



Magnetic Resonance Imaging Findings of the Asymptomatic Shoulder May Impact Performance, Not Future Injury List Placement in Major League Baseball Pitchers

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Purpose: To evaluate preseason shoulder magnetic resonance images (MRIs) obtained from pitchers entering either major or minor league baseball (MLB) and correlate findings with subsequent injury, operative repair, and placement on the injured list (IL). **Methods:** Preseason-MRI of the throwing shoulders of professional-level baseball pitchers, taken during routine evaluations at a single organization (2004-2017) were retrospectively reviewed. Publicly available databases were queried to exclude pitchers with known injuries prior to pre-signing imaging. Three blinded reviewers reviewed all MRI scans independently to evaluate for the presence of abnormalities in the rotator cuff (RTC), labrum, capsule, long-head of the biceps tendon (LHBT), and humeral head. Binary imaging findings were correlated to future placement on the IL for subsequent shoulder complaints. Bivariate statistics using Student's *t*-tests and Fisher exact tests (both $\alpha = .05$) were used in this study. **Results:** A total of 38 asymptomatic pitchers with shoulder MRIs were included. Pitchers had a mean (\pm SD) age of 28.2 ± 4.9 and had pitched an average of 119.6 ± 143.8 career games. Pitchers with partial articular-sided RTC tears ($P = .04$) or intra-articular BT hyperintensity ($P = .04$) on preseason MRI demonstrated an association with the need for future surgery. Pitchers with evidence of labral heterogeneity demonstrated greater total career pitch counts ($10,034.1$ vs $2,465.3$; $P = .04$). Evidence of a posterior-superior humeral cyst was associated with decreased strikeouts per 9 innings (6.1 vs 8.0 ; $P = .039$) and total strikeout percentage (16.1% vs 23.2% ; $P = .04$). **Conclusion:** Although there was a significant difference in the percent of various radiographic findings between the injured and healthy cohort, no MRI findings were predictive of future IL placement or duration of placement. The presence of a posterior superior humeral cyst was associated with decreased strikeout rates at 2 and 3 years, the presence of a labral tear was associated with decreased earned run average (ERA) at 3 years and decreased career strikeout percentages, and increased capsular signal was associated with decreased 5-year ERA. **Level of Evidence:** Level IV, retrospective study.

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Introduction

Major league baseball (MLB) pitchers use high-speed and complex overhead motions in order to pitch at the professional level; however, this motion introduces a significant strain on the arm of the pitcher.¹⁻³ The balance between sufficient laxity to maximize extremes of motion and velocity and adequate stability to prevent subluxation has been referred to as the “throwers paradox.”^{2,4} In this population, common elbow injury patterns include pathology of the ulnar collateral ligament (UCL) and in the shoulder, injuries to the rotator cuff (RTC), glenoid labrum, and biceps tendon.⁵ As might be expected, pitchers are most likely to be put on the injured list (IL) due to injury of the throwing shoulder.⁶

Time lost on the IL comes at a significant financial cost. In 2018, annual salaries of major league pitchers totaled approximately \$1.5 billion, suggesting that pitchers present the largest financial burden with respect to players placed on the IL.⁶⁻⁸ Therefore, there is both a competitive and financial incentive to ensure the health, well-being, and performance of these athletes. This has resulted in significant athletic efforts and team resources being dedicated to predicting risk of injury over the course of an athlete’s career.⁹ Previous literature has suggested that evaluated pitch counts,⁹⁻¹² pitch velocity,^{13,14} and preseason range of motion (ROM)¹⁵ may be modulated in an attempt to provide guidelines to diminish risk of injury. Despite its expense, preseason magnetic resonance imaging (MRI) of asymptomatic athletes has also been employed as a tool for prediction in both MLB and other competitive sports.^{7,16-18}

Magnetic resonance imaging is the most sensitive modality for identifying soft tissue shoulder pathology. However, the utility of indeterminate findings on MRI have yet to be determined.¹⁹⁻²¹ Pathologic findings in asymptomatic shoulders are more prevalent than previously thought, including RTC tears, biceps, and labral lesions; however, these findings have not been correlated with increased rates of IL placement, and have instead been reported to be a function of the number of innings pitched.^{7,16,22} In contrast, MRI findings at the elbow appear to be predictive of injury and have been found to correlate with increased risk of later IL placement, although these results are inconsistent in the literature.^{23,24}

Given the inconsistency in the literature, the purpose of this study was to evaluate preseason shoulder MRIs obtained from pitchers entering either major or minor league baseball and correlate findings with subsequent injury, operative repair, and placement on the IL. Our hypothesis is that asymptomatic structural abnormalities found on preseason MRI would

correlate with rates of injury, surgery, and time spent on the injured list.

Methods

Pitcher Selection

All major and minor league pitchers signed by a single organization from 2005 to 2017 were considered for retrospective review. Pitchers were included if they had an asymptomatic pitching shoulder and had a preseason screening MRI. Pitchers were excluded if they had prior shoulder or elbow surgery, spent any time on the injured list in the last 2 years (i.e., for any injury preventing performance), were symptomatic within the 6 months prior to MRI, or had played less than one full subsequent season in the MLB following return from the IL. Publicly available databases, including “fangraphs.com”²⁵ and “baseball-reference.com”,²⁶ were queried for injury and surgical history, prior injured list placement, and baseline patient characteristics. For the purpose of this study, an MRI of asymptomatic shoulder was defined as those performed at least 6 months prior to IL placement for any shoulder-related injury.²⁴ Consequently, any pitcher with preseason MRI that preceded injured list placement by less than 6 months was categorized as injured. This led to the creation of an asymptomatic and an injured cohort.

Data Collection

Relevant data from athlete medical records were abstracted and collected in a custom data table, including nonoperative treatment of a dominant arm injury, duration of placements on the IL, dominant arm surgery, and nonshoulder injuries. Nonmedical information, including draft year, round, and overall pick number, innings pitched, and games started were collected from publicly available data [ESPN]. Other previously mentioned sources (“fangraphs.com”²⁵ and “baseball-reference.com”²⁶) were used for tabulation of pitching sabermetrics, including earned-runs average (ERA), batting average on balls in play (BABIP), strikeouts per walk (K/BB), strikeouts per 9 innings of play (K/9), walks plus hits per inning pitched (WHIP), pitches per inning, strikeout and strike zone percentages, percent fastballs, fastball velocity and field-independent pitching. These sabermetric data were aggregated at 1, 2, 3, and 5 years relative to the date of initial MRI. Student’s *t*-tests and Fisher exact tests were used to calculate statistically significant differences in sabermetrics between groups. Total career statistics were also collected. Sabermetric statistics were only available for MLB using a combination of PITCHf/x (Sport Vision, Chicago, IL) for data collected after 2007 and Baseball Info Solutions (Coplay, PA) prior to 2007. Sabermetric data were not available for minor league athletes.

Radiographic Analysis

Preseason MRI were reviewed and read by three independent reviewers. Reviewers included two fellowship-trained orthopedic sports medicine surgeons and one fellowship-trained musculoskeletal radiologist. Each reviewer was blinded to pitcher identifiers, subsequent performance or injury, or MRI interpretation by the reading radiologist at the time the study was obtained. Five anatomic components of the shoulder were examined in MRI analysis, including the rotator cuff, labrum, capsule, biceps and humeral head. Anatomic structures of interest and rubric of evaluated pathology are listed below (Table 1). The review process consisted of initial radiographic assessment by a fellowship-trained musculoskeletal radiologist and fellowship-trained orthopedic sports medicine surgeon; if there was agreement by both reviewers, no further assessment was needed. In case of disagreement, the third reviewers (a second fellowship-trained orthopedic sports medicine surgeon) acted as a tie-break. The third reviewer was needed 14 times (<4% disagreement rate).

Statistical Analysis

Statistical analysis was performed using RStudio software version 1.0.143 (R Foundation for Statistical Computing, Vienna, Austria). The injured and healthy cohorts were compared using Student's *t*-test and when necessary, Fisher exact test. Associations between the radiographic findings and future IL placement were assessed using univariate Fisher exact testing. T-statistics were calculated at $\alpha = .05$ comparing the presence and absence of each radiographic parameter in relation to times on the IL, total length of IL placement, and all pitcher-specific statistics (Table 2).

Results

A total of 41 pitchers were evaluated from 2005 to 2017, with the great majority excluded from the current analysis due to either lack of subsequent MLB pitching performance ($n = 5$) or prior time on the

injured list (IL) within 2 years ($n = 4$), or surgery within 2 years ($n = 3$). A total of 29 MLB pitchers were included in our retrospective analysis, 7 of which were subsequently placed on the injured IL for shoulder-related injuries. One pitcher placed on the disabled list required surgery for a subsequent rotator cuff tear with concomitant biceps pathology. Thus, 22 MLB pitchers remained in the "healthy" cohort. With respect to demographics, the injured cohort was significantly older than the healthy cohort (31.9 ± 5.0 vs 27.1 ± 5.0 ; $P = .04$). There were no significant differences between cohorts with respect to height ($P = .60$), weight ($P = .68$), number of games played ($P = .61$), and handedness ($P = .99$) (Table 3).

With respect to the MRI findings examined, pitchers who eventually necessitated IL placement had a greater incidence of supraspinatus tendon heterogeneity (85.7% vs 68.2%), partial articular sided supraspinatus tears (14.3% vs .0%), labral heterogeneity (71.4% vs 40.9%), frank labral tears (28.6% vs 9.1%), intra-articular biceps signals (14.3% vs .0%), and posterior superior humeral cysts (85.7% vs 45.5%). No MRI findings were found to be significant predictors of the duration of time spent on the IL ($P = .279-.896$). With respect to the receipt of future surgery, both partial articular-sided supraspinatus tears ($P = .035$) and intraarticular biceps tendon signals ($P = .035$) were associated with the receipt of future surgery (Table 2). It is noted, however, that only one patient ultimately required shoulder surgery, thereby limiting our assessment.

With respect to sabermetrics, the presence of labral heterogeneity on pre-signing MRI was associated with greater averages for total career pitches (10,034.1 vs. 2,465.3; $P = .039$). Additionally, the presence of a labral tear was associated with decreased ERA at 3 years (2.15 vs 3.86; $P = .002$), increased strikeouts per 9 innings at 2 years (10.9 vs 7.4; $P = .043$), and increased career strike out percentage (25.6% vs. 19.6%, $P = .032$). Similarly, those with increased capsular signal were found to have decreased ERA at 5 years (2.34 vs 5.44;

Table 1. Variables in MRI Analysis

Rotator Cuff	Labrum	Capsular GH Internal Rotation Deficit	Biceps	Humeral Head
Supraspinatus Tendon Insertion Heterogeneity/ Hyperintensity (B)	Labral Heterogeneity/ Hyperintensity (B)	Presence of Increased Capsular Signal (B)	Biceps Signal Extra-articular (B)	Posterior Superior Humeral Cyst (B)
Partial Articular Side Signal (B)	Labral Heterogeneity/ Hyperintensity Location (C)		Biceps Signal Intra-articular (B)	Posterior Superior Humeral Cyst Size (N)
Partial Bursal Side Signal (B)	Labral Tear (B)		Biceps Tear (B)	Additional Findings (FT)
Full Thickness Tear (B)	Labral Tear Location (C)			

Anatomic structures of interest and rubric of evaluated pathology in the MRI analysis. B, binary; C, categorical variable; FT, free text; N, numerical variable.

Table 2. Relationship Between MRI Findings and Future IL Placement and Surgery

MRI finding	Incidence of Finding (Injured vs Healthy)	P Value			
		Future IL Placement	No. of IL Placements	Time on IL	Future Surgery
Supraspinatus tendon heterogeneity/ hyperintensity	85.7% vs 68.2%	.635	.283	.796	.999
Partial supraspinatus tear - articular	14.3% vs .0%	.241	NA	NA	.035
Partial supraspinatus tear - bursal	.0% vs .0%	NA	NA	NA	NA
Full-thickness supraspinatus tear	.0% vs .0%	NA	NA	NA	NA
Labrum signal heterogeneity/ hyperintensity	71.4% vs 40.9%	.215	.077	.518	.483
Frank labral tear	28.6% vs 9.1%	.238	.626	.279	.138
Increased capsular signal	28.6% vs 27.3%	.999	.646	.896	.999
Biceps tendon signal - extra-articular	.0% vs .0%	NA	NA	NA	NA
Biceps tendon signal - intraarticular	14.3% vs .0%	.241	NA	NA	.035
Biceps tendon frank tear	.0% vs .0%	NA	NA	NA	NA
Posterior superior humeral cyst	85.7% vs 45.5%	.093	.170	.121	.999

Bold values represent statistical significance ($P < .05$). IL, injured list; MRI, magnetic resonance imaging; NA, not applicable (analysis could not be performed due to insufficient number of players either in healthy or uninjured group). Comparison between the presence and absence of radiographic parameters listed and their relationship to times on the IL, total length of IL placement, and all pitcher-specific statistics. Both partial articular-sided supraspinatus tears and intraarticular biceps tendon signals were associated with future surgery.

$P = .011$), and increased field independent pitching metrics at 3 years (4.4 vs 3.5; $P = .022$). Pitchers who were found to have a posterior superior humeral cyst on pre-signing MRI, in contrast to the labral or capsular findings noted, had decreased strikeout percentages per 9 innings at 3 years (6.6 vs 13.2; $P = .039$), decreased overall strikeout percentages at 2 years (16.6% vs 23.2%; $P = .044$), and decreased field independent pitching after their first-year pitching (3.1 vs 4.3; $P = .046$) (Table 4).

Discussion

The main finding of this study was that asymptomatic MRI findings may be useful predictors of various pitching performance metrics; however, these findings are not adequately predictive of either the frequency or duration of IL placement. Some specific associations

Table 3. Demographics of Included Pitchers

Characteristic	Injured ($n = 7$)	Healthy ($n = 22$)	P Value
Age (years)	31.9 ± 5.0	27.1 ± 5.0	.040
Height (in)	75.9 ± 2.0	75.4 ± 2.2	.603
Weight (lbs)	208.6 ± 21.4	213.9 ± 31.7	.682
No. Games Played	158.7 ± 207.3	122.0 ± 146.9	.606
Handedness (R/L)	5/2	15/7	.999

In, inches; lbs, pounds; R/L, right/left. Key demographics of included pitchers. Healthy pitchers were significantly younger than injured pitchers, with no other significant differences noted between the groups.

include the presence of labral injury (i.e., heterogeneity, tear) or a posterior superior humeral cyst on pre-signing MRI being associated with increased earned-run averages (ERAs) and decreased strikeout rates (i.e., K/9 innings). Although articular-sided RTC tears and intra-articular injury to the LHBT was found to be associated with future shoulder surgery, limitations in sample size suggest that the presence of multiple shoulder pathologies (i.e., LHBT, labral, RTC) may be more predictive of future surgery, rather than any asymptomatic finding in isolation. These results may be best used to risk stratify pitchers at greatest risk of decreased performance metrics. Future studies, particularly those with increased power would likely benefit from combining MRI data across multiple teams or assessing pitchers through the MLB Health and Injury Tracking System (HITS) database, would be beneficial.

Asymptomatic MRI findings are becoming increasingly commonplace for professional athletes across sporting leagues (i.e., MLB, NFL, MLS, etc.) in the United States.^{17,18,20,21,28} Previous studies have detailed both radiographic and MRI findings commonly found on routine preseason imaging of the throwing shoulder in asymptomatic pitchers.^{7,27,28}

Specifically, a study by Connor et al. demonstrated that the throwing shoulder in overhead athletes may have unique asymptomatic lesions, such as a Bennett lesions and RTC tears.²⁹ Although the prevalence of these asymptomatic lesions of the shoulder and elbow

Table 4. Relationship Between Radiologic Findings and Sabermetric Statistics

Pitching Statistic	P Value				
	Supraspinatus Tendon Heterogeneity/Hyperintensity	Labrum Signal Heterogeneity/Hyperintensity	Labral Tear	Increased Capsular Signal	Posterior Superior Humeral Cyst
ERA – 3 yr			.002		
ERA – 5 yr				.011	
Strikeout per 9 Innings Pitched – 2 yr			.043		
Strikeout per 9 Innings Pitched – 3 yr					.039
Pitches/inning – 1 yr	.044				
Strikeout percentage – 2 yr					.044
Strikeout percentage – career			.035		
Total pitches – career		.039			
Field independent pitching – 1 yr					.046
Field independent pitching – 3 yr				.022	

BABIP, batting average on balls in play; ERA, earned runs average; WHIP, walks and hits per inning pitched. Omitted from table due to lack of significant findings: ERA at 1, 2, 4 years and career; BABIP 1-5 years and career; Strikeouts per 9 Innings at 1, 3 and 4 years and career; WHIP 1-5 years and career; Pitches per inning 2-5 years and career; Strikeout percentage 1, 3, 4 years and career; Strike Zone Percentage 1-5 years and career; Innings Pitched 1-5 years and career; Total pitch count 1-5 years; Percentage Fastball 1-5 year and career; Fastball velocity 1-5 year and career; Field Independent Pitching 2, 4, 5 years and career. Bold values indicate significant relationships between MRI findings and baseball statistics.

continue to be examined, a key question remains – does the presence of these findings on MRI signal greater risk for future IL placement or future surgery? Consequently, can an MLB organization use this information to identify those at risk of injury, and potentially employ strategies (i.e., focused training, monitoring of pitch counts) to decrease future injury risk? The current study suggests that the presence of asymptomatic shoulder findings does not increase the risk of future IL placement. A similar single-team study by Wright et al. suggests that asymptomatic findings on shoulder radiographs of MLB pitchers do not predict time spent on the IL, but are correlated with the number of innings pitched.¹⁶ However, the current study also suggests that the presence of multiple shoulder-related changes on preseason MRI may place an individual at risk for future surgery. Wright's single-team study reports a similar finding, in that the sum of radiographic shoulder findings correlated with the number of innings pitched. All in all, the current study suggests that asymptomatic shoulder findings may represent pitching-related wear on the body, and that injury risk may be related to the total burden of asymptomatic findings as opposed to the presence of isolated findings. Further studies must take into account two important limitations in the current literature: 1) significant heterogeneity among study designs with respect to the imaging findings examined, and 2) limited power in single-team case series. Accordingly, future studies may consider pooling data across single-team case series or utilizing the MLB HITS to aggregate imaging findings across MLB pitchers.

Previous studies have suggested that asymptomatic degenerative changes in the throwing shoulder and elbow occur with greater frequency in pitchers with

greater innings pitched. A single-team case series by Wright et al. found there to be a correlation between innings pitched and the presence of acromioclavicular (AC) joint findings, radial head osteophytes, or the sum of radiographic findings of the shoulder.¹⁶ A single-team study by Lesniak et al. also found that the prevalence of articular-sided RTC tears, full-thickness RTC tears, and SLAP tears increases with increasing pitch counts.⁷ The current study adds to the work by Lesniak et al. by suggesting that earlier inflammatory changes in the RTC and labrum (i.e., signal heterogeneity) also increase as a function of innings pitched. Overall, current data suggest that certain radiographic and MRI findings of the throwing shoulder are associated with increased innings pitched, but they do not predict IL placement or the need for future surgery. This is in contrast to the elbow, where asymptomatic findings (i.e., UCL heterogeneity, UCL-partial tears, posteromedial impingement) have been linked to IL placement and the need for future surgery²⁴ (Table 5).

Although previous literature has begun to examine the relationship between the presence of specific asymptomatic findings on elbow and shoulder MRI,^{7,16,24} the impact of these findings on pitching performance metrics is less clear. Although various MRI findings were found to be associated with decreased pitching performance (i.e., labral tear, capsular hyperintensity, humeral cyst), the presence of a posterior superior humeral cyst was most consistently associated with decreased performance, including increased ERA, decreased strikeout rates, and decreased field-independent pitching (FIP). The humeral head can develop cystic changes in the case of articular and RTC disease, and previous studies have demonstrated that overhead athletes may develop cystic structural lesions

Table 5. Findings Correlated With Increased Innings Pitched

Radiographic Findings	MRI Findings
Sum of radiographic findings of the shoulder ²	Supraspinatus heterogeneity ¹
Acromioclavicular joint findings ²	Labral heterogeneity ¹
Radial head osteophytes ²	RTC tear (i.e., articular surface tear, full-thickness tear) ³ Superior labrum anterior-to-posterior (SLAP) tear ³

Imaging findings correlated with an increase in the number of innings pitched, as described in previous studies.

¹Suggested by data from the current study.

²Suggested by data from Wright et al.³⁴

³Suggested by data from Lesniak et al.²¹

in the shoulder,³⁰⁻³² particularly at RTC tendon footprints.^{29,33,34} The current study suggests that the identification of a posterior superior humeral cyst in the throwing shoulder may represent a novel imaging marker predictive of decreased pitching performance in MLB pitchers. Although all players included in this study were asymptomatic, further studies should consider assessing strength (i.e., internal and external rotation), range of motion, pain, and sabermetric differences in players with and without evidence of a posterior superior humeral cyst.

Limitations

The current study is not without important limitations that all readers must consider. First, with respect to the study methodology, some MRI findings (e.g., RTC, labral tears) are more easily identified than others (e.g., capsular heterogeneity). In addition, there is the possibility of observer bias in the examination of MRIs known by readers to be asymptomatic. To address these limitations, the imaging findings examined in the current study represent a consensus statement among 3 independent reviewers, including two fellowship-trained orthopaedic surgeons and one radiologist trained in musculoskeletal imaging. There was agreement among two reviewers on >95% of imaging findings, and <4% of imaging findings required a 3rd reviewer to act as a tiebreak. Second, the study is limited by its retrospective design and power ($n = 41$). Future studies should consider conducting similar analyses using data aggregated across multiple teams, such as the MLB's HITS. Third, certain limitations in data accuracy exist in using publicly available databases for the purpose of mining data related to IL placement and surgical intervention. However, many previous studies have utilized public data,^{6,11,12,16} most commonly verifying the data collected across two separate publicly available databases. Fourth, because of limitations in the medical data collected on the players included in the study, objective clinic data, such as strength and range of motion, is unavailable. Although patients may

be asymptomatic, the association of specific findings with decreased performance begs the question if specific subclinical deficits in strength, range of motion or pain may exist between pitchers. Lastly, a pitcher was deemed to be "asymptomatic" if the MRI performed was at least 6 months prior to IL placement for any shoulder-related injury. Although arguments can be made in support of a longer period of time (i.e., 1 year), 6 months was deemed to be adequate on the basis of previous literature.²⁴

Other important limitations include those associated with the use of performance metrics to assess pitching performance. Pitching performance is complex, and as such, although a pitcher may have a decreased strikeout percentage, lower pitch count, and decreased fastball speed, other metrics (i.e., ERA, WHIP, KK/walk ratio) may remain the same or even improve. Thus, it is difficult to draw conclusions on pitching performance with a sample size, as it is a multifaceted assessment best assessed with appropriate power. In addition, although we report significant associations between specific asymptomatic findings and the need for future surgery, this was in only one player with complex shoulder pathology, suggesting injury to multiple structures. Thus, we are unable to make any statement regarding asymptomatic MRI findings and the need for future surgery. Moreover, the injured cohort is significantly older than the noninjury cohort, which is a confounding factor on pitcher performance and may contribute to some of the differences in pitching performance we found (31.9 vs. 27.1 years).

Conclusion

Although there was a significant difference in the percent of various radiographic findings between the injured and healthy cohort, no MRI findings were predictive of future IL placement or duration of placement. The presence of a posterior superior humeral cyst was associated with decreased strikeout rates at 2 and 3 years, the presence of a labral tear was associated with decreased ERA at 3 years and decreased career strikeout percentages, and increased capsular signal was associated with decreased 5-year ERA.

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