

Clinical Value of an Acute Popping Sensation in Throwing Athletes With Medial Elbow Pain for Ulnar Collateral Ligament Injury

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Background: Throwing athletes sustaining an ulnar collateral ligament (UCL) injury may recall a popping sensation originating from the medial elbow at the time of injury. There are no studies available that inform clinicians how to utilize this salient anamnestic information and what amount of diagnostic weight to afford to it.

Purpose: To assess the diagnostic value of a popping sensation for significant UCL injury in throwing athletes who sustained an injury causing medial elbow pain.

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

Methods: A total of 207 consecutive patients with throwing-related medial elbow pain were evaluated for UCL injury by the senior author between 2011 and 2016. The presence or absence of a popping sensation was routinely reported by the senior author. Magnetic resonance imaging was evaluated for UCL injury severity and classified into intact, edema/low-grade partial-, high-grade partial-, and full-thickness tears.

Results: The overall frequency of a pop was 26%. The proportion of patients who reported a pop significantly increased with UCL tear severity ($P < .001$), from 13% in patients with low-grade UCL injuries to 26% in patients with high-grade partial-thickness tears and 51% in patients with full-thickness tears. The positive likelihood ratio, negative likelihood ratio, and odds ratio of a popping sensation for significant UCL injury were 3.2, 0.7, and 4.4 ($P < .001$), respectively ($P < .001$). A pop was not associated with either distal or proximal UCL tears ($P \geq .999$).

Conclusion: A popping sensation at the time of injury in throwing athletes with medial elbow pain was associated with UCL injury severity. When a throwing athlete reports a pop, this should moderately increase a clinician's suspicion for a significant UCL injury. Conversely, absence of a pop should not substantially decrease suspicion for significant UCL injury. The findings of this study allow for the clinical interpretation of the salient anamnestic finding of a pop at the time of injury, which can be used for diagnostic purposes as well as patient counseling. This study provides reference foundation for future studies of predictive and diagnostic factors for UCL injury in throwing athletes.

Keywords: elbow; ulnar collateral ligament; popping sensation; tear; diagnostics

Ulnar collateral ligament (UCL) injuries of the elbow are increasingly common in overhead throwing athletes and usually affect the anterior bundle.^{2,5,7,11,14,15} As with most orthopaedic injuries, the assessment of medial elbow pain includes a thorough history and physical examination. Throwing athletes sustaining a UCL injury may recall a popping sensation (feeling or hearing) originating from the medial elbow at the time of injury (Figure 1). Athletes may tell clinicians when they felt a pop, but there are no studies available that inform clinicians how to utilize this

information and what amount of diagnostic weight to afford to it.

A plausible explanation of the popping sensation is an acute disruption of tissue fibers, which may be intuitively associated with a tear. The proximal and distal attachments of the UCL are histologically different—with the proximal attachment to the anteroinferior medial epicondyle having a more perpendicular orientation and with the distal attachment having a more angular orientation—but it is unknown if the popping sensation is related to UCL tear location.^{3,4,8,10} It has been suggested that distal UCL tears have poorer outcomes when managed nonoperatively as compared with proximal tears.^{9,10} Correlations between UCL tears and

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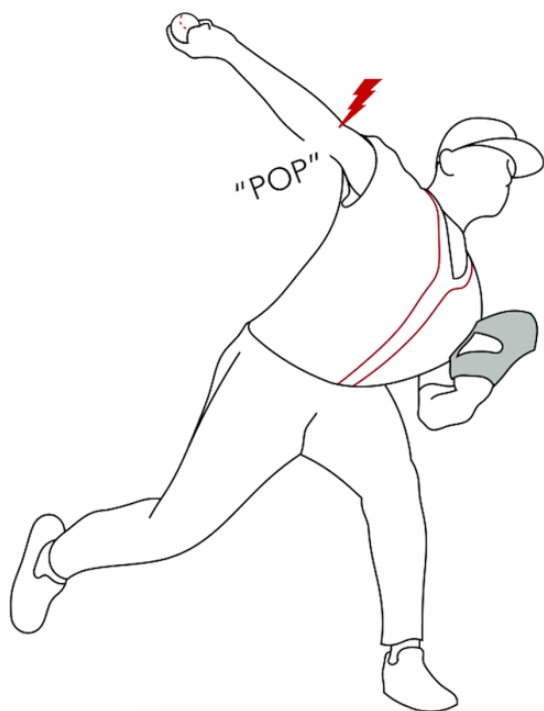


Figure 1. Throwing athletes sustaining an ulnar collateral ligament injury may recall a popping sensation originating from the medial elbow at the time of injury.

anamnestic characteristics, such as the occurrence of a pop, could inform not only the presence of a tear but also the location and therefore its management. A pop at the time of injury has been shown to be one of the factors that can be used to screen for anterior cruciate ligament lesions of the knee, with high diagnostic validity for partial or complete tears.^{6,17}

The purpose of this study was to assess the diagnostic value of the subjective experience of a popping sensation for significant UCL injury among throwing athletes who sustained an injury causing medial elbow pain. In addition, we examined the association of a popping sensation with UCL tear severity and explored whether a pop is associated with tears at either the proximal or distal attachment site of the anterior bundle of the UCL. The hypothesis was that the occurrence of a popping sensation increased the likelihood of a significant UCL tear in throwing athletes with medial elbow pain and was associated with higher tear severity.

METHODS

Study Sample

This study was approved by the Partners Human Research Committee of Massachusetts General Hospital. The institutional Research Patients Data Registry was searched with International Classification of Diseases code 8411 (Ninth Revision) and codes S53.3 and S53.44 (Tenth Revision) and with Current Procedural Terminology codes 24345 and 24246 to identify patients evaluated for concern of UCL injury. A total of 384 patients with medial elbow pain were evaluated at our institution between 2011 and 2016, including 207 consecutive overhead athletes evaluated by the senior author (L.S.O.) for UCL injury.

All medical records were reviewed and assessed by the first author (R.J.M.) and the last author (L.S.O.) using the electronic medical record system (QPID Health Inc). The following data were obtained from the medical records: sex, age, race, hand dominance, side of injury, type of sport, level of play, symptoms onset, and the occurrence or absence of a popping sensation at the time of injury. The senior author routinely asked patients if they did or did not feel a pop at the time of injury and reported either outcome. Patients included in the analysis underwent diagnostic magnetic resonance imaging (MRI) assessment (1.5 or 3.0 T) as part of standard clinical workup, which a fellowship-trained musculoskeletal radiologist specifically evaluated for suspected UCL anterior bundle pathology. MRI results were evaluated after the senior author had obtained the history and performed physical examination.

UCL tear severities were classified into 4 categories, according to the MRI-based classification for UCL injuries by Joyner et al¹²: intact; edema, waviness, low-grade partial-thickness tears; high-grade partial-thickness tears; and complete full-thickness tears (Figure 2). To quantify the diagnostic value of a pop, high-grade partial- and complete full-thickness tears were defined as significant UCL injury.

Statistical Analysis

Data were described with frequencies and percentages for dichotomous and categorical variables, means and standard deviations for normally distributed continuous data, and median and interquartile range for nonparametric continuous data. Two-sided Fisher exact tests were used for the comparison of the frequency of a popping sensation among the 4 UCL tear severity categories, including post

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Ethical approval for this study was obtained from the Partners Human Research Committee (protocol 2014P002065/MGH).

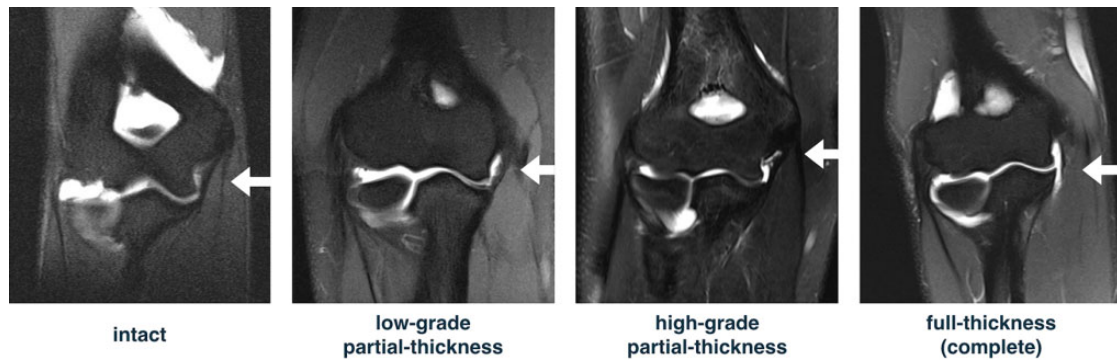


Figure 2. Classification of ulnar collateral ligament injuries (white arrows) into 4 categories: intact; edema, low-grade partial-thickness tears; high-grade partial-thickness tears; and complete full-thickness tears.

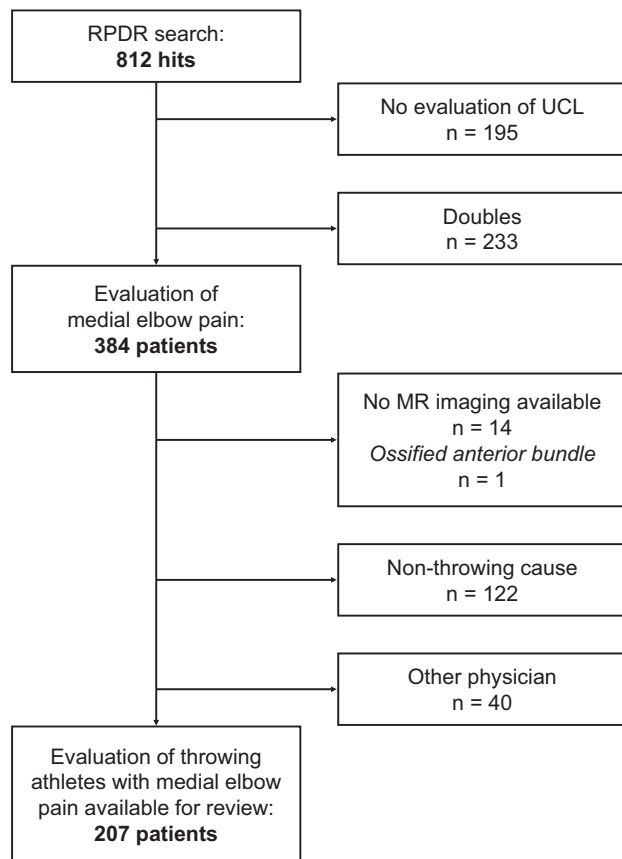


Figure 3. Flowchart of the study sample, including patients who underwent magnetic resonance imaging and excluding patients with nonthrowing causes of injury and patients who were not treated by the senior author. MR, magnetic resonance; RPDR, Research Patients Data Registry; UCL, ulnar collateral ligament.

hoc comparisons, and for the assessment of a relationship between a pop and UCL tear location.

A 2 × 2 contingency table of the occurrence of a pop versus significant UCL injury (defined as a high-grade partial- or full-thickness UCL tear) was used to calculate the prevalence, sensitivity, specificity, positive predictive

value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+), and negative likelihood ratio (LR-) of the subjective sensation of a pop for significant UCL injury, including 95% CI. Logistic regression analysis was used to calculate the odds ratio (OR), including 95% CI and P value. According to McGee,¹³ a LR+ >5 and a LR- <0.2 represent relatively important effects; LRs between 0.2 to 0.5 and between 2 and 5 may be important; and values close to 1.0 represent unimportant effects.

The false discovery rate was used to correct for multiple comparisons (pop vs UCL injury severity and tear location; OR).¹ Adjusted P values <.05 were considered statistically significant. Statistical analysis was performed with STATA/SE 14.2 statistical software (StataCorp LP).

RESULTS

Demographics

The flowchart of the sample selection process is shown in Figure 3. A total of 207 consecutive overhead athletes with medial elbow pain evaluated by the senior author for UCL injury were available for review and included for analysis. The demographic characteristics of the study sample are summarized in Table 1. The study population included mainly white male baseball pitchers at the high school or collegiate level. MRI with intra-articular contrast was performed in 136 of 207 patients (66%), and 71 patients underwent MRI without contrast (34%).

Popping Sensation and UCL Tear Severity

The overall prevalence of a pop in our study population was 26% (95% CI, 20%-32%). Among the subgroup of patients who experienced an acute moment of injury (acute or acute-on-chronic onset of symptoms), the prevalence of a pop was 46% (51 of 111). There were 10 patients without UCL injury (4.8%), 72 with edema/low-grade partial-thickness tears (35%), 80 with high-grade partial-thickness tears (39%), and 45 with complete full-thickness tears (22%). The proportion of patients who reported a pop significantly increased with UCL tear severity (P < .001), from 13% in patients with low-grade UCL injuries (9 of 72) to 26% in patients

TABLE 1
Patient Characteristics (N = 207)

Variable	n (%)	Variable	n (%)
Male sex	201 (97)	Sport	
Age, y, mean ± SD	19.2 ± 3.7	Baseball	194 (94)
Race		Pitcher	162 (84)
White	186 (90)	Catcher	11 (5.7)
Hispanic	6 (2.9)	Other position	21 (11)
Asian	4 (1.9)	Javelin	7 (3.4)
Unknown	11 (5.3)	Softball	5 (2.4)
Dominant-side injury	207 (100)	Quarterback (football)	1 (0.5)
Symptom onset		Level of play	
Acute	92 (44)	High school	92 (44)
Subacute	43 (21)	Collegiate	103 (50)
Acute on chronic	19 (9.2)	Professional	8 (3.9)
Chronic	50 (24)	Recreational	4 (1.9)
Unknown	3 (1.5)		

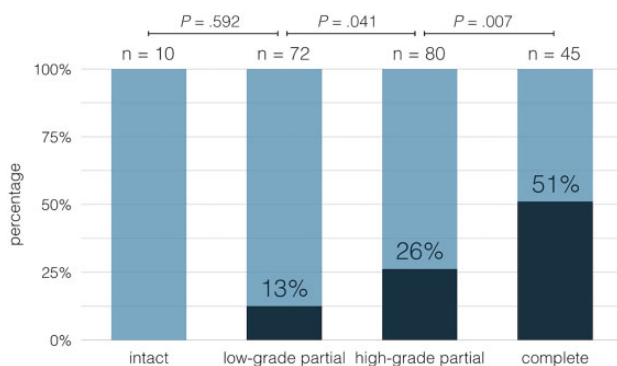


Figure 4. The proportion of patients who felt a pop significantly increased among ulnar collateral ligament injury severity groups.

TABLE 2
Contingency Table (2 × 2) of Popping Sensation
Versus UCL Injury Severity^a

	UCL Tear Severity		Total
	≤ Low Grade	≥ High Grade	
Pop	9	44	53
No pop	73	81	154
Total	82	125	207

^aData are reported as No. UCL, ulnar collateral ligament.

with high-grade partial-thickness tears (21 of 80) and 51% in patients with full-thickness tears (23 of 45) (Figure 4).

Quantification of Popping Sensation

Table 2 shows the frequencies of a popping sensation among high-grade UCL injury (high-grade partial-thickness or full-thickness) and low-grade UCL injury (intact or

low-grade partial). The sensitivity and specificity of a popping sensation for significant UCL injury (high-grade partial- or full-thickness tear) were 35% (95% CI, 27%-44%) and 89% (95% CI, 80%-95%), respectively. The PPV was 83% (95% CI, 70%-92%), and the NPV was 47% (95% CI, 39%-56%). The LR+ was 3.2 (95% CI, 1.6-6.2), and the LR- was 0.7 (95% CI, 0.6-0.9). The OR of a popping sensation for significant UCL injury was 4.4 (95% CI, 2.0-9.5; $P < .001$).

Popping Sensation and UCL Tear Location

A total of 125 patients showed a high-grade partial-thickness or complete full-thickness UCL tear on MRI (60%). Of these tears, 92% (115 of 125) were located at either the distal or the proximal attachment site of the anterior bundle. The remaining 8.0% had a tear of the mid-substance or multiple tears of the anterior bundle and were excluded from this analysis. A popping sensation was not associated with either distal or proximal tears (36% vs 35%; $P \geq .999$) (Appendix Figure A1).

DISCUSSION

In this study, we examined the clinical value of the subjective experience of a popping sensation at the time of injury for significant UCL injury of the anterior bundle in throwing athletes. In our sample, 1 in 4 patients experienced a popping sensation (26%), with a prevalence of 46% among patients who had an acute or acute-on-chronic onset of medial elbow pain that resulted in immediate inability to throw. Based on MRI, 60% of patients had a significant UCL injury of the anterior bundle, defined as high-grade partial-thickness tears or complete full-thickness tears. We observed a significant increase in frequency of a popping sensation among UCL tear severity groups, up to 51% in patients with complete full-thickness tears ($P < .001$). Although the proximal and distal attachments of the UCL are histologically different, this appears to be unrelated to the phenomenon of generating a pop sensation, as no relationship was observed between a pop and UCL tear location ($P \geq .999$).^{3,4,8,10}

Clinical Interpretation of a Pop

For quantification of the popping sensation, we were especially interested in the LRs and OR, as they reflect the predictive ability of the popping sensation for UCL injury and do not depend on disease prevalence. This means that the observed LRs in this study are applicable to other clinical settings if the definition of significant UCL injury is not changed (high-grade partial-thickness and complete full-thickness UCL tears).¹⁶ The feeling or hearing of a pop increased the odds of a high-grade UCL injury in throwing athletes with medial elbow pain by 4.4 times (OR; $P < .001$). Our findings suggest that a pop is 3 times more likely to be reported by patients with high-grade partial- or full-thickness UCL tears as compared with patients with low-grade or

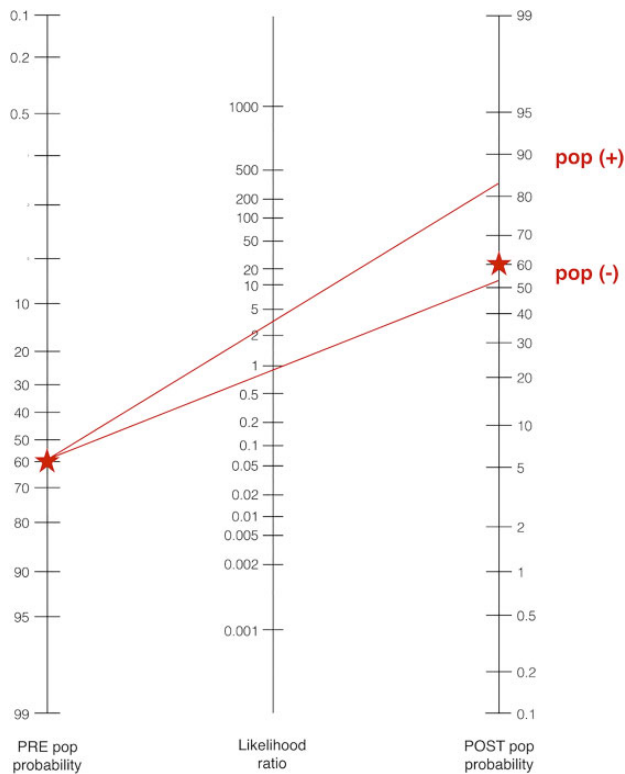


Figure 5. Bayes nomogram of positive (3.2) and negative (0.7) likelihood ratios of popping sensation for high-grade ulnar collateral ligament injury of the anterior bundle, reflecting a moderate increase in likelihood from 0.60 to 0.83 in patients who reported a popping sensation and a nonsubstantial decrease from 0.60 to 0.53 in patients who did not.

no UCL injury (LR+). The absence of a pop was 0.7 times less likely in patients with significant UCL tears as compared with patients with low-grade or no UCL injury (LR-). This means that the reporting of a popping sensation moderately increases the likelihood of a high-grade UCL injury, but the absence of a pop should not substantially decrease clinical suspicion for high-grade UCL injury (Figure 5).¹³ This finding is also reflected by the low sensitivity (35%) and high specificity (89%) of a pop for significant UCL injury.

In our sample, patients who reported a pop had an 83% chance of having significant UCL injury (PPV). Conversely, patients who did not report a pop had a 47% chance of having significant UCL injury (NPV). However, it needs to be considered that these predictive values largely depend on the prevalence of high-grade UCL injury in the examined population; therefore, generalization of these values is limited to settings with a similar prevalence (eg, tertiary referral centers for throwing athletes in the United States).¹⁶ In settings with a lower prevalence of high-grade UCL injuries, PPV will decrease and NPV will increase (whereas the decrease in PPV will be more substantial).¹⁶

Limitations

In addition to the sensitivity of measures of diagnostic accuracy to disease prevalence and disease definition, there are some limitations of this study that require consideration. First, our sample included mainly male baseball pitchers, which may limit the generalizability of our findings to other types of athletes. A second limitation of our study is the retrospective nature of the assessment of UCL tears based on available MRI. The clinical assessment of MRI limits the level of detail of our observations regarding tear characteristics presented in this study. However, experienced musculoskeletal radiologists at our institution assessed all MRI. A third important consideration and avenue for future research is the fact that this study focused on the subjective sensation of a pop as an isolated factor. In clinic, physicians collect a variety of factors, from history taking as well as physical examination, and weigh these to determine a patient's risk of disease or injury. Therefore, future multifactorial studies (including physical examination findings) should be able to determine the diagnostic value of the salient anamnestic finding of a pop in throwing athletes with medial elbow pain in combination with other factors that may predict UCL injury severity. Last, in this study, we did not observe that tear grade was associated with tear location (distal vs proximal injury). However, this analysis may have been limited by the smaller subcohort sample size of distal and proximal high-grade UCL injuries ($n = 115$), and future prospective studies with larger sample sizes may further delineate any associations.

Taking the limitations of the current study into consideration, we believe that this is the first study addressing the salient finding of a popping sensation in throwing athletes with medial elbow pain—a phenomenon that is well known by physicians treating these athletes—quantifying the subjective experience of a pop at the time of injury for the likelihood of significant UCL injury of the anterior bundle.

CONCLUSION

The subjective experience of a popping sensation at the time of injury in throwing athletes with medial elbow pain was associated with UCL injury severity but not UCL tear location. When a throwing athlete reports feeling or hearing a pop, this anamnestic finding should moderately increase a clinician's suspicion for significant UCL injury. Conversely, the absence of a pop should not substantially decrease clinical suspicion for a significant UCL tear. This study provides a reference foundation for future studies of predictive and diagnostic factors for UCL injury in throwing athletes.

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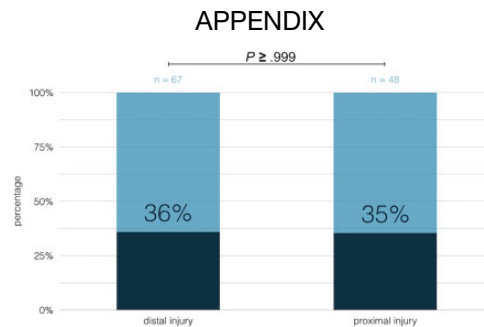


Figure A1. There was no difference in the proportion of patients with a pop between distal and proximal ulnar collateral ligament tears.