Baseball Pitchers who Suffer Latissimus Dorsi and Teres Major Tendon Injuries Have a High Return to Play Rate After Either Operative or Nonoperative Treatment

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Purpose: To provide a concise overview of the prevalence, diagnostic workup, management options, surgical techniques, and reported outcomes in the treatment of latissimus dorsi (LD) and teres major (TM) injuries in professional baseball pitchers. **Methods:** A systematic review of studies reporting on professional baseball players who sustained LD or TM injuries was performed. Data were collected including patient presentation, injury management strategies, return-to-play (RTP) rates, time to RTP, patient-reported outcome measures, player performance after RTP, preinjury factors associated with injury, and complications. **Results:** Nine studies with 159 professional baseball players with a LD or TM injury were identified. All studies (2 retrospective cohort studies with high risk of bias and 7 case series) reported shoulder pain after pitching, and magnetic resonance imaging was performed in all cases to confirm diagnosis. Twenty-three patients underwent surgical treatment, whereas 136 patients underwent nonsurgical treatment. Overall RTP rates and performance between surgical and nonsurgical groups were similar (75% to 100% vs 75% to 93%), although the largest study reported improved performance with surgery. Two studies described a surgical technique with a posterior axillary approach and endosteal button fixation of the LD tendon. All studies reported a progressive strengthening and throwing program prior to returning to sport. **Conclusion:** Professional baseball players who suffer a LD or TM injury have predictable clinical presentations and imaging findings. There is a high RTP rate and performance with both surgical and nonsurgical management. The heterogeneity and low level of evidence of available literature precludes comparative conclusions between treatment approaches. **Level of Evidence:** IV systematic review of Level III and IV studies.

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Injuries to the latissimus dorsi (LD) and teres major (TM) muscles are uncommon, occurring in high-level athletes with repetitive overhead throwing.[1] Overhead throwing motions stress the glenohumeral joint and its dynamic stabilizers, including the LD and TM. Avulsion of the LD and TM or rupture at the myotendinous junction is often a debilitating injury that requires prolonged rehabilitation and missed games.[2]

The LD is a large, triangular muscle innervated by the thoracodorsal nerve, whereas the TM is a smaller, rectangular muscle innervated by the lower subscapular nerve. Activation of the TM and LD is synergistic to adduct, extend, and internally rotate the upper extremity.[3] Although the 2 muscles have unique insertions, a cadaveric study demonstrated a portion of TM muscle fibers inserted directly into the LD tendon in 15 of 18 specimens.[4] Because of this connection and synergistic action, even isolated injuries often involve the other.

In the first study to evaluate muscular activation in the pitching motion, Jobe et al.[5] documented that during the late cocking phase, the LD contracts eccentrically to slow posterior motion of the pitching arm and then transitions to concentric contraction to pull the arm forward in the acceleration phase. Injury to the LD most commonly occurs in the transition from late cocking to the acceleration phase as the muscle transitions from an eccentric to concentric contraction.[2,5-7] Gowan et al.[8] noted significantly higher LD activation in professional pitchers compared with amateur pitchers.

Diagnosing injury to these muscles remains challenging because of nonspecific physical examination findings, injury rarity, and the relatively limited body of literature on the subject.[9] Case reports and case series comprise the current body of literature on these injuries and lack a consensus approach to optimal management.[10] A previous review on LD and TM injuries in baseball players included 29 patients, and only 1 underwent operative intervention.[10] The purpose of this review was to provide a concise overview of the prevalence, diagnostic workup, management options, surgical techniques, and reported outcomes in the treatment of LD and TM injuries in professional baseball pitchers. We hypothesized that baseball pitchers who experience major tendon injuries to the LD, TM, or both would have good outcomes with either operative or nonoperative treatment and a high rate of return to play and performance.

Methods

Data Sources and Searches

A systematic review was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Two authors (A.J.R., C.D.) independently conducted a literature search. The search was conducted from inception to June 23, 2022, through MEDLINE, PubMed, and Scopus databases. Each search included various combinations of the following terms: latissimus OR latissimus dorsi OR teres major AND baseball.

Selection Criteria

All literature pertaining to the LD or TM injuries in professional baseball players from inception to June 2022 was identified. Predefined eligibility criteria consisted of articles written in English or articles with English translation reporting on professional baseball players sustaining LD or TM injuries including randomized controlled trials, observational study designs, case series, and case studies. Exclusion criteria consisted of non-English articles, review articles, articles on LD or TM injuries in athletes playing sports other than baseball, and LD or TM injury imaging studies.

Screening

Sequential screening of the articles was performed by the 2 independent blinded authors in the following systematic approach: assessment of duplicate articles, content within the article title, content of the abstract, and full-text review. Full-text review was performed during the study selection process, if necessary, to determine whether the articles satisfied inclusion and exclusion criteria. The search process is shown in the flow diagram (Fig 1). After application of the inclusion/exclusion criteria, 9 studies were identified for further analysis. No disagreements in study selection were appreciated between authors. To ensure that all available studies were identified, references cited in the included articles were cross-referenced for inclusion if they were overlooked during the initial search, during which no further studies were identified. Study screening was conducted using EndNote (Philadelphia, PA).

Data Extraction

Two independent reviewers (A.J.R., C.D.) evaluated the included studies for data extraction. Data was extracted using Microsoft Excel (Microsoft, Redmond, WA). Data recorded from the included studies included patient presentation, imaging, injury management, return-to-play (RTP) rates, time to RTP, patient-reported outcome measures, player performance after RTP, preinjury factors associated with injury, and complications.

Risk of Bias and Study Design

Included studies were categorized and evaluated according to the Oxford Study Design.[11] Because only Level III cohort studies were included from the systematic review,[12,13] risk of bias was assessed using the ROBINS-I tool.[14]

Statistical Analyses

Given the paucity of literature available on LD or TM tears in professional baseball pitchers, and because each study reported different outcome metrics, meta-analysis was not possible. Therefore the authors elected to proceed with a systematic review with descriptive results to best represent the available data regarding presentation, management options, and outcomes of LD and TM injuries in professional baseball players. Descriptive statistical analysis was conducted where applicable using Microsoft Excel.

Results

Systematic Review

The systematic review identified nine studies with reported patient outcomes in professional baseball players with an LD or TM injury (Table 1).[2,6,7,9,13,15-18]

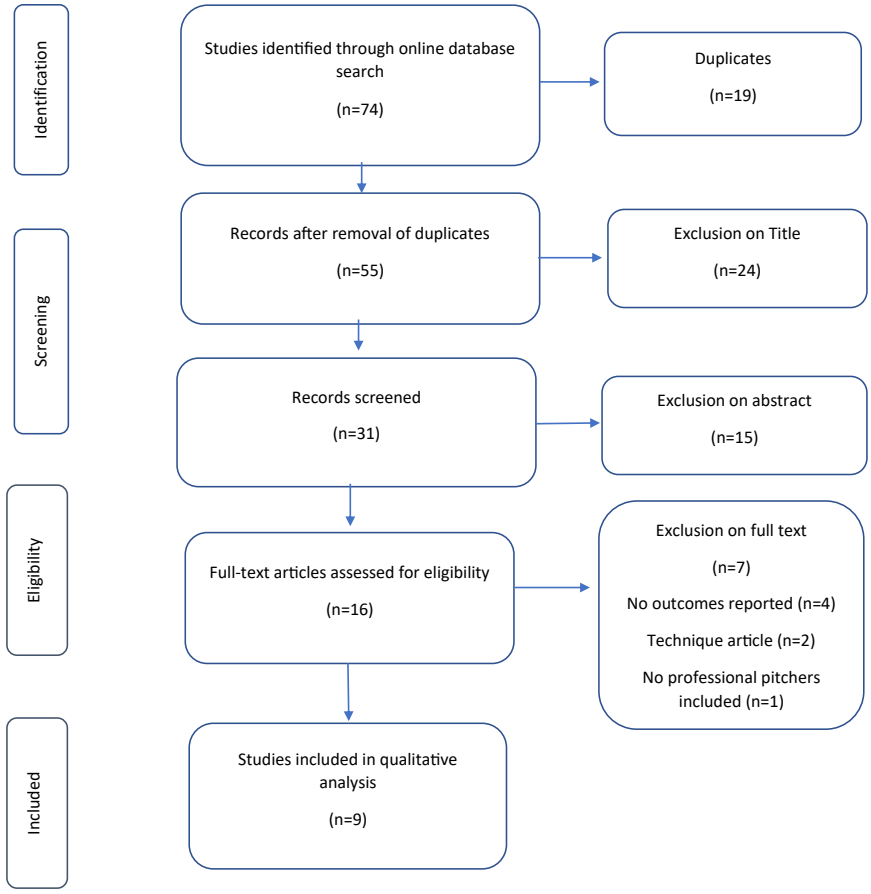

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

In total, 159 professional baseball pitchers who underwent treatment for an LD or TM injury were included in this review. A total of 23 patients underwent surgical management, and 136 patients underwent nonsurgical management. The average age of the professional athletes in this study at the time of injury was 25.9 years.

Study Characteristics

One study was a Level III retrospective case control comparing professional pitchers who suffered an LD or TM injury with matched controls who did not suffer the same injury.[13] Another study was a Level III evidence retrospective cohort study that compares 120 professional baseball players with an LD or TM injury: 13 players underwent surgical management, whereas 107 players elected nonsurgical treatment.[12] The remaining 7 articles were Level IV case series or case studies.[2,7,9,15-18]

Risk of Bias

The epidemiologic case control study with matched controls[13] was determined to have a "serious" level of bias because of missing outcome data and selection of the reported results. The retrospective cohort study with 120 professional baseball players[12] was determined to have a "critical" level of bias because of confounding, selection of participants, missing outcome data, and selection of the reported results.

Epidemiology

Only 1 study included in the review evaluated the epidemiology of LD-TM injuries. Chalmers et al.[13] reported that from 2011 to 2017 there were 242 LD-TM tears recorded in the Major League Baseball (MLB) Health and Injury Tracking System (HITS) database, comprising 0.7% of the 33,592 injuries within the data set. Pitchers accounted for 87% of the players with an LD-TM injury. Again looking at the MLB HITS database, Chalmers et al.[13] found that a higher number of innings pitched per outing, a higher number of batters faced per outing, and being a starting pitcher were all significant risk factors for sustaining an LD-TM tear. Chalmers et al.[13] found no significant association with days of rest and risk of injury.

Diagnosis of LD Injury

Clinical Presentation

Literature reports similar clinical presentations for TM and LD injuries. Five of 9 studies reported that patients commonly felt a sudden pulling sensation in the

Table 1. Functional Outcomes Among Elite Baseball Athletes With Latissimus Dorsi and Teres Major Tendon Injuries

Author	Level of Evidence	Number of Pitchers (Treatment)	Mean Age (y)	Time to RTP	Performance	RTP Rates
Chalmers et al.[13]	III	224 (Not specified)	26	N/R	N/R	N/R
Erickson et al.[6]	III	120 107 (Nonoperative) 13 (Operative)	25.5	Operative: 406 ± 146 days Nonoperative: 170 ± 169 days	Operative pitchers had no difference in any performance metrics; Nonoperative pitchers had increased WHIP and decreased number of games played after injury	75% in both operative and nonoperative management
Erickson et al.[9]	IV	7 (Operative)	29.9	N/R	No difference in performance	100% to same league level
Nagda et al.[2]	IV	16 (Nonoperative)	26.4	35.6 days to throwing; 61.9 days to pitching; 82.4 days missed for pitchers returning same season	N/R	94% returned to same or higher league level
Schickendantz et al.[15]		10 (Nonoperative)	25.4	70% RTP < 90 days 30% RTP > 90 days	N/R	90% returned to same or higher league level
Ellman et al.[7]	IV	1 (Operative)	29	140 days	Similar to preinjury performance	Same level
Leland et al.[16]	IV	2 (Nonoperative)	26.5	65 days	Maintained preinjury velocity and control	Same level
Erickson et al.[17]	IV	1 (Operative)	31	12 months postop, spiral fracture of humerus	N/R	Rehabbing to RTP
Malcolm et al.[18]	IV	1 (Nonoperative)	22	6 months	No impairment of performance	Same level

RTP, return to play; N/R, not reported.

posterior shoulder while throwing, typically during the transition from the late cocking phase to the acceleration phase. [2,7,16-18] Three of 9 studies stated that their patients reported tightness and fatigue in the posterior aspect of shoulder.[2,9,15] Two studies reported that if players continue to throw after the injury, most complain of decreased pitching velocity.[12,19] Six of 9 studies reported that when examined, patients commonly experience pain on palpation of the posterior shoulder,[2,7,9,15,17,18] and 4 studies reported that patients may have palpable or visible defects in the posterior axilla (Fig 2).[6,7,9,17,19] Three studies reported that, when examining shoulder strength, patients will have weakness with adduction and internal and external rotation.[2,7,16]

Advanced Imaging

If an acute tear of the LD or TM is suspected based on clinical presentation, a non-contrast magnetic resonance imaging (MRI) was indicated to assess the extent of the injury.[2,6,12] Importantly, when obtaining an MRI, the field of view needed to be expanded to capture the muscle belly, myotendinous junction, and insertion of LD and TM, because a typical shoulder series may not adequately assess the extent of injury.[2,6] Five of 9 studies commented on the MRI appearance of an LD or TM injury, revealing that coronal, sagittal, or axial sequences often demonstrate an avulsed tendon with T2 signal hyperintensity (Fig 3).[2,7,9,17,19] In the literature, tears were most commonly seen at the myotendinous

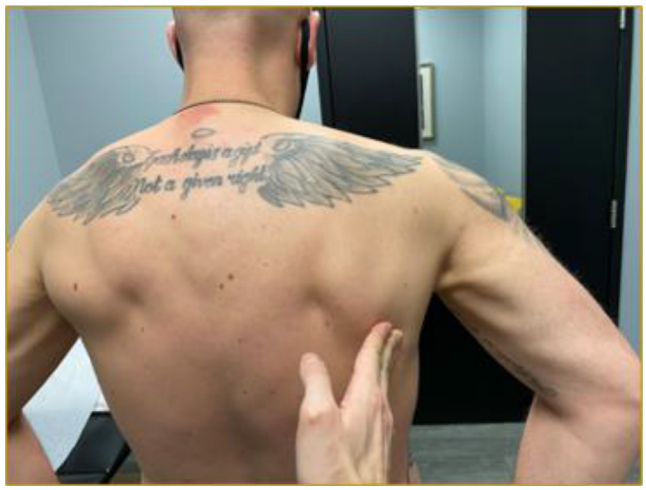

Fig 2. Professional baseball pitcher with notable atrophy of the right posterior axilla compared to the left. He was subsequently diagnosed with a latissimus dorsi tendon tear on magnetic resonance imaging.

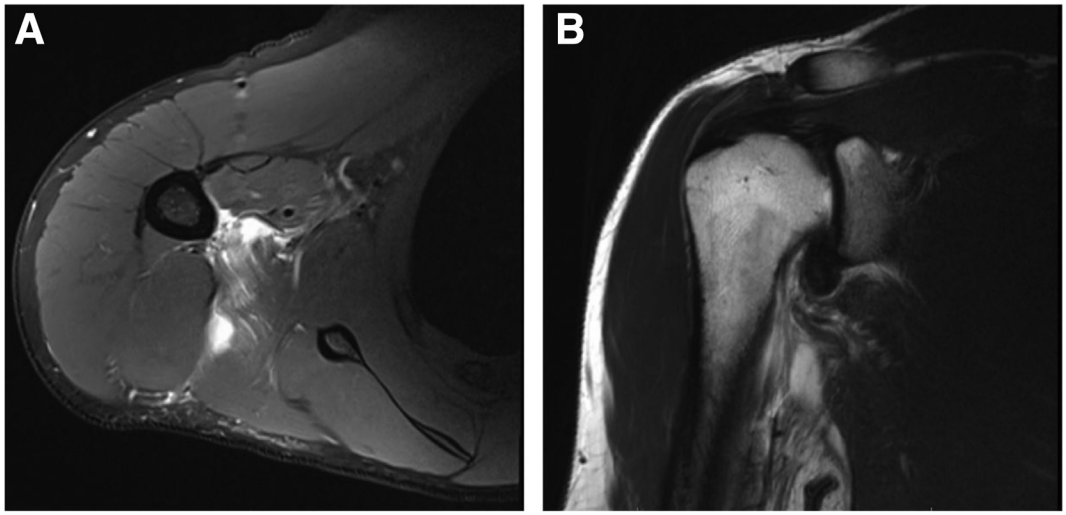

Fig 3. (A) Axial proton density sequences with fat supression and (B) coronal T2 magnetic resonance imaging scan of the right shoulder with hyperintensity demonstrating an acute latissimus dorsi and teres major injury.

junction or tendon-bone interface.[9,15] As 1 author noted, it is difficult to determine whether the tear pattern is isolated LD, TM, or combined, because the LD and TM tendons often coalesce and rotate on themselves before insertion.[12] In some instances, tendon retraction can be seen[7], and as 1 article stated, there is no consensus on the amount of retraction required for operative treatment.[12]

Treatment Options

Nonsurgical Management

Traditionally, LD and TM injuries were managed without surgery.[2,6,12] Five studies included in this review evaluated nonoperative management of LD and TM injuries.[2,12,15,16,18] Typical treatment programs began with a period of rest to address acute inflammation. In 1 of the first studies to evaluate nonoperative management of LD and TM injuries, Nagda et al.[2] treated 16 patients with an initial "shut down" period (1-28 days).[2] On average, the athletes rested for 10 days before starting a rehabilitation program. Leland et al.[16] reported giving 1 patient with an isolated grade II TM strain a 5-day methylprednisolone dose pack on the day of diagnosis before transitioning to oral nonsteroidal anti-inflammatory drugs. However, none of the other authors in the included articles mentioned the use of steroids for acute inflammation. Once the athlete is pain free, gentle range of motion exercises may be initiated before progressing through the physical therapy and rehabilitation program as below.

Surgical Management

Recently, operative treatment of LD and TM injuries in professional baseball pitchers has gained favor, particularly for complete tears or those with tendinous retraction.[1,7,9,10,12,13,15,16] Four studies reported outcomes after surgical management.[7,9,12,17] There are 2 commonly described surgical techniques: a single- or double-incision approach. Ellman et al.[7] used second

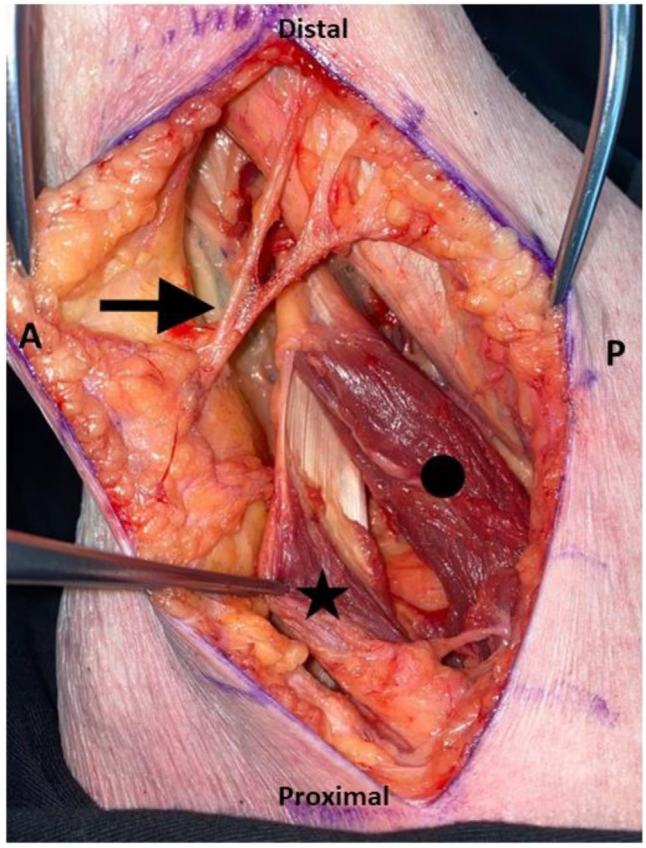

Fig 4. Posterior axillary approach to the left shoulder. The latissimus dorsi (star) and teres major (circle) are demonstrated within the axilla in relation to the posterior brachial cutaneous nerve (arrow).

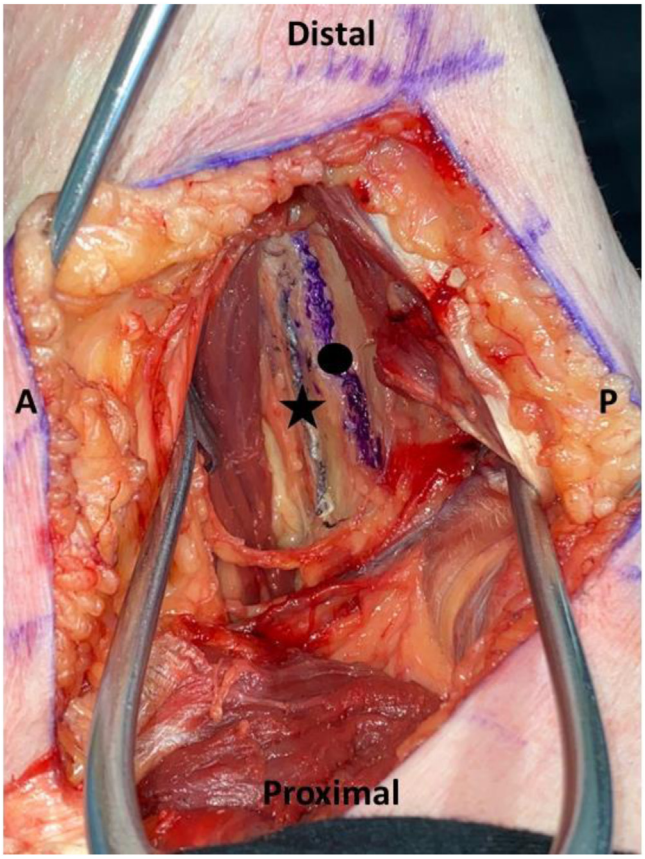

Fig 5. Posterior axillary approach to the left shoulder. The anatomic insertion footprints of the latissimus dorsi (star) and teres major (circle) are demonstrated on the humerus, medial to the bicipital groove.

posterior window in a double incision approach to retrieve retracted tendon with direct visualization due to concern for injury to adjacent radial nerve. Two studies described using the single posterior axillary incision.[9,17] The preferred method is a single posterior axillary incision for both tendon retrieval and visualization of the anatomic footprint of the LD tendon on the proximal humerus.[9,17,19]

Surgical Approach and Technique

The authors' preferred technique, which has been previously published,[19] uses a single posterior axillary incision. The patient is positioned in lateral decubitus with the shoulder in 90° abduction and elbow in 90° flexion and maximum internal shoulder rotation.[19,20] A curvilinear dissection is performed through the subcutaneous tissue with a combination of sharp and blunt dissection through fascial planes until the triceps and pectoralis major are identified. The muscles are separated with blunt dissection to reveal the retracted LD and TM tendons.[19,20] Once the LD and TM tendons have been identified, they are cleared of adhesions to ensure adequate mobilization to the native footprint (Fig 4). Two nonabsorbable sutures are passed through the tendons with a running Krakow configuration with 4 ends available for fixation. Next, the anatomic footprint of the LD tendon is exposed medial to the intertubercular groove in the proximal humerus (Fig 5). Care is used to identify and protect the posterior brachial cutaneous nerve because it lays over the triceps. Retractors are placed to protect the pectoralis major, biceps, and radial nerve anteriorly, and a second retractor placed posteriorly to protect the triceps and posterior brachial cutaneous nerve.[20] The anatomic footprint is visualized, and the tendon is reapproximated with 2 or 3 unicortical endosteal buttons (Fig 6).[9,17,19]

Operative Complications

Timing from injury to surgery can affect distance of tendon retraction and the amount of scar tissue adhesions needed to be released for adequate mobilization. Additionally, with chronic tears, fatty atrophy of the muscle and degradation of tendon integrity can occur, necessitating the use of graft augmentation to strengthen the tendon.[19] Fortunately, many successful surgical outcomes reported in the literature occurred after a trial of nonoperative management and delay to surgery did not negatively impact ultimate outcomes for the athletes. Erickson et al.[9] reported an average time from injury to surgery greater than 1 year for all patients in an initial study, and 97.5 ± 115.5 days from injury to surgery in a second study.[12] One case report of a professional baseball pitcher discussed a spiral fracture of the proximal humerus originating from the inferiormost drill hole from unicortical buttons after surgical repair of LD.[17] The patient suffered the injury while pitching 12 months after surgery. The authors recommended smaller drill holes (3.7 mm down to 3.2 mm) and advanced imaging at 9 to 12 months before full return to sporting activity (RTS).

Physical Therapy, Rehabilitation, and Return to Throwing

After surgery, patients are placed in a sling for 6 weeks with nonweightbearing range of motion (ROM) starting at 2 weeks. At 6 weeks after surgery, light ROM and strengthening can begin.[7,9,17] Patients who do not undergo surgery can begin light ROM and strengthening when they are pain free. None of the included studies detailed a stepwise and specific rehabilitation protocol. The authors of this article assert the following protocol based on our own experience and guidelines proposed in the literature.[19]

Physical Therapy and Return to Throwing Protocol

Once the athlete is pain free through range of motion, the athlete is progressed through a series of shoulder strengthening and stabilization exercises

Fig 6. Suture button placement at the anatomic footprint of the latissimus dorsi and teres major, medial to the bicipital groove as depicted in Figure 5.

such as the Thrower's Ten,[21] or the Advanced Thrower's Ten[22] programs. The authors of this article emphasize full body conditioning, including lower body strengthening, core stability, and cardiovascular training. Once deficits in strength have been addressed, the athlete can begin a progressive throwing program by increasing velocity and distance to long toss, transitioning to throwing off the mound.[9,15] Literature suggests the Interval Throwing Program (ITP)[23]: beginning with crow-hop throwing at progressive distances (45, 60, 90, 120, 150, 180 ft.) before advancing to flat ground throwing at the same distances and finally pitching off the mound at regulation distance (60 ft, 6in.). The Interval Throwing Program emphasizes the use of a crow-hop early in the throwing process to promote proper mechanics and recruitment of the lower body and to optimize the kinetic chain. The duration of each phase is determined by the individual player's symptoms and can only advance to the next phase when the entire throwing motion is pain free. Typical throwing progressions range from 6 to 12 weeks once throwing is begun until unrestricted mound throwing is allowed.

Return to Play Rates

Nonsurgical Management

Historically, nonoperative treatment of LD and TM injuries has resulted in successful RTP rates. Nagda et al.[2] reported 15/16 patients RTP at the same or higher level of play after nonoperative treatment. Nine players without an avulsion injury returned on average in 82.4 days, whereas avulsion injuries in 6 players were season-ending, and the players did not return until the following year. Those who suffered strains returned to throwing off a mound on average 62 days after injury. However, those with avulsions had major setbacks and reduced performance after nonoperative treatment.[2] Additionally, the players who returned to throwing the earliest suffered significant setbacks that delayed their full return.[2]

Other authors have reported worse RTP rates for nonoperative management of LD or TM injury. Erickson et al.[12] determined a 75% RTP rate for 107 professional pitchers with an LD and or TM injury. On average, those who were able to return to play did so at 170 ± 169 days from injury.[12] Schickendantz et al.[15] found 8/10 pitchers RTS at a professional level while throwing the same velocity as before the injury. One pitcher RTS at a professional level but threw at a slower velocity and elected to retire at the end of the season. One pitcher was cut from the team after the injury.[15]

In the case of an isolated TM injury, Malcolm et al.[18] treated 1 pitcher with an isolated TM avulsion who was able to RTS 6 months after injury, and Leland et al.[16] treated 1 patient with an isolated grade II TM strain who RTS at 9 weeks after the injury.

Surgical Management

Because surgical treatment of an LD or TM injury in professional baseball pitchers is an emerging field of study, only 2 studies reported RTP outcomes of players who underwent operative management.[9,12] Erickson et al.[9] published a case series of 8 pitchers, (7 professional, 1 collegiate), and all patients RTS at the same level of play. In a subsequent study, 13 professional pitchers were found to have a 75% RTS after an LD or TM injury, the same rate as the nonoperative cohort. These patients were able to RTS at same level 406 ± 146 days from injury, after a trial of nonoperative management.[12]

RTP Performance

Nonsurgical Management

Only 1 study in this review reported performance metrics after nonsurgical management of an LD or TM injury.[12] The authors reported a significant decline in the primary performance metric walks and hits per innings pitched (WHIP), and secondary metrics hits and home runs given up, and the number of games played

from before injury. They also stated there was no change in the primary performance metrics earned run average (ERA), field-independent pitching, and wins above replacement.

Surgical Management

Two studies in this review reported patient outcomes after operative treatment of an LD or TM injury. A series of 7 professional pitchers who underwent operative fixation of an LD or TM injury demonstrated excellent patient-reported outcomes at the 1-year follow up with a Visual Analog Scale pain score of 0 ± 0, American Shoulder and Elbow Surgeon Score of 100 ± 0, and a Kerlan-Jobe Orthopedic Clinic score of 89 ± 2.[9] Additionally, their pitching performance experienced no significant difference in ERA, innings pitched, games played, or WHIP from before injury to after injury.[9] Another study with a cohort of 13 professional pitchers found there was no significant decline in any primary performance metric, including WHIP, ERA, field-independent pitching, and wins above replacement.[12] This study directly compared an operative to a nonoperative cohort of players with LD or TM injuries and concluded that the operative cohort had better performance metrics after surgery than the nonoperative group.[12] This conclusion was based on the operative cohort maintaining all preinjury performance statistics, whereas the nonoperative group saw a decline in some metrics. This study was a retrospective database study with Level III evidence, and caution should be taken when interpreting conclusions.

Discussion

The most important finding of this study was that professional baseball pitchers have high RTP rates after both operative and nonoperative management of LD and TM injuries. Although our study showed similar RTS rates between treatment groups, the surgical arm had failed conservative treatment before undergoing surgery. Adding this treatment option into the orthopaedic armamentarium could help throwers return, who might not have done so in the past.

Our review identified 9 studies related to LD or TM injuries in professional baseball players. These studies were primarily low level of evidence that included a case series and both cohort studies had high levels of bias. Given the poor quality of available literature, it is difficult to draw definitive conclusions toward treatment recommendations. It is anticipated that the literature on LD and TM injuries will grow as researchers continue to use the MLB HITS database. The MLB HITS database attempts to capture all injuries to major and minor league baseball players affiliated with the MLB.[13] Because the incidence of LD/TM injuries is rare, a large database will provide the framework for future case control studies to help determine treatment algorithms. It is recommended that all future authors include information on time to RTP, and RTP pitching performance metrics (WHIP, IP, ERA, GA) for 2 seasons before and 2 seasons after the injury. Standardization of outcome reporting will allow future studies to conduct statistical meta-analysis of outcomes and provide better insight into how LD and TM injuries should be managed.

LD and TM injuries are rare and typically only occur in elite throwing athletes. It is important that clinicians recognize the clinical presentation and know the treatment options. Although there is a paucity of literature on the injury pattern, existing studies report comparable results with conservative treatment and surgical management for refractory cases.

Limitations

This study is not without limitations. The patient cohort is heterogeneous and includes outcomes of different injuries (strains, partial ruptures, and ruptures) and treatments (operative and nonoperative). Also, studies report different outcome metrics, which makes it difficult to compare studies and draw specific conclusions from the existing literature.

Conclusion

Professional baseball players who suffer a LD or TM injury have predictable clinical presentations and imaging findings. There is a high RTP rate and performance with both surgical and nonsurgical management. The heterogeneity and low level of evidence of available literature precludes comparative conclusions between treatment approaches.

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