair, which may have an influence on range of motion.

We intentionally used one measure of range of motion, passive ER. There is no consensus measure for POSS in the literature. The most well-cited standard set of measures are those reported by Oh et al.[34] They defined shoulder stiffness in the presence of any one of the following criteria. 1) Forward elevation of <120° 2) External rotation with arm by the side <30° or 3) Internal rotation at the back is lower than L3. In our cohort of posterosuperior tears, we felt that subacromial irritation would affect elevation and internal rotation measures. Therefore, we felt ER would be best able to isolate glenohumeral stiffness in our cohort. As such, we classified POSS using Oh et al criteria for ER stiffness only. We understand there are potential weaknesses to this approach and that the definition of POSS needs further clarification and standardization. Patients were prospectively included, and a single surgeon evaluated each of them. Data was retrospectively analyzed. We also acknowledge that our study design does not include all potential predictors of POSS. However, at the time of study design with the available literature, we included as many a feasible.

Strengths of this study include its relatively large study population and its single surgeon operator and assessor.

Conclusion

POSS after RCR is associated with preoperatively elevated HbA1c levels. Patients without a history of diabetes may have an elevated HbA1c level. A single preoperative HbA1c measure may help to identify patients who are at risk of POSS. Furthermore, treatment targeted toward glycemic control may be able to reduce this risk.

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