

Magnetic Resonance Imaging Grading System for Tears of the Latissimus Dorsi and Teres Major

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Background: Recent awareness of latissimus dorsi/teres major (LD/TM) injuries has led to an increase in diagnoses. No magnetic resonance imaging (MRI) classification system specific to the LD/TM exists, nor has tear severity been correlated with ability to return to sport (RTS).

Purpose/Hypothesis: The purpose of this study was to report a novel MRI classification system for LD/TM tears as well as to correlate tear grade with performance and RTS. We hypothesized that the new MRI classification system would have high intra- and interobserver reliabilities and that players with higher grade tears would require operative management.

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

Methods: All patients with LD/TM tears diagnosed by MRI who were under the care of 2 orthopaedic surgeons were included. On 2 occasions 60 days apart, MRIs were reviewed and graded by 2 authors using a new classification system. Intra- and interobserver reliabilities were calculated. Timing from injury to RTS was recorded, and performance upon RTS was analyzed.

Results: The proposed grading system had excellent intra- and interrater reliabilities (Cohen kappa >0.850). A total of 20 male patients (mean \pm SD age, 26 \pm 9.3 years) with LD/TM tears were included (80% were baseball pitchers). Of the 16 players treated operatively, 5 were initially treated nonoperatively by an outside physician but could not RTS (all professional baseball pitchers); 2 of these players had grade IIIA tears and 3 of the players had grade IVA tears. Regardless of initial treatment, ultimately 100% of the professional baseball players were able to RTS at a mean of 8.7 \pm 3.3 months, although the initial nonoperative management failed for some of these players and they needed surgical intervention. No statistically significant differences were found between pre- versus postoperative performance in those professional players who were treated surgically.

Conclusion: The proposed MRI-based grading system for LD/TM tears had excellent reliability. This system may allow physicians to better advise patients and all involved health care providers. Consideration should be given to acutely treat grade III and IV tears with operative repair.

Keywords: latissimus dorsi; teres major; return to play; pitcher; shoulder; Major League Baseball (MLB)

The latissimus dorsi (LD) and teres major (TM) are two powerful adductors and internal rotators of the shoulder that both play a role in the overhead throwing motion.⁸ Although the exact function of these muscles during the overhead pitch is not completely understood, the LD and TM are active during the late cocking, acceleration, and follow-through phases.^{7,8} These 2 muscles often coalesce upon insertion onto the humerus and can be indistinguishable from one another.¹ The LD is most active during the acceleration phase and provides important internal rotation power to accelerate the arm and the ball.⁸ Although relatively rare, injuries to the LD/TM can cause significant problems in the overhead athlete.² Recent evidence has

shown an increase in the number of LD/TM tears reported in professional baseball pitchers.²

With the increase in LD/TM tears and their potential for long-term impairment of function, it is imperative to develop a grading system to improve communication between the physicians, coaches, and trainers who are managing these athletes. No current classification system exists for specific grading of LD/TM tears. Rather, these tears are categorized according to general muscle or tendon injury classifications that do not allow adequate treatment recommendations to be made. Furthermore, although studies including different LD/TM injuries have shown success with both operative and nonoperative management of these injuries in baseball players, tennis players, wrestlers, and other high-level athletes, no treatment algorithm is available for deciding which patients can be successfully treated nonoperatively and which will benefit from surgical repair.^{1-3,6,11-15}

The Orthopaedic Journal of Sports Medicine, 7(3), 2325967119826548
DOI: 10.1177/2325967119826548
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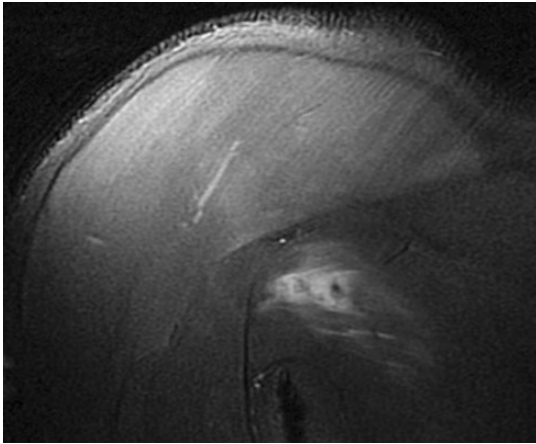


Figure 1. Coronal magnetic resonance image of a grade I latissimus dorsi/teres major tear.

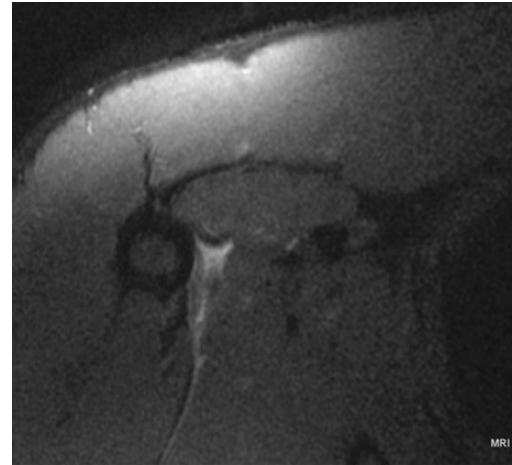


Figure 2. Axial magnetic resonance image of a grade II latissimus dorsi/teres major tear.

Therefore, the purposes of this study were to (1) develop a specific magnetic resonance imaging (MRI) classification system for LD/TM tears and report its reliability, (2) correlate LD/TM tear severity with ability or inability to return to sport (RTS) and evaluate performance upon RTS, and (3) identify predictors of failure of nonoperative management to allow expeditious surgical repair of LD/TM tears. We hypothesized that the new MRI classification system would have high intra- and interobserver reliabilities and that tear severity, as graded by this system, would be associated with ability to RTS as well as performance upon RTS. Furthermore, we hypothesized that players with higher grade tears (grades III and IV) would be more likely to experience failure of nonoperative treatment and would require surgery to allow RTS.

METHODS

The study included all patients who saw one of the study authors between 2010 and 2017 regarding a tear of the LD/TM and who had an MRI available that confirmed this diagnosis. Patients were excluded if they did not have proper imaging available or were determined to not have an LD/TM tear. Institutional review board approval was obtained for this retrospective study. Patients' charts were reviewed to determine when their injury occurred, any

prior treatments rendered by outside physicians, the sports in which patients participated, and how they were ultimately treated by the study author. No patient had received a prior platelet-rich plasma or stem cell injection. For those patients who were professional baseball pitchers, publicly available information was used to record their performance metrics before and after their injury or surgery (<https://www.baseball-reference.com>). Successful treatment was defined as ability to RTS at the same or higher level.

Each MRI was reviewed by 2 authors (H.G.P., B.J.E.), — one was a musculoskeletal radiologist who has been in practice for more than 25 years, the other was a sports medicine fellow—on 2 separate occasions, with 60 days between reviews. Reviewers with different levels of training were chosen to evaluate the reproducibility of this classification system among various experience levels. All MRI sequences were used to formulate the classification. The results were recorded and then compared to obtain intraobserver reliability and interobserver reliability. These authors were blinded to the results of their own first reading, as well as the findings of the other author. The new MRI grading system used for this study was as follows:

- Grade I: Fluid tracking along LD/TM (Figure 1)
- Grade II: Partial-thickness tear (Figure 2)

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One or more of the authors has declared the following potential conflict of interest or source of funding: B.J.E. has received educational support from DePuy and Smith & Nephew. P.N.C. has received educational support from Tornier. H.G.P. has received research support from GE Healthcare and GE/NBA; is a consultant for Ortho RTI, Regeneration Technologies, and Smith & Nephew; has stock/stock options in Imagen; and is a paid associate editor for *Sports Health: A Multidisciplinary Approach*. D.W.A. has received educational support from Arthrex and Stryker. A.A.R. has received research support from Aesculap/B.Braun, Arthrex, Histogenics, Medipost, MLB, NuTech, OrthoSpace, Smith & Nephew, and Zimmer Biomet; is a consultant for Arthrex; is a paid speaker/presenter for Arthrex; receives royalties from Arthrex; and receives publishing royalties from SLACK Inc. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from the Hospital for Special Surgery and Rush University Medical Center (16050203-IRB01, 2017-1506).

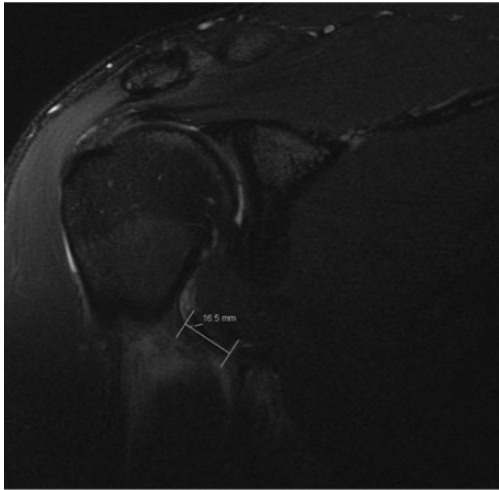


Figure 3. Coronal magnetic resonance image of a grade IIIA latissimus dorsi/teres major tear.

Grade III: Full-thickness tear, <2 cm of retraction (Figure 3)

A: Muscle is torn off of the humerus.

B: Tear is at the musculotendinous junction.

Grade IV: Full-thickness tear, >2 cm of retraction (Figure 4)

A: Muscle is torn off of the humerus.

B: Tear is at the musculotendinous junction (Figure 5).

Players who were treated nonoperatively by this study's senior authors (D.W.A., A.A.R.) were prohibited from pitching for a minimum of 6 weeks or until they were asymptomatic with daily activities and gentle stretching. They then began a scapular stabilization program and, when ready, a return-to-throwing program. Players who were treated operatively underwent repair with our previously published technique.² Following surgery, the repair was protected for 6 weeks. Following this, the athletes began regaining range of motion (ROM) and then began strengthening. When full ROM and strength were achieved, a return-to-throwing program was initiated.

Statistical Analysis

Descriptive statistics were calculated. For professional pitchers, mean per-season preoperative and postoperative performance data were compared by use of paired Student *t* tests and Wilcoxon signed rank tests, as appropriate, based on data normality as assessed with the Kolmogorov-Smirnov test. All analyses were conducted in Excel X (Microsoft) and SPSS 23 (IBM). *P* values less than .05 were considered significant. Intra- and interrater agreement was determined through use of the Cohen kappa. Interrater agreement was determined with data from the first rating occasion. Kappa values were evaluated via the guidelines provided by Landis and Koch,¹⁰ in which values greater than 0.80 are considered to show excellent agreement.

RESULTS

This study included 20 patients with LD/TM injuries, 16 of whom were baseball pitchers. All patients were male; the population had a mean age \pm SD of 26 ± 9.3 years (range, 17-55 years) and an average follow-up duration of 39.8 ± 26.8 months.

With regard to their activities, 16 patients (80%) were baseball pitchers, 1 patient was a kite surfer, 1 patient was a high school rugby player, 1 patient had a water skiing injury, and 1 patient was a weightlifter. Of the pitchers, 3 (19%) were in the major leagues, 7 (44%) were in the minor leagues, and 6 (37%) were in college. Hence, 10 professional baseball players were included. Sixteen baseball players (80%) were over 1 year from injury or surgery (for nonoperatively and operatively treated injuries, respectively), and clinical follow-up was available on 100% of those eligible for 1-year follow-up. Pre- and postoperative performance data were available for 100% of the professional baseball players.

Regarding the MRI classification system, intrarater agreement was 0.854 for rater 1 and 0.850 for rater 2 (ie, excellent agreement). Interrater agreement was 0.850 (ie, excellent agreement). According to this system, 1 patient (5%) had a grade I injury, 4 patients (20%) had grade II injuries, 7 patients (35%) had grade IIIA injuries, and 8 patients (40%) had grade IVA injuries. In total, 16 (80%) were successfully treated surgically and 4 were successfully treated nonoperatively. Of the 16 players treated operatively, 5 were initially treated nonoperatively by an outside physician but did not achieve RTS (all were professional baseball pitchers); 2 of these players had grade IIIA tears and 3 of the players had grade IVA tears. Of the 4 players successfully treated nonoperatively, 1 tear was grade I, 2 tears were grade II, and 1 tear was grade IIIA (Table 1).

Professional Baseball Players

Among the professional baseball players who were more than 1 year out from their date of injury or surgery, 100% were able to return to their prior level of play at a mean of 8.7 ± 3.3 months, regardless of whether they were treated operatively or nonoperatively. However, 5 patients who were initially managed nonoperatively required surgical intervention before they could successfully RTS. Time to return to play was 3.5 ± 2.1 months for the 2 players treated nonoperatively (1 grade II and 1 grade IIIA) and 10.4 ± 0.9 months for the 8 players treated operatively (1 grade II, 3 grade IIIA, and 4 grade IVA). At final follow-up, 91% of the professional baseball players were still active, with 100% (3/3) of major leaguers active and 86% (6/7) of minor leaguers active. Prior to injury, the professional baseball players had a mean of 3.8 ± 2.2 years of professional play, and after their injury, these players had 2.0 ± 1.8 years of professional play. Because only 2 (20%) professional players underwent nonoperative treatment, no statistical comparisons between operative and nonoperative treatment were able to be performed. No statistically significant differences were found between preoperative and

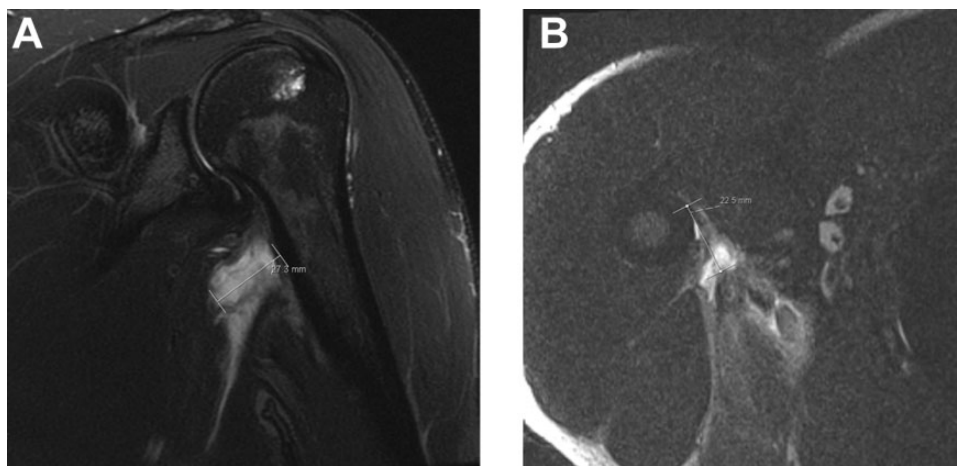


Figure 4. (A) Coronal and (B) axial magnetic resonance images of a grade IVA latissimus dorsi/teres major tear.

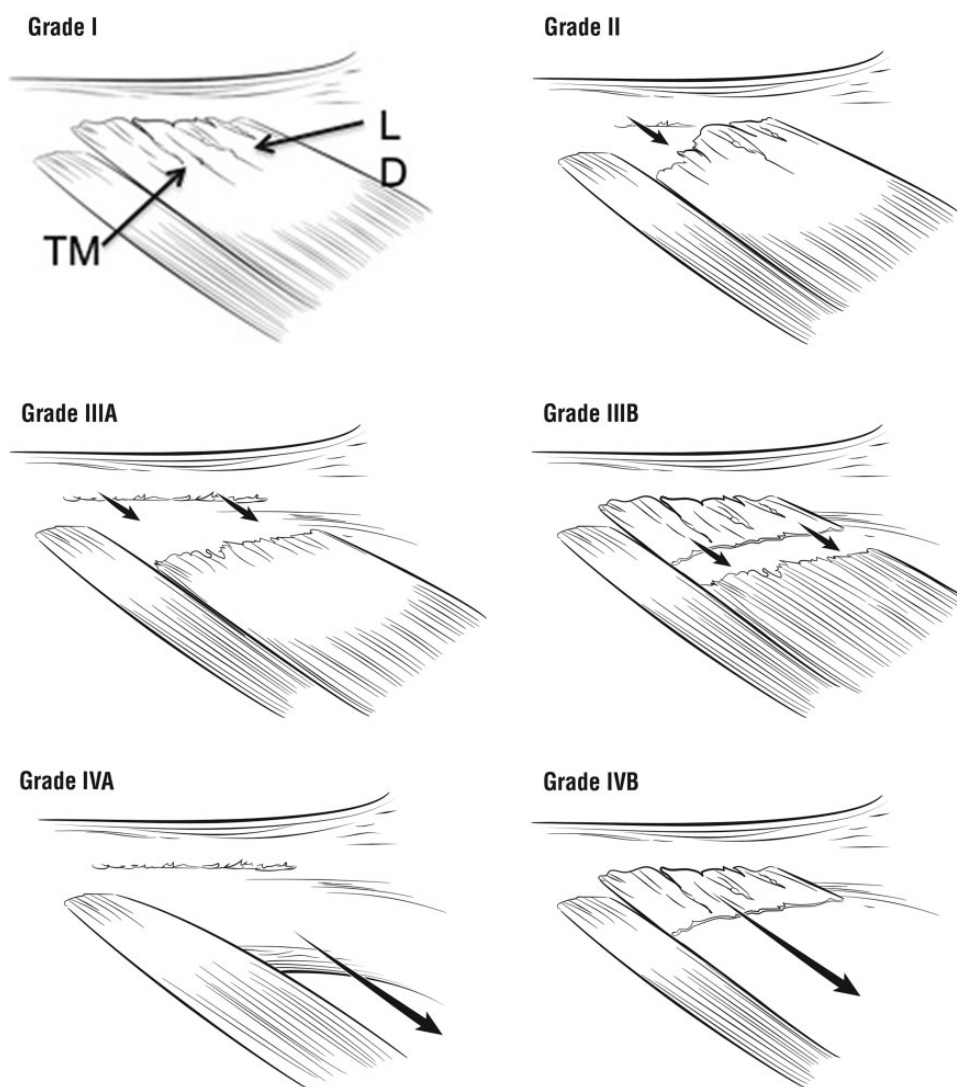


Figure 5. Artist depiction of grades I through IV latissimus dorsi/teres major (LD/TM) tears. A grade I tear entails fluid tracking along the LD/TM. A grade II tear is a partial-thickness tear either at the musculotendinous junction or off of the bone. A grade III tear is a full-thickness tear with <2 cm of retraction. A grade IV tear is a full-thickness tear with >2 cm of retraction. The letter “A” after the tear grade indicates a tear of the tendon off of the humerus, whereas “B” indicates a tear at the musculotendinous junction.

TABLE 1
Breakdown of Tear Grades and Treatments

	Unsuccessfully Treated Nonoperatively	Successfully Treated Nonoperatively	Successfully Treated Operatively
Grade I	0	1	0
Grade II	0	2	2
Grade IIIA	2	1	6
Grade IVA	3	0	8

TABLE 2
Preoperative and Postoperative
Per-Season Performance Data^a

Variable	Preoperative	Postoperative	<i>P</i>
Innings pitched	63.2 ± 51.6	59.5 ± 46.7	.75
Games	18.2 ± 6	18.8 ± 9.6	.893
Wins	3.7 ± 4.2	3.4 ± 3	.813
Losses	3.6 ± 2.5	3.4 ± 3.3	.804
Earned run average	3.4 ± 0.4	4.1 ± 2.2	.427
Complete games	0.3 ± 0.4	0.2 ± 0.4	.311
Shutouts	0.1 ± 0.2	0.1 ± 0.2	.253
Saves	0.9 ± 1.2	1 ± 1.4	.881
Hits	59.9 ± 46.7	56.8 ± 48.5	.776
Runs	27.8 ± 21.4	29 ± 24.7	.792
Home runs	4.3 ± 6	5.7 ± 5.4	.129
Walks	21.4 ± 16.4	20.1 ± 14.9	.819
Hits batted	2.9 ± 2	4.2 ± 4.7	.393
Strikeouts	57.7 ± 48.9	50.2 ± 36	.568
WHIP	1.3 ± 0.1	1.3 ± 0.4	.943

^aData are expressed as mean ± SD. WHIP, walks + hits per innings pitched.

postoperative performance in those professional baseball players who were treated operatively (Table 2).

DISCUSSION

Tears of the LD/TM are an increasingly common problem facing overhead athletes, specifically professional baseball pitchers.^{2,15} Our study hypotheses were confirmed, as the proposed MRI classification system demonstrated excellent intra- and interobserver reliabilities. Furthermore, higher grade tears (grades III and IV) usually necessitated operative intervention whereas lower grade tears were successfully treated nonoperatively (see Table 1).

Our MRI classification system allows for efficient and effective communication between physicians involved in the care and treatment of patients with LD/TM injuries. In addition, the use of this classification system will allow future investigators to determine whether injuries are comparable across studies. Although no tears in this cohort had the "B" subclassification (tears at the musculotendinous junction), we felt it important to include this as a possibility should that tear pattern arise. An example of the value of classifying these injuries, which appear to be most

commonly associated with baseball pitching, is the assessment of ulnar collateral ligament (UCL) injuries of the elbow. Joyner et al⁹ recently developed an MRI classification for UCL tears of the elbow, recognizing the increasing number of UCL injuries in professional baseball players. The authors proposed a grading system of I to IV based on severity, with modifiers based on tear location. Hence, if a player sustains a complete full-thickness tear of the UCL off of the humerus with extravasation of fluid on arthrogram, treating physicians can easily classify this as a grade IIIH tear. The grading systems are very different, as the UCL is a ligament and the LD and TM are tendons; nonetheless, the availability of such grading systems for baseball injuries is important.

The use of the MRI classification system proposed here allows for easier tracking and comparison of players after RTS and their response to various treatments. This in turn provides more accurate information for analyzing the effectiveness of specific treatment modalities for specific LD/TM tear patterns. The comparison of results of variable treatments allows adjustments and the development of appropriate use criteria based on outcomes. We found excellent inter- and intraobserver reliabilities in the novel MRI classification system for LD/TM tears, indicating that this system can be reliably applied by different observers and by the same observer on multiple occasions.

Standard shoulder MRI scans often will not fully visualize the injured LD/TM attachment site, which can make diagnosis, classification, and management of these injuries very difficult. Therefore, clinicians must specify to the radiologist that the LD/TM is an area of interest to ensure that the correct field of view is acquired, commonly by extending the field of view more distally and possibly moving the coil to better image the LD/TM. This can be brought to the radiology technician's attention by providing a suspected diagnosis of LD/TM injury. Another alternative is to obtain lateral chest wall views, which will include the LD/TM. Clinicians should suspect a diagnosis of LD/TM injury if the athlete reports pain in the posterior axillary fold, has pain on resisted shoulder extension or internal rotation, has asymmetry in the posterior axillary fold, or has atypical shoulder pain that does not seem to be attributable to more common causes (eg, biceps, labrum, or rotator cuff injuries).

A limited number of studies of a small number of patients have evaluated the operative and nonoperative treatment of LD/TM tears.^{1-5,13,15} Nagda et al¹³ performed a retrospective review of 16 professional baseball players who were treated nonoperatively for LD/TM tears. Although the authors reported that 6 of the injuries were tendon avulsions and 10 were strains, no further severity classification was provided. The authors found that 15 of the 16 pitchers (94%) returned to the same or higher level of play at an average of 82.4 days and that 9 of 16 injuries (56%) were season ending (5 of the 9 season-ending injuries were complete avulsions). Schickendantz et al¹⁵ reported on 10 professional baseball pitchers who were treated nonoperatively for LD/TM tears and found that 90% were able to return to pitching at 3 months. However, these 2 studies did not include modern-day assessment of the level of return to play and pitching effectiveness.

The largest series on operative treatment of LD/TM injuries to date is by Erickson et al,² who reported on 11 patients who underwent surgical repair of the LD/TM. The authors found that all professional baseball pitchers returned to the same level of play and saw significant improvements in visual analog scale, American Shoulder and Elbow Society, and Kerlan-Jobe Orthopaedic Clinic scores. However, while these 3 studies demonstrate that LD/TM tears can be successfully treated both nonoperatively and operatively, none of them clearly defines the indications for surgical repair or nonoperative management. The results of these studies^{11,13,15} do not provide enough information to develop evidence-based guidelines for treatment of LD/TM injuries.

The most important finding from the current investigation and proposed MRI classification system is that the majority of players with lower grade tears could be successfully managed nonoperatively. However, those players with higher grade tears (grades III and IV) who initially underwent nonoperative management had a very high failure rate of 83.3%. These players were all able to successfully RTS following delayed operative intervention. Hence, we recommend a period of nonoperative management in players who sustain grade I or II tears, with the understanding that these players may take 6 weeks or longer to successfully RTS. However, in players who sustain grade III or IV injuries, we recommend early surgical intervention to repair the LD/TM avulsion. Based on the results of this study, this algorithm appears to provide these athletes with the most predictable and successful RTS outcomes.

Limitations

This was a retrospective study of a relatively small and specific patient population and therefore is subject to the limitations of such a study. Although LD/TM tears are becoming more recognized, they are still much less common than other shoulder and elbow injuries, making it difficult to obtain a large sample size. Furthermore, details of the nonoperative management for the 5 professional baseball pitchers before referral were unknown, although all players underwent a period of rest followed by rehabilitation and a throwing program when they became asymptomatic. An inherent selection bias may have occurred with these patients, as one of the authors (A.A.R.) is a known expert in LD/TM repair, so these athletes could have seen him with their mind set on surgery.

CONCLUSION

The proposed MRI-based grading system for LD/TM tears had excellent reliability in this study. This system may allow physicians to better advise patients and all involved health care providers. Consideration should be given to acutely treat grade III and IV tears with operative repair.

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