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S. S. Shah
Northwell Health

A. Shah

V. Chadayammuri

M. McGill
Northwell Health

N. Wei

See next page for additional authors

Authors
S. S. Shah, A. Shah, V. Chadayammuri, M. McGill, N. Wei, D. V. Tuckman, and N. A. Sgaglione

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Arthroscopic knotless rotator cuff repair: Factors associated with construct selection and recent trends from a manual review of 1617 cases

Sarav S. Shah[a,*], Aalok Shah[a], Vivek Chadayammuri[b], Marlena McGill[a], Nicole Wei[a], David V. Tuckman[a], Nicholas A. Sgaglione[a]

[a] Hofstra Northwell School of Medicine Department of Orthopaedic Surgery, United States
[b] University of Colorado Denver School of Medicine, United States

ABSTRACT

Purpose: Our aim was to identify predictors of construct selection and recent trends for arthroscopic knotless rotator cuff repair (RCR).
Methods: A manual review of 1617 operative reports was performed.
Results: A medium-sized tear had a threefold increase in odds of single row (SR) knotless repair (OR, 6.91; p = 0.009) versus SR knotted (OR, 3.05; p = 0.003). Generalist orthopaedic surgeons were 79% less likely to perform SR knotless repairs versus sports medicine trained specialists (p < 0.001).
Conclusion: There was a significant increase from 2009 to 2016 in SR knotless and double row medial row knotless constructs contrasting the declining use of the SR knotted technique.

1. Introduction

Rotator cuff repair (RCR), already one of the most frequently performed orthopaedic surgical procedures, continues to increase in volume.[1,2] However, there is a lack of clinical agreement about rotator cuff surgery. Scant clinical outcome based evidence exists to support knotted anchor RCR constructs over knotless anchor RCR constructs.[3] Additionally, multiple randomized controlled trials comparing single row (SR) and double row (DR) repairs have shown no difference in clinical outcomes.[4–6] Of note, these studies do not take the subtleties of cuff tear characteristics into account. There is a lack of clear clinical evidence to guide surgeons towards one construct over another namely SR knotted technique versus SR knotless or DR medial row knotted (knotted) technique versus medial row knotless (knotless), thus the question remains as to what drives surgical decision making. It has been suggested that existing practice patterns, in the absence of clear evidence, drive RCR decision making,[7] thus the primary purpose of our study was to identify predictors for surgeons' preference of repair construct. Secondarily, we sought to determine recent trends in repair construct selection. Our hypothesis was that fellowship training in sports medicine would be a predictor for knotless construct utilization and there was an increased SR knotless and DR knotless construct utilization from 2009 to 2016.

2. Methods

2.1. Data source

A retrospective manual review of operative reports from arthroscopic RCR procedures collected from a combination of surgical billing databases from September 2009 to June 2016 was performed. By examining every operative note, we were able to extrapolate specific information and prevent inconsistencies that occur in database queries.[8] The review encompassed 4 university-based locations (2 ambulatory surgery centers [ASC] and 2 general hospital settings) including a total of 18 orthopaedic surgeons, 12 of which are fellowship trained sports medicine specialists. There was no external funding source for this work, there are no potential conflicts, and none of the surgeons had a financial interest in any of surgery centers. The study was approved by Long Island Jewish Medical Center Institutional Review Board. The data was identified from the surgical billing databases using the Current Procedural Terminology (CPT) code 29827 (Arthroscopy, shoulder, surgical; with rotator cuff repair). The CPT code was then cross-referenced manually with the International Classification of Diseases (ICD)-9 diagnosis codes 727.61 (non-traumatic complete rupture of rotator cuff), 726.10 (disorder shoulder tendon cuff), or ICD-10 diagnosis codes M75.100 (unspecified rotator cuff tear or rupture of unspecified shoulder, not specified as traumatic) and M75.120, M75.121, M75.122 (complete rotator cuff tear or rupture of unspecified, right, or left

* Corresponding author at: 270-05 76th Ave Suite 250, New Hyde Park, NY, United States.
E-mail address: sshah17@northwell.edu (S.S. Shah).

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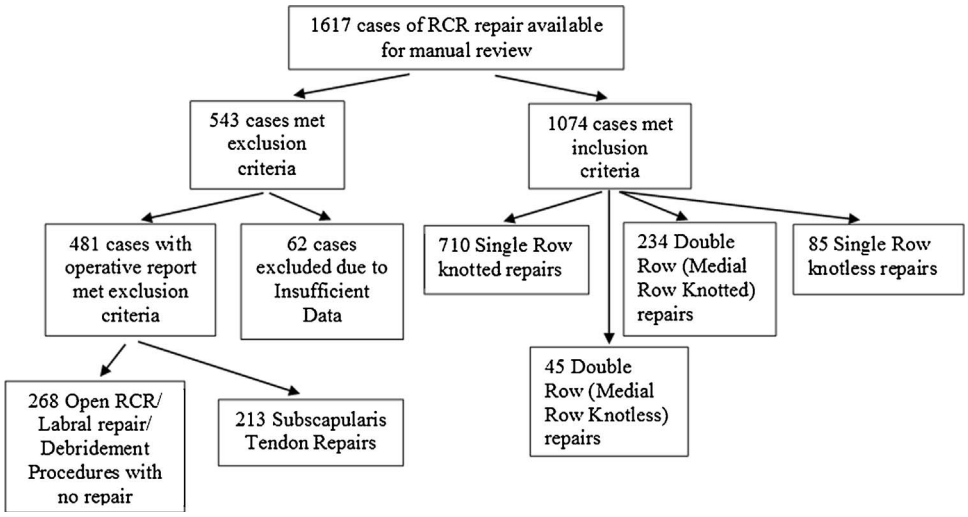

Fig. 1. Flow Chart delineating manual review process.

shoulder, not specified as traumatic). From the hospital electronic health record (EHR), we obtained information on surgeon, primary payer status, patient age, sex, ethnicity, and BMI.

2.2. Manual chart review

After completing the demographic portion, every operative note was examined by two authors. The operative note examination was used to determine surgeon-estimated tear size based on intraoperative measurement, number of anchors used in the repair, and type of repair construct utilized. Each repair was designated as either a SR knotted, SR knotless, DR medial row knotted (knotted), or DR medial row knotless (knotless) technique. A DR knotted technique included repairs utilizing a "hybrid" technique, knotting medial anchor eyelet stitches, and independently bridging tapes to the lateral row. Patients that underwent an open RCR, no repair (debridement or capsulorrhaphy), labral repair, subscapularis repair, or side-to-side repair utilizing no anchors were excluded. Lastly, patients with insufficient data in the operative report were also excluded due to lack of details regarding the construct selection (Fig. 1).

2.3. Statistical analysis

All variables were evaluated for distribution of normality using a combination of histograms, quantile–quantile (Q–Q) plots, and Shapiro-Wilk tests. Descriptive statistics were summarized as means and standard deviations (SD) for normally-distributed quantitative variables, medians and interquartile ranges (IQR) for non-normally distributed quantitative variables, and as counts and frequencies for categorical variables. Comparisons between independent groups were performed using Kruskall-Wallis H tests with Mann-Whitney U post-hoc tests for non-normally distributed quantitative variables and cross-tabulation with Chi-square analysis or Goodman and Kruskall's gamma tests for categorical variables. The Cochran-Armitage Test for Trend was used to evaluate changes in the proportion of outpatient cases and type of surgery performed annually.

Univariate analyses were performed using the following variables: surgeon reported size of tear [small (< 1 cm), medium (1–3 cm), large (3–5 cm), or massive (> 5 cm)], fellowship training in sports medicine, and number of anchors used in the repair. All significant ($p < 0.05$) or near-significant factors ($p < 0.10$) from the univariate analyses were entered into separate stepwise, backwards multivariate logistic regression models with type of RCR construct as the outcomes variable. Statistical significance for all comparisons was set at $p < 0.05$ (two-tailed). All analyses were conducted using IBM SPSS Statistics Software (Version 23.0, IBM, Chicago, IL, USA).

Table 1
[1] Breakdown of Patient Demographics.

Patient Demographics (N = 1074)	
Age, mean (SD), y	57.4 (11.33)
BMI, mean (SD), kg/m^2	29.9 (5.7)
Gender, male, n (%)	628 (58.5)
Ethnicity, n (%)	
Caucasian	596 (55.5)
African American	94 (8.8)
Hispanic/Latino	4 (0.4)
Asian/Pacific Islander	36 (3.4)
Native American/Alaskan	2 (0.2)
Other	61 (5.7)
Not Reported	281 (26.2)
Primary Payer Status, n (%)	
Private	781 (72.7)
Self-Pay	5 (0.5)
Mix of Private/Self-Pay	4 (0.4)
Medicare/Medicaid	282 (26.3)
Unreported	2 (0.2)

3. Results

3.1. Participants and descriptive data

Of the 1617 procedures reviewed, 1074 (58.5% male and 41.5% female) met inclusion criteria with a mean age and BMI of 57.43 years and 29.9 kg/m2, respectively. A majority of patients were of Caucasian ethnicity; however, this finding is limited as 26.2% of included patients elected not to report. Payment for clinical services was primarily in the private-care setting, with another 26.3% of patients on Medicare/Medicaid at time of surgery. Additional demographic data is summarized in Table 1. Among all patients undergoing surgical repair for rotator cuff tears (RCT), 61.0% were treated by a fellowship-trained sports medicine specialist. RCR was performed using a SR knotted construct in 66.1% cases, DR knotted construct in 21.8% cases, SR knotless construct in 7.9% cases, and DR knotless construct in 4.2% cases. Additionally, over the course of the study period, a large majority of cases were performed in the ambulatory surgery outpatient setting compared to the inpatient hospital setting. Additional clinical characteristics are characterized in Table 2.

[1] Breakdown of patient demographics obtained from manual review of operative reports.

Table 2
[2] Clinical Characteristics (N = 1074).

Distribution of Fellowship Training of Treating Surgeons, n (%)	
Sports	655 (61.0)
Hand	4 (0.4)
Sports & Hand	30 (2.8)
Trauma	231 (21.5)
General	147 (13.7)
Pediatrics	2 (0.2)
Foot/Ankle	5 (0.5)
Size of Rotator Cuff Tear, n (%)	
Small (< 1 cm)	186 (17.3)
Medium (1–3 cm)	602 (56.1)
Large (3–5 cm)	163 (15.2)
Massive (> 5 cm)	123 (11.5)
Type of Repair, n (%)	
Single row, knotted	710 (66.1)
Single row, knotless	85 (7.9)
Double (medial) row, knotted	234 (21.8)
Double (medial) row, knotless	45 (4.2)
Setting of Surgical Repair, n (%)	
Outpatient	928 (86.4)
Inpatient	146 (13.6)

(G = 0.600, p < 0.001; Fig. 3). An equivalent number of anchors were placed in repairs performed using a DR knotless (median = 4, IQR = 2.0) or DR knotted techniques (median = 3.0, IQR = 2.0; U = 5037.5, p = 0.606). As expected, the number of anchors utilized in SR repairs was significantly less than that for the DR repair techniques (p < 0.001) (Table 3).

3.3. Multivariate logistic regression analysis

All significant (p < 0.05) or near-significant factors (p < 0.10) from univariate analyses were entered into separate multivariate logistic regression models to identify independent predictors for each repair construct. A medium sized RCT was associated with a three-fold increase in odds of SR knotless construct utilization (OR, 6.91; 95% CI, 1.61–29.59; p = 0.009) compared to a SR knotted construct (OR, 3.05; 95% CI, 1.46–6.39; p = 0.003). Additionally, the presence of a massive RCT significantly decreased the likelihood of the surgeon utilizing a DR knotless construct (OR, 0.12; 95% CI, 0.05–0.31; p < 0.001). Generalist orthopaedic surgeons were significantly less likely to perform SR knotless repairs compared to fellowship trained sports medicine specialists (OR, 0.21; 95% CI, 0.02–0.176; p < 0.001).

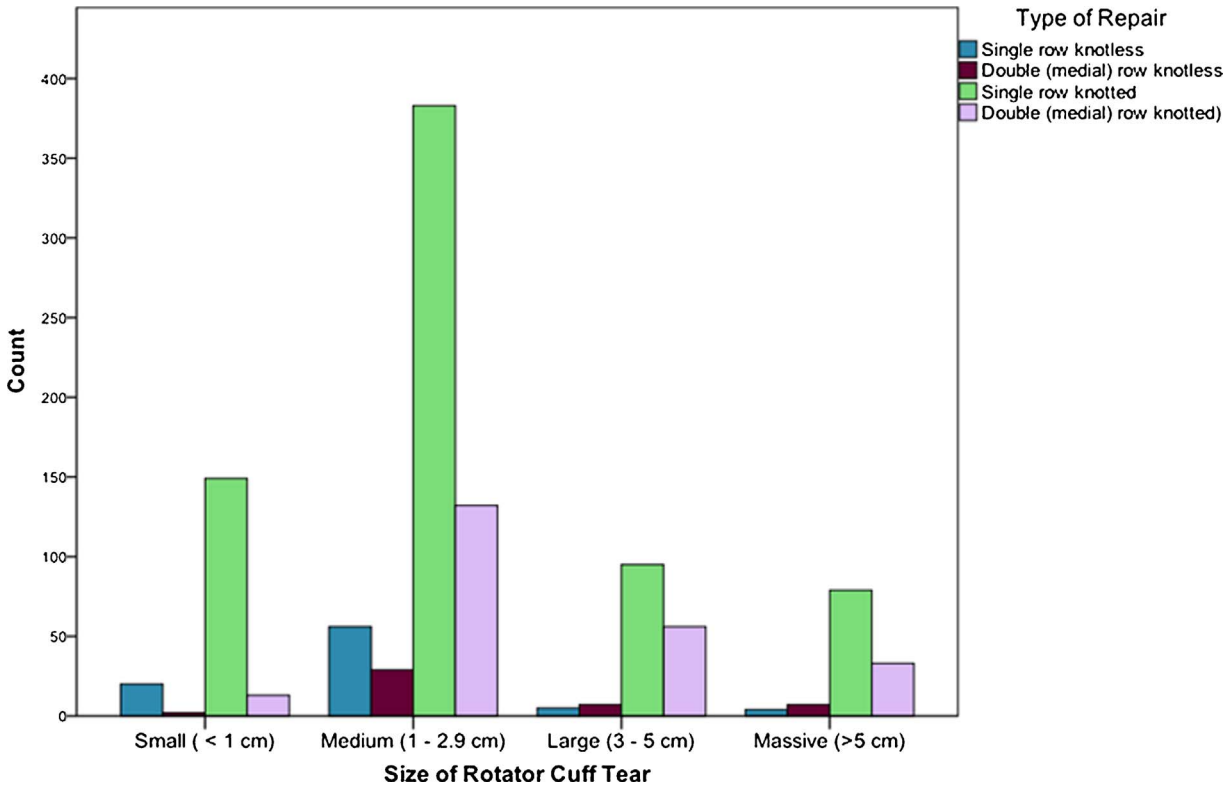

Fig. 2. Comparison of types arthroscopic rotator cuff repair types based on size of rotator cuff tear. Over the past seven years, the Single Row knotted repair was the most common type of repair.

3.2. Univariate analysis

There was a significant association observed between type of surgical repair and size of rotator cuff tear (G = 0.261, p < 0.001; Fig. 2). Additionally, there was a significant positive association between size of rotator cuff tear and number of anchors placed during surgical repair

3.4. Distribution of types of surgical repair and setting of procedure from 2009 to 2016

There was a significant linear increase in the annual percentage of RCR performed using the SR knotless construct, from 2.4% in 2009 to 19.7% by 2016 (p < 0.001). A significant linear increase was also observed in the annual percentage of DR knotless repairs, from 0.8% in 2009 to 13.5% in 2016 (p < 0.001). In contrast, rates of RCR performed using the SR knotted construct decreased significantly per year, from 76.6% in 2009 to 46.3% in 2016 (p < 0.001; Fig. 4). Annual

[2] Clinical Characteristics of Rotator Cuff Repair cases including surgeon specialty, Size of tear, Repair Construct Selection, and Setting of Surgical Procedure.

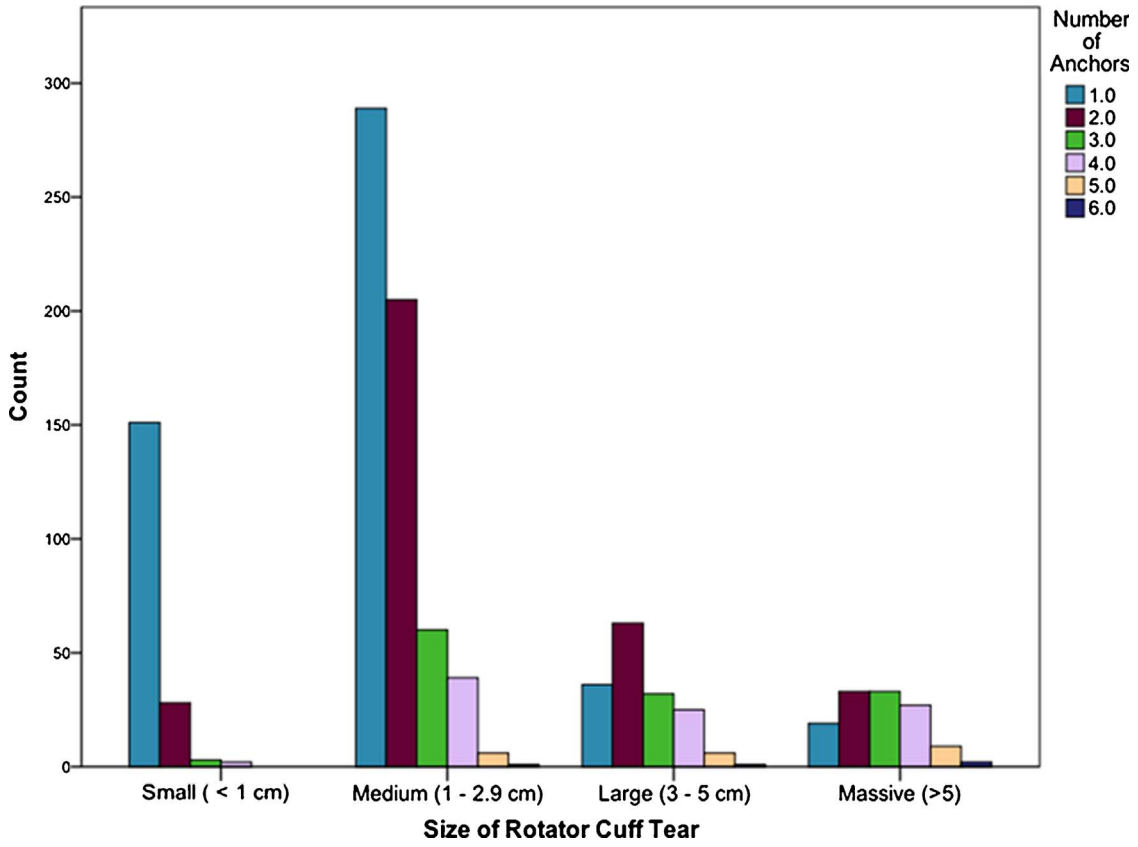

Fig. 3. Comparison of number of anchors utilized based on size of rotator cuff tear. There is a positive association between the size of rotator cuff tear and number of anchors placed during surgical repair. Also, significantly more anchors were utilized in Double Row repairs versus Single Row repairs.

Table 3
[3] Number of Anchors is Dependent on Rotator Cuff Repair Type (N = 1074).

Type of Repair	Number of Anchors	
	Median	Interquartile Range
Single Row, Knotless	1.0	1.0
Single Row, Knotted	1.0	1.0
Double Row, Knotless	4.0	2.0
Double Row, Knotted	3.0	2.0

proportion of DR knotted repairs did not vary significantly over the study period and constituted an average of 21.3% of all RCR each year. With regards to the setting of operative repair, there was a significant linear increase in the annual proportion of RCRs performed in the ambulatory surgery outpatient setting, from 69.3% in 2009 to 94.4% in 2016 ($p < 0.001$; Fig. 5). In fact, less than 6% of all rotator cuff surgeries were performed in an inpatient hospital setting from 2013 to 2016.

4. Discussion

Arthroscopically performed RCR procedures are becoming more prevalent as techniques improve and training evolves to adopt these techniques. As these techniques become more popular, there has been an increased focus on choice of repair and cost. Currently, there is limited clinical evidence to support arthroscopic knotless repair over knotted repairs. In the lone outcomes cohort study looking at SR knotted versus SR knotless versus open RCR, SR knotless repair was shown to have an improved clinical outcome.[3] Studies like the one presented here are important because, in the absence of clear evidence, existing practice patterns drive decision making in RCR.[7] Additionally, divergences in clinical opinions may be responsible for variations in the utilization of these procedures.[9] In consideration of this, we present factors associated with surgeon selection for RCR construct. Our results can help shed light for providers regarding the types of repair constructs chosen for specific tear sizes. Furthermore, understanding surgical factors associated with construct selection is important for RCR when advocating for changes in outpatient surgical reimbursements.[7]

The results of our study show a medium sized RCT was associated with a threefold increase in odds of SR knotless construct utilization compared to the classic SR knotted construct. Mook et al[10] states that knotless techniques are simple, may reduce operative time, and decrease the risk of impingement from the repair itself by completely eliminating the subacromial knot burden. Not surprisingly, we found the presence of a massive RCT significantly decreased the likelihood of the surgeon utilizing a DR knotless construct. Multiple studies have shown the biomechanical importance of a knotted medial row in a DR repair.[11–16] Additionally, generalist orthopaedic surgeons were significantly less likely to perform SR knotless repairs compared to fellowship trained sports medicine specialists. One potential reason for this finding may be that these relatively newer techniques are more commonly being utilized in sports medicine fellowships, and thus more commonly employed in practice by these fellowship trained sports medicine specialists.

Our evaluation of surgical trends over the past 7 years showed there was a significant linear increase in the annual percentage of the SR knotless and DR knotless constructs from 2.4% to 19.7% ($p < 0.001$) and 0.8% to 13.5% ($p < 0.001$) from 2009 to 2016, respectively. In contrast, rates of RCR performed using the SR knotted technique decreased significantly per year, from 76.6% in 2009 to 46.3% in 2016 ($p < 0.001$). Factors likely contributing towards our observed increase

[3] Number of anchors utilized based on repair construct selection.

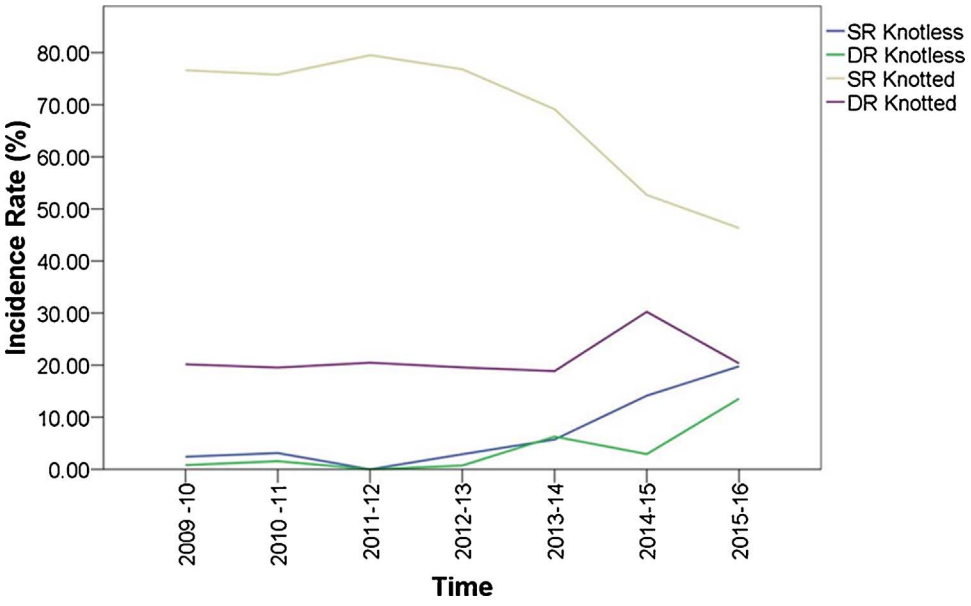

Fig. 4. Line Graph depicting incidences of various types of rotator cuff repair from 2009 to 2016. There was a significant linear increase in the annual percentage of rotator cuff repair performed using the Single Row knotless technique, from 2.4% in 2009 to 19.7% by 2016 ($p < 0.001$). A significant linear increase was also observed in the annual percentage of Double Row medial row knotless repairs, from 0.8% in 2009 to 13.5% in 2016 ($p < 0.001$). In contrast, Single Row knotted technique decreased significantly per year, from 76.6% in 2009 to 46.3% in 2016 ($p < 0.001$).

in knotless repair constructs include direct benefits such as an increased load to failure[17,18] as well as indirect benefits like relative ease of placement/fixation without the worry of knot or loop security[19,20] and decreased surgical times.[21]

Prudent use of consumable resources is a key point of emphasis for cost containment in arthroscopic shoulder surgery, particularly with respect to implantable suture anchors.[22–24] The typical knotless suture anchor is 25.53% more expensive than the typical knotted suture anchor at our institutions. Narvy et al[22] identified consumables, specifically suture anchors, as the main cost driver. The authors of this study propose that when conducting a cost analysis, it is important to include in the analysis potential benefits that may not be purely financial. The added cost of knotless constructs may be offset by the decreased surgical times and relative ease of placement/fixation without the worry of knot or loop security. Our results confirm that knotless construct utilization is on the rise, thus identifying a significant need for high level clinical outcomes evidence to justify the added expense of knotless anchors.

This study has several limitations. The query was garnered from databases in a university setting database. It remains unclear if the experience at these locations is applicable to national trends and norms as experience varies between private and academic settings and resident training programs versus non-training programs. However, the data is unbiased from a financial standpoint, as none of the surgeons had an interest in the surgery centers or were pressured to use a cheaper implant construct. In this regard, the data truly reflects an analysis of financially unbiased construct selection. Additionally, we feel this data may still be useful as the data was collected in the second most diverse county in the United States with both ASC and general hospital models along multiple surgeons of both generalist and sports medicine fellowship training. Drawing corollaries from large datasets about clinical activities has limitations also.[2] Data sets derived from billing information are a valuable tool; however, there are constraints to administrative databases as well.[25] We attempted to address these potential issues by examining every surgeon's operative note. Another limitation is that a longer collection period might have given further details and

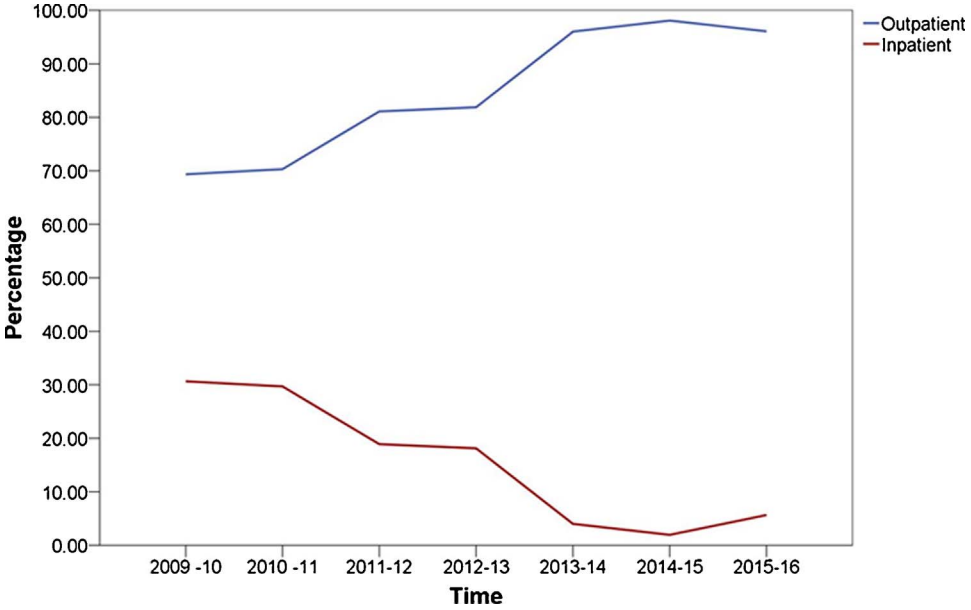

Fig. 5. Line Graph depicting setting of rotator cuff repair from 2009 to 2016. There was a significant linear increase in the annual proportion of rotator cuff repairs performed in the outpatient setting, from 69.3% in 2009 to 94.4% in 2016 ($p < 0.001$). It is noteworthy that less than 6% of all rotator cuff surgeries were performed in an inpatient setting during the last three years of the study period.

variations of each collection point. Furthermore, surgeon estimation for tear size may add observer bias. Finally, we were also unable to determine if there were any concomitant procedures (e.g., acromioplasty and/or biceps tenotomy/tenodesis) performed at the time of the arthroscopic procedure.

5. Conclusion

The results of our study show a medium sized RCT was associated with a threefold increase in odds of SR knotless construct utilization. Additionally, generalist orthopaedic surgeons were significantly less likely to perform SR knotless repairs. Our evaluation of surgical trends from 2009 to 2016 showed that there was a significant increase in the utilization of SR knotless and DR medial row knotless constructs contrasting the declining use of the SR knotted technique. Thus, revealing a need for high level clinical outcomes evidence to justify the added expense associated with knotless anchors. Studies like the one presented here are important because, in the absence of clear evidence, existing practice patterns drive decision making in RCR.[7] Our results can help shed light for providers regarding the types of repair constructs chosen for specific tear sizes. Furthermore, understanding surgical factors associated with construct selection is important for RCR when advocating for changes in outpatient surgical reimbursements.[7]

Conflict of interest

None.

Statement

IRB Statement: IRB #: HS16-0356.

The above referenced project meets the criteria outlined in 45 CFR 46.110 and 21 CFR 56.110 for EXPEDITED REVIEW and has been approved.

Financial Disclosures

Dr. Nicholas A. Sgaglione reports personal fees from Biomet:, personal fees from Wolters Kluwer Health — Lippincott Williams & Wilkins:, outside the submitted work.

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