Predicting Radiographic Changes at the First Visit Following Operative Repair of Distal Radius Fractures

Daniel D. Bohl, MPH, Andrea B. Lese, MD, Joseph T. Patterson, MD, Jonathan N. Grauer, MD, Seth D. Dodds, MD

Purpose To test the hypothesis that clinical assessment reliably identifies patients with radiographic changes (including loss of reduction, hardware failure, and hardware migration) at the initial visit following operative repair of distal radius fractures.

Methods We identified 102 patients undergoing operative repair of distal radius fractures. Radiographs and clinical notes were reviewed.

Results At the initial postoperative visit, 11 patients had more than normal postoperative pain, 0 had deformity, 0 had crepitus with gentle motion, and 0 had instability at the fracture site on examination. These 11 patients were considered to have positive clinical assessments, but none had radiographic changes on x-rays taken that day. Three patients had negative clinical assessments but had radiographic changes noted at the initial postoperative visit. There were no additional radiographic changes between the series taken at the initial postoperative visit and series taken at later postoperative visits.

Conclusions These data suggest that for purposes of detecting radiographic changes, radiography at the initial visit is helpful, whereas radiography at subsequent visits may not be. Radiography at subsequent visits may be useful to monitor bony healing, which we did not investigate. *(J Hand Surg Am. 2015;40(1):49–56. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic IV.

Key words Distal radius fracture, operative repair, physical examination, follow-up radiographs.

It is common practice to image distal radius fractures intraoperatively using fluoroscopy. It is also common practice to take x-rays at one or more subsequent outpatient follow-up encounters.

Routine postoperative follow-up imaging in other areas of orthopedics has fallen under increased scrutiny. Studies after elective spine surgeries have identified few important findings on follow-up radiographs and have generally concluded that these radiographs have limited clinical utility and could be discontinued.[1–4] Findings have been similar in total joint arthroplasty.[5,6]

Ghattas et al examined the radiographs of 200 consecutive patients taken at the first postoperative visit after operative repair of the array of fractures seen in a general orthopedic surgery office.[7] The authors found that one patient (0.5%) had a radiographic change from the immediate postoperative radiograph to the postoperative follow-up radiograph. The authors concluded that routine postoperative imaging at the first postoperative visit after operative repair had low clinical utility and could be discontinued.

From the Department of Orthopaedics and Rehabilitation, Yale School of Medicine, New Haven, CT.

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Corresponding author: Seth D. Dodds, MD, Yale School of Medicine, 800 Howard Ave., New Haven, CT 06510; e-mail: seth.dodds@yale.edu.

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One limitation of the study conducted by Ghattas et al was the heterogeneity of the fractures studied.[7] Because patients presented with a wide array of fractures, the sample size for any particular type of fracture was limited. For instance, the study included only 16 fractures involving the wrist.

Given the frequency of operative repair of distal radius fractures and in the context of the study conducted by Ghattas et al,[7] we wanted to study the reliability of clinical assessment (history and physical) for detecting radiographic changes (defined as loss of reduction, hardware failure, or hardware migration) at the initial follow-up visit after operative repair of distal radius fractures. Our hypothesis was that clinical assessment would reliably identify cases with radiographic changes at the initial postoperative visit and thereby justify a change in practice to obtaining radiographs only for patients with positive clinical assessments.

We also tested several secondary hypotheses—factors that might be used to predict cases with radiographic changes at the initial postoperative visit. These factors included fracture comminution, patient age, nonrigid/semirigid internal fixation (vs rigid internal fixation), and Soong classification on the intraoperative radiograph.

METHODS

The billing database of our large academic practice was searched for Current Procedural Terminology codes 25607, 25608, and 25609 (operative repairs of distal radius fractures) performed during 2007 to 2011 on patients over 18 years of age. Among these cases, inclusion criteria were the availability of an outpatient clinical note during postoperative weeks 1 to 2 (defining the initial postoperative visit) and the availability of at least one anterioposterior and one lateral x-ray image taken during surgery, at the initial postoperative visit (early postoperative series), and during postoperative weeks 6 to 28 (late postoperative series [the latest available series was used]).

Clinical notes from the initial postoperative visit were reviewed for the following history and physical examination findings: greater than normal postoperative pain, deformity, crepitus with gentle motion, or instability at the fracture site. Patients were considered to have greater than normal postoperative pain if they had pain that did not improve over time, failure to reduce postoperative analgesic use over time, or presentation with pain as a primary complaint. Any patient with a note describing one of these criteria was considered to have a positive clinical assessment for a possible radiographic change. All other patients were considered to have negative clinical assessments.

Intraoperative, early postoperative, and late postoperative radiographs were reviewed. Measurements were made and compared over time as an objective indicator for radiographic change. A radiographic change was considered to have occurred if any of the following thresholds were met between the intraoperative and early postoperative series or the intraoperative and late postoperative series: change in radial inclination 15° or greater, change in radial height 5 mm or greater, change in ulnar variance 5 mm or greater, change in volar tilt 15° or greater, increase in intra-articular step-off/gap 2 mm or greater, new development of hardware failure (ie, breakage), or new development of hardware migration.

Comminuted fractures were considered to be AO classification types 23-A3, 23-C2, and 23-C3. Older age was considered to be 60 years or greater. Nonrigid fixation was considered to be any construct that did not include a plate (K-wire only or fragment-specific wire form only), and semirigid fixation was considered to be any construct that did include a plate. Plate location was determined on the intraoperative radiograph as described by Soong et al,[8] where grade 0 was plate dorsal to critical line; grade 1 was plate volar to critical line and proximal to volar rim; and grade 2 was plate volar to critical line and at volar rim.

Our institutional review board approved this study with a waiver for informed consent.

RESULTS

A total of 291 patients were identified by the current procedural terminology search, of which 246 had intraoperative images saved to the electronic record (for the others, intraoperative fluoroscopy was likely used, but images were not saved to the electronic record). Of these, 114 patients met the strict criteria of having at least one anterioposterior and one lateral radiograph available from their first visit 1 to 2 weeks after surgery and the same projections taken during postoperative weeks 6 to 28. These strict criteria had been set in order to conclude the study with a suggested imaging algorithm based on our specific criteria for timing of postoperative radiographs. Of these 114 patients, 102 patients had notes available from the first postoperative visit. These 102 patients constituted the study population. The average times after surgery when the early and late postoperative series were obtained were 1.8 ± 0.5 (mean ± standard deviation) weeks and 14.7 ± 6.1 weeks,

TABLE 1. Patient Population

	Number*	Percent†
Total	102	100
Age, y (mean 52.6; standard deviation 15.7)		
18−39	19	19
40−49	18	18
50−59	31	30
60−69	19	19
≥ 70	15	15
Sex		
Female	67	66
Male	35	34
Side of injury		
Left	51	50
Right	51	50
AO classification		
23-A2	9	9
23-A3	6	6
23-B1	5	5
23-B2	2	2
23-B3	3	3
23-C1	14	14
23-C2	16	16
23-C3	40	39
No injury film	7	7
Skin status		
Closed	99	97
Open	3	3
Current procedural terminology code		
25607 (ORIF extra-articular distal radius fracture)	11	11
25608 (ORIF intra-articular distal radius fracture with 2 fragments)	36	35
25609 (ORIF intra-articular distal radius fracture with 3 or more fragments)	55	54
Fixation type		
Volar plate	75	74
Volar plate, lag screws	1	1
Volar plate, 2 dorsal non-spanning plates, K-wire	1	1
Volar plate, K-wire	9	9
Dorsal nonspanning plate(s)	3	3
Dorsal nonspanning plate, K-wire	1	1
Dorsal spanning plate	5	5
Dorsal spanning plate, K-wire	2	2
K-wire	2	2
Fragment specific plate	2	2
Fragment specific wire form	1	1
Soong classification		
Grade 0 (plate dorsal to critical line)	44	43
Grade 1 (plate volar to critical line, proximal to volar rim)	38	37
Grade 2 (plate volar to critical line, at volar rim)	4	4
No volar plate	16	16

ORIF, open reduction internal fixation.
*Each section sums to 102.
†Each section sums to 100%.

respectively. The patient population is depicted in Table 1.

At the initial postoperative visit, 11 patients had more than normal postoperative pain, 0 had deformity, 0 had crepitus with gentle motion, and 0 had instability at the fracture site. These 11 patients were considered to have positive clinical assessments. On radiographic series taken at the initial postoperative visit, none of these 11 patients had radiographic changes (positive predictive value of clinical assessment = 0%; Table 2).

Among all patients, there were 3 cases of radiographic changes visible on radiographic series taken at the initial postoperative visit. All of these occurred in patients who had negative clinical assessments (sensitivity of clinical assessment = 0%; Table 2).

There were no additional radiographic changes between the initial postoperative series and late postoperative series.

The first patient with a radiographic change was a 71-year-old woman who had undergone operative repair with a volar plate for an AO 23-C2−type fracture. Although the intraoperative series showed a neutral volar tilt, the early and late postoperative series showed dorsal tilts of 17° and 20°, respectively (Fig. 1). The change was associated with loss of the 90° angle between the distal locking screws and the volar plate. This technical failure of the construct was likely due to placement of too few distal screws. An additional set of distal screw holes just proximal to the 4 placed screws had been left empty. The surgeon now places 6 distal screws, 4 in that most distal row, and 2 immediately proximal to that when using this particular plate.

TABLE 2. Accuracy of Clinical Assessment for Predicting Radiographic Change at the Initial Follow-Up Visit

	Radiographic Assessment*		
Clinical Assessment	Positive	Negative	
Positive	True positives 0	False positives 11	Positive predictive value 0%
Negative	False negatives 3	True negatives 88	Negative predictive value 97%
	Sensitivity 0%	Specificity 89%	

*Radiographic assessment is considered to be the standard, and clinical assessment is considered to be the test.

FIGURE 1: Radiographic change in a 71-year-old woman who had undergone open reduction internal fixation with a volar plate for an AO 23-C2–type fracture. Although the intraoperative series showed **A** neutral volar tilt, the early and late postoperative series showed dorsal tilts of **B** 17° and **C** 20°, respectively. The loss of reduction was associated with loss of the 90° angle between the distal locking screws and the volar plate.

The second patient was a 48-year-old man who had undergone operative repair with a fragment-specific construct and K-wire fixation for an AO 23-B3–type fracture. Although the intraoperative series showed an intra-articular gap of 0.5 mm, the early and late postoperative series showed intra-articular gaps of 5 mm and 6 mm, respectively (Fig. 2). The development of this intra-articular gap was associated with volar displacement of the volar rim.

The third patient was a 34-year-old man who had undergone operative repair with a volar plate, 2 dorsal nonspanning plates, and K-wires for an AO 23-B1–type fracture. Although there was no intra-articular gap visible on the intraoperative series, the early and late postoperative series showed intra-articular gaps of 3 mm and 4 mm, respectively (Fig. 3). The development of this intra-articular gap was associated with radial displacement of a large fragment that constituted about one third of the radial surface of the radiocarpal joint.

With respect to the secondary hypotheses, the sensitivities, specificities, positive predictive values, and negative predictive values are provided in Table 3 (fracture comminution), Table 4 (patient age $\geq$ 60 y), Table 5 (nonrigid/semirigid internal fixation [vs rigid internal fixation]), and Table 6 (Soong classification 1–2 [vs Soong classification 0] on the intraoperative radiograph) nonrigid/semirigid.

DISCUSSION

As health care costs continue to rise, routine postoperative radiographs after common orthopedic procedures have come under increased scrutiny.[1–7] In this context, we conducted a study to determine the reliability of clinical assessment (history and physical) for detecting radiographic changes at the initial follow-up visit after operative repair of distal radius fractures. We hypothesized that clinical assessment would reliably identify cases of radiographic change at the initial postoperative visit, therefore justifying a change in practice to only ordering radiographs in patients with positive clinical assessments.

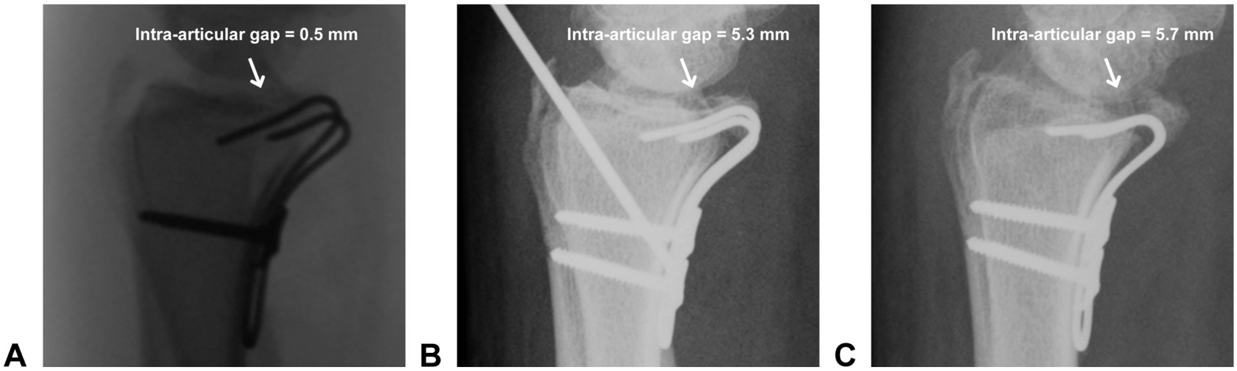

FIGURE 2: Radiographic change in a 48-year-old man who had undergone open reduction internal fixation with a fragment-specific construct and K-wire fixation for an AO 23-B3−type fracture. Although the intraoperative series showed **A** an intra-articular gap of 0.5 mm, the early and late postoperative series showed intra-articular gaps of **B** 5 mm and **C** 6 mm, respectively. The development of this intra-articular gap was associated with volar displacement of the volar rim.

FIGURE 3: Radiographic change in a 34-year-old man who had undergone open reduction internal fixation with a volar plate, 2 dorsal nonspanning plates, and K-wires for an AO 23-B1−type fracture. Although there was **A** no intra-articular gap visible on the intraoperative series, the early and late postoperative series showed intra-articular gaps of **B** 3 mm and **C** 4 mm, respectively. The development of this intra-articular gap was associated with radial displacement of a large fragment that contributed to about half of the radiocarpal joint.

At the initial postoperative visit, 11% of patients had positive clinical assessments. We had hypothesized that these patients were more likely than the other patients to have radiographic changes; hence, we had considered that it might be cost-effective to order radiographs only for these individuals. None of these individuals had radiographic changes at the initial postoperative visit, however. That is, the positive predictive value of clinical assessment was 0%.

Among all patients, 3% had radiographic changes at the initial postoperative visit, although none of these patients had positive clinical assessments. That is, the sensitivity of clinical assessment was 0%.

These results represent a firm rejection of our hypothesis. The data indicate that history and physical examination are not sufficient to identify radiographic changes occurring before the first postoperative visit. Hence, if a surgeon seeks to identify radiographic changes similar to those shown in Figures 1 to 3, they should not rely on clinical assessment alone.

The specificity of a test is not impacted by the prevalence of disease, but the positive predictive value is. The low positive predictive value may be at least in part be due to the low prevalence of radiographic changes (< 3%). That is, if there had been more radiographic changes, it is probable that the positive predictive value would have been greater.

Also, no radiographic changes occurred between the early and late postoperative series. Radiographs at the initial postoperative visit were actually much more likely to demonstrate radiographic changes than radiographs obtained at subsequent postoperative visits, which in no case showed any change. Hence, whereas radiographs at the first postoperative visit may be of greatest value to surgeons for monitoring for loss of reduction, hardware failure, or hardware

TABLE 3. Accuracy of Fracture Comminution for Predicting Radiographic Change at Initial Follow-Up Visit

	Radiographic Assessment*†		
Fracture Comminution	Positive	Negative	
Positive	True positives 1	False positives 61	Positive predictive value 2%
Negative	False negatives 2	True negatives 31	Negative predictive value 94%
	Sensitivity 33%	Specificity 34%	

*Radiographic assessment is considered to be the standard, and fracture comminution is considered to be the test.
†The total number is only 95 (not 102) because 7 patients did not have injury films available.

TABLE 4. Accuracy of Age ≥ 60 y for Predicting Radiographic Change at Initial Follow-Up Visit

	Radiographic Assessment*		
Age ≥ 60 y	Positive	Negative	
Positive (≥ 60 y)	True positives 1	False positives 33	Positive predictive value 3%
Negative (< 60 y)	False negatives 2	True negatives 66	Negative predictive value 97%
	Sensitivity 33%	Specificity 67%	

*Radiographic assessment is considered to be the standard and age ≥ 60 y is considered to be the test.

migration, radiographs at subsequent visits may be less likely to yield this information.

Ghattas et al examined the radiographs of 200 consecutive patients taken at the first postoperative visit after operative repair of fractures throughout the body.[7] The authors found that only one patient (0.5%) had a radiographic change from the immediate postoperative radiograph to the postoperative follow-up radiograph. The rate of radiographic change at the initial postoperative visit in the present study was 3%, six times higher than that in the study by Ghattas et al.[7] This is in part what led to the different conclusions of the 2 studies. The difference in these results may be reconciled by considering that Ghattas et al likely used less sensitive criteria for radiographic change, and in particular loss of reduction.[7] Their study included all types of fractures throughout the body, and they did not indicate if they developed a specific set of criteria for quantifying radiographic change (like that defined for distal radius fractures in the present study). Moreover, as the patients in the study by Ghattas et al were seen by orthopedic generalists,[7] it is possible that the fracture patterns were generally simpler and the patients generally more likely to heal than those seen by the hand specialists in the present study. Finally, Ghattas et al included many diaphyseal fractures,[7] which may be less likely to have loss of reduction, hardware failure, or hardware migration than the metaphyseal and intra-articular fractures in the present study.

Ghattas et al did not determine the rate of radiographic loss of reduction, hardware failure, or hardware migration at subsequent visits,[7] and so their rate cannot be compared with the rate in the present study of 0%. Radiographs taken at subsequent visits may primarily be used to monitor for bony healing; hence, although there may be low utility associated with monitoring for loss of reduction, hardware failure, or hardware migration, surgeons who find it important to closely watch the progression of bone healing may find utility there.

None of our tested secondary hypotheses (fracture comminution, patient age, stability of fixation, and Soong classification) performed particularly well at predicting radiographic changes at the initial postoperative visit (Tables 3–6); however, all performed better than clinical assessment. Among fractures treated with a volar plate, Soong classification indicating

TABLE 5. Accuracy of Nonrigid/Semirigid Fixation for Predicting Radiographic Change at Initial Follow-Up Visit

	Radiographic Assessment*		
Nonrigid/Semirigid Fixation	Positive	Negative	
Positive (nonrigid/semirigid)	True positives	False positives	Positive predictive value
	1	2	33%
Negative (rigid)	False negatives	True negatives	Negative predictive value
	2	97	98%
	Sensitivity	Specificity	
	33%	98%	

*Radiographic assessment is considered to be the standard, and nonrigid/semirigid internal fixation is considered to be the test.

TABLE 6. Accuracy of Soong Classification 1 or 2 for Predicting Radiographic Change at Initial Follow-Up Visit

	Radiographic Assessment*†		
Soong 1–2	Positive	Negative	
Positive (Soong 1–2)	True positives	False positives	Positive predictive value
	2	40	4%
Negative (Soong 0)	False negatives	True negatives	Negative predictive value
	0	44	100%
	Sensitivity	Specificity	
	100%	52%	

*Radiographic assessment is considered to be the standard, and Soong 1–2 is considered to be the test.
†The total number is only 86 (not 102) because 16 patients did not have volar pates.

protrusion of the plate volar to the critical line (Soong classification 1–2) had sensitivity of 100% for predicting radiographic change. Among cases with volar plates, about half had Soong 1 or 2 scores (42 of 86). Only 2 of 86 cases had radiographic change. Given the high number of Soong 1 or 2 scores but low number of cases with radiographic change, the 100% sensitivity is probably not reliable. Specifically, because there were so many cases with Soong 1 or 2 scores, the 2 cases with radiographic change could easily have occurred in cases with Soong 1 or 2 scores by random chance alone. Hence, the 100% sensitivity probably cannot be used to draw conclusions. That is, we should not use a Soong score of 1 or 2 as a criterion for determining who should get radiographs at the first postoperative visit. However, the high sensitivity could be in part related to failure to bring the distal portion of the plate into full apposition with the distal radius (resulting in the plate being volar to the volar rim and consequently receiving a Soong score of 1 or 2), resulting in a loose construct, increased shear forces, and loss of reduction. It could also be related in part to suboptimal reduction (resulting in the volar rim being dorsal to the plate and consequently receiving a Soong score of 1 or 2), instability, and loss of reduction. Although the Soong classification was initially shown to predict volar tendon rupture, future studies might investigate whether the Soong score predicts fracture displacement. Despite this finding, the positive predictive value of Soong grades 1 or 2 was only 5%, limiting its usefulness in guiding who should receive radiographs at the initial postoperative visit.

There are several limitations to this study. First, postoperative imaging patterns may vary between institutions, so the results reported here might not be universally applicable. Second, although we endeavored to create an objective set of criteria for clinical and radiographic assessment, human error could still have resulted in misclassification. Finally, the study was limited by sample size and in particular by the fact that patients had to be excluded due to failure to meet the study's strict inclusion criteria for timing of postoperative radiographs. These strict criteria were set so that the study's results could be used to propose a fairly specific imaging algorithm. Because this study was a retrospective review of a clinical practice, many patients missed or delayed appointments or were lost to follow-up and hence could not be included.

These data are intended to have clinical applicability for surgeons who seek a balance between identifying the vast majority of cases of radiographic changes and reducing resource waste due to excess imaging. Based on these data, we propose a simple, cost-effective imaging algorithm of radiographically assessing all patients at the initial postoperative visit followed by clinical assessment at subsequent visits in patients with normal postoperative symptoms and normal clinical examinations. Surgeons should obtain radiographs to monitor fracture healing as needed and perhaps an additional radiograph for documentation of final healing, but these latter actions were not investigated by this study.

The intervention we evaluated here is of relatively low cost and low risk to the patient. At our institution, the current cost of radiographs of the wrist is approximately $140. As can be extrapolated from data compiled by Mettler et al,[9] the radiation exposure for 2 views of the wrist is 0.002 mSv. The hypothesis of the study was that clinical assessment would detect radiographic changes, rendering radiography at the initial postoperative visit unnecessary in patients with negative clinical assessments. If our data had allowed us to accept this hypothesis, we would have proposed that we could eliminate radiography at the initial postoperative visit in patients with negative clinical assessments (89% of our patients). On average, then, this would have saved us $125 ($140 $\times$ .892) per patient and would have resulted in 0.00178 mSv (0.002 mSv $\times$ .892) less radiation exposure per patient. Relative to the cost of additional surgery or a volar tendon repair, this cost is small. Similarly, this radiation dose is small (consider that the radiation exposure for 2 views of the lumbar spine is 3.0 mSv).[9]

The intervention has the potential to yield important information that may affect outcomes. It is possible that, because the cost and risk are low, it would be worthwhile to obtain radiographs for the very reason that the consequences of missing a case of loss of reduction, hardware failure, or hardware migration can be serious, with the potential for severe consequences if not discovered in a timely fashion. It is for these reasons—in conjunction with our results that history and physical, fracture comminution, age, rigidity of internal fixation, and Soong classification poorly predict radiographic change—that we encourage routine radiography in all patients at the initial postoperative visit after operative repair of distal radius fractures.

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