



Prognostic utility of an magnetic resonance imaging-based classification for operative versus nonoperative management of ulnar collateral ligament tears: one-year follow-up

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Background: A recently introduced classification of medial ulnar collateral ligament (UCL) tears has demonstrated high interobserver and intraobserver reliability, but little is known about its prognostic utility. The purpose of this study was to assess the relationship of the magnetic resonance imaging (MRI)-based classification system and nonoperative vs. operative management. Secondary objectives included subanalysis of baseball players.

Methods: Eighty-five consecutive patients with UCL tears after a standardized treatment paradigm were categorized as operative vs. nonoperative. UCL tears of patients with a minimum of 1-year follow-up were retrospectively classified using the MRI-based classification system. Subanalyses for baseball players included return-to-play and return-to-prior performance.

Results: A total of 80 patients (62 baseball players, 54 pitchers) met inclusion criteria. A total of 51 patients underwent surgery, and 29 patients completed nonoperative management. In baseball players, 59% of the proximal tears were treated nonoperatively and 97% of the distal tears were treated operatively; 100% of the proximal partial-thickness tears and 100% of the distal complete tears were treated nonoperatively and operatively, respectively. Patients with distal (odds ratio: 48.4, $P < .0001$) and complete (odds ratio: 5.0, $P = .004$) tears were more likely to undergo surgery. Baseball players, regardless of position, were determinants of operative management, and there was no difference in return-to-play clearance and return-to-prior performance between the operative and nonoperative groups.

Conclusion: A reliable 6-stage MRI-based classification addressing UCL tear grade and location may confer decision making between operative and nonoperative management. Complete and distal tears carry a markedly increased risk of failing nonoperative care compared with proximal, partial tears.

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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.^{5,7,8,13} This demand from high-level athletes with UCL injuries has been met with the evolution of contemporary surgical approaches and reconstruction strategies.^{3,14} Although surgical management has translated to improved functional and patient-reported outcomes, identifying which patients would most benefit from UCL reconstruction remains to be determined.^{16,20,22,23,24,25} Hurwit et al¹⁴ 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 consensus regardless of 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. Ford et al¹⁰ reported that partial tears diagnosed on magnetic resonance imaging (MRI) had success in the nonoperative management of UCL injuries among professional baseball players, although the tear grade in deciding operative vs. nonoperative treatment was not examined because high-grade tears automatically underwent surgery. In an MRI-based study by Frangiamore et al¹² reviewing 32 professional baseball pitchers undergoing nonoperative management for their UCL tear, a treatment protocol was introduced that described indications for UCL reconstruction among elite Major League Baseball (MLB) pitchers. Furthermore, the study 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.¹² Ramkumar et al²¹ introduced an MRI-based classification that accounted for both tear location and degree (Table I), which demonstrated high intraobserver and interobserver reliability among 9 readers across multiple institutions.

The proposed MRI-based classification has demonstrated high reliability, but clinical decision making

between operative and nonoperative management remains to be determined to ensure that the MRI-based classification is meaningful. As such, the primary objective of this study was to assess the relationship of the MRI-based classification system and nonoperative vs. operative management. Secondary objectives included a subanalysis of specifically baseball players, including return-to-play (RTP) and return-to-prior performance (RPP). In doing so, we hope to establish a classification system for staging UCL tears that is not only clear and reliable but also capable of guiding clinical decision making between operative and nonoperative treatment.

Materials and methods

This was a retrospective chart review. This study was approved by the institutional review board. Using the proposed classification scheme in Table I from Ramkumar et al,²¹ the MRIs of 85 consecutive patients from January 1, 2016, to December 31, 2017, with UCL tears from the practice of a single surgeon specializing in UCL management were retrospectively classified via a chart review. All MRIs were performed at the senior authors' institution using a 3T 10° to 20° down coronal sequence, per institutional protocol, and reviewed by the senior surgeon. Patients who followed up for a minimum of 1 year after the diagnosis were separated into operative and nonoperative arms after completing a standardized nonoperative protocol.

Patient cohort and treatment protocol

The retrospective cohort of 85 consecutive patients consisted of individuals with UCL pathology regardless of activity, sport, and level of competition. A subanalysis for the group of 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). Level of competition was extracted to determine if the player returned to at least the same level at 1-year follow-up.

All patients underwent a trial of 3 months' rest and a nonoperative rehabilitation program, per the senior author's standard protocol for all patients with UCL tears. Baseball players underwent a specific throwing rehabilitation program, consisting of a period of throwing rest and range of motion exercises in the first week followed by protective rotator cuff strengthening in the second week. The third week consisted of advanced rotator cuff and forearm strengthening, with 2-hand and 1-hand plyometric exercises in weeks 4 and 5, respectively. Some players

Table I Six-stage magnetic resonance imaging-based classification for ulnar collateral ligament tears by Ramkumar et al²¹

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

supplemented their nonoperative management with platelet-rich plasma therapy ($n = 3$). The MRI date was used as the index injury date for standardization and internal consistency. Failure of a nonoperative program was defined as recurrent pain or weakness requiring a surgical intervention after completing the nonoperative course. Patients who never required surgery within the first year of diagnosis and performed the nonoperative protocol were grouped into the nonoperative pool. Patients who underwent surgery after failing a trial of nonoperative treatment were grouped into the operative pool. Patient characteristics such as age, sport, position, prior elbow surgeries, RTP clearance at 1 year, and RPP status at 1 year were also extracted. Clearance of all activities was used as the metric to account for patients who were medically capable of returning but did not due to social or personal reasons, particularly for amateur and adolescent athletes. As described by Fedoriv et al,⁹ RPP status among baseball players was defined by returning to the same level or quality of competition (A, AA, AAA, MLB) or higher. Among athletes not in baseball, RPP status was defined by return to the same level of competition (high school, collegiate, professional).

Inclusion and exclusion criteria

Inclusion criteria are as follows: (1) patients with a UCL injury who tried initial nonoperative management; (2) patients with 1-year follow-up data including RPP and time to RPP; and (3) presence of demographic data including age and sports, including position data for baseball players. Exclusion criteria are as follows: (1) patients who were lost to follow-up at 1 year ($n = 1$); (2) prior elbow surgery or concomitant elbow pathology (dislocation, fracture); and (3) patients who elected to undergo immediate operative intervention ($n = 4$). Despite the senior author's encouragement to pursue nonoperative management, reasons for immediate operative intervention were acute injuries with significant pain ($n = 3$) and patient preference to forego nonoperative management ($n = 1$). Two reviewers classified each MRI and were blinded to the treatment arm. A third reviewer arbitrated any discrepancy.

Statistical analysis

Differences between the operative and nonoperative groups analyzed in terms of age, sport, and position (pitchers vs. position players) for both the general and baseball subgroup analysis were compared for potential confounders between operative and nonoperative groups using a Student's *t*-test. A priori power analysis indicated that a sample size of 58 would be sufficient to detect a significant interaction effect with a power of 0.90, an alpha of 0.05, and anticipated effect size (Cohen's *d*) of 0.80. As such, we reviewed the charts of 85 patients with UCL tears to account for patients who may be lost to follow-up or fail to meet inclusion criteria.

Patients in operative and nonoperative treatment groups were analyzed by the UCL 6-stage classification, tear location (proximal, midsubstance, distal), and degree (partial, complete). Sets of inputted data were generated using SPSS (IBM Corp, Armonk, NY, USA) analyzed by logistic regression and odds ratios (ORs) for both baseline and follow-up outcomes. Confidence intervals were generated for all ORs. The achievement of statistical significance ($P \leq .05$) was incorporated into the evaluation. One-way analysis of variance was used to derive ORs between each of the 6 classifications for the general pool and baseball players.

Results

Demographics

The general pool of patients who met all inclusion criteria consisted of a total of 80 patients, 51 of whom (64%) underwent surgery and 29 of whom (36%) underwent nonoperative management. The patients were statistically different in terms of age, as the nonoperative group of 27.35 years was significantly older compared with the operative group of 20.02 years ($P = .003$). Baseball player status was a determinant of operative intervention compared with the non-baseball patients in the pool (OR: 76.6, $P = .0032$). The baseball subgroup of patients who met all inclusion criteria consisted of a total of 62 patients, 47 of whom (77%) underwent surgery (42 pitchers, 5 position players) and 15 of whom (23%) underwent nonoperative management (12 pitchers, 3 position players). The patients in the baseball subgroup were not statistically different in terms of age, because the nonoperative group of 21.40 years was not significantly older compared with the operative group of 19.77 years ($P = .32$). The mean age of baseball players was 20.13 years, with a mean age of 19.89 years for pitchers and 20.60 years for position players. Non-baseball players were an average of 32.49 years old. Baseball position was not a determinant of operative intervention because no statistical difference was found among pitchers and position players ($P = .35$). The most common non-baseball sports were football ($n = 4$) and lacrosse ($n = 2$), with the remaining 12 players from various activities including wrestling, mixed martial arts, softball, and work-related injuries. Of the 80 studies, only 1 required a third reviewer to arbitrate.

Operative versus nonoperative management

For the general pool, patients with distal (OR: 61.2, 95% confidence interval [CI]: 7.6-493, $P < .0001$) and complete (OR: 4.7, 95% CI: 1.7-13.3, $P = .003$) tears were more likely to proceed to operative management. For the baseball pool, patients with distal (OR: 65.0, 95% CI: 3.6-1173, $P = .0002$) and complete (OR: 5.5, 95% CI: 1.3-22.8, $P = .003$) tears were more likely to proceed to operative management. A total of 23 of 30 patients (12 of 17 baseball players) with 1A and 1B tears succeeded nonoperative treatment, whereas 35 of 37 patients (33 of 34 baseball players) with 3A and 3B tears failed nonoperative management and proceeded to surgery. [Tables II and III](#) detail the frequency of patients stratified by MRI 6-stage classification for the general pool and baseball subgroup, respectively. The risk of a 3B tear proceeding to surgery compared with a 1B tear was 5 times higher (OR: 5.2, $P < .01$). For full OR analysis comparing operative risk between each of the 6 classifications, see [Table IV](#) for full analysis of variance results for both the general pool and baseball subgroup.

Table II Summary of eligible patients with ulnar collateral ligament tears stratified by magnetic resonance imaging-based classification

	Nonoperative	Operative	Total
1A	18	1	19
1B	5	6	11
2A	2	4	6
2B	2	5	7
3A	2	14	16
3B	0	21	21
Partial	22	19	41
Complete	7	32	39
Proximal	23	7	30
Midsubstance	4	9	13
Distal	2	35	37

Table III Summary of eligible baseball players with ulnar collateral ligament tears stratified by magnetic resonance imaging-based classification

	Nonoperative	Operative	Total
1A	10	0	10
1B	2	5	7
2A	0	4	4
2B	2	5	7
3A	1	13	14
3B	0	20	20
Partial	11	17	28
Complete	4	30	34
Proximal	12	5	17
Midsubstance	2	9	11
Distal	1	33	34

Return-to-play clearance and return-to-prior performance

Among the 51 patients in the general operative group, 46 were cleared to return to their sport or activity (92%) and 41 returned to their same level of competition (80%). Reasons for not returning to the same performance were as follows: recurrent pain ($n = 1$), ipsilateral shoulder injury ($n = 3$), or reported loss of interest in the activity at 1 year ($n = 1$). Among the 29 patients in the general nonoperative group, 25 were cleared to return to their sport or activity (86%) and 23 returned to their same level of competition (79%). Reasons for not returning to the same performance were as follows: recurrent pain ($n = 1$) or reported loss of interest in the activity at 1 year ($n = 1$). Both the RTP clearance and RPP rates in the general operative group vs. nonoperative group were statistically different (RTP clearance: $P = .28$; RPP: $P = .92$).

Players in the baseball subgroup analysis similarly demonstrated no statistically significant differences between RTP clearance ($P = .23$) and RPP ($P = .33$) between those managed operatively and nonoperatively. [Table V](#) details the full results of RTP clearance and RPP.

Discussion

Our retrospective study of 80 consecutive patients with a minimum follow-up of 1 year from a single specialized surgeon practice represents the largest cohort of UCL tears examining nonoperative vs. operative management to date. In this study, a previously proposed 6-stage MRI-based classification with high intraobserver and interobserver reliability accounting for location and grade of UCL tears was found to carry clinical decision-making value for both the general population and baseball players alike.^{4,21} After baseball players with UCL tears, regardless of position, were found to more frequently fail nonoperative management despite a specialized throwing program, a subgroup analysis

of baseball players was performed and found similar results as the general population: (1) distal tears are 60 times more likely to require surgery and (2) complete tears are 5 times more likely to require surgery. However, patients within the nonoperative group did not differ from those in the operative group in terms of RTP clearance and RPP for the general population and baseball players.

Although our knowledge of functional UCL anatomy and reconstructive options grows, the evidence behind pursuing nonoperative vs. operative management has previously been elusive. Presently, there exists a high degree of surgeon variability in deciding between surgical reconstruction and nonoperative, regimented rehabilitation with UCL pathoanatomy, sport, or other patient factor considerations factoring into play.¹⁴ Rettig et al reported a 42% success rate of nonoperative management, although no specific history or physical examination findings predictive of failure were identified.²² Frangiamore et al¹² were the first to describe a treatment algorithm centered on nonoperative management, which demonstrated that distal (OR: 12.4, 95% CI: 1.5-102.7, $P = .02$) UCL tears seen on MRI led to a higher incidence of nonoperative treatment failure requiring surgical intervention with 9 of 11 distal tears failing nonoperative management and 17 of 21 proximal tears succeeding nonoperative; high-grade tears were associated with an increased risk of failing nonoperative management, although this was not statistically significant (OR: 3.83, 95% CI: 0.46-31.5, $P = .21$). The follow-up design and increased power of the study afforded the ability to reach several important conclusions. Both distal and high-grade tears led to a statistically significant 60-fold and 5-fold increased risk, respectively, of failing nonoperative management for both the general pool and baseball players. This suggests that patients with 1A tears should be more strongly considered for nonoperative rehabilitation, as opposed to 3B tears, which by comparison have a 14-fold increased chance of failing nonoperative treatment and may benefit from earlier surgical intervention. The results in [Table IV](#) illustrate risk

Table IV Full analysis of variance analyzing the risk of failing nonoperative management among general pool and baseball subgroup

	General OR	General <i>P</i> value	Baseball OR	Baseball <i>P</i> value
1A vs. 1B	5.5307	.002689	7.8837	.0010053
1A vs. 2A	5.5751	.0024223	9.1939	.0010053
1A vs. 2B	6.3628	.0010053	7.8837	.0010053
1A vs. 3A	10.305	.0010053	12.1986	.0010053
1A vs. 3B	12.722	.0010053	14.044	.0010053
1B vs. 2A	1.0155	.8999947	2.4794	.5026982
1B vs. 2B	1.4847	.8999203	0	.8999947
1B vs. 3A	3.5774	.128546	2.5179	.486771
1B vs. 3B	5.1926	.0058235	3.5387	.1407905
2A vs. 2B	0.3639	.8999947	2.4794	.5026982
2A vs. 3A	1.8504	.7533114	0.6853	.8999947
2A vs. 3B	3.0617	.2666153	0	.8999947
2B vs. 3A	1.5079	.8906151	2.5179	.486771
2B vs. 3B	2.7835	.3712287	3.5387	.1407905
3A vs. 3B	1.6016	.8530513	1.1149	.8999947

OR, odds ratio.

Table V Full return-to-play clearance and return-to-prior performance data for both the general pool and baseball subgroup pool of patients with ulnar collateral ligament tears

	General operative	Baseball operative	General nonoperative	Baseball nonoperative
RTP clearance	46 (90.2%)	39 (83.0%)	25 (86.2%)	14 (93.3%)
RPP	41 (80.4%)	35 (74.5%)	23 (79.3%)	13 (86.7%)

RTP, return-to-play; *RPP*, return-to-prior performance.

stratification when directly comparing UCL tears and may aid in counseling, although more patients are required to fully assess the risk of requiring surgical intervention for each player's demands and pathoanatomy. The MRI-based classification certainly may not be the only factor guiding clinical decision making, because patients with the throwing demands of baseball players failed nonoperative management more so than the general pool.¹¹ No difference was found between pitchers and position players, although the 8 position players compared with 54 pitchers in our subgroup analysis may preclude us from detecting a true difference.

The RTP clearance and RPP metrics were found to have no differences for these athletes, suggesting no long-term advantage of operative treatment over nonoperative treatment. Compared with those patients who never underwent UCL reconstruction, patients who did undergo surgery have been found to have satisfactory return to sports and prior performance 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 slugging percentage, and isolated power. Catchers, however, did suffer the lowest RPP rate of 56% with decreases in home run rate, runs batted in, and isolated power.² Jack et al¹⁵ 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 al¹⁰ reported nonoperative success in 28 MLB players with partial UCL tears, albeit without delineating location of pathology (proximal vs. distal), and recommended the need for an MRI grading system to predict RTP and need for surgery. After Ramkumar et al introduced an MRI-based grading system that accounts for partial vs. complete tears, as well as proximal vs. distal tears as suggested by Frangiamore et al, the classification was found to be highly reliable and simple across 9 fellowship-trained specialists and 7 institutions.^{17,21} Joyner et al¹⁶ similarly proposed an MRI-based classification, although this was correlated with valgus laxity and not tear location, tear thickness, or functional demand. However, a Joyner III-U would correlate with a 3B and a Joyner I-H with a 1A although intermediate levels warrant an additional study. To predict the need for surgery and RTP, this classification 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 nonoperative management with the expectation that returning to prior level of performance is likely with either surgical intervention or nonoperative management. Although all studied patients underwent a trial of 3 months of nonoperative management, the data suggest that this period may be too protracted for those with

distal and complete tears likely headed for surgery. Regardless of tear location, the patients decided without surgeon influence whether to opt for surgery or continue rehabilitation after the nonoperative trial. However, results of this study indicate that patients with distal and complete tears warrant earlier surgical intervention because nonoperative care may not be as effective and is now becoming routine in the senior author's practice.

This study is not without limitations. The retrospective nature of the study precluded the advantages of a prospective design that could strictly assign patients to a nonoperative arm with a longer nonoperative period or surgical arm with an abbreviated nonoperative period based on MRI and functional status to determine which patient-related factors truly guide treatment plan. Although the a priori power analysis required a minimum of 58 patients, which was met for both the general pool ($n = 80$) and baseball subgroup ($n = 62$), additional position players ($n = 8$) in the baseball subgroup would have been ideal to extract more position-specific data when comparing against the pitcher population ($n = 54$). An additional consideration that would be beneficial in counseling athletes regarding returning to play after UCL tear would be data related to the speed with which the athlete may expect to RTP for nonoperative vs. operative management. The retrospective nature of this study precluded accurate documentation and capture of time to RPP earlier than 1 year. Furthermore, the mean time of RTP for amateur and professional athletes ranges from 11 to 18 months, suggesting that the 1-year follow-up window may be too short to accurately characterize RTP. Although this was not an endpoint of the study, only 16 pitchers and 4 position players from the operative baseball subgroup had accurately documented time to RPP data. Despite the lacking power to drive conclusions, pitchers returned to prior performance an average of 38.8 weeks (range: 36.4-43 weeks) after surgery compared with position players who returned 25.1 weeks (range: 23.8-26.8 weeks) after surgery; all procedures were UCL reconstructions. No specific nonoperative time to RPP data were available, and this represents an area of study in expectation management for athletes undergoing operative vs. nonoperative management. Although this study outlines a clear blueprint for proximal, partial, distal, and complete tears, midsubstance tears require further study. Among the 11 midsubstance tears available, 9 required operative intervention; it is also important to note that in the initial study by Ramkumar et al,²¹ 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. Magnetic resonance arthrography (MRA) may aid in accurate diagnosis of these tears, although further study is required.^{1,19} For example, Magee¹⁸ concluded MRAs to be more accurate than MRIs after comparing 54 UCL cases of 3T MRIs to 3T MRAs. A total of 9 MRA cases demonstrated intact

collaterals or tendons, whereas the MRI indicated tearing; similarly, a total of 16 MRA cases demonstrated torn collaterals or tendons, whereas the MRI indicated no tearing; these conclusions were confirmed at the time of surgery. It is important to note that the proposed classification was based on MRIs, not MRAs. Although MRIs are more readily accessible, the reliability and validity of the proposed classification using MRAs or 3T sequences are unknown and warrant consideration.⁶ Although patient demands and expectations are likely to be the greatest determinants for those with midsubstance tears, randomized control design may offer further insight. An additional limitation was the follow-up period of 1 year, which carries the risk of missing revision UCL procedures and understating RPP. Longer term follow-up would be beneficial to establish the natural history and performance after patients complete either treatment arm.

Conclusion

A reliable 6-stage MRI-based classification addressing UCL tear grade and location predicts clinical decision making between operative and nonoperative management after identifying complete and distal tears that carry a markedly increased risk of failing nonoperative care compared with proximal and partial tears. When taken together with the player's sporting demands, classification of UCL pathoanatomy on MRI confers the desired treatment plan without sacrificing return to prior performance.

Disclaimer

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