## Title

Arthroscopic Rotator Cuff Repair Results in Lower Two-Year Reoperation Rates Compared With Open Rotator Cuff Repair in a Large Cross-sectional Cohort.



## Journal

Arthroscopy, sports medicine, and rehabilitation, 3(6)

## ISSN

2666-061X

## Authors

Truong, Nicole M
Cevallos, Nicolas
Lansdown, Drew A
et al.

## Publication Date

2021-12-01

## DOI

10.1016/j.asmr.2021.10.008

Original Article

# Arthroscopic Rotator Cuff Repair Results in Lower Two-Year Reoperation Rates Compared With Open Rotator Cuff Repair in a Large Cross-sectional Cohort

Nicole M. Truong, B.S., Nicolas Cevallos, B.S., Drew A. Lansdown, M.D., C. Benjamin Ma, M.D., Brian T. Feeley, M.D., and Alan L. Zhang, M.D.

**Purpose:** To use a large, contemporary database to perform a cross-sectional analysis of current practice trends in rotator cuff repair (RCR) for the treatment of full-thickness rotator cuff tear (RCT) and determine outcomes of arthroscopic and open RCR, including hospital readmissions and 2-year reoperation rates with accurate laterality tracking using *International Classification of Diseases*, Tenth Revision (ICD-10) codes. **Methods:** The PearlDiver Mariner dataset was used to query patients with full-thickness RCTs from 2010 to 2017. Propensity-score matching was performed to account for differences in age and comorbidities and allow for comparison between those undergoing open RCR and arthroscopic RCR. Subsequent procedures were tracked using ICD-10 codes to identify ipsilateral surgery within 2 years of index surgery. Hospital and emergency department admission within 30 days of surgery were investigated. **Results:** Of 534,076 patients diagnosed with full-thickness RCT, 37% underwent RCR; 73% of which were arthroscopic. From 2010 to 2017, arthroscopic RCRs increased from 65% to 80%, whereas open RCRs decreased from 35% to 20% ($P < .0001$). Younger patients underwent arthroscopic RCR more frequently, and patients who underwent open RCR had greater rates of 30-day emergency department (7.0%) and hospital readmission (2.0%) compared with arthroscopic RCR (6.3%, 1.0%, respectively) ($P < .0001$). For 24,392 patients with ICD-10 coding and 2-year follow-up, 10.4% of patients required reoperation, with the most common procedure being revision RCR, and 1.3% required conversion to arthroplasty. Open RCRs were more likely to require subsequent surgery (11.3%) compared with arthroscopic RCR (9.5%) ($P < .0001$). Patients aged 50 to 59 had the greatest rate of reoperation (14.0%), but no patients younger than age 40 years required reoperation, and no patients younger than age 50 years required conversion to arthroplasty. **Conclusions:** The frequency of arthroscopic RCR has continued to increase compared to open RCR. In this large cross-sectional analysis, arthroscopic RCR demonstrated lower 2-year reoperation rates and 30-day readmission rates compared to open RCR. **Level of Evidence:** III, cross-sectional study.

*Department of Orthopaedic Surgery, University of California-San Francisco, San Francisco, California, U.S.A.*

*The authors report the following potential conflicts of interest or sources of funding: D.A.L. reports grants from Arthrex and Smith & Nephew, outside the submitted work. C.B.M. reports grants from Anika, personal fees from ConMed Linvatec, grants and personal fees from Histogenics, personal fees from Medacta, grants from Samumed, personal fees from SLACK and Stryker, grants from Zimmer, and personal fees from Tornier, outside the submitted wor. B.T.F reports Associate Editor for the Journal of Shoulder and Elbow Surgery and research funding from the National Institutes of Health. A.L.Z. reports personal fees from Stryker and DePuy Mitek, outside the submitted work. Full ICMJE author disclosure forms are available for this article online, as supplementary material.*

*Received June 19, 2021; accepted October 19, 2021.*

*Address correspondence to Alan L. Zhang, M.D., 1500 Owens St., Box 3004, San Francisco, CA 94158. E-mail: alan.zhang@ucsf.edu*



*2666-061X/21900*

*https://doi.org/10.1016/j.asmr.2021.10.008*

Rotator cuff tears (RCTs) have been described as one of the most common shoulder injuries associated with increasing age,[1,2] with an estimated occurrence in 30% of adults older than age 60 years and 62% of adults older than age 80 years.[3] As such, rotator cuff repair (RCR) surgery has become one of the most frequently performed shoulder procedures in orthopaedic surgery.[1,2] The exact incidence of RCTs and RCRs in the United States is currently unknown, but Mather et al.[1] estimated that, as of 2013, RCTs accounted for more than 4.5 million hospital visits in the US each year and more than 250,000 RCRs were performed annually. The implementation of administrative claims databases and Current Procedural Technology (CPT) codes has helped to increase the amount of information available regarding this topic.[4,5] For example, Colvin et al.[6] used the National Hospital Discharge Survey and the National Survey of

**Table 1.** Distribution of Patients With Complete Rotator Cuff Tear Diagnosis Undergoing Rotator Cuff Repair by Year, Age Group, and Sex

| | Number of Patients With Complete Rotator Cuff Tear Diagnosis | Number of Patients Undergoing Rotator Cuff Repair | Percent of Patients Undergoing Rotator Cuff Repair | *P* Value |
|---|---|---|---|---|
| Total | 534,076 | 196,518 | 36.8% | |
| Age group, y | | | | |
| 10-19 | 1,478 | 79 | 5.3% | |
| 20-29 | 3,529 | 357 | 10.1% | |
| 30-39 | 13,969 | 3,657 | 26.2% | |
| 40-49 | 67,027 | 26,105 | 38.9% | |
| 50-59 | 165,590 | 72,590 | 43.8% | |
| 60-69 | 190,391 | 85,264 | 44.8% | |
| 70-79 | 135,094 | 48,559 | 35.9% | <.0001 |
| Sex | | | | |
| Female | 259,920 | 92,347 | 35.5% | |
| Male | 274,154 | 104,171 | 38.0% | <.0001 |

Ambulatory Surgery databases and found that the volume of all RCRs increased by 141% from 1996 to 2006.

The prevalence and continued increase in incidence of RCTs and RCRs necessitates further evaluation of surgical treatments. Previous studies have indicated that there has been a large rise in the use of arthroscopic surgery compared with open surgery to repair RCTs. A study conducted by Day et al. examined the Humana insurance database and found that between 2007 and 2015, the proportion of arthroscopic RCR surgeries increased from 56.9% to 75.1%.[7] Studies using the National Surgical Quality Improvement Program database found that, between 2005 and 2014, patients who underwent arthroscopic RCR demonstrated a 0.5% lower risk of infection or hospital readmission within 30 days postoperatively.[8,9] Jensen et al.[10] found similar results using the Medicare claims database of 372,109 patients who underwent RCR, with 0.86% of patients undergoing open repair diagnosed with an infection within 6 months compared with 0.37% of those who received arthroscopic repair.

Previous research has yielded conflicting results regarding longer-term outcomes of arthroscopic RCR compared with open RCR, particularly with respect to rates of revision surgery. In a prospective cohort study of 72 patients, Millar et al.[11] found similar rates of revision (10%) following open or arthroscopic RCR

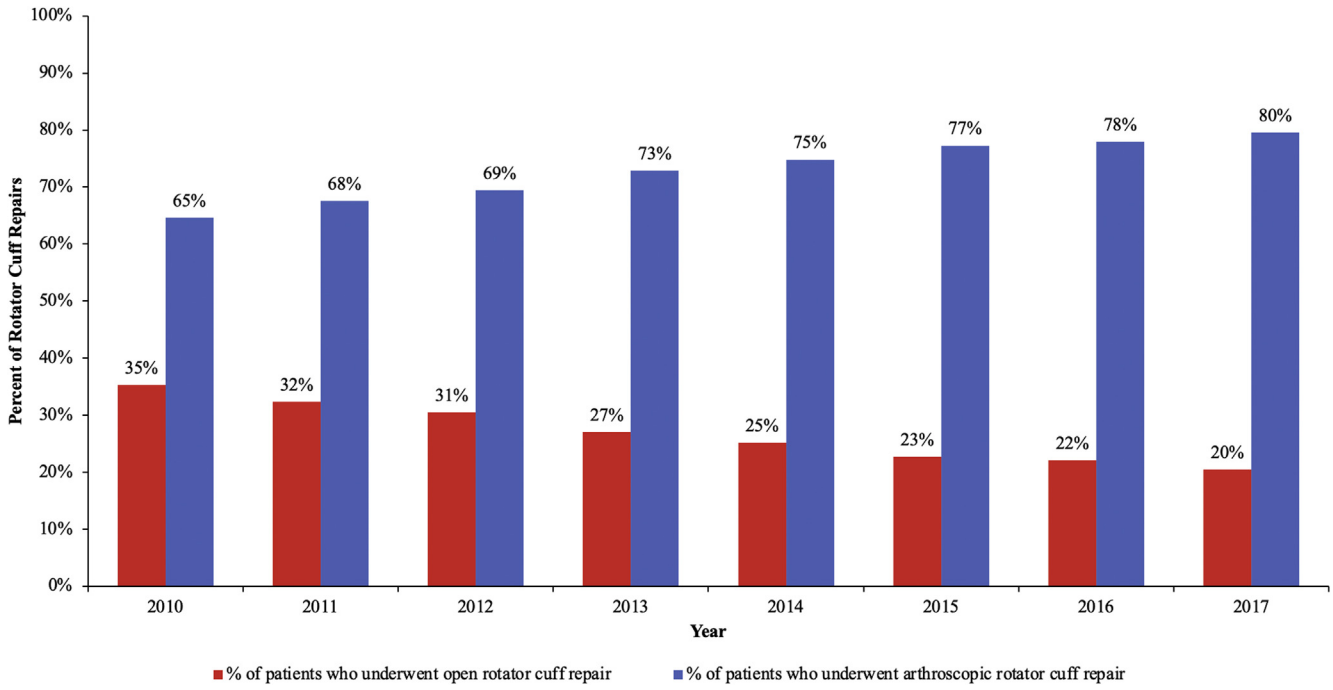


**Fig 1.** Rotator cuff repair trends by year. The percentage of patients undergoing arthroscopic or open rotator cuff repair is shown by year.

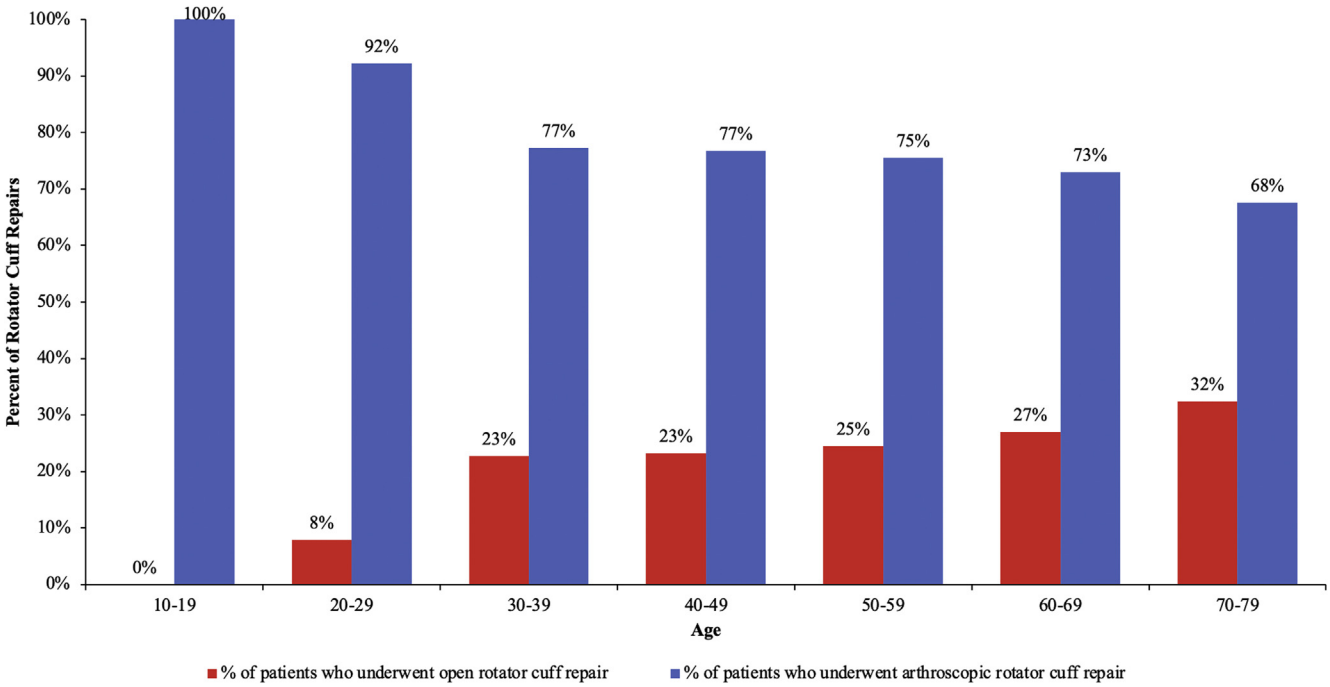


**Fig 2.** Rotator cuff repair trends by age. The percentage of patients undergoing arthroscopic or open rotator cuff repair is shown by age group.

within 6- to 24-month follow-up. Database studies that used the Humana, MarketScan Commercial Claims and Encounters, or New York Statewide Planning and Research Cooperative System database found revision rates between 2.9% and 7.41% within 2 years, which reached 9.6% within 5 years following arthroscopic RCR only.[12-15] However, previous database studies did not compare rates of reoperation between arthroscopic and open RCR and are limited in the ability to accurately track revision surgeries due to a lack of laterality tracking with *International Classification of Diseases* of the Ninth Revision (ICD-9) diagnosis codes.

The purpose of this study is to use a large, contemporary database to perform a cross-sectional analysis of current practice trends in RCR for the treatment of full-thickness RCT and determine outcomes of arthroscopic and open RCR, including hospital readmissions and 2-year reoperation rates with accurate laterality tracking using ICD-10 codes. We hypothesized that arthroscopic RCR would continue to increase in frequency and result in lower reoperation and readmission rates compared with open RCR.

## Methods

This cross-sectional analysis used the Mariner dataset (PearlDiver Technologies, Colorado Springs, CO), a national orthopaedic database containing more than 122 million deidentified patient records from 2010 to 2020. Institutional review board approval was exempt from this study due to analysis of only de-identified data. CPT and ICD-9 and *International Classification of Diseases*, Tenth Revision (ICD-10) were used to query patient records. The PearlDiver collection consists of government, cash, and various private insurance patient populations. To acquire the requested demographic parameters and subsequent analysis of demographic trends, such as 10-year age groups, year of service, comorbidities, and patient sex, ICD and/or CPT codes were searched separately or in combination.

Patients with full-thickness RCT pathology were identified with ICD-9 and ICD-10 codes (Appendix Table 1, available at www.arthroscopyjournal.org). RCR procedures were divided by CPT codes into arthroscopy (CPT-29827) or open surgery (CPT-23410, CPT-23412, CPT-23420). Propensity score matching was then performed between these 2 cohorts to account for any differences in age, Charlson Comorbidity Index, tobacco use, diabetes, and heart disease. Propensity score matching ensures covariates are similar between 2 cohorts, which allows for one-to-one or pair matching between individuals, and analysis of a score matched sample can be used for direct comparison of outcomes.[16] The years 2010 through 2017 were incorporated to query for patients undergoing RCR surgery. Patients from 2018 through 2020 were excluded because they failed to meet criteria for 2-year follow-up. PearlDiver consists of a distinct code in each query to allow for patient tracking without counting multiple patient occurrences. Furthermore, as laterality was ensured via ICD-10 codes to confirm the subsequent procedure was on the ipsilateral side of the index surgery, only

**Table 2.** ED and Hospital Readmission Rates After Rotator Cuff Repair by Age Group and Sex

| | Percentage of Patients with ED Admission within 30-days of Arthroscopic Rotator Cuff Repair | Percentage of Patients with ED Admission within 30-days of Open Rotator Cuff Repair | *P* Value | Percentage of Patients with Hospital Readmission within 30 Days of Arthroscopic Rotator Cuff Repair | Percentage of Patients with Hospital Readmission Within 30 Days of Open Rotator Cuff Repair | *P* Value |
|---|---|---|---|---|---|---|
| Total | 6.3% | 7.0% | <.0001 | 1.0% | 2.0% | <.0001 |
| Age group, y | | | | | | |
| 10-19 | 0.0% | 0.0% | | 0.0% | 0.0% | |
| 20-29 | 0.7% | 0.0% | | 0.0% | 0.0% | |
| 30-39 | 9.0% | 10.7% | | 0.0% | 0.0% | |
| 40-49 | 6.6% | 7.7% | | 0.7% | 1.2% | |
| 50-59 | 5.1% | 6.2% | | 0.7% | 1.4% | |
| 60-69 | 4.5% | 5.3% | | 0.8% | 1.5% | |
| 70-79 | 5.9% | 5.7% | | 1.0% | 2.6% | |
| Sex | | | | | | |
| Female | 6.6% | 7.1% | | 1.0% | 2.0% | |
| Male | 6.0% | 6.8% | | 1.0% | 2.1% | |

ED, emergency department.

patients from years when ICD-10 coding was available (2015-2017) were tracked for subsequent procedures. Appendix Table 2, available at www.arthroscopyjournal.org, demonstrates the subsequent surgeries examined within 2 years following index surgery. In addition, demographic data for adverse advents, such as hospital readmission and ED admission within 30-days of index RCR, also were analyzed.

The Cochran–Armitage independence test for trend was used for categorical data analysis to assess for the presence of an association between age group or year and the number of procedures done. $\chi^2$ tests were performed to determine whether age group or sex had any independent effect on rates of readmission or revision surgery, as well as to analyze if the type of index surgery (open or arthroscopic RCR) had any independent effect on rates of revision surgery or conversion to shoulder arthroplasty. GraphPad Prism Statistics/Data Analysis software, (GraphPad Software, Inc., La Jolla, CA) was used for statistical analysis. $P < .05$ was considered statistically significant.

## Results

In total, 534,076 patients were identified with a full-thickness RCT diagnosis between 2010 and 2017. Of these patients, 196,518 (36.8%) underwent RCR surgery (Table 1). In total, 53,531 of these procedures (27.2%) were performed using an open approach, and 142,987 (72.8%) were performed using an arthroscopic approach. Between 2010 and 2017, the percent of

**Table 3.** Distribution of Patients Undergoing Revision Surgery Within 2 Years Following Rotator Cuff Repair

| | Number of Patients Undergoing Rotator Cuff Repair | Number of Patients Undergoing Revision Surgery | Percent of Patients Undergoing Revision Surgery | *P* Value | Number of Patients Requiring Conversion to Shoulder Arthroplasty | Percent of Patients Requiring Conversion to Shoulder Arthroplasty | *P* Value |
|---|---|---|---|---|---|---|---|
| Total | 24,392 | 2,537 | 10.4% | | 316 | 1.3% | |
| Index surgery | | | | | | | |
| Open index rotator cuff repair | 12,196 | 1,376 | 11.3% | | 162 | 1.3% | |
| Arthroscopic index rotator cuff repair | 12,196 | 1,161 | 9.5% | <.0001 | 154 | 1.3% | .65 |
| Age group, y | | | | | | | |
| 10-19 | 0 | 0 | 0.0% | | 0 | 0.0% | |
| 20-29 | 0 | 0 | 0.0% | | 0 | 0.0% | |
| 30-39 | 219 | 0 | 0.0% | | 0 | 0.0% | |
| 40-49 | 2,181 | 230 | 10.5% | | 0 | 0.0% | |
| 50-59 | 6,927 | 968 | 14.0% | | 32 | 0.5% | |
| 60-69 | 9,334 | 1,200 | 12.9% | | 132 | 1.4% | |
| 70-79 | 5,653 | 435 | 7.7% | <.0001 | 130 | 2.3% | <.0001 |
| Sex | | | | | | | |
| Female | 11,464 | 1,134 | 9.9% | | 184 | 1.6% | |
| Male | 12,928 | 1,403 | 10.9% | <.0001 | 132 | 1.0% | .0034 |

arthroscopic RCRs increased from 65% to 80%, whereas the percent of open RCRs decreased from 35% to 20% (Fig 1; $P < .0001$). Patients aged 60 to 69 years had the greatest frequency of RCTs and RCRs (45%) (Fig 2). Young patients underwent arthroscopic repair more than open surgery (100% in 10- to 19-year age group and 92% in 20- to 29-year age group) (Fig 2). Male patients had a greater incidences of complete RCT and underwent surgical repair at slightly greater rates (38.0%) compared with female patients (35.5%; Table 1; $P < .0001$). The rate of arthroscopic (72.8%) versus open surgery (27.2%) was similar for both male and female patients.

Within 30 days of surgery, 7.0% of patients who underwent open RCR required subsequent ED admission and 2.0% required hospital readmission (Table 2). Both rates were significantly greater compared with that of patients who underwent arthroscopic RCR at 6.3% and 1.0%, respectively (Table 2; $P < 0.0001$). Hospital readmissions risk increased with age, as patients aged 70 to 79 years had the greatest frequency with 2.6% following open RCR and 1.0% following arthroscopic RCR (Table 2). Rates of readmission were similar between male and female patients (Table 2).

After propensity score matching, between 2015 and 2017, 24,392 patients with ICD-10 codes for laterality tracking underwent RCR, and 2,537 (10.4%) of these individuals required at least one revision surgery (Table 3). In total, 316 patients within this group required conversion to shoulder arthroplasty (1.3%; Table 3). Individuals who underwent initial open RCR required significantly greater rates of revision surgery (11.3%) compared with those who underwent initial arthroscopic RCR (9.5%) (Table 3; $P < .0001$). Rates of conversion to shoulder arthroplasty were 1.3% following either open or arthroscopic RCR ($P = .65$; Table 3). In total, 84% of revision procedures following index arthroscopic surgery were performed arthroscopically, and 16% were performed with an open approach. In comparison, for revision procedures following initial open RCR, 52% were performed using an open approach whereas 48% were performed arthroscopically. Male patients had greater rates of revision surgery (10.9%) than female patients (9.9%) (Table 3; $P < .0001$), but lower rates of conversion to shoulder arthroplasty (1.0% vs 1.6%) (Table 3; $P = .0034$).

Patients aged 50 to 59 years underwent subsequent revision procedures most frequently (14.0%), followed by those aged 60 to 69 years (12.9%), 40 to 49 years (10.5%), and 70 to 79 years (7.7%) (Table 3; $P < .0001$). No patients younger than 40 years of age underwent revision surgery after RCR, and all patients requiring reoperation underwent arthroscopic revision more frequently than open revision (Fig 3). The greatest frequency of conversion to shoulder arthroplasty occurred within patients aged 70 to 79 years (2.3%), whereas no patients younger than 50 years of age required conversion to shoulder arthroplasty (Table 3; $P < .0001$). Of the patients undergoing revision surgery after an index arthroscopic RCR, 58.4% had arthroscopic revision RCR and 46.7% had arthroscopic subacromial decompression (Table 4). Open revision RCR accounted for 57.0%, whereas arthroscopic subacromial decompression accounted for 25.5% of revision surgeries following an index open RCR (Table 4).

## Discussion

In this study, we found that rates of arthroscopic RCR incrementally increased annually while rates of open RCR decreased from 2010 to 2017. In addition, open RCR demonstrated a greater reoperation rate than arthroscopic RCR after propensity score matching.

Overall, we found that 73% of RCRs were performed arthroscopically and 27% were performed using an open approach, with the rate of arthroscopic RCR increasing through 2017. These trends are similar to those found in older database studies. Between 2004 and 2017, the percentage of arthroscopic RCRs ranged between 65% to 85%, and the percentage of open RCRs ranged between 15% and 35% depending on the database and ICD codes used for query.[7-10,17,18] Several studies have noted a rise in incidence of arthroscopic RCRs and corresponding decline in incidence of open RCRs.[6,7,10,18,19] Zhang et al.[18] and Day et al.[7] found that the proportion of open RCR increased with increasing patient age, and Day et al.[7] also found no significant difference between male and female patients in the proportion of arthroscopic or open surgeries,[7] which aligned with our current study's results.

We found an overall revision rate of 10.4 % for RCR from 24,392 patients within 2 years of index surgery. The most common subsequent procedure after arthroscopic or open index surgery by far was revision RCR, which was similar to a previous report by Mahure et al.[13] Although no patients younger than age 40 years underwent reoperation, our overall rate of reoperation was higher than those found in previously reported database studies, which looked at revision rates following arthroscopic RCR only. One study using the New York Statewide Planning and Research Cooperative System database of index arthroscopic RCR found a 6% arthroscopic revision rate of their total population of 30,430 patients within 2 years.[13] It is possible that our study showed greater reoperation rates because our cohort only included patients with diagnoses of full-thickness RCTs. Previous database studies used CPT and ICD-9 procedure codes to track patients and therefore were unable to determine whether tears were partial or complete. Full-thickness tear diagnoses may be more likely to select for large and massive cuff tears,

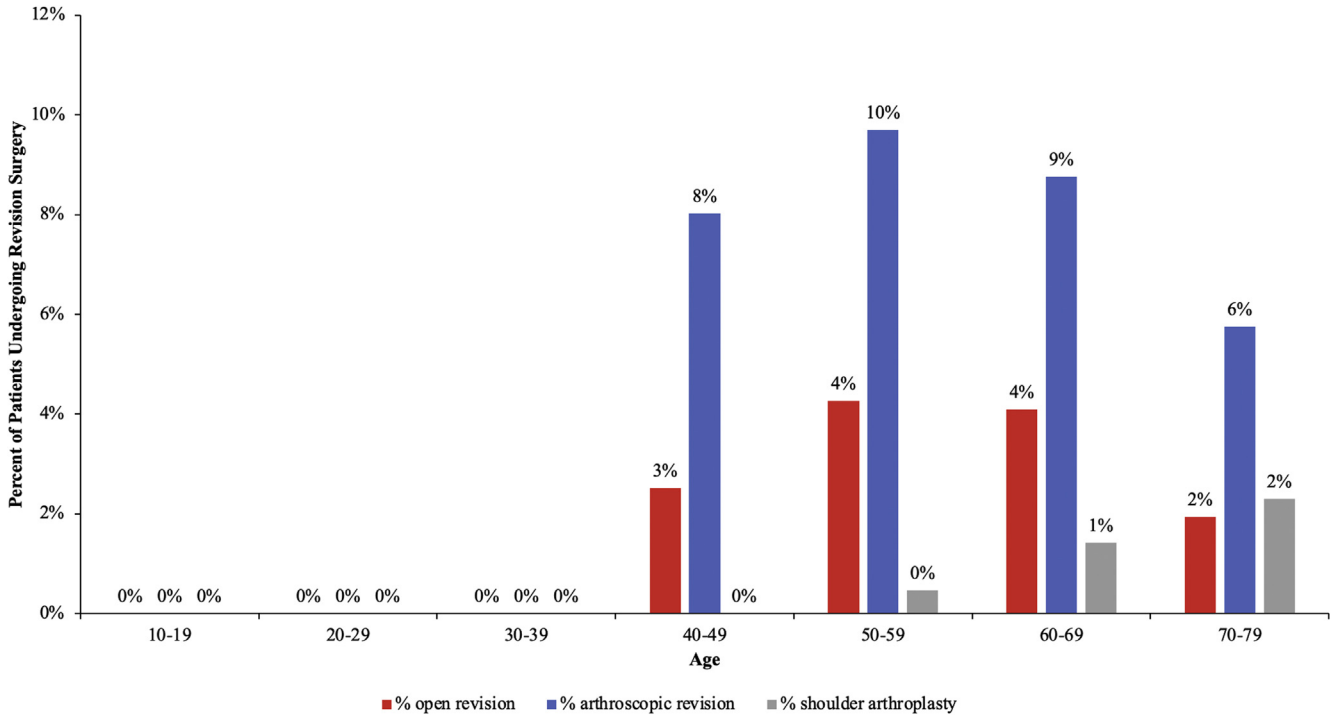


**Fig 3.** Revision rotator cuff repair age trends. The percentage of patients requiring revision arthroscopic rotator cuff repair, revision open rotator cuff repair, or shoulder arthroplasty is shown by age group.

which have been reported to have higher re-tear rates compared to small and partial cuff tears.[20-25] An additional study conducted by Fu et al.[12] using the Humana database found an overall revision rate of 9.6% after 5 years follow-up in a patient cohort of 2,759. Their study also incorporated ICD-9 diagnosis codes for partial tear of rotator cuff, which can account for the lower revision rate.

Our study showed that open RCR was more likely to require reoperation compared with arthroscopic RCR when analyzing within 2 years of index surgery and with propensity score matching between cohorts. Of the patients who underwent a primary open RCR, 11.3% required a revision surgery whereas 9.5% of arthroscopic surgeries required revision. To our knowledge, there is a lack of database studies comparing revision rates between arthroscopic and open RCR, but some systematic reviews and cohort studies have found similar results to our study indicating open RCRs to be associated with greater

**Table 4.** Distribution of Subsequent Procedures Performed Within 2 Years Following Rotator Cuff Repair

| Type of Procedure | Open Index Rotator Cuff Repair | Arthroscopic Index Rotator Cuff Repair |
|---|---|---|
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; acute | 11.3% | 1.6% |
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; chronic | 35.0% | 2.8% |
| Reconstruction of complete shoulder (rotator) cuff avulsion chronic (includes acromioplasty) | 10.7% | 0.9% |
| Tenodesis of long tendon of biceps | 9.3% | 8.0% |
| Arthroplasty glenohumeral joint; total shoulder (glenoid and proximal humeral replacement, e.g., total shoulder) | 14.1% | 13.3% |
| Arthroscopy shoulder surgical; debridement limited | 15.1% | 7.9% |
| Arthroscopy shoulder surgical; debridement extensive | 19.1% | 27.2% |
| Arthroscopy shoulder surgical; distal claviculectomy including distal articular surface (Mumford procedure) | 14.0% | 17.8% |
| Arthroscopy shoulder surgical; decompression of subacromial space with partial acromioplasty with or without coracoacromial release | 25.5% | 46.7% |
| Arthroscopy shoulder surgical; with rotator cuff repair | 18.0% | 58.4% |
| Arthroscopy shoulder biceps tenodesis | 4.0% | 10.8% |

Percentages total over 100% because the same patient can have multiple Current Procedural Terminology codes per surgery.

frequencies of complications. In a systematic review conducted by Nho et al.[26] that analyzed the clinical and complication results between arthroscopic and open procedures, they found in the retrospective cohort studies there were approximately twice the number of revision cases in the open group and overall higher number of complications. In addition, in a cohort study conducted by Jensen et al.,[10] of 372,109 RCRs, patients in the open surgery group were more likely to incur complications, such as infection and shoulder stiffness, relative to arthroscopic repairs. Moreover, in an 11,314-patient study using the National Surgical Quality Improvement Program database by Day et al.,[9] there was a greater 30-day complication rate and greater deep wound infection rate in the open group. These findings are in agreement with our study as evidenced by greater rates of emergency department and hospital admission within 30 days of surgery in the index open surgery group compared to arthroscopy. It is possible that the greater incidence in revision surgery and complication rates is due to a greater proportion of patients with large and massive tears requiring open procedures. Our analysis used propensity score matching to account for differences in age and comorbidities, including diabetes, tobacco use, and heart disease, as these have been shown to increase risk of RCR failure and complications.[14,27-29]

Two previous studies have analyzed the rate of conversion from RCR to shoulder arthroplasty (total or reverse total shoulder arthroplasty). In a retrospective cohort study within the Kaiser health care system, 882 patients underwent RCR in 2008, and 12 (1.4%) required arthroplasty at 2-year follow-up.[30] This rate was similar at 20-year follow-up. Of 322 patients who underwent RCR in France in 1994, 5 (1.5%) required total shoulder arthroplasty (TSA).[31] In our cohort, we found a similar overall rate of conversion of 1.3%, but when stratified by age, the risk of conversion was greater than that of previous studies, as 2.3% of 70- to 79-year-old patients underwent conversion but no individuals younger than 50 years converted to TSA or revision TSA.

Lastly, demographic analysis of our cohort showed that following full-thickness RCT, 37% of patients required RCR, which falls within the range of prior database studies that assessed rates of RCR following RCT in a Medicare population. Jensen et al.[10] found that on average, between 2005 to 2011, the annual rate of RCR following RCT was 28%, whereas Varkey et al.[32] showed that 45% of 878,049 patients diagnosed with a RCT underwent repair from 2005 to 2012. Our results also showed male patients had greater rates of surgical treatment, with the 50 to 69 years age range being the most common for surgery. This is similar to Chapman et al.,[33] who showed male patients were more likely to receive surgery in the Medicare population and previous database studies reporting the 50- to 59-year[18] and 65- to 69-year age groups as the most likely for surgical repair.[7]

### Limitations

It is important to view our findings within the context of its limitations that are inherent in administrative database studies. Our results are dependent on accurate ICD and CPT coding. We incorporated inclusion and exclusion criteria for codes, but the processes for administrative data entry may be associated with chances for errors. Another limitation includes the lack of characterization and classification of RCTs. Reoperation and complication rates may certainly be affected by size, chronicity, and fatty infiltration of RCTs, but our data do not allow for assessment of these factors. Open RCRs may have been needed for larger, more complex tear patterns that were too difficult to perform arthroscopically which would lead to higher failure rates, but this could not be evaluated by the available data as we could not account for tear size in this database. In addition, as administrative coding does not allow for specification of which specific rotator cuff tendon was repaired, our reoperation rate may include repair of a different rotator cuff tendon than from the index surgery and not necessarily a revision repair of the same tendon. Although we were able to perform propensity score matching for comorbidities and our database query language accounted for the index surgery to be the primary surgery, if the patient had a previous shoulder surgery or RCR outside of the database time range (2010-2017), this would not be accounted for. Our data also do not allow for classification of different surgeon levels of training and experience, which could have affected which patients were able to receive an open or arthroscopic repair and subsequent rates of reoperation. Although ICD-10 codes allowed our study to track for extremity laterality, our sample size for reoperation analysis was limited because this coding was only available starting in 2015. Furthermore, patients who may have changed insurance plans following index procedure may not have sufficient follow-up documented in the database. However, the Mariner dataset set has additional insurance plans compared to previous versions of PearlDiver, therefore this limitation can be reduced.

## Conclusions

The frequency of arthroscopic RCR has continued to increase compared with open RCR. In this large cross-sectional analysis, arthroscopic RCR demonstrated lower 2-year reoperation rates and 30-day readmission rates compared to open RCR.

## References

1. Mather RC, Koenig L, Acevedo D, et al. The societal and economic value of rotator cuff repair. *J Bone Joint Surg Am* 2013;95:1993-2000.

2. Yamamoto A, Takagishi K, Osawa T, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg* 2010;19:116-120.
3. Dang A, Davies M. Rotator cuff disease: Treatment options and considerations. *Sports Med Arthrosc Rev* 2018;26: 129-133.
4. Jacobs JJ, King TRW, Klippel JH, et al. Beyond the decade: Strategic priorities to reduce the burden of musculoskeletal disease. *J Bone Joint Surg Am* 2013;95: e1251-1256.
5. Pugely AJ, Martin CT, Harwood J, Ong KL, Bozic KJ, Callaghan JJ. Database and registry research in orthopaedic surgery: Part I: Claims-based data. *J Bone Joint Surg Am* 2015;97:1278-1287.
6. Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. *J Bone Joint Surg Am* 2012;94:227-233.
7. Day MA, Westermann RW, Bedard NA, Glass NA, Wolf BR. Trends associated with open versus arthroscopic rotator cuff repair. *HSS J* 2019;15:133-136.
8. Baker DK, Perez JL, Watson SL, et al. Arthroscopic versus open rotator cuff repair: Which has a better complication and 30-day readmission profile? *Arthroscopy* 2017;33: 1764-1769.
9. Day M, Westermann R, Duchman K, et al. Comparison of short-term complications after rotator cuff repair: Open versus arthroscopic. *Arthroscopy* 2018;34:1130-1136.
10. Jensen AR, Cha PS, Devana SK, et al. Evaluation of the trends, concomitant procedures, and complications with open and arthroscopic rotator cuff repairs in the Medicare population. *Orthop J Sports Med* 2017;5:2325967117731310.
11. Millar NL, Wu X, Tantau R, Silverstone E, Murrell GAC. Open versus two forms of arthroscopic rotator cuff repair. *Clin Orthop Relat Res* 2009;467:966-978.
12. Fu MC, O'Donnell EA, Taylor SA, et al. Delay to Arthroscopic rotator cuff repair is associated with increased risk of revision rotator cuff surgery. *Orthopedics* 2020;43: 340-344.
13. Mahure SA, Mollon B, Shamah SD, Zuckerman JD, Kwon YW, Rokito AS. The incidence of subsequent surgery after outpatient arthroscopic rotator cuff repair. *Arthroscopy* 2016;32:1531-1541.
14. O'Donnell EA, Fu MC, White AE, et al. The effect of patient characteristics and comorbidities on the rate of revision rotator cuff repair. *Arthroscopy* 2020;36: 2380-2388.
15. Varshneya K, Safran MR, Sherman SL, Abrams GD. Costs, complications, and reoperations associated with primary arthroscopic rotator cuff repair with or without acromioplasty and/or biceps tenodesis. *Arthrosc Sports Med Rehabil* 2020;2:e369-e376.
16. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res* 2011;46:399-424.
17. Kelly BC, Constantinescu DS, Vap AR. Arthroscopic and open or mini-open rotator cuff repair trends and complication rates among American Board of Orthopaedic Surgeons Part II Examinees (2007-2017). *Arthroscopy* 2019;35:3019-3024.
18. Zhang AL, Montgomery SR, Ngo SS, Hame SL, Wang JC, Gamradt SC. Analysis of rotator cuff repair trends in a large private insurance population. *Arthroscopy* 2013;29: 623-629.
19. Arshi A, Kabir N, Cohen JR, et al. Utilization and costs of postoperative physical therapy after rotator cuff repair: A comparison of privately insured and Medicare patients. *Arthroscopy* 2015;31:2392-2399.e1.
20. Abtahi AM, Granger EK, Tashjian RZ. Factors affecting healing after arthroscopic rotator cuff repair. *World J Orthop* 2015;6:211-220.
21. Le BTN, Wu XL, Lam PH, Murrell GAC. Factors predicting rotator cuff retears: An analysis of 1000 consecutive rotator cuff repairs. *Am J Sports Med* 2014;42:1134-1142.
22. Lee YS, Jeong JY, Park C-D, Kang SG, Yoo JC. Evaluation of the risk factors for a rotator cuff retear after repair surgery. *Am J Sports Med* 2017;45:1755-1761.
23. McElvany MD, McGoldrick E, Gee AO, Neradilek MB, Matsen FA. Rotator cuff repair: Published evidence on factors associated with repair integrity and clinical outcome. *Am J Sports Med* 2015;43:491-500.
24. Oh JH, Kim SH, Ji HM, Jo KH, Bin SW, Gong HS. Prognostic factors affecting anatomic outcome of rotator cuff repair and correlation with functional outcome. *Arthroscopy* 2009;25:30-39.
25. Tashjian RZ, Hollins AM, Kim H-M, et al. Factors affecting healing rates after arthroscopic double-row rotator cuff repair. *Am J Sports Med* 2010;38:2435-2442.
26. Nho SJ, Shindle MK, Sherman SL, Freedman KB, Lyman S, MacGillivray JD. Systematic review of arthroscopic rotator cuff repair and mini-open rotator cuff repair. *J Bone Joint Surg Am* 2007;89:127-136 (suppl 3).
27. Hong C-K, Chang C-J, Kuan F-C, et al. Patients with diabetes mellitus have a higher risk of tendon retear after arthroscopic rotator cuff repair: A meta-analysis. *Orthop J Sports Med* 2020;8:2325967120961406.
28. Santiago-Torres J, Flanigan DC, Butler RB, Bishop JY. The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *Am J Sports Med* 2015;43:745-751.
29. Taylor SA, Degen RM, White AE, et al. Risk factors for revision surgery after superior labral anterior-posterior repair: A national perspective. *Am J Sports Med* 2017;45: 1640-1644.
30. Apfel A, Lin CC, Burfeind W, Dillon MT, Navarro RA. Characteristics of rotator cuff repairs revised to shoulder arthroplasty. *Arch Bone Joint Surg* 2020;8:575-580.
31. Herve A, Thomazeau H, Favard L, et al. Clinical and radiological outcomes of osteoarthritis twenty years after rotator cuff repair. *Orthop Traumatol Surg Res* 2019;105: 813-818.
32. Varkey DT, Patterson BM, Creighton RA, Spang JT, Kamath GV. Initial medical management of rotator cuff tears: A demographic analysis of surgical and nonsurgical treatment in the United States Medicare population. *J Shoulder Elbow Surg* 2016;25:e378-e385.
33. Chapman CG, Floyd SB, Thigpen CA, Tokish JM, Chen B, Brooks JM. Treatment for rotator cuff tear is influenced by demographics and characteristics of the area where patients live. *JB JS Open Access* 2018;3:e0005.

# Appendix

**Appendix Table 1.** CPT/ICD Codes Queried

| Description | CPT/ICD Codes Queried |
|---|---|
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; acute | CPT-23410 |
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; chronic | CPT-23412 |
| Reconstruction of complete shoulder (rotator) cuff avulsion chronic (includes acromioplasty) | CPT-23420 |
| Arthroscopy shoulder surgical; with rotator cuff repair | CPT-29827 |
| Complete rotator cuff tear diagnoses | ICD-9-D-72761, ICD-10-D-M75120, ICD-10-D-M75121, ICD-10-D-M75122 |

CPT, Current Procedural Terminology; ICD, *International Classification of Diseases*.

**Appendix Table 2.** CPT Codes Queried for Subsequent Surgeries

| Description | CPT/ICD Codes Queried |
|---|---|
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; acute | CPT-23410 |
| Repair of ruptured musculotendinous cuff (e.g., rotator cuff) open; chronic | CPT-23412 |
| Reconstruction of complete shoulder (rotator) cuff avulsion chronic (includes acromioplasty) | CPT-23420 |
| Tenodesis of long tendon of biceps | CPT-23430 |
| Arthroplasty glenohumeral joint; total shoulder (glenoid and proximal humeral replacement (e.g., total shoulder) | CPT-23472 |
| Arthroscopy shoulder surgical; debridement limited | CPT-29822 |
| Arthroscopy shoulder surgical; debridement extensive | CPT-29823 |
| Arthroscopy shoulder surgical; distal claviculectomy including distal articular surface (Mumford procedure) | CPT-29824 |
| Arthroscopy shoulder surgical; decompression of subacromial space with partial acromioplasty with or without coracoacromial release | CPT-29826 |
| Arthroscopy shoulder surgical; with rotator cuff repair | CPT-29827 |
| Arthroscopy shoulder biceps tenodesis | CPT-29828 |

CPT, Current Procedural Terminology; ICD, *International Classification of Diseases*.