

Clinical Utility of an MRI-Based Classification System for Operative Versus Nonoperative Management of Ulnar Collateral Ligament Tears

A 2-Year Follow-up Study

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Background: A recently introduced classification system of medial ulnar collateral ligament (UCL) tears accounting for location and severity has demonstrated high interobserver and intraobserver reliability, but little is known about its clinical utility.

Purpose: The primary purpose of this study was to assess the relationship of the magnetic resonance imaging (MRI)-based classification system in predicting which athletes had success with nonoperative versus operative treatment after completing a standardized rehabilitation program. A secondary objective included return to play (RTP) and return to prior performance (RPP) analyses of baseball players.

Study Design: Cohort study; Level of evidence, 3.

Methods: After an a priori power analysis, 58 consecutive patients with UCL tears and a minimum of 2-year follow-up were retrospectively divided into 2 groups: those who successfully completed operative treatment and those who completed nonoperative treatment. The MRI-based classification stages accounting for UCL tear location and severity were compared between the nonoperative and operative groups. A subanalysis for baseball players, including RTP and RPP, was performed.

Results: A total of 58 patients (40 baseball players [34 pitchers]) met inclusion criteria. Of these patients 35 (32 baseball players [27 pitchers]) underwent surgery, and 23 (8 baseball players [7 pitchers]) underwent nonoperative management. No patients in the nonoperative arm crossed over to surgery after completing the rehabilitation program. Patients with distal tears (odds ratio, 48.0; $P = .0004$) and complete tears (odds ratio, 5.4; $P = .004$) were more likely to undergo surgery. Baseball players, regardless of position, were confounding determinants of operative management, although there was no difference in RTP and RPP between treatment arms.

Conclusion: A 6-stage MRI-based classification system addressing UCL tear location and severity may help early decision making, as patients likely to fail nonoperative treatment have complete, distal tears, whereas those with proximal, partial tears may be more amenable to nonoperative management.

Keywords: UCL; staging; nonoperative management; MRI validation

Injuries to the medial ulnar collateral ligament (UCL) of the elbow are increasingly diagnosed and treated, particularly among baseball players and other overhead-throwing athletes.^{3,7,9,10,15,21} While surgical management has translated to improved functional and patient-reported outcomes, identifying which patients will most likely benefit

from UCL reconstruction remains elusive.^{16,18,22,27-29} With the advent of UCL reconstruction, the volume of procedures has increased, as reported in the peer-reviewed literature and public media.^{3,9,25,26} However, in 2 reports by Camp et al,^{4,5} the incidence of UCL reconstructions may be decreasing among professional baseball players but increasing in younger, minor league players. Hurwit et al¹⁶ surveyed 159 members of the American Shoulder and Elbow Surgeons and found that professional athletes and those with complete tears were indicated for surgery by

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TABLE 1
MRI-Based Classification of UCL Tears
According to Ramkumar et al^{23a}

Stage	Description
1A	Partial tear of the proximal/humeral UCL
1B	Complete tear of the proximal/humeral UCL
2A	Partial tear of the midsubstance UCL
2B	Complete tear of the midsubstance UCL
3A	Partial tear of the distal/ulnar UCL
3B	Complete tear of the distal/ulnar UCL

^aMRI, magnetic resonance imaging; UCL, ulnar collateral ligament.

consensus regardless of the tear location; opinion was more divided on how to treat partial tears or nonprofessionals.

Nonoperative treatment for patients with UCL tears has only recently been broached in the literature.²⁰ Ford et al¹² reported that partial UCL tears diagnosed on magnetic resonance imaging (MRI) had success with nonoperative management among professional baseball players, although the tear severity was not examined as a factor in deciding operative versus nonoperative treatment because patients with high-grade tears automatically underwent surgery.^{1,8} To examine tear severity as a determinant for operative versus nonoperative treatment, an MRI-based study by Frangiamore et al¹⁴ reviewed 32 professional baseball pitchers who underwent nonoperative management for their UCL tear. These authors found that 9 of 11 patients who failed nonoperative management had distal tears, and 17 of 21 who did not fail had proximal tears, suggesting that location may play a role in treatment decision making. Ramkumar et al²³ introduced an MRI-based classification system that accounted for both tear location and severity (Table 1), which demonstrated high intraobserver and interobserver reliability among 9 readers across multiple institutions.

The proposed MRI-based classification system has demonstrated acceptability and reproducibility; however, the role of this classification in clinical decision making between operative and nonoperative management remains to be determined. The primary objective of this study was to assess whether the MRI-based classification system was able to predict which athletes had success with nonoperative versus operative treatment after completing a standardized rehabilitation program. We hypothesized that the classification system will clinically correspond with operative versus nonoperative management. A secondary objective was to evaluate return to play (RTP) and return to prior performance (RPP) for baseball players treated

nonoperatively and operatively. We hypothesized that RTP and RPP rates will be similar regardless of operative versus nonoperative management. In performing this study, we hope to clarify the clinical applicability of UCL pathoanatomy on MRI, with particular respect to tear location and severity, in determining operative versus nonoperative treatment.

METHODS

This was a retrospective chart review approved by an institutional review board. After an a priori power analysis, 65 consecutive patients from June 1, 2015 to June 30, 2016 with UCL tears and a minimum of 2-year follow-up were retrospectively classified into those who underwent operative treatment and those who underwent nonoperative treatment. All patients had first undergone a trial of 3 months' rest and a nonoperative rehabilitation program, per the senior author's (M.S.S.) standard protocol for all patients with UCL tears. Baseball players had undergone a specific throwing rehabilitation program, consisting of a period of rest and range of motion exercises in the first week, followed by protective rotator cuff strengthening in the second week, advanced rotator cuff and forearm strengthening in the third week, and 2-hand and 1-hand plyometric exercises in weeks 4 and 5, respectively. After week 5, additional therapy and rehabilitation, involving the entire upper extremity including periscapular strengthening, were conducted per the senior author's recommended protocol. Some players supplemented their nonoperative management with platelet-rich plasma therapy (n = 2).

All MRI was performed at the senior author's institution using a 3.0-T scanner (Signa 3T; GE Healthcare) with a 10° to 20° down coronal sequence (coronal T2 fat saturated: 14-cm field of view, 5000 ms repetition time, 55 ms echo time, 2.0-mm slice thickness), per the institutional protocol, and were reviewed by the senior surgeon (M.S.S.). Using the MRI-based classification system in Table 1,²³ the UCL tears of 58 patients from the practice of a single surgeon (M.S.S.) specializing in UCL management were retrospectively classified. Examples of stage 1B and 3A tears are shown in Figure 1.

Patient Cohort and Treatment Protocol

The retrospective cohort of 58 consecutive patients consisted of those with UCL tears regardless of activity, sport, and level of competition. A subanalysis for the group of

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Ethical approval for this study was waived by the Cleveland Clinic Institutional Review Board.



Figure 1. Examples on coronal magnetic resonance imaging (MRI) of a (A) stage 1B tear and (B) stage 3A tear according to the MRI-based classification.

baseball players, including pitchers, was performed to control for treatment bias due to throwing demands and expectations with throwing compared with position players. For the general pool, differences between the operative and nonoperative groups were analyzed in terms of age and sport. For the baseball subgroup analysis, differences between the operative and nonoperative groups were analyzed in terms of age, sport, and position (pitchers vs position players). The level of competition was collected to determine if the player returned to at least the same level at 2-year follow-up.

Patients who failed the initial trial of rest and rehabilitation by exhibiting recurrent pain or weakness underwent surgical reconstruction of the UCL. Patients who improved under the initial nonoperative trial underwent further rehabilitation treatment for a 1.5-month period under the senior author's direction. Patients who never required surgery within the first 2 years of diagnosis and followed the nonoperative protocol were categorized into the nonoperative group. Patients who underwent surgery after failing the nonoperative trial were categorized into the operative group. Patient characteristics such as age, sport, position, prior elbow surgery, and RTP and RPP status at 2 years were also collected. As described by Fedoriw et al,¹¹ RPP among baseball players was defined as returning to the same level or quality of competition (A, AA, AAA, Major League Baseball [MLB]) or higher; among athletes not playing baseball, RPP was defined as returning to the same level of competition (high school, collegiate, professional).

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) patients with a UCL injury who tried initial nonoperative management; (2) patients with 2 years of follow-up data including RPP and time to RPP; and (3) presence of demographic data including age and sport, as well as position data for baseball players. Exclusion criteria were as follows: (1) patients who were lost to follow-up at 2 years, (2) prior elbow surgery or a concomitant elbow injury (dislocation, fracture), and (3) patients who elected to undergo immediate operative intervention. Reasons for immediate operative intervention

were acute injuries with significant pain and patient preference to forgo nonoperative management.

Retrospective MRI Classification

Two reviewers (P.N.R., H.S.H.) separate from the original MRI-reading radiologist and orthopaedic surgeon (M.S.S.) each classified the MRI scans and were blinded to the treatment arm, per the methodology outlined by Frangiamore et al.¹⁴ A third reviewer (S.J.F.) arbitrated any discrepancy.

Statistical Analysis

Differences between the operative and nonoperative groups analyzed in terms of age for both the general pool and baseball subgroup were compared for potential confounders. The Student *t* test was used for the age distribution comparison between the groups. An a priori power analysis indicated that a sample size of 42 patients would be sufficient to detect a significant interaction effect with a power of 0.80, alpha of .05, and anticipated effect size (Cohen *d*) of 0.80. Variables included in the power analysis were baseball player versus non-baseball player status as independent variables and operative versus nonoperative treatment as dependent variables. As such, we reviewed the charts of 58 patients with UCL tears to account for patients who may have been lost to follow-up or failed to meet inclusion criteria.

Patients in the operative and nonoperative groups were analyzed by MRI-based classification of the tear (6 stages), tear location (proximal, midsubstance, distal), and tear severity (partial, complete). Sets of inputted data were generated using SPSS software (IBM) analyzed by logistic regression and odds ratios (ORs) for both baseline and follow-up outcomes. Also, 95% CIs were generated for all ORs. Achievement of statistical significance ($P \leq .05$) was incorporated into the evaluation. We performed a combination of 1-way analysis of variance (ANOVA) with post hoc Tukey honestly significant difference analysis, in line with previous studies.^{19,26} One-way ANOVA was first used to evaluate whether a statistical difference in treatment outcomes existed between the 6 different classification stages, followed by post hoc Tukey analysis to determine which head-to-head comparisons were significantly different from each other. Logistic regression was then used to produce ORs, and the combination of ANOVA and post hoc Tukey analysis was performed to produce *P* values of the head-to-head comparisons. This sequence of ANOVA, regression analysis, and post hoc Tukey honestly significant difference analysis was repeated for baseball players. To determine if baseball player status (non-baseball player vs baseball player) and baseball player position (pitcher vs nonpitcher) were determinants of operative treatment, simple regression analysis without any additional post hoc analysis was performed for a comparison of the 2 groups. The independent variable was UCL tear classification stage, and operative outcome was the dependent variable evaluated.

RESULTS

Demographics

Within the general pool of 58 patients who met the inclusion criteria, there were 35 (60%) who underwent surgery and 23 (40%) who underwent nonoperative treatment. The patients were statistically different in terms of age, as the nonoperative group was significantly older compared with the operative group (30.1 vs 19.9 years; $P = .0002$). Baseball player status was a determinant of operative management compared with non-baseball player status in the general pool (OR, 76.6; $P = .0032$). The baseball subgroup of patients who met all inclusion criteria consisted of 40 patients: 32 (80%) who underwent surgery (27 pitchers, 5 position players) and 8 (20%) who underwent nonoperative treatment (7 pitchers, 1 position player). Within the baseball subgroup, the nonoperative group was found to be older than the operative group (22.7 vs 19.5 years; $P = .0091$). Baseball position was not a determinant of operative management, as no statistical difference was found between pitchers and position players ($P = .36$). The most common nonbaseball sports were football ($n = 3$) and lacrosse ($n = 2$).

Operative Versus Nonoperative Management

One-way ANOVA confirmed for both the general pool ($P < .0001$) and baseball subgroup ($P < .0001$) that there existed a statistically significant difference in treatment outcomes between the 6 different classification stages. For the general pool, patients with either distal tears (OR, 48.0 [95% CI, 5.7-402.8]; $P = .0004$) or complete tears (OR, 5.4 [95% CI, 1.7-17.4]; $P = .004$), regardless of location, were more likely to proceed to operative management after a 3-month trial of nonoperative treatment. For the baseball subgroup, patients with distal tears were more likely (OR, 36.4 [95% CI, 1.9-69.3]; $P = .017$) to proceed to operative management. Additionally, those with complete tears proceeded to operative management more than nonoperative management (OR, 6.6 [95% CI, 1.1-38.6]; $P = .036$). Overall, 18 of 23 patients (6/10 baseball players) with stage 1A and 1B tears successfully underwent nonoperative treatment, whereas 24 of 25 patients (22/22 baseball players) with stage 3A and 3B tears failed nonoperative management and proceeded to surgery. Tables 2 and 3 detail the number of patients stratified by the MRI-based 6-stage classification system for the general pool and the baseball subgroup, respectively.¹⁴ The risk of a stage 3B tear proceeding to surgery compared with a stage 1A tear was nearly 10 times higher (OR, 10.5; $P = .001$). See Table 4 for all the ORs from the logistic regression analysis comparing operative risk between each of the 6 classification stages.

RTP and RPP

Among the 35 patients in the operative group for the general pool, 32 (91%) were cleared to return to their sport or activity, and 32 (91%) returned to their same level of competition. Reasons for not returning to same

TABLE 2
General Pool of Patients With UCL Tears (N = 58)
Stratified by MRI-Based Classification^a

Stage	Nonoperative	Operative	Total
1A	14	1	15
1B	4	4	8
2A	2	1	3
2B	2	5	7
3A	1	10	11
3B	0	14	14
Partial	17	12	29
Complete	6	23	29
Proximal	18	5	23
Midsubstance	4	6	10
Distal	1	24	25

^aData are reported as No. MRI, magnetic resonance imaging; UCL, ulnar collateral ligament.

TABLE 3
Subgroup of Baseball Players With UCL Tears (n = 40)
Stratified by MRI-Based Classification^a

Stage	Nonoperative	Operative	Total
1A	6	0	6
1B	0	4	4
2A	0	1	1
2B	2	5	7
3A	0	9	9
3B	0	13	13
Partial	6	10	16
Complete	2	22	24
Proximal	6	4	10
Midsubstance	2	6	8
Distal	0	22	22

^aData are reported as No. MRI, magnetic resonance imaging; UCL, ulnar collateral ligament.

performance level were recurrent pain ($n = 1$), ipsilateral shoulder injury ($n = 1$), or reported loss of interest in the activity at 2 years ($n = 1$). Among the 23 patients in the nonoperative group for the general pool, 22 (96%) were cleared to return to their sport or activity, and 21 (91%) returned to their same level of competition. The reason for the single patient not returning to same performance level was reported loss of interest in the activity at 2 years. Both the RTP and RPP rates in the operative group versus nonoperative group were statistically nonsignificant (RTP: $P = .36$; RPP: $P = .54$).

Players in the baseball subgroup similarly demonstrated no statistically significant differences between RTP ($P = .87$) and RPP ($P = .87$) for the operative and nonoperative groups. Table 5 details the full results of RTP and RPP.

DISCUSSION

Our retrospective study of 58 consecutive patients with a minimum follow-up of 2 years from a single-surgeon

TABLE 4
Logistic Regression With Post Hoc Tukey Analysis
for the Risk of Failing Nonoperative Management^a

	General Pool		Baseball Subgroup	
	OR	P Value	OR	P Value
1A vs 1B	4.1425	.0538029	9.3333	.0010053
1A vs 2A	1.7646	.7873006	9.3333	.0010053
1A vs 2B	5.9212	.0014606	7.7349	.0010053
1A vs 3A	8.8817	.0010053	11.431	.0010053
1A vs 3B	10.5113	.0010053	12.2068	.0010053
1B vs 2A	1.0303	.8999947	0.0000	.8999947
1B vs 2B	1.7328	.799938	2.7463	.3965014
1B vs 3A	3.6846	.1143597	0.0000	.8999947
1B vs 3B	4.7215	.0184694	0.0000	.8999947
2A vs 2B	2.3104	.5703793	2.7463	.3965014
2A vs 3A	3.6995	.1117297	0.0000	.8999947
2A vs 3B	4.3855	.0348692	0.0000	.8999947
2B vs 3A	1.6862	.8184486	3.4157	.1786697
2B vs 3B	2.5831	.4598082	3.6717	.1250011
3A vs 3B	0.9443	.8999947	0.0000	.8999947

^aOR, odds ratio.

TABLE 5
RTP and RPP Rates^a

	Operative		Nonoperative	
	General Pool	Baseball Subgroup	General Pool	Baseball Subgroup
RPP	91.4	90.6	91.3	87.5
RTP	91.4	90.6	95.6	87.5

^aData are reported as percentages. RPP, return to prior performance; RTP, return to play.

practice represents the largest cohort of UCL tears examining nonoperative versus operative management to date. In this study, a previously proposed 6-stage MRI-based classification system with high intraobserver and interobserver reliability, accounting for location and severity of UCL tears, was found to carry clinical decision-making value for both the general population and baseball players alike.^{6,23} UCL tears in both general athletes and baseball players, regardless of position, were found to more frequently fail nonoperative management, despite a specialized rest and rehabilitation program if the tear was distal (stage 3) and complete (substage B). For baseball players specifically, distal tears were 36 times more likely and complete tears 7 times more likely to fail nonoperative management and require surgery. However, patients within the nonoperative group did not differ from those in the operative group in terms of RTP and RPP within both the general pool and baseball subgroup.

While our knowledge of functional UCL anatomy and reconstruction options grows, the evidence behind pursuing nonoperative versus operative management has previously been elusive. Presently, there exists a high degree

of surgeon variability in deciding between surgical reconstruction and nonoperative rehabilitation for UCL pathology.¹⁶ Rettig et al²⁴ reported a 42% success rate for nonoperative management, although no specific history or physical examination findings predictive of failure were identified. Frangiamore et al¹⁴ were the first to describe a treatment algorithm centered on nonoperative management, which demonstrated distal UCL tears seen on MRI led to a higher incidence of nonoperative treatment failure requiring surgery, with 9 of 11 distal tears failing nonoperative management and 17 of 21 proximal tears achieving success with nonoperative management (OR, 12.4 [95% CI, 1.5-102.7]; $P = .02$). High-grade tears were associated with an increased risk of failing nonoperative management, although this was not statistically significant (OR, 3.8 [95% CI, 0.5-31.5]; $P = .21$).¹⁴ The follow-up design and increased power of the study by Frangiamore et al¹⁴ afforded the ability to reach several important conclusions.

In the current study, distal tears and complete tears led to a statistically significant 48-fold and 5-fold increased risk, respectively, of patients in the general pool failing nonoperative management. This suggests that patients with stage 1A tears should be more strongly considered for nonoperative treatment, as opposed to stage 3B tears, which by comparison have a 10-fold increased chance of failing nonoperative treatment and may benefit from earlier operative management. The results in Table 4 illustrate risk stratification when directly comparing UCL tears and may aid in counseling, although more patients are required to fully assess the risk of requiring operative intervention for each player's demands and pathoanatomy. The MRI-based classification system certainly does not stand alone as the sole determinant of clinical decision making, as more patients in the baseball subgroup with throwing demands failed nonoperative management compared with those in the general pool.¹³ No difference was found between pitchers and position players, although the 6 position players compared with 34 pitchers in our subgroup analysis may have precluded us from detecting a true difference.

No significant differences in either the RTP or RPP metrics were found between the operative and nonoperative groups, which suggests there is no long-term advantage of operative treatment over nonoperative treatment. Compared with patients who have never undergone UCL reconstruction, patients who do undergo surgery have been found to have satisfactory RTP and RPP rates.² In line with the rates found in our study, Begly et al² reported in a retrospective study of 35 position players that the RPP rate was 80% without major losses in wins above replacement, on-base plus slugging, and isolated power. Catchers, however, suffered the lowest RPP rate of 56%, with decreases in the home run rate, runs batted in, and isolated power.² Jack et al¹⁷ reported no difference in RPP rates and on-field performance statistics for position players and pitchers in a retrospective series of 34 MLB players after UCL reconstruction. In the nonoperative literature, Ford et al¹² reported success in 28 MLB players with partial UCL tears and recommended the use of an MRI grading system to predict RTP and the need for surgery, which this study hoped to accomplish. The classification system we used has

demonstrated that patients with distal and complete tears should be more readily considered for UCL reconstruction, especially among baseball players. However, patients with proximal or partial tears may be counseled to pursue non-operative management, with the expectation that returning to prior levels of performance is likely with either operative or nonoperative management.

This study has some limitations. The retrospective nature of the study precluded the advantages of a prospective design that could strictly assign patients to a nonoperative or operative arm based on MRI. Additionally, the retrospective nature of this study precluded accurate documentation and capture of time to RPP earlier than 2 years. While the a priori power analysis required a minimum of 42 patients, which was met for the general pool (N = 58), we were underpowered for the baseball subgroup (n = 40), and additional position players in the baseball subgroup would have been ideal to extract more position-specific data when comparing against the pitcher population (n = 34). No specific timeline to RPP after nonoperative treatment were available, and this represents an area of future study in expectation management for athletes undergoing operative versus nonoperative management.

Among the 10 midsubstance (stage 2) tears available, 6 required operative intervention; it is also important to note that in the initial study by Ramkumar et al,²³ midsubstance tears found on MRI only correlated with intraoperative findings 40% of the time, implying further consideration of how to approach athletes with these tears. For patients with stage 2 tears, this analysis does not provide sufficient evidence to indicate operative versus nonoperative treatment on MRI findings alone. The study included 2 players from each group receiving platelet-rich plasma treatment determined by the senior author, potentially confounding the results. Performance-based statistics such as wins above replacement and slugging percentage would also provide more in-depth on-the-field tracking of postoperative performance. An additional limitation was the follow-up period of 2 years, which carries the risk of missing revision UCL procedures and understating RPP. A longer term follow-up would be beneficial to establish the natural history and performance after patients complete either treatment arm.

CONCLUSION

A 6-stage MRI-based classification system addressing UCL tear severity and location may confer early decision making, as patients likely to fail nonoperative treatment have complete, distal tears, whereas those with proximal, partial tears may be more amenable to nonoperative management. The results of this study provide a foundation for identifying which patients, after accounting for functional demands, warrant surgical intervention versus conservative management based on MRI findings.

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