How much valgus instability can be expected with ulnar collateral ligament (UCL) injuries? A review of 273 baseball players with UCL injuries

Jeremy R. Bruce, MD*, Ryan Hess, MD, Patrick Joyner, MD, James R. Andrews, MD

The Andrews Institute, Gulf Breeze, FL, USA

**Background:** The dynamic stress radiograph of the elbow was designed to help the clinician better define valgus laxity and instability in the throwing athlete. However, no large study has quantified the amount of laxity in athletes with ulnar collateral ligament (UCL) injuries. We hypothesized that valgus stress radiographs in patients with UCL injuries will demonstrate a significantly greater amount of valgus stress opening of the dominant elbows compared with the nondominant elbow.

**Methods:** Bilateral elbow static and stress radiographs that were taken as part of our standard preoperative workup were retrospectively reviewed in 273 baseball players who had undergone UCL reconstruction. The valgus stress radiograph protocol used a Telos stress device (SE 2000) to provide 15 daN of stress in a standardized fashion.

**Results:** The thrower’s elbow with a UCL injury opened 0.4 mm more than the uninjured side. Those with complete tears (N = 76), determined by magnetic resonance imaging findings, opened 0.6 mm on average, which was significantly more than in those with partial tears (N = 150), which opened an average of 0.1 mm.

**Conclusion:** Stress radiography of the dominant elbow in baseball players with UCL injuries showed it to have 0.4 mm greater opening compared with the nondominant arm. Larger average openings (0.6 mm) can be expected with full-thickness UCL tears compared with partial-thickness tears (0.1 mm). This suggests that large openings on stress radiography may not be a critical component for predicting who will require surgical reconstruction for UCL injuries but may be more useful in differentiating complete from partial tears.

**Level of Evidence:** Level III, Diagnostic Study.
© 2014 Journal of Shoulder and Elbow Surgery Board of Trustees.

**Keywords:** Ulnar collateral ligament; elbow x-ray; valgus stress; elbow imaging
co-primary restraint only at 120° of flexion but provides secondary restraint at 30° and 90° of flexion. The posterior bundle, which is a thickening of the joint capsule, provides secondary restraint only at 30°.

The pitcher places large amounts of stress on the UCL with pitching, specifically during the late cocking and acceleration phases while moving from elbow flexion toward rapid extension. The athlete places the UCL near its maximal tensile strength with every high-velocity pitch. This helps explain why UCL injuries are common in this group of throwing athletes.

A thorough history in the thrower will often provide the clinician with critical information in a patient with a suspected UCL injury. Some patients report immediate acute pain with a feeling of a “pop”; others complain of vague symptoms affecting their pitching ability. Manual valgus stress testing can often be difficult on physical examination. In the asymptomatic throwing athlete, some laxity due to accommodation from the valgus forces related to throwing can be expected, making it even more difficult to detect pathologic laxity.

The valgus stress radiograph of the elbow has been used to aid in diagnosis of UCL tears. However, few data are available to provide the clinician with expected measurements to determine acquired laxity vs pathologic instability in throwing athletes. If it is proved to be reliable, elbow stress radiography would be a cost-effective means for predicting UCL tears compared with magnetic resonance imaging (MRI). However, if low correlation of radiographic and clinical findings is noted with stress radiographs, this added cost and radiation exposure may not be warranted. This study was designed to define expected values for valgus opening with elbow stress radiographs in a large cohort of throwing athletes who failed to respond to conservative treatment and required UCL reconstruction.

Materials and methods

Approval was received from our Institutional Review Board to retrospectively review the charts and radiographic data of patients who had undergone UCL reconstruction procedures from 2009 to 2013 by the senior author at our institution. The outpatient surgical center billing office was used to identify such patients by the Current Procedural Terminology code 24346. There were 292 UCL reconstructions performed by the senior author. Of the 292 UCL reconstructions, 9 patients were excluded because of lack of radiographic information. An additional 9 athletes did not meet the inclusion criteria of being a baseball player with a throwing position, and level of competition.

Our study included 273 male baseball players who required surgical reconstruction for UCL injuries on the throwing arm. The criteria for surgical reconstruction included continued pain with throwing in those with partial tears on MRI and having failed to respond to at least 3 months of rehabilitation. In those with complete UCL tears on MRI, the patients were offered surgical reconstruction if they planned to continue playing baseball at a competitive level.

The UCL reconstruction was performed with a modified Jobe technique as described in previous literature. The native UCL was visualized under the flexor digitorum profundus muscle fibers as part of every approach. The superficial fibers are visualized at the joint line, then the deep fibers are exposed by making a longitudinal incision from the origin near the medial epicondyle to its insertion near the sublime tubercle. This gives exposure to the elbow joint for ulnar tunnel referencing and can give visualization of undersurface tears. The native ligament was repaired with side-to-side sutures after the ulnar tunnels had been drilled. We think it is often difficult to fully differentiate high-grade partial tears from complete tears. Therefore, surgical visualization was not used to classify complete vs partial tears. We instead used MRI to classify partial vs complete tears.

MRI analysis was available for 226 of the 273 subjects. As a major referral center for UCL injuries, many athletes arrived with MRIs already having been performed. The MRI was used if it was a 1.5T or 3.0T MRI with intra-articular administration of gadolinium and of sufficient quality to determine UCL status. An MRI at our facility with intra-articular administration of gadolinium in a 3.0T magnet was performed if the patient had not had MRI yet or if the MRI study was not of sufficient quality. The groups were subclassified and analyzed for partial vs complete tears on the basis of MRI findings reviewed by the author. There were 150 players with partial tears (67%) and 76 players with complete tears (33%). Complete tears were classified as having complete rupture of the UCL off the humeral or ulnar side with fluid extravasation from the joint. Partial tears were classified as having fluid or signal within the ligament or partial undersurface tears demonstrated by a T sign as described in previous literature.

The 226 athletes included in the study had a mean age of 20.3 years (range, 13-37 years), with 64 at the high-school level (28%), 102 at the college level (45%), and 60 at the professional level (27%). There were 193 pitchers (85%), 9 catchers (4%), and 24 position players (11%). The dominant arm was right in 79% (179) of the cases and left in 21% (47) of the cases. The UCL reconstruction was performed with ipsilateral palmaris longus in 146 cases (65%), contralateral gracilis in 73 cases (32%), and contralateral palmaris longus in 9 cases (4%).

Standard radiographs performed at our facility for throwing elbow injuries include static anteroposterior, lateral, oblique, and reverse axial (cubital tunnel) views of the injured elbow. The stress and nonstress views of the dominant (injured) and nondominant elbow are performed in a standard technique, similar to that previously described in the literature.

The stress view uses a Telos stress device (SE 2000; Telos, Weiterstadt, Germany) to provide 15 daN of valgus stress (Figs. 1 and 2). The nonstress radiograph is taken before the stress radiograph in the apparatus to try to standardize the position for comparative views. The nondominant (uninjured) elbow is placed in the valgus stress device by our radiology technician with the patient sitting on a stool and the arm resting on the x-ray table in abduction and external rotation. The elbow is flexed 20° to 30° to unlock the bone conformity at the elbow joint, and the forearm is in full supination. A nonstress anteroposterior view is taken in this position before force is applied for the stress view. The nonstress and stress views are then repeated on the injured elbow.

The amount of valgus stress opening was calculated by a 1-line method for radiographic measurements similar to that described in
The lead author (J.B.) performed all the measurements blinded to the dominant vs the nondominant extremity. The medial joint space distance was measured by finding the most distal point of the medial trochlea and measuring the vertical distance across the joint to the ulnar coronoid (Figs. 3 and 4). The valgus stress opening for each arm was calculated by subtracting the joint space distance (d) for the nonstress (NS) view from the stress (S) view (Sd – NSd = valgus opening). The nondominant (ND) elbow opening was subtracted from the dominant (D) opening to give final valgus opening measurements (D – ND = final valgus opening). The final valgus opening measurement was positive if the opening on the dominant side was greater than on the nondominant side (most common) and negative if the opening on the dominant side was less than on the nondominant side.

The measurements were performed on picture archiving and communication system workstations (Centricity PACS, version 2.1; GE Healthcare Systems, Chalfont St. Giles, UK) with high-resolution monitors to measure the medial joint space to the nearest 0.1 mm.

The intraclass correlation coefficient was determined for interobserver and intraobserver agreement before the measurements were made. For the interobserver portion, the intraclass correlation coefficients for dominant elbow (D) opening, nondominant elbow (ND) opening, and dominant-nondominant difference (D-ND) were classified as excellent by the 1-line
method. For the intraobserver portion, the 1-line method showed good agreement for D opening, ND opening, and D-ND.

**Data analysis**

A dependent *t* test with a significance set at the .05 level was used to assess differences in medial joint space opening between stress and nonstress views on each arm as well as to determine differences between dominant and nondominant medial joint space opening.

**Results**

The overall average opening (D-ND) for all 226 subjects was 0.4 mm (±0.8 mm) greater on the dominant extremity than on the nondominant extremity, which was statistically significant (*P* < .001) (Table I). The average nondominant medial elbow joint space was 3.6 mm without stress and 4.6 mm with stress, giving an opening with stress of 1.0 mm. The average dominant medial elbow joint space was 3.6 mm without stress and 5.0 mm with stress, giving an opening with stress of 1.4 mm. The overall average opening (D-ND) of 0.4 mm was calculated by subtracting the nondominant arm opening of 1.0 mm from the dominant arm opening of 1.4 mm.

The average opening for the 76 players with complete tears was 0.6 mm (±0.9 mm), which was significantly more (*P* < .001) than that of the 150 players with partial tears, who had 0.1 mm (±0.8 mm) of opening (Tables II and III). The range of excess opening (D-ND) was −3.2 mm to 2.8 mm for partial tears (Fig. 5). The range of excess opening (D-ND) was −1.8 mm to 3.1 mm for complete tears (Fig. 6).

The cutoff of 0.5 mm as a surgical indication would have given us a high false-negative rate as only 73 of 226 (32%) of our patients had more than 0.5 mm of opening. However, the 0.5-mm cutoff did help predict complete tears as 51% (39 of 76) had more than 0.5 mm of opening compared with 29% (44 of 150) with partial tears. Some subjects even had more opening on the nondominant extremity than on the dominant extremity, which was seen in 54 of 150 (36%) with partial tears and 15 of 76 (20%) with complete tears.

Our finding of 0.4 mm of excess opening was found to be significant; however, there was much variability in these findings as our standard deviation was 0.8 mm. There were 69 patients (31%) who had less opening on the injured side than on the uninjured side.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Radiographic stress and nonstress medial joint space measurements for injured and uninjured elbows in all baseball players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Uninjured, SD (range)</td>
</tr>
<tr>
<td>Nonstress radiograph</td>
<td>3.6 ± 0.6 mm (2.1-5.9)</td>
</tr>
<tr>
<td>Stress radiograph</td>
<td>4.6 ± 0.8 mm (2.9-8.2)</td>
</tr>
<tr>
<td>Stress-nonstress</td>
<td>1.0 ± 0.6 mm (−0.2-4.1)</td>
</tr>
<tr>
<td>SD, standard deviation.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table II</th>
<th>Radiographic stress and nonstress medial joint space measurements for injured and uninjured elbows in baseball players with partial tears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Uninjured, SD (range)</td>
</tr>
<tr>
<td>Nonstress radiograph</td>
<td>3.6 ± 0.6 mm (2.1-5.9)</td>
</tr>
<tr>
<td>Stress radiograph</td>
<td>4.6 ± 0.8 mm (2.9-8.2)</td>
</tr>
<tr>
<td>Stress-nonstress</td>
<td>1.0 ± 0.6 mm (−0.2-4.1)</td>
</tr>
<tr>
<td>SD, standard deviation.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table III</th>
<th>Radiographic stress and nonstress medial joint space measurements for injured and uninjured elbows in baseball players with complete tears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Uninjured, SD (range)</td>
</tr>
<tr>
<td>Nonstress radiograph</td>
<td>3.7 ± 0.6 mm (2.5-5.9)</td>
</tr>
<tr>
<td>Stress radiograph</td>
<td>4.7 ± 0.8 mm (2.2-5.0)</td>
</tr>
<tr>
<td>Stress-nonstress</td>
<td>1.0 ± 0.6 mm (0-3.2)</td>
</tr>
<tr>
<td>SD, standard deviation.</td>
<td></td>
</tr>
</tbody>
</table>
It has been quoted in the literature that 3 mm of opening on a valgus stress radiograph is diagnostic for instability.\(^1\,^7\) Thompson et al noted that 88% of their patients undergoing UCL reconstruction had excess medial elbow opening >2 mm on manual stress radiography compared with the contralateral side.\(^16\) Our data differ from these previous findings in that we found only an average of 0.34 mm of excess opening (D-ND) on stress radiographs in baseball players with UCL injuries requiring reconstruction. In our study, only 9 of 273 patients (3.3%) had excess opening (D-ND) of more than 2 mm, and just 2 of 273 patients (0.7%) had excess opening of 3 mm or more compared with the noninjured side. The reason for the large difference in these findings is unclear but may be related to the use of the Telos device in our study vs manual stressing of the elbow as used in the previous study.\(^16\)

Rijke et al evaluated 42 athletes with suspected UCL tears with stress radiographs.\(^13\) They found that complete and large partial tears could be detected with medial joint gapping of more than 0.5 mm. Those with medial space opening smaller than 0.5 mm were found to have normal ligaments or smaller partial UCL tears that could be managed conservatively. The validity of their technique was tested by examining cadaveric specimens with varying amounts of UCL sectioning. Medial opening was 0.2 mm in cadaver specimens with intact UCLs. The amount of medial opening increased linearly with increased amount of UCL severing, with up to 2.8 mm noted with complete transection of the ligament.\(^13\) The increase in medial joint space gapping was also noted in our study in comparing partial and complete tears (0.1 mm and 0.6 mm, respectively), but not to the degree of opening noted in their study.

Although the data in the study by Rijke et al provided specific numbers to correlate UCL tears to medial opening on stress views, only 17 patients underwent surgical procedures to verify the status of the ligament.\(^13\) Of the 17 patients, only 12 patients had surgically proven tears (2 moderate and 10 complete). In addition, these measurements were taken with hard-copy radiographs by use of loupe magnification.\(^13\)

The findings of the current study contradict the previously published data by Rijke et al. There does not appear to be a set parameter or a definitive amount of opening that can be used as an indicator for pathologic laxity requiring surgical intervention. The cutoff of 0.5 mm as a surgical indication, as proposed by Rijke et al, would have given us a high false-negative rate as only 73 of 226 (33%) of our patients had more than 0.5 mm of excess opening (D-ND).

A small amount of excess opening (D-ND) may be considered adaptive and normal in pitchers. Ellenbecker et al found that in 40 asymptomatic professional pitchers, the dominant medial joint space opens an average of 0.32 mm more on stress radiography compared with the nondominant elbow.\(^6\) This is similar to the findings of Singh et al, who described a cohort of asymptomatic collegiate baseball players in which 0.37 mm of increased elbow laxity was noted.\(^15\) The amount of opening found in these two studies was similar to that found in the current study (0.4 mm) of injured baseball players from the high-school, collegiate, and professional levels. Although all studies noted statistically significant amounts of opening, all were less than 0.5 mm. On the basis of these data and the data from the current study, there may be essentially no difference in the dominant elbow valgus laxity of an asymptomatic thrower and one who goes on to require UCL reconstruction. This highlights the challenge of identifying pathologic laxity of the elbow during physical examination of throwing athletes.

The similar amount of opening between asymptomatic and symptomatic baseball players raises several important concerns. A possible explanation for the similar findings could be that asymptomatic patients have acquired non-pathologic laxity in their UCLs over time until the ligament...
finally becomes painful and pathologic. Another theory for
the similar findings is that the symptomatic athletes may
have more laxity but the valgus stress radiograph is
not detecting the difference. This could be seen if the
symptomatic elbows are guarding because of pain during
the valgus stress radiograph procedure, limiting the
true opening measurement. Testing of a patient under
anesthesia may give a more accurate result, such as
that seen in arthroscopic evaluation of valgus laxity in
UCL-incompetent elbows.8,14,17 However, this is not prac-
tical in the clinical setting as part of a standard evaluation.
Another possible explanation for the lower numbers found
in the current study is that 15 daN of force may not be truly
recreating the forces seen with throwing a baseball but
giving subthreshold stress that is similar in symptomatic
and asymptomatic throwers. Our study more closely
resembled the valgus opening measurements done on
asymptomatic patients than those done on symptomatic
patients in several of the previous studies, showing
much larger amounts of valgus opening. The variability
and small amounts of opening suggest that stress radiog-
raphy may not be as critical as initially thought for
predicting UCL injuries that will require surgical
reconstruction.

This study has several limitations. One limitation is that
it was a retrospective review, and data were not collected in
a prospective manner. However, the radiographs were per-
formed in a standard manner by the same radiology tech-
nician. Another limitation is that 47 patients were excluded
because of lack of sufficient MRI data. As part of the
surgical procedure, the UCL was examined. However, we
think it is challenging during surgery to differentiate a high-
grade partial tear from a complete tear, which can be more
reliably interpreted with MRI.

Conclusion

The elbow valgus stress radiograph was found to pro-
cede an average of 0.4 mm of excess opening (D-ND) in
the injured elbow of baseball players undergoing UCL
reconstruction. Larger average openings (0.6 mm) can
be expected with full-thickness UCL tears compared
with partial-thickness tears (0.1 mm). This suggests that
large openings on stress radiography may not be critical
for predicting who will require UCL reconstruction but
may be more useful in differentiating complete from
partial tears.

Disclaimer

The authors, their immediate families, and any research
foundation with which they are affiliated did not receive
any financial payments or other benefits from any
commercial entity related to the subject of this article.

Acknowledgment

The authors acknowledge Charles Leddon and Aaron
Mates for assistance with this project.

References

1. Ahmad CS, ElAttrache NS. Elbow valgus instability in the throwing
2. Andrews JR, Jost PJ, Cain LE. The ulnar collateral ligament pro-
4. Chen FS, Rokito AS, Jobe FW. Medial elbow problems in the
gracilis tendon in athletes with intraligamentous bony excision:
doi.org/10.1177/0363546512446927
joint laxity in professional baseball pitchers. A bilateral comparison
7. Eygendaal D, Heijboer MP, Obermann WR, Rozing PM. Medial
instability of the elbow: findings on valgus load radiography and MRI
8. Fields LD, Altchek DW. Evaluation of the arthroscopic valgus insta-
9. Floris S, Olsen BS, Dalstra M, Sojbjerg JO, Sneppen O. The medial
collateral ligament of the elbow joint: anatomy and kinematics. J
10. Jones KJ, Osbahr DC, Schrupp MA, Dines JS, Altchek DW. Ulnar
collateral ligament reconstruction in throwing athletes: a review of
.org/10.2106/jbjs.k.01034
12. Morrey BF, An KN. Articular and ligamentous contributions to the
13. Rijke AM, Goitz HT, McCue FC, Andrews JR, Berr SS. Stress radi-
14. Schwab GH, Bennett JB, Woods GW, Tullos HS. Biomechanics of
ear instability: the role of the collateral ligament. Clin
15. Singh H, Osbahr DC, Wickman MQ, Kirkendall DT, Speer KP. Valgus
laxity of the ulnar collateral ligament of the elbow in collegiate ath-
16. Thompson WH, Jobe FW, Yocom LA, Pink MM. Ulnar collateral
ligament reconstruction in athletes: muscle-splitting approach
without transposition of the ulnar nerve. J Shoulder Elbow
17. Timmerman LA, Schwartz ML, Andrews JR. Preoperative evaluation of
the ulnar collateral ligament by magnetic resonance imaging and