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Performance and return to sport following rotator cuff surgery in professional baseball players

Brandon J. Erickson, MD[a,*], Peter N. Chalmers, MD[b], John D'Angelo, BA[c], Kevin Ma, BA[c], Anthony A. Romeo, MD[a]

[a]*Rothman Orthopaedic Institute, New York, NY, USA*
[b]*Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT, USA*
[c]*Major League Baseball Commissioner's Office, New York, NY, USA*

Background: While many injuries to the rotator cuff in professional baseball players can be managed nonoperatively, recovery fails to occur with nonoperative treatment in some players and surgery on the rotator cuff is performed in an attempt to return to sport (RTS).
Methods: All professional baseball players who underwent rotator cuff surgery between 2010 and 2016 were included by use of the Major League Baseball injury database. Demographic and performance data (before and after surgery) for each player were recorded. Preoperative and postoperative performance metrics were then compared.
Results: Overall, 151 professional baseball players underwent rotator cuff débridement (n = 130) or rotator cuff repair (n = 21). In the rotator cuff repair group, 6 (28.6%) underwent single-row repair, 5 (23.8%) underwent double-row repair, and 10 (47.6%) underwent side-to-side repair. Among the 11 players who underwent either single- or double-row repair, the average number of anchors used per repair was 2.09 ± 1.1 (range, 1-4). Most performance metrics declined following rotator cuff débridement. For players who underwent débridement, the RTS rate was 50.8% (42.3% at the same level or a higher level and 8.5% at a lower level). For players who underwent repair, the RTS rate was 33.3% (14.3% at the same level or a higher level and 19% at a lower level). Most players underwent at least 1 concomitant procedure at the time of rotator cuff surgery.
Conclusion: Rotator cuff débridement is significantly more common than repair in professional baseball players, with 86% of all rotator cuff surgical procedures reported as débridement. RTS rates following débridement and repair are disappointing, at 50.8% and 33.3%, respectively. For players who do return, performance declines after surgery.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Major League Baseball (MLB); rotator cuff; repair; débridement; shoulder; return to sport (RTS)

This study was performed with the approval of the Major League Baseball Players Association and the Major League Baseball Commissioner's Committee on Medical Research. As all information that was reviewed was deidentified, no institutional review board approval was required.

*Reprint requests: Brandon J. Erickson, MD, Hospital for Special Surgery, 535 E 70th St, New York, NY 10021, USA.
E-mail address: brandon.j.erickson@gmail.com (B.J. Erickson).

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The rotator cuff is a dynamic stabilizer of the glenohumeral joint and plays an important role in the overhead throwing motion.[4,7] When a baseball player enters the deceleration phase of the throwing cycle, the rotator cuff is tasked with resisting the distractive forces that are placed on the glenohumeral joint.[14] The rotator cuff may also store elastic stretch during the late cocking phase that is then dissipated into humeral rotation to create ball velocity during the acceleration phase. As baseball players progress to higher levels of play, the amount of force and torque on the shoulder only increases, such that a professional baseball player's shoulder can rotate at an angular velocity approaching 7000° per second, the fasted recorded human movement.[6] Furthermore, when posterior structures contract from repetitive trauma, the humeral head can move in a pathologic manner and cause partial-thickness tears of the undersurface of the rotator cuff from internal impingement.[21] Hence, professional baseball players are a unique group of individuals who place a tremendous amount of stress on the rotator cuff. Unfortunately, as the throwing motion is one of the most demanding athletic movements, the rotator cuff can sustain injuries over time from resisting these distractive forces, from storing these stresses, or from impinging between the glenoid and humeral head.[1,6] These injuries can range from tendinosis and tendinitis to partial-thickness tears and, finally, to full-thickness tears.

The mainstay of treatment for pathologic shoulder conditions in the overhead athlete is conservative treatment with rest, rehabilitation focusing on range of motion and strengthening of the stabilizing muscles of the shoulder, and a gradual return-to-throwing program.[3,25,26] As results following surgical treatment of rotator cuff injuries have been poor, surgery is most commonly considered a procedure of last resort for professional baseball players in whom all attempts at conservative treatment have failed and who are unable to return to sport (RTS).[7,13] Unfortunately, surgeons and players are placed in a difficult position when adequate nonoperative treatments have been attempted but players are still unable to RTS, as there are limited options aside from surgery at that point if the desire to play remains. The results following rotator cuff débridement or repair have not been well reported in the elite group of professional baseball players, and thus, surgeons have limited data confined to small case series with which to counsel players. Klouche et al[13] reported a 49.9% RTS rate in professional or competitive athletes participating in varying sports following rotator cuff repair, while Mazoue and Andrews[16] reported just an 8% RTS rate in 16 professional baseball players after rotator cuff repair.

The purpose of this study was to determine the rate of RTS in professional baseball pitchers following rotator cuff surgery and the performance after RTS. We hypothesized that there would be an unacceptably low rate of RTS in professional baseball players following rotator cuff surgery, with a decline in performance, specifically related to the primary outcome performance variables of win-loss percentage, walks plus hits per inning pitched, fielding independent pitching, and wins above replacement, in players who are able to RTS.

Methods

All professional baseball players who underwent surgery involving the rotator cuff between 2010 and 2016 were eligible for inclusion. One author (B.J.E.) reviewed the deidentified operative report for each player. Deidentified surgical data including tear size, repair vs. débridement, concomitant procedures, and so on were recorded (Table I). All players identified were included in this study as it related to RTS rate. RTS was deemed to have occurred if a player played in any professional game after injury. Players who underwent rotator cuff surgery with a minimum of 12 months' follow-up were included in the study. The subject inclusion criterion was any male, professional baseball player (after being drafted or having played at least 1 game in professional baseball prior to rotator cuff surgery). The subject exclusion criteria were collegiate (National Collegiate Athletic Association) players and players who never played professional baseball.

Baseball players who returned to professional baseball and had played in at least 1 game were included in the preinjury and postinjury in-game performance statistical analysis. Player demographic and performance measure data were collected (Tables I-III). In-game performance variables were analyzed as an average over the preinjury and postinjury course of players' careers. As there were significantly more players who underwent rotator cuff débridement, both pitching and batting metrics could be compared between preoperative and postoperative values for this group. However, as the number of players who underwent rotator cuff repair followed by successful RTS was small, only pitching statistics could be compared for this group, as the study was underpowered to report differences in batting statistics.

Statistical analysis

After the calculation of descriptive statistics, data were assessed for normality using the Kolmogorov-Smirnov test. Thereafter, parametric and nonparametric tests were used as appropriate. Performance data were classified as either greater than 1 year before injury or greater than 1 year postoperatively, and intervening data were excluded.

Preinjury and postoperative averages were calculated based on data type. In particular, performance data exist as both counts (eg, number of at bats) and percentages (eg, batting average). Count data were averaged on a per-year basis. Average data were averaged on a weighted basis via the number of games played per year. Preinjury and postoperative data were then compared using paired Student *t* tests and related-samples Wilcoxon signed rank tests. Study subject data were compared using Student *t* tests and Mann-Whitney *U* tests. These were performed within both the repair and débridement groups.

RTS was determined based on the maximum preinjury and postoperative level of play, with levels of play arranged as follows: Major League, AAA, AA, A+, A, rookie, foreign, and fall. Players could thus be considered to have not returned, to have returned but at a lower level, or to have returned at the same level or at a higher level.

Results

Overall, 130 professional baseball players underwent rotator cuff débridement while 21 underwent rotator cuff repair (Table I). The surgical information gleaned directly from review of the operative reports for these patients was separated by partial- vs. full-thickness tears and the amount of the rotator cuff involved (Table I). Of note, there were 9 players with partial-thickness tears who underwent side-to-side repair, 7 players with partial-thickness tears that were completed and repaired at the time of surgery (1 of which was repaired side to side), and only 5 players (4%) who were treated for full-thickness rotator cuff tears (of these 5 players, 4 underwent double-row repair and 1 underwent single-row repair). Among the 7 players with partial-thickness tears that were completed and repaired, the tear thickness was 90% in 4, 80% in 2, and 50% in 1; moreover, 3 underwent double-row repair, whereas 4 underwent single-row repair. Furthermore, among the 21 players who underwent rotator cuff repair, single-row repair was performed in 6 (28.6%); double-row repair, in 5 (23.8%); and side-to-side repair, in 10 (47.6%). Among the 11 who underwent either single- or double-row repair, the average number of anchors used per repair was 2.09 ± 1.1 (range, 1-4). Regarding tear location, of the anterior supraspinatus tears (n = 48), 29 (60.4%) were in pitchers and 19 (39.6%) were in position players. Of the tears of the supraspinatus plus infraspinatus or the infraspinatus only (n = 101), 74 (73.3%) were in pitchers and 27 (26.7%) were in position players. Of the 151 players included in this study, 141 underwent surgery on their throwing shoulder whereas 10 underwent surgery on their non-throwing shoulder (3 pitchers, 2 outfielders, 2 third basemen, 1 catcher, 1 first baseman, and 1 shortstop).

When we compared the performance metrics (both pitching and batting) before and after surgery for professional baseball players who underwent rotator cuff débridement, players declined in performance in the majority of metrics (Table II). There were no metrics in which batters improved postoperatively. For pitching metrics, while the raw data demonstrated that pitchers improved regarding the number of hits allowed, walks allowed, runs allowed, earned runs allowed, and home runs allowed, they declined in the number of innings pitched and number of batters faced, as well as many other metrics. With fewer innings pitched and batters faced, the improvement regarding the number of hits allowed, walks allowed, and so on may have been a result of the decreased number of batters faced after RTS and not a true reflection of improved performance over preinjury levels.

When we compared the pitching performance metrics before and after surgery for professional baseball players who underwent rotator cuff repair, no significant differences were seen in any of the performance metrics (Table III). The RTS rates for pitchers who underwent rotator cuff débridement and those who underwent repair are shown in Table IV, with almost 50% of players who underwent rotator cuff débridement unable to RTS and two-thirds of the players who underwent repair unable to RTS.

Finally, a total of 273 varying concomitant procedures were performed at the time of rotator cuff débridement or repair in these players (Table V). Overall, 125 players (83.8%) underwent at least 1 concomitant procedure, and most players underwent more than 1 concomitant procedure at the time of rotator cuff surgery.

Table I Demographic information of professional baseball players who underwent either repair or débridement of rotator cuff

	Débridement	Repair
Age, mean ± SD, yr	24.9 ± 3.8	24.6 ± 4.1
Position		
Pitcher	91	1
Catcher	6	3
Infielder	20	4
Outfielder	13	13
League		
Major	24	1
Minor	106	20
Tear location		
Anterior supraspinatus	40	8
Supraspinatus and infraspinatus	64	8
Infraspinatus	24	5
Subscapularis	2	0
Side		
Articular	123	18
Bursal	3	0
Tear, %		
<25	81	2
25-50	26	6
50-75	6	0
>75	8	1
Tear size, cm		
<1	2	1
1-3	7	1

SD, standard deviation.

Discussion

Baseball is one of the most demanding sports on the shoulder as the repetitive torque and force generated when throwing a baseball are not seen in any other sport.[6] This repetitive stress on the shoulder can lead to injuries that are recalcitrant to nonoperative measures, specifically those to the rotator cuff. Surgery is considered in an attempt to

Table II Comparison of performance metrics (both pitching and batting) before and after surgery in professional baseball players who underwent rotator cuff débridement

	Mean difference (preoperative − postoperative)	95% CI of difference		*P* value
		Lower	Upper	
Pitching statistics				
Win-loss percentage	−0.002	−0.095	0.091	.963
Earned run average	−0.206	−0.772	0.359	.465
Average runs	−0.130	−0.800	0.539	.695
WHIP	−0.057	−0.178	0.063	.345
Hits per 9 innings	−0.035	−0.837	0.767	.929
Home runs per 9 innings	−0.099	−0.274	0.075	.256
Walks allowed per 9 innings	−0.452	−1.164	0.258	.206
Strikeouts per 9 innings	−0.328	−1.134	0.477	.415
Strikeouts per walk	0.036	−1.081	1.155	.947
Wins per year	1.495	0.580	2.411	.002*
Losses per year	1.310	0.509	2.111	.002*
Games per year	−3.395	−9.296	2.505	.251
Games started per year	5.933	3.756	8.109	<.001*
Games finished per year	−2.891	−6.388	0.605	.102
Complete games per year	0.141	0.035	0.248	.011*
Shutouts per year	0.051	0.010	0.092	.015*
Saves per year	−0.431	−2.301	1.439	.644
Innings pitched per year	24.188	11.767	36.610	<.001*
Hits per year	21.967	9.072	34.861	.001*
Runs per year	11.100	4.477	17.723	.002*
Earned runs per year	9.155	3.577	14.732	.002*
Home runs per year	1.110	−0.354	2.575	.133
Walks allowed per year	6.608	2.120	11.096	.005*
Intentional walks per year	−0.184	−0.600	0.230	.374
Shutouts per year	17.754	6.723	28.785	.002*
Hit batters per year	1.252	0.494	2.009	.002*
Balks per year	0.137	−0.156	0.430	.351
Wild pitches per year	1.214	0.204	2.224	.020*
Batters faced per year	104.097	51.978	156.216	<.001*
Wins above replacement (pitchers)	0.732	0.230	1.233	.009*
Fielding independent pitching	−25.566	−44.415	−6.717	.013*
Batting statistics				
Games per year	20.637	2.321	38.954	.029*
Plate appearances per year	91.832	18.991	164.673	.016*
At bats per year	77.141	12.251	142.031	.022*
Runs per year	16.050	7.430	24.670	.001*
Hits per year	25.173	7.914	42.432	.006*
Doubles per year	3.630	−0.264	7.525	.066
Triples per year	1.640	0.902	2.377	<.001*
Home runs per year	2.488	0.477	4.499	.018*
Runs batted in per year	7.466	0.182	14.749	.045*
Stolen bases per year	13.095	4.815	21.375	.003*
Caught stealing per year	5.755	2.627	8.883	.001*
Walks per year	2.016	0.965	3.067	.001*
Strikeouts per year	11.580	4.147	19.013	.004*
Total bases per year	11.117	−3.498	25.734	.129
Double plays grounded into per year	0.504	−1.719	2.729	.642
Hit by pitch per year	1.384	0.552	2.216	.002*
Sacrifice hits per year	1.171	0.180	2.162	.023*
Sacrifice flies per year	0.554	−0.229	1.338	.156
Intentional walks per year	0.442	0.134	0.750	.007*
On base + slugging percentage	0.046	0.004	0.088	.032*
Wins above replacement (batters)	0.245	−0.194	0.686	.249

CI, confidence interval; *WHIP*, walks plus hits per inning pitched.
Tear percentage and size were not reported in all operative reports.
* Statistically significant.

Table III Comparison of pitching performance metrics before and after surgery in professional baseball players who underwent rotator cuff repair

Pitching statistics	Mean difference (preoperative – postoperative)	95% CI of difference		*P* value
		Lower	Upper	
Win-loss percentage	0.081	−0.213	0.377	.356
Earned run average	−0.928	−3.835	1.979	.385
Average runs	−1.155	−3.349	1.039	.192
WHIP	−0.208	−1.111	0.693	.515
Hits per 9 innings	0.224	−2.793	3.242	.828
Home runs per 9 innings	0.238	−0.780	1.258	.510
Walks allowed per 9 innings	−2.114	−8.072	3.843	.341
Strikeouts per 9 innings	−0.979	−4.947	2.988	.489
Strikeouts per walk	1.245	−1.938	4.429	.302
Wins per year	3.468	−3.787	10.725	.226
Losses per year	2.449	−4.901	9.800	.367
Games per year	7.673	−11.478	26.824	.292
Games started per year	7.511	−8.542	23.565	.233
Games finished per year	−0.434	−5.742	4.873	.811
Complete games per year	0.330	−0.485	1.145	.288
Shutouts per year	0.170	−0.204	0.545	.244
Saves per year	51.945	−48.566	152.457	.199
Innings pitched per year	53.257	−55.730	162.245	.218
Hits per year	21.140	−34.329	76.609	.312
Runs per year	19.192	−32.172	70.557	.320
Earned runs per year	5.314	−6.601	17.230	.251
Home runs per year	10.163	−26.269	46.595	.440
Walks allowed per year	0.216	−1.328	1.762	.686
Intentional walks per year	37.344	−47.273	121.962	.255
Shutouts per year	1.993	−3.845	7.833	.357
Hit batters per year	0.713	−0.515	1.942	.162
Balks per year	1.421	−3.003	5.846	.382
Wild pitches per year	212.068	−222.386	646.524	.218

CI, confidence interval; *WHIP*, walks plus hits per inning pitched.
Batting performance metrics and advanced metrics could not be analyzed because of the low number of players.

Table IV Rate of return to sport and level of return to sport for professional baseball players who underwent débridement or repair of rotator cuff

Level of return	Débridement, n (%)	Repair, n (%)
No return	64 (49.2)	14 (66.7)
Lower	11 (8.5)	4 (19)
Same or higher	55 (42.3)	3 (14.3)

Table V Number of concomitant procedures performed in professional baseball players who underwent rotator cuff repair or débridement

Anatomic location	Total no. of concomitant procedures
Labrum	178
AC joint	3
Glenoid	7
Biceps tendon	7
Capsule	14
Other	64

AC, acromioclavicular.
Some players underwent more than 1 concomitant procedure in each category. The concomitant procedures within each group are as follows: labrum—anterior débridement and/or repair (54), inferior débridement and/or repair (8), superior débridement and/or repair (38), and posterior débridement and/or repair (78); AC joint—distal clavicle resection (open or arthroscopic) (3); glenoid—chondroplasty and/or débridement (6) and microfracture (1); biceps tendon—débridement (2) and tenodesis (5); capsule—capsulorrhaphy, débridement, or repair (14); and other—humeral head chondroplasty (2), latissimus tendon repair (1), acromioplasty (2), bursectomy alone (23), bursectomy and coracoacromial ligament release (11), subacromial space diagnostic arthroscopy (1), subacromial decompression (16), suprascapular nerve release (2), anterior rotator interval procedure (2), teres major repair (1), and ganglion cyst removal (1).

return the player to sport only when all efforts at nonsurgical treatment have failed, often including a variety of theoretical and unproven physical modalities. Our hypotheses were both confirmed and rejected as there was a low rate of RTS in professional baseball players following rotator cuff surgery with a decline in performance in those who underwent débridement but, surprisingly, not in those who underwent repair and had a successful RTS. This may be because of the reduced numbers of innings pitched and batters faced, which affect the overall count-related metrics. Furthermore, a significant number of concomitant procedures were performed in these players at the time of rotator cuff débridement or repair that speaks to the initially attempted nonoperative management and resorting to surgery only as a last option.

The baseball throwing motion requires a complex and intricate interplay of shoulder, as well as whole-body, mechanics to generate an accurate, powerful throw.[1,2,8] With each throw, the shoulder can rotate at an angular velocity approaching 7000° per second.[6] The angular velocity that is generated must be slowed down during the deceleration phase, in which the rotator cuff (and deltoid) approaches its ultimate tensile strength by creating compressive forces of over 1000 N.[14] This stress on the rotator cuff can lead to partial-thickness tears or complete tears. However, there is a second phenomenon, commonly known as ‘‘internal impingement,’’ that can lead to injury of the rotator cuff during the overhead throwing motion. When the posterior capsule is tight, when a player has microinstability of the shoulder, or in a player with scapulothoracic dyskinesis, the humeral head can translate excessively away from a centered position on the glenoid, leading to abnormal contact in the abducted and externally rotated position, compressing the articular side of the rotator cuff between the glenoid and/or labrum and the greater tuberosity.[18] This can lead to damage to either the posterosuperior or anterosuperior aspect of the rotator cuff.[1] Unfortunately, while these theories and others regarding rotator cuff injuries in baseball players exist, the precise etiology of these injuries is still unknown. The lack of understanding of the exact cause of these rotator cuff injuries may be part of the reason injury prevention efforts have not been perfected. Currently, there is little evidence to suggest that an improved understanding of the pathomechanics that lead to shoulder injuries has provided an opportunity for preventive programs to reduce the overall incidence of these injuries in baseball. More sophisticated technology such as wearable sensors may help to reveal threshold levels of injury risk.

When baseball players sustain an injury to the rotator cuff, they are initially managed conservatively, unless the injury is a full-thickness tear incurred during a traumatic event such as sliding into a base or colliding with a boundary wall.[19] Several studies have found that deficits of total shoulder motion, of shoulder external rotation, and of shoulder internal rotation increase a player’s risk of shoulder injury.[9,12,19,26,27] Hence, rehabilitation initially focuses on increasing the player’s shoulder range of motion, followed by strengthening of the scapular stabilizing muscles and then, finally, full assessment and treatment of any deficits recognized within the throwing kinetic chain. While the large majority of baseball players RTS following successful conservative treatment, a select group cannot. In these athletes, surgical intervention is offered. Unfortunately, the results of our study echo those of previous studies with less-than-ideal RTS rates and with a decline in performance in those players who were able to RTS.[7,11,13] A recent systematic review found an RTS rate of 49.9% in professional athletes (baseball players, tennis players, and golfers) following rotator cuff surgery, which aligns with our findings.[13] Reynolds et al[20] reported on 82 professional baseball pitchers after rotator cuff débridement and found that 55% were able to RTS at the same level, which mirrors the results of our study. One interesting finding from this study was the breakdown of repair vs. débridement based on position. The majority of rotator cuff repairs were performed in outfielders (62%), while only 1 (5%) was performed in a pitcher. This finding may indicate the reluctance to perform rotator cuff repair in pitchers as the results following repair in this group of athletes have historically been less than ideal.[7,16]

One concerning characteristic of the surgical treatment was the large number of concomitant procedures performed in these players at the time of their rotator cuff débridement or repair. As mentioned earlier, the shoulder is under tremendous stress during the throwing motion, and as such, there can be progressive subclinical changes that occur over time, such as partial fraying of the labrum or rotator cuff, as well as increased anterior capsular laxity with decreased posterior capsular laxity.[8,24] While the shoulder is typically not symptomatic to the point of surgical intervention, these changes can be a source of pain and disability for baseball players, thus necessitating surgical intervention. The clinical assessment and ability to clearly identify the source of the symptoms can be challenging, despite a thorough physical examination repeated multiple times, supplemented by advanced imaging such as magnetic resonance imaging (MRI). There are numerous studies that have shown MRI-positive pathology in baseball players without clinically relevant symptoms, challenging the physician to determine the source of impairment in the symptomatic shoulder.[5,10,15,17,22]

Hence, when a shared decision among the player, the physician, and other third parties commonly involved in the process leads to shoulder surgery, the treating surgeon may feel obligated to address multiple pathologic findings visualized on MRI and at the time of arthroscopy of the shoulder (labrum, capsule, rotator cuff, and so on). The assumption is that the source of pain and impairment may be related in large part to the principal finding of rotator cuff tearing but augmented by the associated pathologic findings. The concomitant procedures are confounding variables that could not be isolated as almost every player underwent some form of concomitant procedure at the time of rotator cuff repair or débridement. Although these concomitant procedures introduce heterogeneity regarding the players studied, concomitant procedures are inherent to treating high-level overhead athletes’ rotator cuff injuries. Our conclusion from this study, as well as several previous studies, is to pursue a thorough program of nonoperative management as the current results regarding RTS are unpredictable. Many high-level players are able to RTS and perform at preinjury levels despite the initial clinical findings and MRI appearance of rotator cuff and labral injuries. Further studies evaluating nonoperative biological interventions such as platelet-rich plasma or stem cell injections in these athletes are necessary to determine whether the RTS rates and performance can be improved despite documented structural pathology.[23]

Limitations

This study did not use public data but rather used the Major League Baseball Health and Injury Tracking System (HITS) database to ensure accuracy regarding these patients. Furthermore, all deidentified operative reports and available operative images (although <25% of cases had operative images available) were reviewed to remove any possibility of including a player who did not undergo some form of rotator cuff surgery. While the Major League Baseball database was used, there is the possibility that some players who underwent surgery on the rotator cuff were not entered into the database and were therefore missed. No information regarding history, physical examination findings, and nonoperative treatment was available for review, and this information was thus not included. Similarly, performance and RTS could not be compared between nonoperatively and operatively treated groups of baseball players as this information was unavailable. There were a significant number of concomitant procedures performed in these players, which adds a confounding variable to their ability to RTS and their performance on RTS. The contribution of these associated procedures to the final outcome is unknown. Furthermore, the repair cohort was small, so batting performance metrics could not be analyzed. Comparisons within the group, such as preinjury to postoperative performance comparisons, may be underpowered.

Conclusion

Rotator cuff débridement is significantly more common than repair in professional baseball players, with 86% of all rotator cuff surgical procedures reported as débridement. RTS rates following débridement and repair are disappointing, at 50.8% and 33.3%, respectively. For players who do return, performance declines following rotator cuff surgery.

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