The drop sign, a radiographic warning sign of elbow instability

Ralph W. Coonrad, MD,[a] Thomas F. Roush, MD,[b] Nancy M. Major, MD,[a] and Carl J. Basamania, MD,[a]
Durham, NC

Persistent instability or redislocation is uncommon but of significant concern in treating elbow dislocations. Finding an objective, static radiographic sign that might correlate with the presence of instability was the purpose of this study. Pre- and post-reduction radiographs of 10 consecutive simple and complete adult elbow dislocations were reviewed and compared with radiographs of 20 consecutive adult elbows without any trauma history. A statistically significant measured increase in static ulnohumeral distance was noted on the routine unstressed post-reduction lateral radiographs of patients sustaining dislocation. We have termed this increased distance the drop sign. It differs from the radiographic ulnohumeral separation noted during O'Driscoll's test for posterolateral rotary instability, which is present only with axial compression. The drop sign becomes concerning only if persistent after the first reduction radiograph and may be a warning sign of the presence of instability. (J Shoulder Elbow Surg 2005;14:312-317.)

Elbow dislocations are commonly encountered by orthopaedic surgeons and emergency medicine physicians alike. The elbow is second only to the shoulder in the incidence of nonprosthetic joint dislocation, and the incidence of elbow dislocation is much more common in children. As a result of the elbow's congruent articular configuration, stiffness has historically been the most common posttraumatic complication. However, its solution by immediate or early motion has evolved only in recent years, largely as a result of our better understanding of the pathomechanics and pathoanatomy of elbow dislocation. This has altered our treatment algorithm from historically prolonged casting to immediate mobilization, brief splinting, or protective hinge bracing as determined by instability testing, recognizing that the forces of muscle loading tend to stabilize this congruous joint. The rare problem of persistent instability or redislocation when it occurs, however, can be troublesome for the managing surgeon. It is toward these latter 2 problems that this study is directed. After manipulative reduction or when spontaneous relocation occurs, a routine lateral radiograph may sometimes show widening or separation of the ulnohumeral space, without dislocation of the proximal radioulnar joint (Figure 1). We have termed this increased distance between the trochlea and the sigmoid notch the drop sign. The purpose of this report is to draw attention to this sign, which we have found likely to be associated with complete disruption or attenuation of either the lateral or medial ligament complex, or both (Figures 1 and 2). It differs from the radiographic ulnohumeral separation or perching sometimes noted during O'Driscoll's test for posterolateral rotary instability, which is present only with axial compression and valgus stress.[10,11]

The pathomechanics and pathoanatomy of an index simple elbow dislocation or subluxation have been reported by multiple authors and texts on the subject. O'Driscoll et al[10] have presented their pathoanatomic description as a sequential process that occurs with simple dislocation of the elbow, commencing in a clockwise direction with forearm external rotation on the trunk and a resulting elbow supination moment. After this, a valgus moment is produced as a result of the location of the traumatic mechanical axis medial to the elbow. Thus, supination and valgus moments, combined with requisite axial compression, have been used to reproduce dislocations in controlled experimental settings. This description by O'Driscoll et al represented an update of the original posterolateral rotational displacement theory of Osborne and Cotterill.[12] The latter authors similarly proposed an elbow supination moment coupled with valgus stress and furthermore postulated the concomitant anatomic process of the superior stripping of the lateral collateral ligament and tearing of the posterolateral capsule.

O'Driscoll et al[11] divided the soft-tissue disruption, which occurs with elbow dislocation, into 3 distinct and sequential stages. Stage I represents disruption of at least the lateral ulnar collateral ligament,[1] which

From the Division of Orthopedic Surgery[a] and Department of Radiology,[b] Duke University.
Reprint requests: Ralph W. Coonrad, MD, 3534 Rugby Road, Durham, NC 27707(E-mail: *rwcoonrad@aol.com*).

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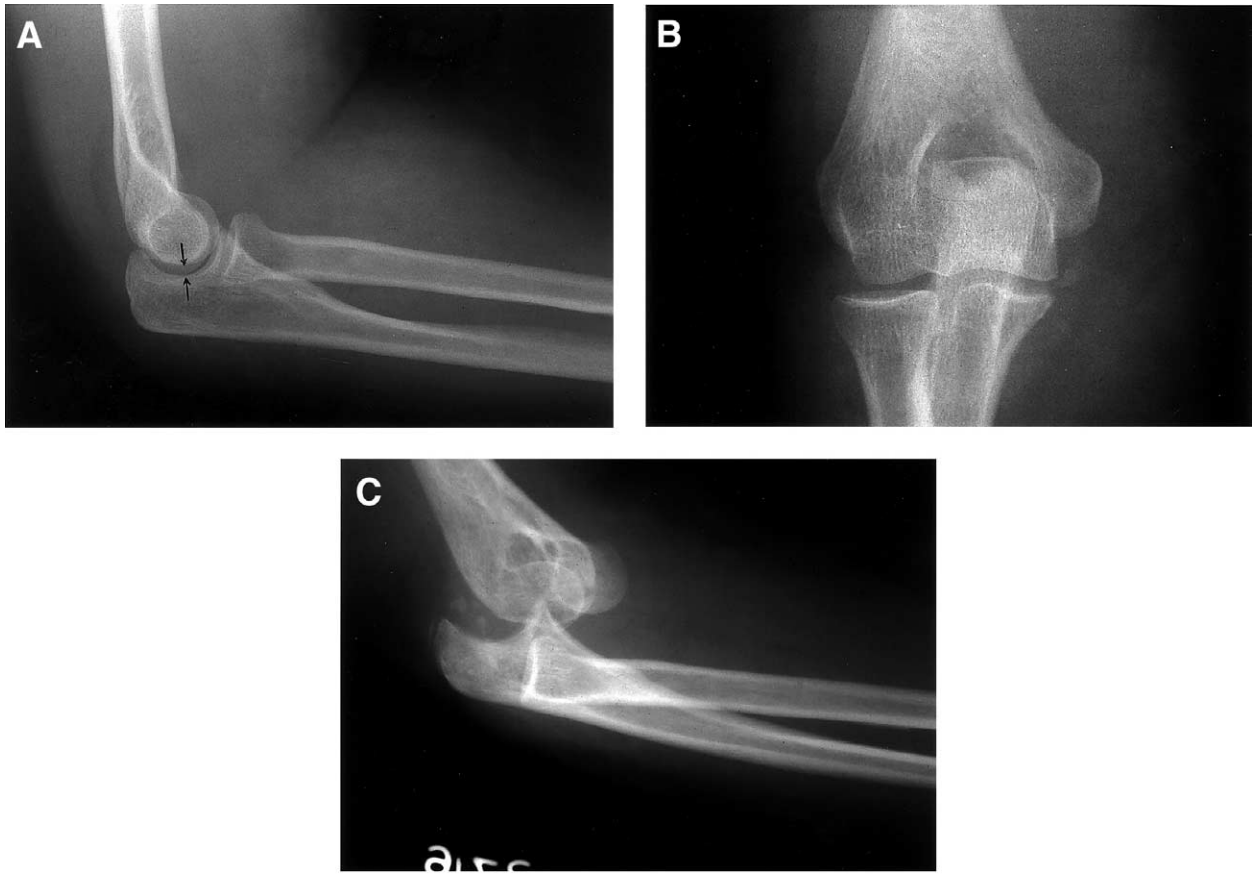

Figure 1 A 68-year-old woman sustained a Smith-type fracture of the distal radius. Concomitant radiographs of the elbow (**A** and **B**) were interpreted as being negative for osseous injury. A drop sign was not noted on the lateral film at that time. Occult dislocation of the elbow occurred while the patient's arm was immobilized in a long arm cast for the wrist fracture, was discovered 5 weeks after injury (**C**), and required open treatment. Complete tears of the medial and lateral ligament complexes were found at operation.

produces posterolateral rotary subluxation of the elbow. Stage II encompasses incomplete posterolateral dislocation produced by anterior and posterior soft-tissue disruption. This produces the radiographic correlate of a perched coronoid on the trochlea. Stage IIIa involves extension to the medial side of the elbow including damage to the posterior bundle of the medial collateral ligament (MCL) complex. Of note, the anterior bundle of the MCL complex may remain intact at this stage. The intact anterior bundle then provides a pivot by which posterolateral rotation can occur. In stage IIIb, the entire MCL complex is compromised. Thus, varus/valgus instability is introduced. This explanation is consistent with the most common type of elbow dislocation being posterolateral.

Some radiographic correlates to these ligamentous injuries have been described previously in the literature. However, we are not aware of any studies observing the static radiographic findings after isolated and sequential severance of each component of the medial and lateral collateral ligament complexes. Furthermore, it has been the observation of the senior author (R.W.C.) over many years that the delayed presence of radiographic widening or separation of 1 or both sides of the joint (drop sign) on a routine lateral radiograph after elbow trauma suggests capsular/ligamentous compromise and persistent instability. The drop sign refers to the increase in distance between the trochlea and olecranon and, if persistent radiographically after initial reduction, may often be a part of the picture of chronic instability or herald redislocation (Figure 2). No absolute measurements of the ulnohumeral interspace have been made during these observations over the years; rather, redislocation or chronic instability has not uncommonly been noted when an increased ulnohumeral distance is still present on routine follow-up radiographs taken after loading occurs, days, weeks, or longer after index reduction or while the arm is in a cast. The desire to correlate this observation by clinical assessment has prompted this investigation.

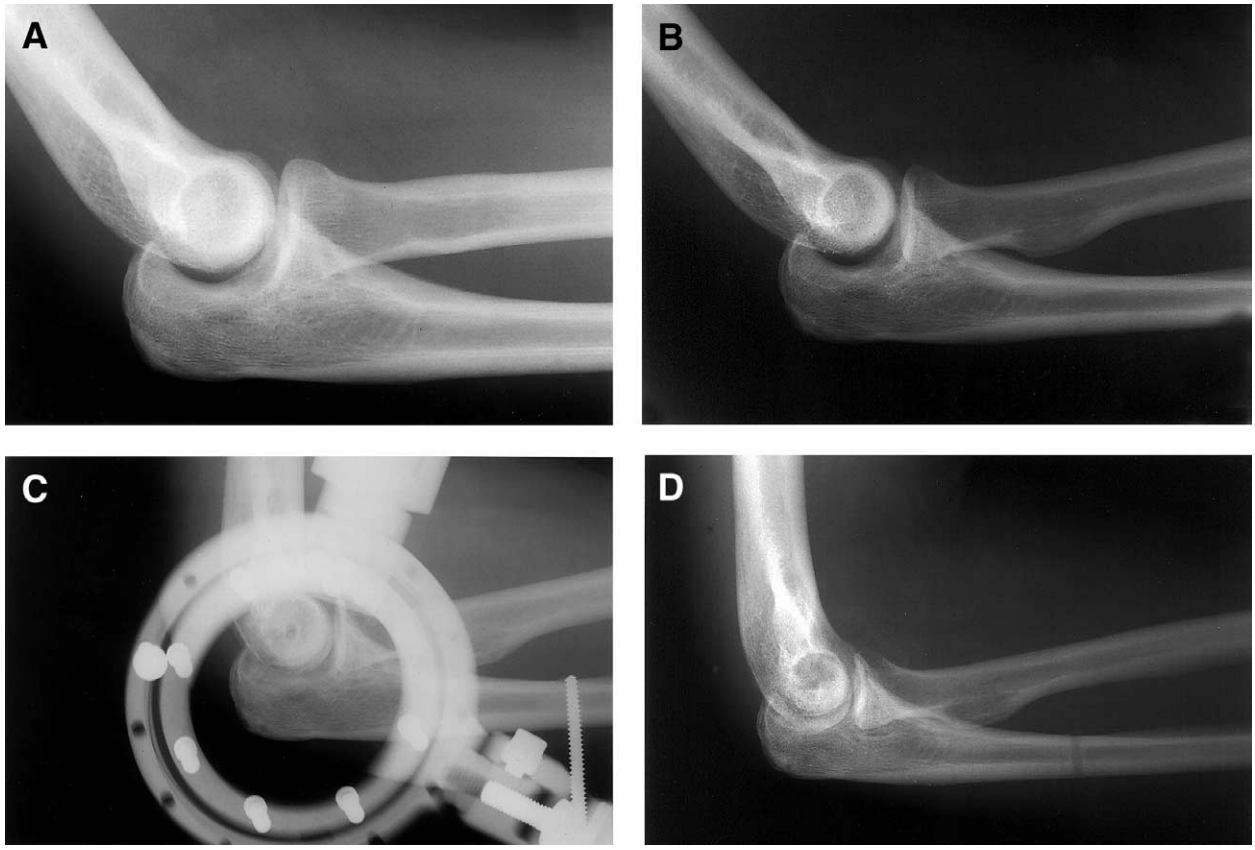

Figure 2 A 24-year-old man fell while playing basketball and sustained a posterior dislocation of the elbow. The dislocation self-reduced (**A**), and the patient did not undergo immobilization after being seen and was lost to follow-up. At a return visit 4 weeks after injury, gross varus and valgus clinical instability was noted, along with loss of active flexion and extension as a result of pain and subluxation. **B**, A magnetic resonance image revealed total torn medial and lateral collateral ligament complexes. Open reduction and stabilization with a dynamic external fixator were carried out (**C**), and after 4 weeks of stabilized motion in the fixator, the range of motion was 35° to 135° (**D**). A drop sign was noted (**A** and **B**).

MATERIALS AND METHODS

This study was divided into 2 clinical parts. The first consisted of the evaluation and measurement of the ulnohumeral distance present on post-reduction lateral radiographs of adult patients presenting with simple, complete, nonprosthetic elbow dislocation to the emergency department at a level-I trauma center. After approval from the institutional review board, we initially obtained a list of all dislocations with and without fractures about the elbow from a search by *International Classification of Diseases, Ninth Revision* codes from January 1998 through August 2002. A total of 183 patients were identified. After a preliminary review of the radiographs of these patients whose diagnoses included multiple fractures and fracture dislocations about the elbow, we found that both the diagnoses and radiographic measurements were too variable to be included in this study. Therefore, we excluded all complex dislocations and included only the simple, complete dislocations. In all, there were only 11 uncomplicated simple and complete dislocations of record. Of these 11 patients (group A), 10 had pre- and post-reduction lateral radiographs on file. Each lateral view was taken according to our institutional protocol with the elbow flexed to 90°, centered over the trochlea, with the forearm in neutral rotation and with the arm lying flat on a cassette on the table. This routine position was that used in our institution to obtain lateral views even under conditions of trauma, being as close to a true lateral radiograph of the elbow as possible, as described by London.[6] The trochlear sulcus was clearly visualized, and this was the proximal portion of the ulnohumeral measurement. The distal point of measurement was the intersection of the vertical line from the horizontal point of the trochlear sulcus with the articular surface of the olecranon. These measurements were recorded on films obtained with the following descriptors: Kodak Xomat (Eastman Kodak, Rochester, NY) regular cassettes of 10 × 12–inch dimensions, 48-inch target film distance with 50 to 60 kilovolt peak (kVp), 600 milliamperes (ma), and a 0.0125-second exposure time. Measured ulnohumeral distances are recorded in Table I, along with measurements at final follow-up and period of time to follow-up.

Second, to obtain a clinical comparison and control

Table 1 Ulnohumeral distance measurements on lateral radiographs of 10 consecutive adult patients with simple elbow dislocation

PT. No.	Elbow	Immediate Post-Reduction Ulnohumeral Distance	Follow-Up Interval (Months)	Final Follow-Up Ulnohumeral Distance
1.	R	4mm	2	3mm
2.	R	5mm	36	N/A*
3.	L	4mm	14	3mm
4.	R	10 mm	68	4mm
5.	R	5mm	2	3mm
6.	L	3mm	3	3mm
7.	R	4mm	12	3mm
8.	R	9mm	4	3mm
9.	L	8mm	1	4mm
10.	L	7mm	58	4mm

*unsatisfactory radiograph for measurement after fixator removal

Table 2 Measurement of ulnohumeral distance on lateral radiographs of 20 "normal" adult elbows

Pt. No.	Ulnohumeral Distance	Pt. No.	Ulnohumeral Distance
1.	2mm	11.	2mm
2.	2mm	12.	3mm
3.	2mm	13.	3mm
4.	2mm	14.	3mm
5.	2mm	15.	3mm
6.	2mm	16.	3mm
7.	2mm	17.	3mm
8.	2mm	18.	3mm
9.	2mm	19.	3mm
10.	2mm	20.	3mm

group, an adult series of 20 consecutive lateral elbow radiographs (group B) interpreted as normal by the attending radiologist on duty at the time of patient presentation were evaluated by the authors. Normal was defined as the absence of fracture, dislocation, qualitative bone abnormality, or joint effusion. The measured ulnohumeral distances recorded from this portion of the analysis can be found in Table II. The Wilcoxon rank sum test was used to compare the data between groups A and B.

RESULTS

In this clinical study, a review of the post-reduction lateral radiographs of 10 adult patients after simple, complete elbow dislocation (group A) revealed the presence of a drop sign in 9 of 10 patients in whom the radiographically measured ulnohumeral distance was 4 mm or more. The 1 patient not considered to have a drop sign in this small series had a measured ulnohumeral distance of 3 mm (Table I). Of the 10 patients, 8 were treated with splinting, 1 was treated with a hinged brace, and 1 did not undergo immobilization. All had full mobilization within 2 weeks. In 2 of 10 patients, instability developed and redislocation occurred, and they were treated secondarily with a dynamic external fixator with ultimate restoration of stability. All 10 patients had clinical stability at follow-up.

In comparison, the measured ulnohumeral distance on each of the 20 consecutive normal lateral elbow radiographs (group B) reviewed was 3 mm or less (Table II). There was a statistically significant ($P < .0001$) increase in ulnohumeral distance when the immediate post-reduction values in group A were compared with the values in group B.

DISCUSSION

Stiffness after dislocation at the elbow is ordinarily of more concern than the uncommon occurrence of chronic instability or redislocation. Previous reports have shown that immediate or early mobilization results in only rare instances of redislocation (Johanson,[3] 0/31 elbows; Protzmann,[13] 0/27 elbows; and Mehlhoff et al,[7] 0/52 elbows). The contribution of the primary and secondary elbow stabilizers has been well documented in the literature.[2,8–10,14,15] Similarly, the performance of elbows with ligamentous deficiency during stress testing is predictable and can be identified during physical examination of the traumatized elbow and by radiographic and scanning techniques. Studies to quantify the ligamentous compromise in terms of varus and valgus instability have been performed.[16] Sojbjerg et al[16] specifically evaluated the role of the MCL complex for individual component contribution to varus and valgus instability, as well as internal and external rotary instability. They concluded that the anterior band of the MCL was the prime stabilizer to valgus and internal rotatory stress. They added that this stabilization occurred only between 20° and 120° of flexion. The inherent elbow stability outside of this flexion range precluded any valid measurements. Thus, the 90° flexion position used when lateral elbow radiographs were obtained was within the range in which the MCL normally provides stability.

In performing ulnohumeral measurement, it is im-

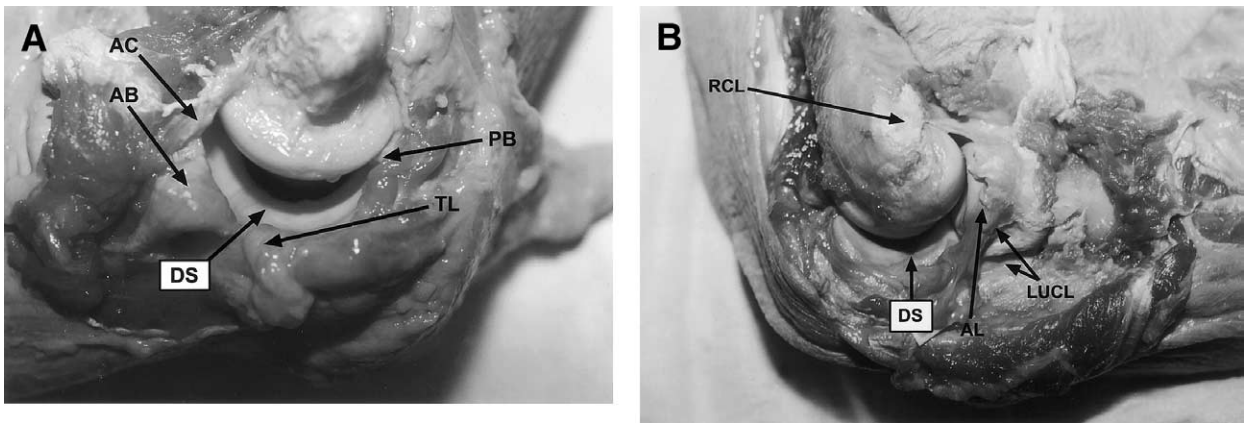

Figure 3 (A), The drop sign (*DS*) of a gravity-separated ulnohumeral joint space is demonstrated on a fresh tissue specimen with the medial ligamentous/capsular complex reflected. *AC*, Anterior capsule; *AB*, anterior band; *TL*, transverse ligament; *PB*, posterior band. **(B)**, The drop sign (*DS*) of a gravity-widened ulnohumeral joint space is demonstrated on a fresh tissue specimen with the lateral ligamentous/capsular complex reflected. *RCL*, Radial collateral ligament; *AL*, annular ligament; *LUCL*, lateral ulnar collateral ligament.

portant that the measured distance be from the trochlear sulcus to the olecranon. This might be confusing from a lateral radiograph until one realizes that the sulcus is more proximal in location and more circular with a smaller radius when compared with the capitellum (Figure 1, *A*). According to London,[6] a true lateral radiograph of the elbow requires concentric positioning of the 3 arcs represented by the trochlear sulcus, the capitellum, and the medial margin of the trochlea, with the x-ray beam at an angle of about 7° to compensate for the varied degree of valgus angle of the articular surface.

To our knowledge, radiographic studies to identify specific ligamentous/capsular compromise without any type of stress testing have not been formally reported. Authors reporting series of prospective and elective operative treatment of elbow dislocations have almost universally found disruption of the adjacent capsule coexistent with complete tears of either the medial or lateral ligament complexes.[4,5,12] If we accept the sequential mechanism of elbow dislocation described by O'Driscoll et al,[10] progressive capsular disruption occurs with successive stage advancement. To correlate the radiographic drop-sign increase in ulnohumeral distance with the pathoanatomy of dislocation described by O'Driscoll et al, one would have to consider that it represents a level of soft-tissue disruption beyond the perching level between stages II and IIIa on the lateral side and/or IIIb on the medial side. The role and effect of the dynamic stabilizers preclude any attempt to correlate specifically damaged soft-tissue structures at the elbow scientifically by merely observing radiographs. We also agree with the statement of Johanson[3] that "any attempt to reconstruct in autopsy material the stresses to which the elbow is exposed to in an accident is of limited value, since muscular activity and interplay between groups of muscles, body weight, rate of fall are of decisive importance to the injuries resulting from events in the accident." Our primary objective in this study was to draw attention to the significance of the sign as a warning of the presence of instability and concern if it persists or recurs after an index reduction film is obtained. Noting a delayed drop sign after initiating early mobilization of a dislocated elbow may suggest the need for repeated stability testing, protective bracing, a dynamic fixator, or an open ligamentous repair. The latter, or each step, could be preceded by a confirmatory magnetic resonance imaging scan for accurate assessment of the soft-tissue structures disrupted.

A limitation of our study is the lack of standardization of radiographs, as the clinical films were not made under the authors' direct supervision in the emergency or radiology departments. In addition, the radiographs were obtained in different locations, at different times, and under traumatic circumstances. Therefore, interpretation of our recorded measurements can only reflect the authors' effort to interpret the findings and measurements as closely as possible. In most instances of instability, when a drop sign is present, gross ulnohumeral separation is obvious without measurement. We have determined its significance in a small number of cases when the ulnohumeral distance was greater than or equal to 4 mm (Figures 1 and 2). It would be impossible from an ulnohumeral distance measurement alone to determine which ligamentous structures are precisely involved without the use of additional radiographic modalities (mag-

netic resonance imaging) or operative exposure. The anatomy of the drop sign is shown in Figure 3, *A* and *B*. Detection of the drop sign is no substitute for careful physical examination and stress testing. Rather, it appears to be only an at-risk indicator suggestive of instability, present immediately after index reduction, but it is noteworthy if it does not disappear on follow-up while the patient's arm in a cast or after mobilization loading.

In an effort to establish a possible correlative radiographic measurement of the radiocapitellar interval and alignment, as a possible associated sign of instability, all radiographs observed in this study were reviewed, and the slight variations in patient and x-ray beam positioning were found to be too variable to be controlled. It is of interest that the drop sign can occur without radioulnar dissociation and may indicate a rotational deformity on either side of the joint.

In conclusion, the drop sign is an objective, static radiographically measurable increase in ulnohumeral distance that may be present on immediate post-reduction lateral radiographs, which usually disappears after muscle loading with mobilization; concern is warranted only when the sign is still present on follow-up radiographs with the patient's arm in a cast or after mobilization is initiated. If persistent instability is then determined by stress testing, consideration may need to be given to further protected motion by use of a hinged brace, dynamic external fixator, or open restoration of ligamentous and/or muscular stability. Stability evaluation at each follow-up visit is mandatory. Prolonged incongruous motion from instability can only be catastrophic if not addressed. Further correlative radiographic and anatomic studies of the ulnohumeral interval after trauma will be required before definite predictive instability can be based on this sign.

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