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Influence of surgeon, patient, and radiographic factors on distal radius fracture treatment

V. Neuhaus[1,2], A. G. Bot[1], T. G. Guitton[1] and D. C. Ring[1]

Abstract

The purpose of this study was to evaluate surgeon, patient, and radiographic factors influencing the recommendation for operative treatment in distal radius fractures. In a web-based study 252 orthopaedic surgeons from a variety of countries reviewed 30 consecutive sets of radiographs of patients that presented to our emergency department with a fracture of the distal radius. Surgeons were randomly assigned to receive either 'Radiographs only' or 'Radiographs and clinical information'. Surgery was recommended on average 52% of the time whether or not surgeons received clinical information. Female surgeons, surgeons with less than 21 years of experience, and hand surgeons were more likely to recommend operative treatment, but these factors explained only 1% of the variation. Radiographic criteria (intra-articular fractures, ulnar styloid fractures, dorsal comminution, dorsal tilt, and ulnar variance) explained 49% of the variation. The overall agreement on treatment was moderate and slightly higher among surgeons that received radiographs alone.

Level of Evidence: Level II, therapeutic; not a clinical study

Keywords

Distal radius fracture, interobserver agreement, operative treatment, patient characteristics, surgeon characteristics

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Introduction

The incidence of distal radius fracture is expected to increase in the next 20 years (Christensen et al., 2009; Court-Brown and Caesar, 2006; Freedman et al., 2002). In wealthy countries, the trend is to treat distal radius fractures with open reduction and internal fixation (Chung et al., 2009; Koval et al., 2008). But there is no consensus regarding indications for surgery and there is inadequate data to determine the optimal operative technique (Nazar et al., 2009). The American Academy of Orthopaedic Surgeons (AAOS) clinical practice guidelines for the treatment of distal radius fractures found insufficient data to determine the role of operative treatment (Lichtman et al., 2011). It is not clear from current data whether radiographic alignment correlates with symptoms and disability (Bentohami et al., 2013; Finsen et al., 2013).

Fracture pattern, stability, and displacement are considered as crucial decision-making points (Kodama et al., 2013; Ng and McQueen, 2011). Next to fracture morphologic issues, the age of the patient, regional location, and being a member of a hand surgical society had the greatest influence on decision making in recent studies of regional variations in the United States, independent of patient factors such as sex and race, and surgeon factors such as the teaching status of the hospital and the geographic density of surgeons (Chung et al., 2011; Fanuele et al., 2009). Decision-making in distal radius fracture is a complex process. This process needs to be broken down into component parts and be analysed which ones have the greatest

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Table 1. Surgeons' characteristics.

Values	Total		Radiographs and clinical information		Radiographs only		*p*-value
	n = 252		*n* = 125		*n* = 127		
	n	%	*n*	%	*n*	%	
Sex							
Male	237	94%	118	94%	119	94%	0.82
Female	15	6.0%	7	5.6%	8	6.3%	
Area of practice							
Asia	12	4.8%	6	4.8%	6	4.7%	0.051
Australia	8	3.2%	1	0.8%	7	5.5%	
Europe and United Kingdom	77	31%	31	25%	46	36%	
United States and Canada	135	54%	79	63%	56	44%	
Other	20	7.9%	8	6.4%	12	9.4%	
Years of practice							
0–5 years	91	36%	47	38%	44	35%	0.79
6–10 years	43	17%	21	17%	22	17%	
11–20 years	78	31%	40	32%	38	30%	
21–30 years	40	16%	17	14%	23	18%	
Supervision of surgical trainees							
Yes	217	86%	105	84%	112	88%	0.34
No	35	14%	20	16%	15	12%	
Specialty							
Trauma and Orthopaedic	94	37%	40	32%	54	43%	0.13
Shoulder and elbow	39	15%	16	13%	23	18%	
Hand and wrist	108	43%	64	51%	44	35%	
Other	11	4.4%	5	4.0%	6	4.7%	

influence. We wonder how much influence surgeon and patient factors, including radiographic parameters, have on variation and agreement of surgeon recommendation for operative treatment of distal radius fractures. In particular, we wonder how much influence information about the patient's age, sex, and health status has on recommendations for surgery and agreement between surgeons compared with decision-making based on radiographs alone.

The primary null hypothesis is that there is no difference in average percentage recommendation for operative treatment of a distal radius fracture between surgeons given radiographs alone compared with those given radiographs and patient information. The secondary study questions addressed: (1) surgeon factors associated with greater likelihood of recommending operative treatment; (2) differences in interobserver agreement among surgeons with and without patient information; and (3) patient factors associated with a greater likelihood of recommending operative treatment.

Methods

Orthopaedic surgeons from Asia, Australia, Europe, North America, and South America participating in the Science of Variation Group (SOVG), a voluntary web-based collaborative of experienced orthopaedic surgeons without a direct relation to industry (Guitton and Ring, 2011), were invited to evaluate 30 patients with a distal radius fracture in an online survey in 2013. The raters evaluated radiographs and some clinical information, and were merely asked to recommend operative or non-operative treatment. All members of the SOVG were first randomized on a 1:1 basis using a computer random number generator in Excel before sending out the invitation to receive information about the patient along with the radiographs, or radiographs alone. There was no time limit to complete the questionnaire.

A total of 252 of the 677 invited surgeons (37%) completed the study (Table 1). They were not involved in the treatment of the patients presented in this study cohort, made independent ratings of all presented cases, did not receive any incentives other than group authorship of the resulting article, and most of them already participated in prior SOVG studies. A total of 125 raters were assigned to the group 'Radiographs and clinical information' and 127 to the group 'Radiographs only'. The surgeons in the two

Table 2. Patients' characteristics.

Patient	Age (y)	Sex	Side	Comorbidities*	Osteoporosis	Medications	AO-type	Ulnar involvement	Dorsal tilt (°)	Dorsal comminution	Ulnar variance
1	76	F	R	3		Yes	C	No	22	Yes	Positive
2	63	F	R	0			A	Yes	28	Yes	Negative
3	71	F	R	0	Present		C	Yes	30	Yes	Positive
4	60	F	R	0		Yes	C	No	29	Yes	Positive
5	27	M	L	0			A	No	−10	No	Negative
6	51	M	L	0			C	No	20	Yes	Positive
7	49	M	L	0			C	Yes	14	Yes	Positive
8	66	F	R	0			C	Yes	5	Yes	Positive
9	26	F	L	0			A	No	12	No	Negative
10	62	F	L	1			C	Yes	−10	Yes	Negative
11	46	M	R	0			A	Yes	18	No	Negative
12	83	F	L	3	Present		A	Yes	2	Yes	Positive
13	56	F	R	0			A	Yes	2	Yes	Negative
14	62	F	L	0			A	Yes	0	No	Negative
15	57	F	R	2		Yes	C	Yes	30	Yes	Negative
16	25	F	L	0			A	No	−4	Yes	Positive
17	78	F	L	1	Present		A	No	0	Yes	Negative
18	29	M	L	0			A	Yes	10	No	Positive
19	60	F	R	1			A	Yes	45	Yes	Positive
20	73	F	L	2		Yes	C	Yes	18	Yes	Positive
21	65	F	R	1		Yes	A	Yes	33	Yes	Negative
22	43	M	L	6			C	Yes	22	Yes	Positive
23	59	M	L	0			C	Yes	24	Yes	Positive
24	28	M	R	0			C	No	−10	No	Negative
25	64	F	L	0			A	No	0	Yes	Negative
26	27	F	L	0			A	No	0	No	Negative
27	23	F	R	0			A	No	12	No	Negative
28	84	M	R	5			C	Yes	−10	No	Negative
29	23	F	R	0			B	No	−10	No	Negative
30	68	F	L	2			C	Yes	22	Yes	Positive

F: female; M: male; R: right; L: left; AO: Arbeitsgemeinschaft für Osteosynthesefragen.
*Quantified with the continuous Charlson Comorbidity Index Score.

groups were comparable with respect to sex, area of practice, years of practice, supervision of surgical trainees, and specialty.

Under institutional review board (IRB) approval, a total of 30 consecutive patients presenting at our emergency department with a distal radius fracture were identified from a prospectively collected database. Inclusion criteria were (1) adult patients (≥18 years) and (2) availability of clinical information as well as radiographs. All observers viewed standard posteroanterior and lateral radiographs taken in the emergency department prior to manipulative reduction. Observers that also received patient information read a paragraph containing the sex, age, side, concomitant injuries, comorbidities (detailed medical information; quantified with the continuous Charlson Comorbidity Index Score (Charlson et al., 1987; Kirkland et al., 2011) for statistical analysis), relevant clinical findings, and relevant medications such as acetylsalicylic acid, clopidrogel, warfarin, and chemotherapeutic agents (Tables 2 and 3).

Statistical analysis

First, for all available surgeon factors (randomization, sex, area of practice, years of practice, supervision of surgical trainees, and specialty) the average operative treatment recommendation rates were compared in bivariate analysis using chi-square tests for both randomization groups together while using the frequency mode (Table 4), and all significant or nearly significant parameters ($p<0.1$) were next entered into a backward logistic regression model to evaluate the best predictors at the $p\leq0.05$ level (Table 5). Second, the multirater agreement of the treatment recommendation (binary; operative versus non-operative) – overall and split for all available surgeon factors – was calculated with the Fleiss' generalized Kappa (Hallgren, 2012; King, 2012; Venkataraman et al., 2006), which is a statistical chance-corrected measure for assessing multirater agreement with binary ratings (Table 6). The calculated measures are presented as a value between 0 and 1 and are called Kappa value.

Table 3. Treatment choice.

Patient	Total		Radiographs and clinical information		Radiographs only	
	Rate#		Rate#		Rate#	
	n	%	*n*	%	*n*	%
1	179	71	75	60	104	82
2	190	75	106	85	84	66
3	211	84	105	84	106	83
4	231	92	114	91	117	92
5	19	7.5	15	12	4	3.1
6	250	99	125	100	125	98
7	183	73	96	77	87	69
8	93	37	42	34	51	40
9	172	68	92	74	80	63
10	242	96	119	95	123	97
11	196	78	109	87	87	69
12	17	6.7	2	1.6	15	12
13	136	54	70	56	66	52
14	29	12	11	8.8	18	14
15	225	89	105	84	120	94
16	82	33	44	35	38	30
17	27	11	18	14	9	7.1
18	82	33	54	43	28	22
19	232	92	113	90	119	94
20	206	82	93	74	113	89
21	179	71	74	59	105	83
22	241	96	118	94	123	97
23	247	98	123	98	124	98
24	12	4.8	7	5.6	5	3.9
25	12	4.8	7	5.6	5	3.9
26	20	7.9	15	12	5	3.9
27	62	25	42	34	20	16
28	30	12	6	4.8	24	19
29	8	3.2	2	1.6	6	4.7
30	181	72	98	78	83	65

#Surgeons who reported offering operative treatment.

They were interpreted according to the guidelines by Landis and Koch (1977): 0.01 through 0.20 represent slight agreement; 0.21 to 0.40 fair agreement; 0.41 to 0.60 moderate agreement; 0.61 to 0.80 substantial agreement; and above 0.81 is considered almost perfect agreement. Two-sample independent Z-tests were performed for each variable to compare the calculated kappa for 'Radiographs only' with that of 'Radiographs and clinical information'.

Among the cohort receiving radiographs only, we studied the influence of radiographic factors such as intra-articular fracture, ulnar styloid process fracture, dorsal tilt, dorsal comminution (≥3 fragments), and ulnar variance on recommendation for operative treatment. Among the group of observers that received patient information, we studied the influence of radiographic factors, age, sex, side, comorbidities, known osteoporosis, and relevant medications on recommendations for operative treatment (Table 7). All factors with $p < 0.1$ in bivariate analysis were entered into a backward logistic regression model to look for factors independently associated with a recommendation for operative treatment (Table 8).

Results

The recommendation for operative treatment was similar for both, surgeons who received patient information and radiograph and those that received radiographs alone (53% vs. 52%, $p = 0.39$) (Tables 3 and 4).

Female surgeons, surgeons from countries other than Europe and North America (United States and Canada), surgeons with less than 21 years of practice, and hand and wrist surgeons were more likely to recommend operative treatment. A multivariable model retained surgeon sex (female, OR 1.5), other countries (vs. North America, OR 1.4), years of practice less than 21 years (OR 1.2), and the specialty 'Hand and wrist' (vs. Trauma and orthopaedic, OR 1.3) but accounted for only 1% of the variation ($R^2 = 0.011$, area under the curve [AUC] = 0.55) (Table 5).

The overall agreement was moderate ($\kappa = 0.49$). Surgeons provided radiographs alone agreed slightly, but significantly more often on operative treatment than surgeons provided radiographs and patient information. Hand and wrist doctors, doctors from North America, and doctors with up to 5 years of practice were slightly, but significantly more likely to agree on treatment (Table 6).

Surgeon's recommendation for operative treatment was related to AO-type (AO: Arbeitsgemeinschaft für Osteosynthesefragen), fracture of the ulnar styloid, dorsal comminution, dorsal tilt, and ulnar variance. Among observers receiving patient information, patient sex, side, comorbidities, known osteoporosis, and medications also influenced treatment recommendations (Table 7). The best multivariable model for patient factors associated with recommendation for operative treatment included radiographic parameters (intra-articular fracture, fracture of the ulnar styloid, dorsal comminution, more dorsal tilt, and positive ulnar variance) in both groups. The best multivariable model for the group that received information also included male patients, right wrist, fewer comorbidities, no osteoporosis, and no relevant medications. Each model accounted for comparable amounts of variation: 49% for radiographs only ($R^2 = 0.49$, AUC = 0.86) vs. 48% with patient information ($R^2 = 0.48$, AUC = 0.86) (Table 8).

Table 4. Surgeon factors associated with greater likelihood of recommending operative treatment, bivariate analysis.

Surgeon factor	Rate#	Interquartile range	*p*-value
Randomization			0.39
Radiographs and clinical information	53%	13%	
Radiographs only	52%	13%	
Sex			<0.001*
Male	52%	17%	
Female	62%	17%	
Area of practice			<0.001*
United States and Canada	53%	13%	
Europe and United Kingdom	51%	20%	
Other	58%	20%	
Years of practice			0.027*
0–5 years	54%	17%	
6–10 years	54%	13%	
11–20 years	53%	17%	
21–30 years	49%	18%	
Supervision of surgical trainees			0.12
Yes	52%	17%	
No	55%	17%	
Specialty			<0.001*
Trauma and orthopaedic	51%	20%	
Shoulder and elbow	51%	13%	
Hand and wrist	56%	13%	

#Surgeons who reported offering operative treatment.
*Entered in multivariable logistic regression.

Table 5. Surgeon factors associated with greater likelihood of recommending operative treatment, multivariable analysis.

Surgeon factor	OR	95% CI		*p*-value
		Lower	Upper	
Sex				
Female	1.5	1.2	1.8	<0.001
Area of practice				
Other vs. United States and Canada	1.4	1.2	1.6	<0.001
Years of practice				
0–5 years vs. 21–30 years	1.2	1.0	1.4	0.020
6–10 years vs. 21–30 years	1.2	1.0	1.4	0.023
11–20 years vs. 21–30 years	1.2	1.0	1.4	0.013
Specialty				
Hand and wrist vs. Trauma and orthopaedic	1.3	1.2	1.5	<0.001

CI: confidence interval; OR: odds ratio.
Best model: $r^2 = 0.011$; AUC 0.55 (0.54–0.57).

Discussion

There is insufficient evidence to determine which distal radius fractures benefit from surgery, substantial unexplained variation in surgery rates, and recently observed changes in surgery rates that are not based on scientific data. We are curious about factors associated with recommendation for surgery. This study randomized surgeons to receive patient information and radiographs, or radiographs alone prior to giving treatment recommendations.

The study has several limitations. First, only surgeons participating in the SOVG were evaluated.

Table 6. Differences in interobserver agreement among surgeons.

Multirater agreement	Total			Radiographs and clinical information			Radiographs only			Z-value	*p*-value
	Agreement	Kappa	SE	Agreement	Kappa	SE	Agreement	Kappa	SE		
Overall	Moderate	0.49	0.0017	Moderate	0.49	0.0030	Moderate	0.52	0.0025	7.3	<0.001
Area of practice											
United States and Canada	Moderate	0.55	0.0025	Moderate	0.51	0.0036	Substantial	0.63	0.0057	18.5	<0.001
Europe and United Kingdom	Moderate	0.43	0.0034	Moderate	0.46	0.0090	Moderate	0.42	0.0057	3.1	0.002
Other	Moderate	0.43	0.012	Moderate	0.48	0.032	Moderate	0.45	0.015	0.7	0.45
Years of practice											
0–5 years	Moderate	0.52	0.0040	Moderate	0.49	0.0068	Moderate	0.58	0.0072	9.3	<0.001
6–10 years	Moderate	0.49	0.0074	Moderate	0.44	0.014	Moderate	0.55	0.013	5.7	<0.001
11–20 years	Moderate	0.48	0.0044	Moderate	0.52	0.0084	Moderate	0.45	0.0074	6.2	<0.001
21–30 years	Moderate	0.48	0.0067	Moderate	0.48	0.016	Moderate	0.50	0.012	1.1	0.27
Supervision of surgical trainees											
Yes	Moderate	0.49	0.0017	Moderate	0.48	0.0031	Moderate	0.51	0.0028	7.0	<0.001
Specialty											
Trauma and orthopaedic	Moderate	0.45	0.0028	Moderate	0.45	0.0065	Moderate	0.47	0.0049	3.4	0.001
Shoulder and elbow	Moderate	0.49	0.0068	Moderate	0.46	0.017	Moderate	0.53	0.012	3.3	0.001
Hand and wrist	Moderate	0.54	0.0046	Moderate	0.52	0.0065	Moderate	0.58	0.0085	5.2	<0.001

SE: standard error.

This study group may be a rather academically inclined group and perhaps not representative of the average surgeon. Second, the radiographs were not standardized; however, all surgeons had the same radiographs to interpret, and the radiographs were used to care for actual patients. Third, a small amount of clinical information was presented. Occupation, handedness, lifestyle, and other important factors might have influenced the decision-making process. And last, we did not evaluate patient's preferences and outcome.

We found that surgeons receiving clinical information in addition to radiographs were equally likely to recommend surgery and less likely to agree with their colleagues on recommended treatment. Perhaps this is due, in part, to the fact that most published treatment recommendations focus on fracture pattern and stability criteria, and few reports analysed patient factors – mainly age and activity (Arora et al., 2009, 2011; Hove et al., 1994; Kodama et al., 2013; Mackenney et al., 2006).

The finding that hand and wrist surgeons (Chung et al., 2009, 2011), and younger surgeons (Koval et al., 2008) are more likely to recommend operative treatment is consistent with other studies. The observation that female surgeons were more likely to recommend operative treatment may be spurious since only 6% of the participating surgeons were women. The multivariable model also explained only 1% of the variation and, therefore, other factors must be evaluated.

Hand surgeons and younger surgeons are more likely to agree with each other as well. The overall agreement was moderate, which is higher than expected in view of the low degree of interobserver and intraobserver agreement for any of the often used distal radius fracture classifications and inconclusive clinical practice guidelines (Andersen et al., 1996; Kural et al., 2010; Lichtman et al., 2011).

Our finding that radiographic factors are the predominant influence on recommendations for operative treatment is consistent with other studies (Kodama et al., 2013; Mackenney et al., 2006). Among the subset of surgeons that received patient information, other patient factors – such as male sex and fewer comorbidities – were included in a best-fit multivariable model, but did not explain any more of the variation than radiographic factors alone.

Surgical decision-making is complex. The way to study this complex process is to break it down into component parts and see which ones have the greatest influence. Since no clinical outcome data was analysed, we could only present agreement on treatment recommendation and factors associated with the recommendation for an operation with this simplified web-based vignette study. We could not conclude if

Table 7. Patient factors associated with greater likelihood of recommending operative treatment, bivariate analysis.

Patient factor	Radiographs and clinical information	*p*-value	Radiographs only	*p*-value
	Rate#		Rate#	
Age	Continuous	0.23		
Sex				
Male	58%	<0.001*		
Female	51%			
Side				
Left	52%	0.016*		
Right	55%			
Comorbidities	Continuous∇	<0.001*		
Osteoporosis				
No	56%	<0.001*		
Known osteoporosis	33%			
Medications				
No	49%	<0.001*		
Relevant medication	74%			
AO-type				
Extra-articular (AO-type A)	41%	<0.001*	36%	<0.001*
Intra-articular (AO-type B or C)	66%		69%	
Ulnar styloid process fracture				
No	37%	<0.001*	34%	<0.001*
Yes	64%		67%	
Dorsal comminution				
No	28%	<0.001*	22%	<0.001*
Yes	66%		68%	
Dorsal tilt	Continuous	<0.001*	Continuous	<0.001*
Ulnar variance				
Positive	69%	<0.001*	70%	<0.001*
Negative	40%		38%	

#Surgeons who reported offering operative treatment.
*Entered in multivariable logistic regression.
∇Measured with Charlson Comorbidity Index Score.

the decision-making was correct or clinically beneficial. The evaluation of important clinical information is still essential and may lead to better clinical decisions. In the absence of evidence, surgeons tend to fall back to what they are comfortable with and their usual habits (Hageman et al., 2013). Our research found that, in the absence of definitive evidence to direct treatment recommendations for distal radius fractures, surgeons are strongly influenced by radiographic factors and there is surprisingly little influence from patient factors. Future research will address the influence of patient preferences on recommendations for surgery.

Conflict of interests

All named authors hereby declare that they have no relevant direct conflicts of interest to disclose. DC Ring has relevant financial activities outside the submitted work.

Collaborators

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Table 8. Patient factors associated with greater likelihood of recommending operative treatment, multivariable analysis.

Patient factor	Radiographs and clinical information				Radiographs only			
	OR	95% CI		*p*-value	OR	95% CI		*p*-value
		Lower	Upper			Lower	Upper	
Sex								
Male	1.7	1.4	2.2	<0.001				
Side								
Right	2.5	2.0	3.0	<0.001				
Comorbidities								
Continuous	0.82	0.77	0.89	<0.001				
Osteoporosis								
Known osteoporosis	0.25	0.18	0.35	<0.001				
Medications								
Relevant medication	0.34	0.25	0.47	<0.001				
AO-type								
Intra-articular (AO-type B or C)	3.7	3.0	4.7	<0.001	4.1	3.4	4.9	<0.001
Ulnar styloid process fracture								
Yes	1.2	1.0	1.5	0.022	1.6	1.4	2.0	<0.001
Dorsal comminution								
Yes	3.0	2.3	3.8	<0.001	2.4	2.0	3.0	<0.001
Dorsal tilt								
Continuous	1.11	1.10	1.12	<0.001	1.09	1.08	1.09	<0.001
Ulnar variance								
Positive	2.3	1.8	2.9	<0.001	1.9	1.5	2.4	<0.001

CI: confidence interval; OR: odds ratio; AO: Arbeitsgemeinschaft für Osteosynthesefragen.
Best model for 'Radiographs and clinical information': $r^2 = 0.48$; AUC 0.86 (0.85–0.87).
Best model for 'Radiographs only': $r^2 = 0.49$; AUC 0.86 (0.85–0.87).

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