Injections Prior to Rotator Cuff Repair Are Associated With Increased Rotator Cuff Revision Rates

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Purpose: To determine whether shoulder injections prior to rotator cuff repair (RCR) are associated with deleterious surgical outcomes. **Methods:** Two large national insurance databases were used to identify a total of 22,156 patients who received ipsilateral shoulder injections prior to RCR. They were age, sex, obesity, smoking status, and comorbidity matched to a control group of patients who underwent RCR without prior injections. The 2 groups were compared regarding RCR revision rates. **Results:** Patients who received injections prior to RCR were more likely to undergo RCR revision than matched controls (odds ratio [OR], 1.52; 95% confidence interval [CI], 1.38-1.68; $P < .0001$). Patients who received injections closer to the time of index RCR were more likely to undergo revision ($P < .0001$). Patients who received a single injection prior to RCR had a higher likelihood of revision (OR, 1.25; 95% CI, 1.10-1.43; $P = .001$). Patients who received 2 or more injections prior to RCR had a greater than 2-fold odds of revision (combined OR, 2.12; 95% CI, 1.82-2.47; $P < .0001$) versus the control group. **Conclusions:** This study strongly suggests a correlation between preoperative shoulder injections and revision RCR. There is also a frequency dependence and time dependence to this finding, with more frequent injections and with administration of injections closer to the time of surgery both independently associated with higher revision RCR rates. Presently, on the basis of this retrospective database study, orthopaedic surgeons should exercise due caution regarding shoulder injections in patients whom they are considering to be surgical candidates for RCR. **Level of Evidence:** Level III, therapeutic study.

Rotator cuff (RC) pathology is pervasive and leads to an estimated 4.5 million physician visits per year in the United States.[1] Initial management options for these injuries include physical therapy, injections, and surgical repair. However, whether a period of nonoperative treatment should be used prior to rotator cuff repair (RCR) remains controversial. Primary care providers and orthopaedic surgeons alike frequently treat subacromial impingement and partial-thickness rotator cuff tears (RCTs) with corticosteroid injections (CSIs) or nonsteroidal anti-inflammatory drug injections.[2-6] More recently, biological injections such as platelet-rich plasma and stem cells have been investigated for their pain-relieving and anti-inflammatory potential in the nonoperative care of RC pathology.[7-10] Nevertheless, a significant proportion of patients who experience initial symptomatic relief with injections will go on to require surgical intervention as the effectiveness of nonoperative measures wanes.[11] This is increasingly true for RCTs, a subgroup of shoulder pathology for which no injectable has shown the ability to heal the torn tendon-bone interface. In fact, CSIs, which represent the vast majority of shoulder injections performed clinically,[5,12] have come under scrutiny for their detrimental effects on tendon tissue properties and potential for hastening tear propagation.[13-17] The clinical efficacy of CSIs is similarly controversial, and they generally provide only a short period of potential pain relief or functional improvement.[4,13-18] Currently, there is a fundamental lack of knowledge regarding the extent to which preoperative injections affect RCR outcome.

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The purpose of this study was to determine whether shoulder injections prior to RCR are associated with deleterious surgical outcomes. It was hypothesized that preoperative shoulder injections would be correlated with higher revision RCR rates. Furthermore, it was hypothesized that there would be both frequency- and time-dependent effects where a higher frequency of preoperative injections and a shorter duration between injection and surgery would be associated with increased revision RCR rates.

Methods

After institutional review board approval, deidentified patient data from Humana (Louisville, KY), a large national private insurer, was queried using the PearlDiver program (PearlDiver, Colorado Springs, CO). A retrospective review of the entire database from January 2007 through June 2016 was conducted. Similarly, all deidentified Medicare patient data in the database, from January 2005 through December 2014, were collected and reviewed.

Identification of Shoulder Injections

Shoulder injections were identified with relevant Current Procedural Terminology (CPT) code 20610. Because this code can apply to knees and hips as well, only patients who received injections and carried a shoulder-related diagnosis on the same visit as the injection code were included for analysis. Shoulder-related diagnoses (e.g., shoulder pain or stiffness) were identified using *International Classification of Diseases, Ninth Revision* codes. To increase the confidence of a shoulder-specific issue, patients could not have a hip- or knee-related diagnosis noted on the same visit to be included in the study. Patients whose injections were not specified for laterality were excluded.

Identification of RCR

Patients undergoing RCR were identified using CPT codes 29827, 23410, 23412, and 23420, which encompass both open and arthroscopic repairs. Revision RCR was defined as any repeated RCR procedure performed on the ipsilateral shoulder after the index procedure. Patients who underwent RCR or revision RCR without laterality specified were excluded.

RCR After Injection

Any patient who received a prior shoulder injection within 1 year of an ipsilateral RCR was included in the experimental group (injection group). Conversely, shoulders that underwent RCR but never received injections at any point prior to surgery were included in the control group (noninjection group). Basic demographic data were obtained for both groups. In addition, smoking status, obesity, and the mean Charlson Comorbidity Index (CCI)[19] were determined for both groups. The CCI is a commonly used adjustment index used to gauge a patient's health status, including comorbidities such as diabetes and heart failure, in a summative manner.[20]

To control for confounding variables, both groups were matched by age, sex, obesity, smoking status, and CCI. These matched study groups were then analyzed for revision RCR rates, the primary outcome measure. Two subanalyses were also performed to determine the temporal effects (time between last injection and RCR) and frequency effects (number of injections prior to RCR) of injections on the risk of revision RCR. In both subgroup analyses, the injection groups were again matched to the control group by age, sex, obesity, smoking status, and CCI.

Statistical Analysis

Revision RCR rates were compared using odds ratios (ORs) and confidence intervals (CIs). Statistical significance was set at $P < .05$ for all testing. Statistical tests were performed with Microsoft Excel (Microsoft, Redmond, WA) and STATA (StataCorp, College Station, TX).

Results

A total of 474,333 patients (491,751 shoulders) underwent primary RCR and met the inclusion and exclusion criteria. The demographic characteristics of the study groups are summarized in Table 1. Overall, 41.0% of patients who received shoulder injections had laterality coded. The existence of laterality coding for RCR varied from 77.7% to 85.7% based on surgical approach (open or arthroscopic) and insurance database (Medicare or Humana). An ipsilateral injection was performed in the year leading up to surgery in 22,375 shoulders (4.55%) (Table 1). Patients who received at least 1 injection in the year prior to surgery were more likely to be younger, to be female patients, to be obese, to have a smoking history, and to have a lower CCI (Table 1). Before matching, shoulders that received preoperative injections were at a statistically significantly increased odds of requiring revision RCR (OR, 1.52; 95% CI, 1.32-1.68; $P < .0001$). The increase in revisions was still significant when stratifying by surgical technique: arthroscopic RCR (OR, 1.59; 95% CI, 1.47-1.72; $P < .0001$) or open RCR (OR, 1.73; 95% CI, 1.55-1.92; $P < .0001$) (Fig 1). The overall revision rate for this unmatched study group, regardless of surgical approach, was 4.7% for patients who received injections and 3.0% for patients who did not receive injections ($P < .0001$). Of those who received injections prior to surgery, most received only 1 injection (72.4%), with 72.9% in the arthroscopic subgroup and 71% in the open subgroup (Fig 2).

Table 1. Demographic Data for Complete Study Group

	No Injection	Injection	*P* Value
Total No. of patients	452,324	22,009	
Total No. of shoulders	469,376	22,375	
Arthroscopic RCR*	290,390 (61.9%)	15,053 (67.3%)	
Open RCR*	178,986 (38.1%)	7,322 (32.7%)	
Age			.012†
<65 yr	86,346 (19.1%)	6,197 (28.2%)	
65-69 yr	151,358 (33.5%)	6,137 (27.9%)	
70-74 yr	109,816 (24.3%)	5,219 (23.7%)	
75-79 yr	65,117 (14.4%)	2,938 (13.3%)	
80-84 yr	25,206 (5.6%)	1,062 (4.8%)	
≥85 yr	6,101 (1.3%)	290 (1.3%)	
Unknown	8,380 (1.9%)	166 (0.8%)	
Sex			<.0001†
Female	220,829 (48.8%)	11,211 (50.9%)	
Male	223,114 (49.3%)	10,632 (48.3%)	
Unknown	8,381 (1.9%)	166 (0.8%)	
Obesity	117,213 (25.9%)	6,628 (30.1%)	<.0001†
Smoker	82,115 (18.2%)	4,381 (19.9%)	<.0001†
CCI	4.19 ± 2.08	3.45 ± 2.9	<.0001†

NOTE. Data are presented as number of patients or mean ± standard deviation unless otherwise indicated.

CCI, Charlson Comorbidity Index; RCR, rotator cuff repair.

*The numbers are reported based on the number of shoulders, not the number of patients.

†Statistically significant ($P < .05$).

In the matched analysis, the injection group consisted of 21,796 patients with RCRs (22,156 shoulders), with a median of 1 injection prior to RCR. The noninjection control group consisted of 22,053 patients with RCRs (again, 22,156 shoulders) who were matched for age, sex, obesity, smoking status, and CCI (Table 2). In a comparison between the matched groups, we found a significantly increased odds of revision in the injection group (OR, 1.52; 95% CI, 1.38-1.68; $P < .0001$) (Fig 3). The overall revision rate for this matched group was 4.7% for patients who received injections and 3.2% for patients who did not receive injections ($P < .0001$).

Effect of Time Duration Between Injection and RCR

The previously matched groups were used to investigate the effect of time between the last injection and surgery. The duration of time between injection and RCR was divided into 1-month increments and compared with matched controls in the noninjection group (Fig 4A). As stated previously, we found a statistically significantly increased odds of a revision after RCR if an injection was performed prior to index surgery. However, a significant effect of length of time between injection and RCR was also found. The highest odds of undergoing a revision was present if the injection and subsequent RCR were only separated by a month. There was a progressive decrease in the odds of needing a revision as the duration between injection and RCR lengthened; however, a statistically significantly increased odds of a subsequent revision was still found if the injection occurred 12 months prior to the RCR. This effect of time on revision risk was consistent across both arthroscopic RCR and open RCR (Fig 4 B and C, respectively).

Effect of Injection Frequency on RCR Revision

Finally, a subgroup analysis was performed to examine the effect of injection frequency on revision rate after index RCR (Fig 5). The results of this subgroup analysis showed a cumulative effect of injections prior to RCR. Although a single injection increased the odds of revision after index RCR (OR, 1.25; 95% CI, 1.10-1.43; $P < .0001$), patients who received 2 or more injections experienced an

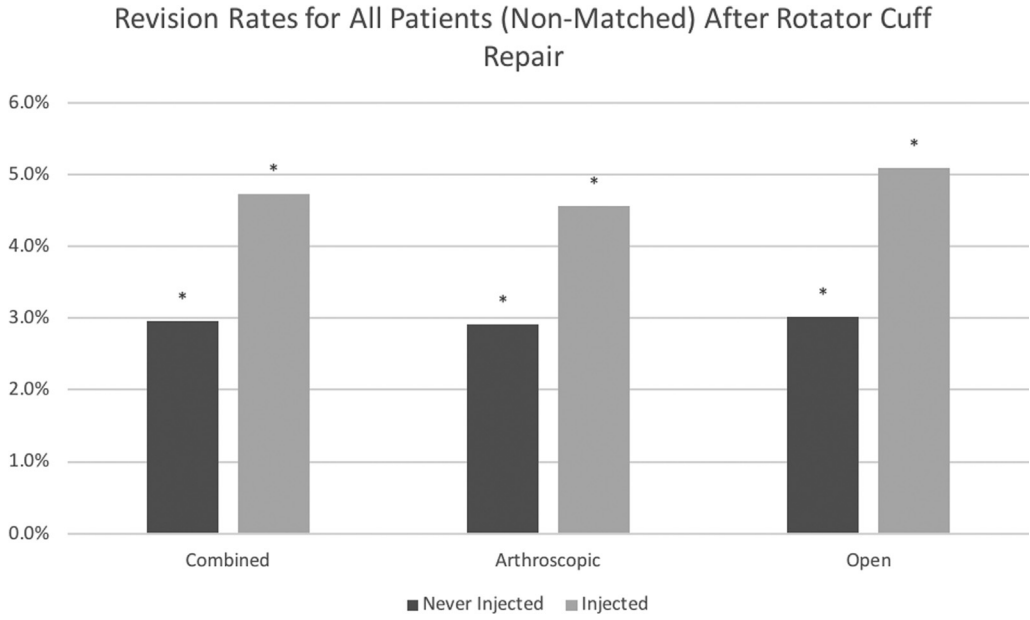

Fig 1. Comparison of rotator cuff revision rates between patients with preoperative injections and patients with no preoperative injections prior to index rotator cuff repair. Asterisks indicate significantly different ($P < .05$) revision rates between the injection and noninjection groups.

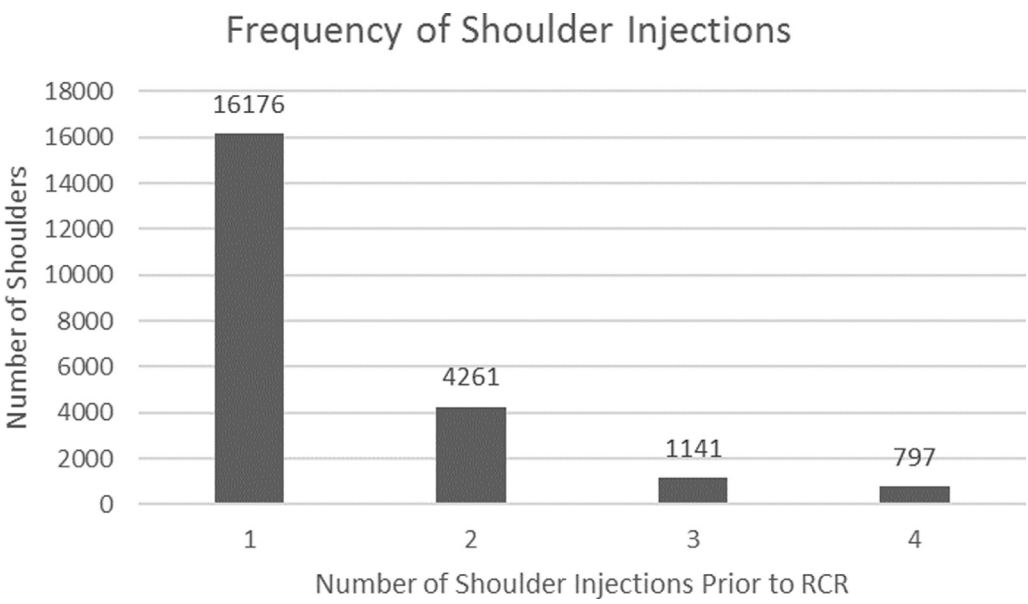

Fig 2. Frequency distribution by number of injections performed prior to rotator cuff repair (RCR) in injection group.

over 2-fold increased odds of undergoing a revision RCR after index RCR (OR, 2.12; 95% CI, 1.82-2.47; $P < .0001$). This effect of multiple injections on revision risk was consistent across both arthroscopic and open procedures (Fig 5). As previously stated, patients experienced a nearly 46.8% increased risk of revision RCR if they had received at least 1 injection prior to RCR (3.2% vs 4.7%), but with multiple injections, the effect size exceeded a 100% increase.

Table 2. Summary of Matched Study Groups

	No Injection	Injection	*P* Value
Total No. of patients	22,053	21,796	
Total No. of shoulders	22,156	22,156	
Arthroscopic RCR*	14,973	14,935	
Open RCR*	7,221	7,221	
Age			.980
<65 yr	6,170 (28%)	6,102 (28%)	
65-69 yr	6,148 (27.9%)	6,115 (28.1%)	
70-74 yr	5,277 (23.9%)	5,225 (24%)	
75-79 yr	2,955 (13.4%)	2,943 (13.5%)	
80-84 yr	1,058 (4.8%)	1,054 (4.8%)	
≥85 yr	252 (1.1%)	253 (1.2%)	
Unknown	193 (0.9%)	104 (0.5%)	
Sex			.761
Female	11,210 (50.8%)	11,111 (51%)	
Male	10,647 (48.3%)	10,526 (48.3%)	
Unknown	196 (0.9%)	159 (0.7%)	
Obesity	6,774 (30.7%)	6,640 (30.5%)	.566
Smoker	4,325 (19.6%)	4,274 (19.6%)	.994
CCI	3.4 ± 2.82	3.39 ± 2.82	.7090

NOTE. Data are presented as number of patients or mean ± standard deviation unless otherwise indicated. No difference was shown between the injection and noninjection study groups across age, sex, obesity, smoking status, and CCI.

CCI, Charlson Comorbidity Index; RCR, rotator cuff repair.

*The numbers are reported based on the number of shoulders, not the number of patients.

Discussion

The main finding of this study is that there is a strong correlation between preoperative shoulder injections and the need for revision RCR after the index RCR. In addition, there is a frequency dependence and time dependence to this finding, with more frequent injections and with administration of injections closer to the time of surgery both independently associated with higher revision RCR rates.

Injections are common and have garnered broad acceptance among nonoperative physicians and orthopaedic surgeons treating shoulder pain.[5,12] Recently, the substances available for injection have also broadened to include platelet-rich plasma, stem cells, and nonsteroidal anti-inflammatory drugs, as well as corticosteroids. Of these, corticosteroids are the most commonly injected substance and have been used preoperatively for conservative management and as an adjunct to surgical repair.[21-23] In one study, nearly 70% of patients undergoing arthroscopic repair for a partial-thickness RCT had received at least 1 CSI prior to surgery, and up to 19% of patients undergoing RCR receive a CSI after surgery.[23,24] Nonoperative physicians treating shoulder pain frequently turn to CSIs for management.[12] A survey found that 94% of general practitioners believe that subacromial CSIs are useful in the treatment of RC pathology.[12]

Despite their availability and widespread acceptance, corticosteroids remain controversial in the context of RC disease. The biological evidence that high-dose and/or high-frequency CSIs can irreparably damage the tendon-bone interface is well elucidated.[13-15,17] Receiving multiple CSIs has been cited as a cause of poor biological healing, regardless of their effect on outcomes, by the American Academy of Orthopaedic

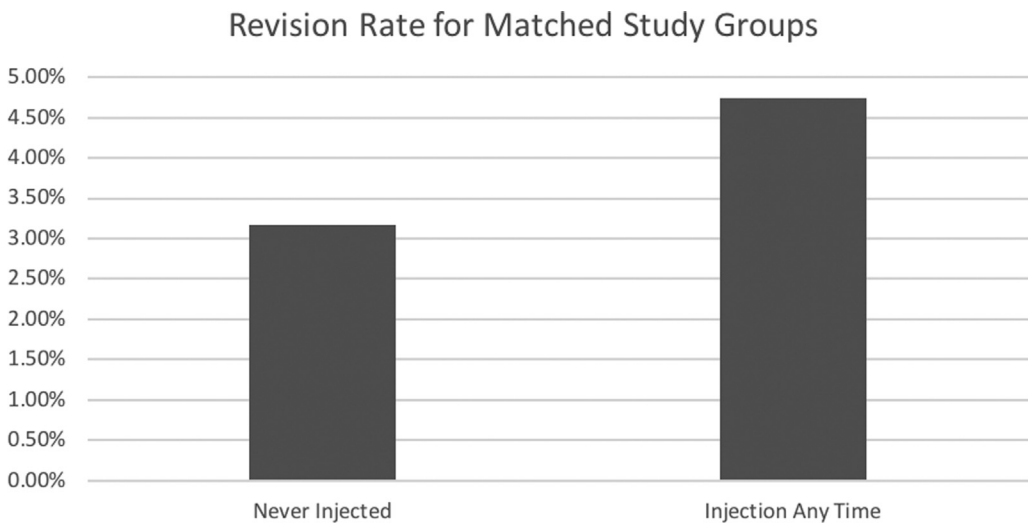

Fig 3. Overall odds ratio for revision in matched injection group: 1.52 (95% confidence interval, 1.38-1.68; $P < .0001$).

Surgeons in their guidelines for optimizing the management of full-thickness RCTs.[25]

These warnings are grounded in studies indicating that corticosteroids may alter collagen composition and extracellular matrix, thereby interfering with the healing process in the setting of an acute tendon tear.[26] Mikolyzk et al.[15] noted that a single dose of corticosteroids significantly weakens both intact and injured RC tendons. Repeated injections may lead to further tissue compromise and deterioration at the tendon-bone interface.[14] In the context of an RCR, this may lead to weakening at the repair site that goes undetected by the treating surgeon at the time of RCR. A biomechanical study showed that suture anchor pullout strength is transiently decreased after CSIs.[13] On the basis of the current body of evidence, the increased likelihood of revision RCR after preoperative shoulder injections may be partially attributed to the soft-tissue damage caused by corticosteroid administration.

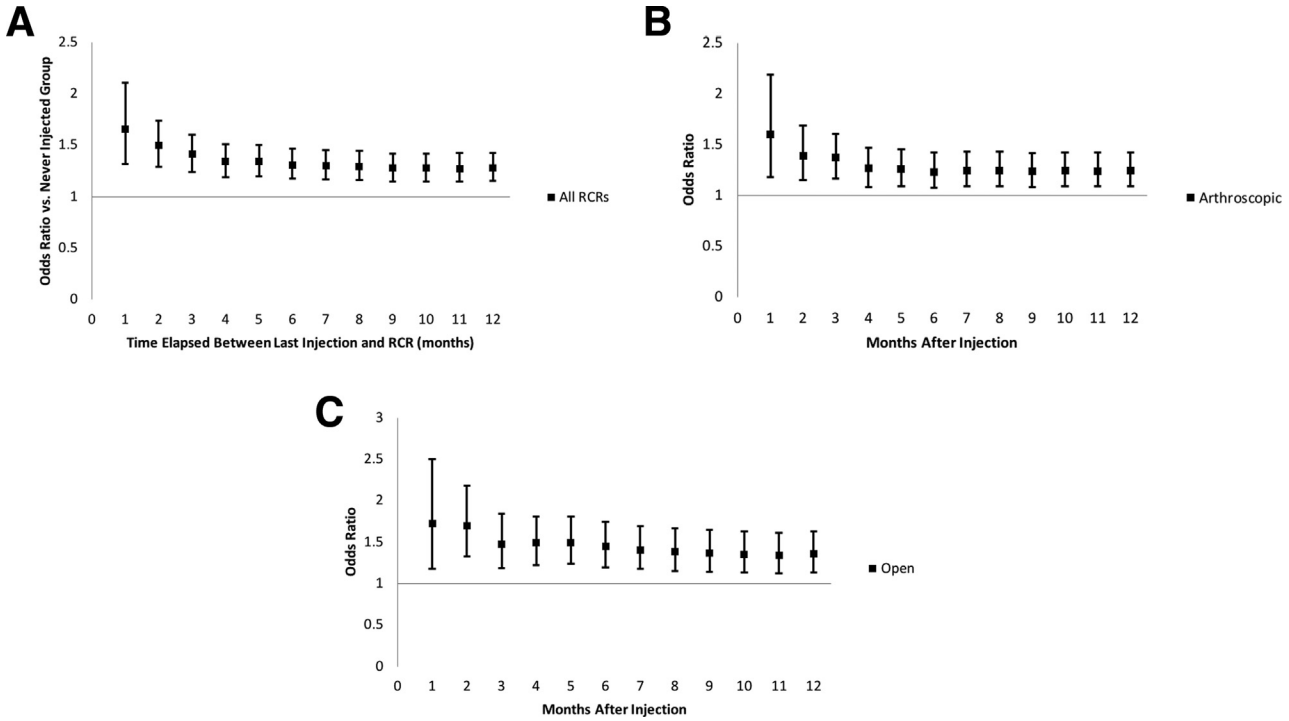

Fig 4. (A) Odds ratio for rotator cuff repair (RCR) revision in patients who received injections compared with controls who never received injections, with pooled arthroscopic and open procedures. (B) Odds ratio for arthroscopic RCR revision rate in patients who received injections compared with controls who never received injections. (C) Odds ratio for open RCR revision rate in patients who received injections compared with controls who never received injections.

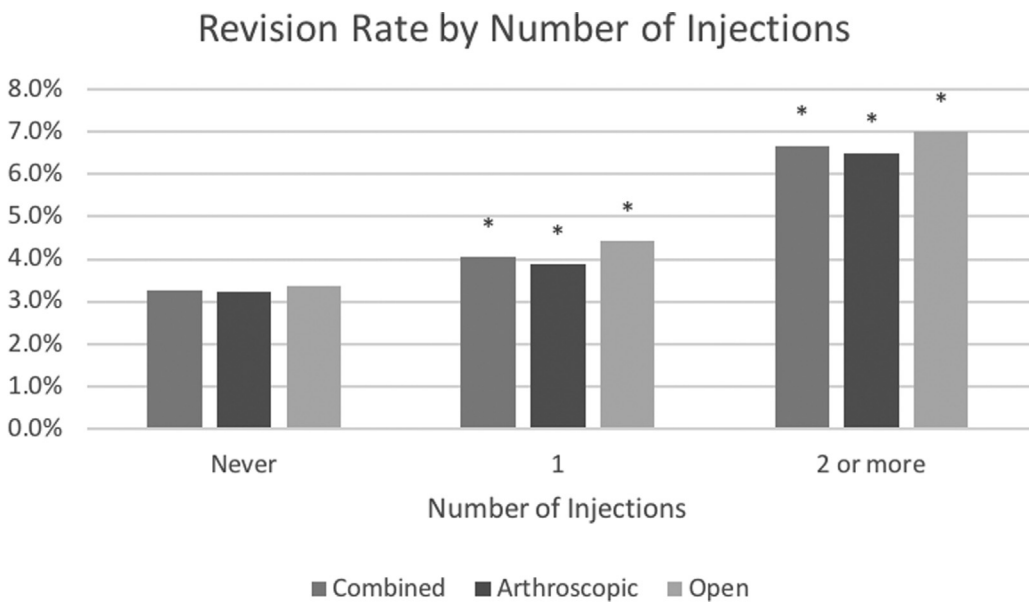

Fig 5. Revision rate, odds ratio (OR), and 95% confidence interval (CI) by injection count against matched group (matched for Charlson Comorbidity Index, age, sex, and smoking status). Asterisks indicate significant differences ($P < .05$) relative to shoulders that never received injections. For all rotator cuff repairs (RCRs) (medium gray), 1 injection versus no injection showed an OR of 1.25 (95% CI, 1.10-1.43; $P < .0001$) and 2 or more injections versus no injection showed an OR of 2.12 (95% CI, 1.82-2.47; $P < .0001$). For arthroscopic RCRs (dark gray), 1 injection versus no injection showed an OR of 1.21 (95% CI, 1.06-1.39; $P = .0068$) and 2 or more injections versus no injection showed an OR of 2.09 (95% CI, 1.79-2.45; $P < .0001$). For open RCRs (light gray), 1 injection versus no injection showed an OR of 1.33 (95% CI, 1.04-1.69; $P = .0042$) and 2 or more injections versus no injection showed an OR of 2.16 (95% CI, 1.63-2.86; $P < .0001$).

Despite emerging evidence surrounding the potential deleterious effects of CSIs on tendon integrity, they remain a common management modality for RC and shoulder pathology. However, the clinical results of their use are mixed, and it may be that patients and providers are sacrificing long-term outcomes for short-term gains in pain relief.[4,22,27,28] Perdreau and Joudet[28] investigated CSIs for postoperative pain relief as part of a multimodal approach to analgesia after RC surgery. In the first 48 hours after RCR, intra-articular injection with morphine and methylprednisolone was shown to decrease pain intensity, reduce the use of intravenous morphine, and increase the time to first intravenous morphine bolus without altering the complication or infection risk.[28] This study had a very short follow-up period (4.5 months) and the functional scores were no different at the study end point, thus making it impossible to evaluate whether the improvements in the immediate postoperative period warrant any long-term risks of functional deterioration, failure, or ultimately, revision. In another study of pain and function after RCR, Shin et al.[22] found that severe, persistent pain (>1 month) can be effectively treated with a single postoperative CSI and reported no apparent deleterious effects from the steroid injection with no RCR failures as measured by postoperative magnetic resonance imaging. However, the difference in pain reduction and functional improvement between patients who received injections and controls was absent just 1 month after CSIs. Although this study benefited from a longer follow-up period (2 years), the sample size was relatively small (just 72 patients received injections), which may make it difficult to detect the contribution of CSIs to the failure or revision rate. Donohue et al.[24] reported improved function after RCR for patients who received a preoperative CSI, and this effect was largest for those who received the injection within 3 months prior to surgery. However, pain scores were equivalent with those of controls, and this retrospective study suffered from a small sample size and short follow-up. Our study overcomes many of the limitations of these prior studies by reporting a much larger sample size.

In the nonoperative setting, CSIs may also decrease pain and improve function, but the results are temporary and may not be altogether benign given their soft-tissue effects. A meta-analysis of CSIs for conservative management of RCTs did show a small but transient decrease in pain scores, but this disappeared by 3 months and was not benefited by multiple injections.[4] Furthermore, Alvarez et al.[29] found in a Level I randomized controlled trial that a CSI was no more effective than an analgesic injection. Ramirez et al.[30] reported that among patients given a CSI for

partial-thickness RCTs, deterioration to full-thickness tears occurred in 17% of cases, which was significantly greater than in controls. It remains unclear whether patients who receive injections for RC pathology without clear evidence of a tear go on to more rapid progression of disease.[31] It must also be remembered that in certain patient populations, additional caution is warranted given the risk of negative effects, such as hyperglycemia in diabetic patients.[32] This study adds to the existing evidence that shoulder injections should be used judiciously in the treatment of RC pathology. The strengths of this study are its large, national sample size and matched-group analysis. These findings corroborate basic science literature that warns of harmful biomechanical and biological effects of CSIs on RC tendons.[13-17,33,34]

Limitations

Reliance on coding accuracy is a weakness of this study, as with any retrospective database study, although rigorous inclusion and exclusion criteria were applied to minimize this problem. Because of the demographic involved, eliminating patients with any history of knee or hip problems at any time point reduces the sizes of the study groups too much to perform a thorough analysis. In addition, the study could not control for duration of symptoms prior to RCR, tear size, tear pattern, repair technique, tissue quality, reason for revision, Workers' Compensation status, and adherence to postoperative rehabilitation protocols. Because patients were not evaluated clinically, it is not possible to know how many patients with suboptimal functional outcomes from either group simply elected not to undergo revision surgery. Similarly, the exact medication and dose injected in each patient cannot be determined because of CPT coding limitations and must rely on inference from existing studies. It must also be noted that only about 5% of patients in this study received a shoulder injection within the year prior to RCR. This seemingly low rate compared with the historical reported frequency of injections in RC tendinopathy may be due to patients having received injections outside of the 1-year window. Finally, although not a per se limitation, it is important to note that *P* values can be disproportionately magnified in a very large study sample.[35]

Conclusions

This study strongly suggests a correlation between preoperative shoulder injections and revision RCR. There is also a frequency dependence and time dependence to this finding, with more frequent injections and with administration of injections closer to the time of surgery both independently associated with higher revision RCR rates. Presently, on the basis of this retrospective database study, orthopaedic surgeons should exercise due caution regarding shoulder injections in patients whom they are considering to be surgical candidates for RCR.

References

1. Aleem AW, Brophy RH. Outcomes of rotator cuff surgery: What does the evidence tell us? *Clin Sports Med* 2012;31:665-674.
2. Cook T, Minns Lowe C, Maybury M, Lewis JS. Are corticosteroid injections more beneficial than anaesthetic injections alone in the management of rotator cuff-related shoulder pain? A systematic review. *Br J Sports Med* 2018;52:497-504.
3. Weiss LJ, Wang D, Hendel M, Buzzerio P, Rodeo SA. Management of rotator cuff injuries in the elite athlete. *Curr Rev Musculoskelet Med* 2018;11:102-112.
4. Mohamadi A, Chan JJ, Claessen FM, Ring D, Chen NC. Corticosteroid injections give small and transient pain relief in rotator cuff tendinosis: A meta-analysis. *Clin Orthop Relat Res* 2017;475:232-243.
5. Abdul-Wahab TA, Betancourt JP, Hassan F, et al. Initial treatment of complete rotator cuff tear and transition to surgical treatment: Systematic review of the evidence. *Muscles Ligaments Tendons J* 2016;6:35-47.
6. Min KS, St Pierre P, Ryan PM, Marchant BG, Wilson CJ, Arrington ED. A double-blind randomized controlled trial comparing the effects of subacromial injection with corticosteroid versus NSAID in patients with shoulder impingement syndrome. *J Shoulder Elbow Surg* 2013;22:595-601.
7. Eliasberg CD, Dar A, Jensen AR, et al. Perivascular stem cells diminish muscle atrophy following massive rotator cuff tears in a small animal model. *J Bone Joint Surg Am* 2017;99:331-341.
8. Jo CH, Lee SY, Yoon KS, Shin S. Effects of platelet-rich plasma with concomitant use of a corticosteroid on tenocytes from degenerative rotator cuff tears in interleukin 1beta-induced tendinopathic conditions. *Am J Sports Med* 2017;45:1141-1150.
9. Zhang JY, Fabricant PD, Ishmael CR, Wang JC, Petrigliano FA, Jones KJ. Utilization of platelet-rich plasma for musculoskeletal injuries: An analysis of current treatment trends in the United States. *Orthop J Sports Med* 2016;4:2325967116676241.
10. Shams A, El-Sayed M, Gamal O, Ewes W. Subacromial injection of autologous platelet-rich plasma versus corticosteroid for the treatment of symptomatic partial rotator cuff tears. *Eur J Orthop Surg Traumatol* 2016;26:837-842.
11. Kweon C, Gagnier JJ, Robbins CB, Bedi A, Carpenter JE, Miller BS. Surgical versus nonsurgical management of rotator cuff tears: Predictors of treatment allocation. *Am J Sports Med* 2015;43:2368-2372.
12. Johansson K, Oberg B, Adolfsson L, Foldevi M. A combination of systematic review and clinicians' beliefs in interventions for subacromial pain. *Br J Gen Pract* 2002;52:145-152.
13. Dolkart O, Chechik O, Bivas A, et al. Subacromial corticosteroid injections transiently decrease suture anchor pullout strength: Biomechanical studies in rats. *J Shoulder Elbow Surg* 2017;26:1789-1793.

14. Maman E, Yehuda C, Pritsch T, et al. Detrimental effect of repeated and single subacromial corticosteroid injections on the intact and injured rotator cuff: A biomechanical and imaging study in rats. *Am J Sports Med* 2016;44:177-182.
15. Mikolyzk DK, Wei AS, Tonino P, et al. Effect of corticosteroids on the biomechanical strength of rat rotator cuff tendon. *J Bone Joint Surg Am* 2009;91:1172-1180.
16. Harada Y, Kokubu T, Mifune Y, et al. Dose- and time-dependent effects of triamcinolone acetonide on human rotator cuff-derived cells. *Bone Joint Res* 2014;3:328-334.
17. Dean BJ, Franklin SL, Murphy RJ, Javaid MK, Carr AJ. Glucocorticoids induce specific ion-channel-mediated toxicity in human rotator cuff tendon: A mechanism underpinning the ultimately deleterious effect of steroid injection in tendinopathy? *Br J Sports Med* 2014;48:1620-1626.
18. Hart L. Corticosteroid and other injections in the management of tendinopathies: A review. *Clin J Sport Med* 2011;21:540-541.
19. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. *J Clin Epidemiol* 1994;47:1245-1251.
20. Austin SR, Wong YN, Uzzo RG, Beck JR, Egleston BL. Why summary comorbidity measures such as the Charlson Comorbidity Index and Elixhauser score work. *Med Care* 2015;53:e65-e72.
21. Marks D, Bisset L, Comans T, et al. Increasing capacity for the treatment of common musculoskeletal problems: A non-inferiority RCT and economic analysis of corticosteroid injection for shoulder pain comparing a physiotherapist and orthopaedic surgeon. *PloS One* 2016;11:e0162679.
22. Shin SJ, Do NH, Lee J, Ko YW. Efficacy of a subacromial corticosteroid injection for persistent pain after arthroscopic rotator cuff repair. *Am J Sports Med* 2016;44:2231-2236.
23. Skedros JG, Adondakis MG, Knight AN, Pilkington MB. Frequency of shoulder corticosteroid injections for pain and stiffness after shoulder surgery and their potential to enhance outcomes with physiotherapy: A retrospective study. *Pain Ther* 2017;6:45-60.
24. Donohue NK, Prisco AR, Grindel SI. Pre-operative corticosteroid injections improve functional outcomes in patients undergoing arthroscopic repair of high-grade partial-thickness rotator cuff tears. *Muscles Ligaments Tendons J* 2017;7:34-39.
25. American Academy of Orthopaedic Surgeons. *Appropriate use criteria for optimizing the management of full-thickness rotator cuff tears*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2013.
26. Lee HJ, Kim YS, Ok JH, Lee YK, Ha MY. Effect of a single subacromial prednisolone injection in acute rotator cuff tears in a rat model. *Knee Surg Sports Traumatol Arthrosc* 2015;23:555-561.
27. Baverel L, Boutsiadis A, Reynolds RJ, Saffarini M, Barthélémy R, Barth J. Do corticosteroid injections compromise rotator cuff tendon healing after arthroscopic repair? *JSES Open Access* 2018;2:54-59.
28. Perdreau A, Joudet T. Efficacy of multimodal analgesia injection combined with corticosteroids after arthroscopic rotator cuff repair. *Orthop Traumatol Surg Res* 2015;101:S337-S345.
29. Alvarez CM, Litchfield R, Jackowski D, Griffin S, Kirkley A. A prospective, double-blind, randomized clinical trial comparing subacromial injection of betamethasone and xylocaine to xylocaine alone in chronic rotator cuff tendinosis. *Am J Sports Med* 2005;33:255-262.
30. Ramirez J, Pomes I, Cabrera S, Pomes J, Sanmarti R, Canete JD. Incidence of full-thickness rotator cuff tear after subacromial corticosteroid injection: A 12-week prospective study. *Mod Rheumatol* 2014;24:667-670.
31. Bhatia M, Singh B, Nicolaou N, Ravikumar KJ. Correlation between rotator cuff tears and repeated subacromial steroid injections: A case-controlled study. *Ann R Coll Surg Engl* 2009;91:414-416.
32. Moon HJ, Choi KH, Lee SI, Lee OJ, Shin JW, Kim TW. Changes in blood glucose and cortisol levels after epidural or shoulder intra-articular glucocorticoid injections in diabetic or nondiabetic patients. *Am J Phys Med Rehabil* 2014;93:372-378.
33. Gruson KI, Ruchelsman DE, Zuckerman JD. Subacromial corticosteroid injections. *J Shoulder Elbow Surg* 2008;17:118s-130s.
34. Honda H, Gotoh M, Kanazawa T, et al. Effects of lidocaine on torn rotator cuff tendons. *J Orthop Res* 2016;34:1620-1627.
35. Lin M, Lucas HC Jr, Shmueli G. Research commentary—Too big to fail: Large samples and the p-value problem. *Inf Syst Res* 2013;24:906-917.