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Original Research

Trends in the Utilization of Computed Tomography in Operative Treatment of Distal Radius Fractures

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A R T I C L E I N F O

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Purpose: To identify patient, surgeon, and injury characteristics associated with preoperative computed tomography (CT) scan utilization for operative distal radius fractures (DRF). In addition, we aimed to determine if preoperative CT was associated with treatment methods other than isolated volar-locked plating (VLP).
Methods: We retrospectively reviewed all operatively treated adult DRFs within our health care system from 2016 to 2020. Baseline demographics, injury, treatment characteristics, and the fellowship training of the 44 included surgeons were recorded. We compared cases with and without a preoperative CT, and an adjusted logistic regression model was generated to determine the odds of having a preoperative CT.
Results: A total of 1,204 operatively treated DRFs performed by 44 surgeons were included. CT utilization increased during the study period. Intra-articular fractures accounted for 76% of cases, and preoperative CT scans were ordered in 243 of 1240 cases (20%). Overall, isolated VLP was used in 83% of cases. Cases with a preoperative CT were more likely to be treated with an alternative method of fixation (such as dorsal plating). The adjusted logistic regression model demonstrated that male sex (OR 1.62; 95% CI: 1.16, 2.26), intra-articular fractures (OR 3.11; 95% CI: 1.87, 5.81), and associated fractures (OR 2.69; 95% CI: 1.82, 3.98) had a significantly increased odds of having a preoperative CT. Fellowship training was not associated with increased CT utilization overall, but hand surgeons were more likely to use a CT in Orthopaedic Trauma Association-C3 fractures.
Conclusions: Patient and injury characteristics are associated with CT utilization in operative DRFs. Preoperative CTs are associated with alternative fixation approaches, as cases with a CT were more likely to use fixation methods other than isolated VLP. The costs and benefits of CT scans must be carefully weighed against whether this modality adds value or improves outcomes in treating DRFs.
Level of evidence: Prognostic II.

Distal radius fractures (DRF) are one of the most common injuries in adults, accounting for 18% of all fractures.[1,2] DRF appear to have a bimodal distribution, with the overall incidence increasing over time.[1,3] In patients over the age of 65, surgical indications and treatment protocols remain controversial.[4–7] Results of recent prospective and randomized studies comparing outcomes of surgical and nonsurgical treatment of DRF have had conflicting results.[4–7] In addition, treating these injuries is associated with an increasing economic burden for patients and the health care system. In 2007, it was estimated that $170 million was spent on DRF management in the Medicare population alone.[8] For operatively treated DRF, surgical costs can account for 61% to 91% of total costs; however, imaging costs related to plain radiography and computed tomography (CT) scans can drive variations in cost.[9–11]

At present, the American Academy of Orthopaedic Surgeons Clinical Practice Guidelines state that indications for operative treatment of DRFs in nongeriatric patients include radial shortening >3mm, dorsal tilt >10°, or intra-articular displacement

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>2mm.[12] Although these parameters are typically assessed with plain radiographs, the interobserver reliability for this modality is poor.[13−16] The use of CT scans has been shown to increase the agreement in fracture classification and aid in the identification of intra-articular fracture lines.[17−21] These studies have surveyed surgeons and assessed both fracture classification and proposed treatment plans; however, it is less clear if the use of advanced imaging is associated with actual changes in surgical management. Furthermore, advanced imaging modalities (including CT scans) are increasingly used during emergency department visits related to fractures with unclear clinical benefits relative to cost.[22] The clinical utility of a preoperative CT scan remains uncertain, and it is unknown if the use of preoperative CT scans is associated with improvements in patient outcomes.

The purpose of this investigation was to identify patient demographic factors and injury patterns associated with the use of preoperative CT scans for operatively managed DRF. In addition, we aimed to determine whether the use of preoperative CT scans was associated with methods of DRF fixation other than isolated volar-locked plating (VLP). Furthermore, we aimed to determine if surgeon training was associated with the use of preoperative CT scans.

Materials and Methods

Institutional review board approval was obtained for this retrospective investigation. Our institutional billing database was used to identify all patients 18 years of age or older who underwent operative treatment of a distal radius fracture within our health care system between 2016 and 2020. The following Current Procedural Terminology codes were used to identify included fractures: 25607 (Open treatment of distal radial extra-articular fracture or epiphyseal separation, with internal fixation), 25608 (Open treatment of distal radial intra-articular fracture or epiphyseal separation; with internal fixation of two fragments), and 25609 (Open treatment of distal radial intra-articular fracture or epiphyseal separation; with internal fixation of three or more fragments). Our system, located in the northeastern United States, comprises multiple hospitals. The main clinical center is a rural, academic, level-I trauma center that functions as a tertiary referral center for orthopedic trauma and upper-extremity surgery.

A manual chart review was performed in each case. Patients were excluded if they underwent operative treatment for a nonunion or malunion of the distal radius. Baseline demographics were recorded for each patient, including age, sex, laterality, body mass index, current tobacco use, and the American Society of Anesthesiologists rating. To account for patients that underwent bilateral procedures, all analyses were performed on a per-case (as opposed to a per-patient) basis.

Preoperative imaging studies were reviewed by two separate authors in order to classify all included DRFs. Any disagreements between the two authors were resolved by a third author. We used the Orthopaedic Trauma Association (OTA) classification for DRFs. Fractures were classified as OTA-A (extra-articular), OTA-B (partial articular), or OTA-C (complete articular). In addition, OTA-C fractures were subclassified as OTA-C1, OTA-C2, or OTA-C3. Associated osseous injuries involving the ipsilateral upper extremity were recorded, as was the presence of a preoperative CT scan of the distal radius.

Intraoperative and immediate postoperative radiographs were reviewed to categorize the type of operative treatment. In cases where patients underwent planned, staged operative treatment (for example, irrigation and debridement with external fixation followed by definitive fixation), we recorded only the definitive treatment procedure. The following treatment categories were established:

Table 1
Baseline Demographics for All Included Cases

Demographic Variable	All Cases (N = 1204)
Age (y), mean (SD)	55 (17)
Male, n (%)	395 (33)
Right wrist involved, n (%)	581 (48)
BMI, mean (SD)*	29 (7)
Current tobacco use, n (%)	285 (24)
ASA rating, mean (SD)	2.3 (0.6)
Operative time in minutes, mean (SD)	89 (48)
Surgeon performing ORIF, n (%)	
Hand surgeon	561 (47)
Trauma surgeon	396 (33)
Other	247 (21)
Preoperative CT scan ordered, n (%)	243 (20)
Extra-articular DRF (OTA-A), n (%)	288 (24)
Intra-articular DRF, n (%)	916 (76)
OTA-B	151 (13)
OTA-C	765 (64)
C1	196 (26)
C2	308 (40)
C3	261 (34)
Cases with any associated UE injury, n (%)	685 (57)
Cases with an associated UE injury (excluding distal ulna), n (%)	180 (15)
Open fracture, n (%)	33 (3)

ASA, American Society of Anesthesiologists; BMI, body mass index; UE, upper-extremity.
* BMI data were missing for 83 patients.

Table 2
Treatment Information for All Included Distal Radius Fracture Cases

Treatment Type	All Cases (N = 1204)
Volar plate (VLP), n (%)	1088
VLP only	1002 (83)
VLP + K-wires	14 (1)
VLP + supplemental lunate facet fixation	12 (1)
VLP + independent screws	3 (<1)
Volar rim plate	29 (2)
VLP + supplemental bone graft	7 (0.6)
VLP + radial column plate	12 (1)
VLP + dorsal plate	7 (0.6)
VLP + ex-fix	2 (<1)
Dorsal plate, n (%)	17 (1.4)
Dorsal spanning bridge plate, n (%)	27 (2)
Radial styloid plate, n (%)	6 (<1)
Ex-fix, n (%)	29 (2)
K-wires, n (%)	33 (3)
Screws, n (%)	4 (<1)

1. Volar locking plate fixation.
2. Isolated dorsal plate fixation.
3. Isolated radial styloid plate fixation.
4. Dorsal bridge plate fixation.
5. Isolated screw fixation.
6. Kirschner wire (K-wire) fixation only.
7. External fixation (Ex-fix) with or without supplemental K-wires.

We further subcategorized VLP fixation to account for variations in treatment. There were 44 surgeons that performed procedures during the study period. Fellowship training of the surgeon performing the procedure was recorded and classified as either fellowship-training hand surgeon, fellowship-trained orthopedic trauma surgeon, or other. Although this study was retrospective in nature and included multiple surgeons over a 5-year period, we considered isolated VLP fixation to be the conventional method of DRF fixation for the purposes of this study, especially considering that >80% of fractures were fixed using this technique. No surgeon

Table 3
Comparison of Operatively Managed Distal Radius Fracture Cases With and Without Preoperative CT Scans

Variable	Cases With CT N = 243 (20%)	Cases Without CT N = 961 (80%)	*P* Value
Demographics			
Age (y), mean (SD)	53 (17)	56 (17)	.06
Male, n (%)	115 (47)	280 (29)	<.05
Right wrist involved, n (%)	111 (46)	470 (49)	.37
BMI, mean (SD)	30 (7)	29 (7)	<.05
Current tobacco use, n (%)	65 (27)	220 (23)	.21
ASA rating, mean (SD)	2.3 (0.7)	2.3 (0.6)	.16
Operative time in minutes, mean (SD)	106 (58)	84 (44)	<.05
Surgeon performing ORIF, n (%)			
Hand surgeon	122 (50)	439 (46)	
Trauma surgeon	89 (37)	307 (32)	<.05
Other	32 (13)	215 (22)	
Extra-articular DRF (OTA-A), n (%)	19 (8)	269 (28)	<.05
Intra-articular DRF, n (%)	224 (92)	692 (72)	<.05
OTA-B	28 (12)	123 (13)	.59
OTA-C	196 (81)	569 (59)	<.05
OTA-C1	39 (16)	157 (16)	.91
OTA-C2	99 (41)	209 (22)	<.05
OTA-C3	58 (24)	203 (21)	.35
Cases with an associated UE injury (excluding distal ulna), n (%)	79 (33)	101 (11)	<.05
Cases with any associated UE injury, n (%)	173 (71)	512 (53)	<.05
Open DRF, n (%)	12 (5)	21 (2)	<.05
Treatment			
VLP only, n (%)	156 (64)	846 (88)	<.05
VLP only or K-wire, n (%)	160 (66)	875 (91)	<.05
VLP + volar rim plate, n (%)	19 (8)	10 (1)	<.05
VLP + VLP, n (%)	5 (2)	7 (0.7)	.07
VLP + radial column, n (%)	3 (1)	9 (1)	.72
VLP + dorsal, n (%)	4 (2)	3 (0.3)	<.05
Dorsal plate, n (%)	11 (5)	6 (0.6)	<.05
Radial styloid plate, n (%)	2 (0.8)	4 (0.4)	.35
Bridge plate, n (%)	17 (7)	10 (1)	<.05
Ex-fix, n (%)	9 (4)	20 (2)	.14

ASA, American Society of Anesthesiologists; BMI, body mass index; ORIF, open reduction, internal fixationupper-extremity; UE, upper-extremity; VLP, volar locked plating.

in our system used dorsal plate fixation as their primary method of stabilization for extra-articular fractures.

Statistical analysis

Descriptive statistics were generated for case characteristics such as demographics, procedure, and treatment characteristics. A chi-square or Fisher exact test was used where appropriate to compare categorical characteristics between cases with and without preoperative CT scans. In addition, a Wilcoxon two-sample test was performed to compare the differences in continuous characteristics between the groups. To examine the odds of having a CT scan before surgery, an adjusted logistic regression model was generated. *P* values of < .05 were considered statistically significant.

Results

A total of 1,204 operatively treated DRF cases were included. Table 1 provides demographic information for all the included cases. Included cases were performed by a total of 44 different surgeons. Fellowship-trained hand surgeons performed 561 out of 1,204 (47%) cases. The mean age for cases with a CT scan was 53 years compared with 56 years for cases without a CT scan ($P = .06$). Intra-articular fractures accounted for 916 (76%) cases, and preoperative CT scans had been ordered in 243 (20%). Table 2 provides operative treatment details for all the included cases. VLP-only fixation was used in 83% of cases.

Table 3 includes comparisons of cases with and without preoperative CT scans. Cases with a preoperative CT were more likely to be treated with an alternative method of fixation, such as a volar rim plate, dorsal plate, or dorsal spanning bridge plate ($P < .05$). Table 4 presents a logistic regression model with adjusted ORs predicting the chance of having a preoperative CT scan. The adjusted logistic regression model demonstrated that male sex (OR 1.62; 95% CI: 1.16, 2.26), intra-articular fractures (OR 3.11; 95% CI: 1.87, 5.81), and cases with an associated upper-extremity fracture (OR 2.69; 95% CI: 1.82, 3.98) had a significantly increased odds of having a preoperative CT scan ($P < .05$). Surgeon fellowship training

Table 4
Adjusted Logistic Regression Model Predicting the Odds of Having a Preoperative CT Scan for Operatively Managed DRF

Variable	Adjusted OR (95% CI)	*P* Value
Demographics		
Male sex	1.62 (1.16, 2.26)	<.05
BMI	1.01 (0.99, 1.04)	.23
Operative time	1.00 (1.00, 1.01)	.05
Surgeon performing ORIF		
Trauma	Reference	
Hand	0.97 (0.68, 1.39)	.07
Other	0.58 (0.36, 0.95)	
Intra-articular DRF	3.11 (1.87, 5.18)	<.05
Associated UE injury (excluding distal ulna)	2.69 (1.82, 3.98)	<.05
Open DRF	1.13 (0.48, 2.63)	.78
Treatment		
Volar locking plate only	0.46 (0.30, 0.69)	<.05
Dorsal plate only	3.49 (1.15, 10.61)	<.05
Dorsal bridge plate	2.38 (0.95, 5.96)	.07

BMI, body mass index; ORIF, open reduction, internal fixationupper-extremity; UE, upper-extremity.

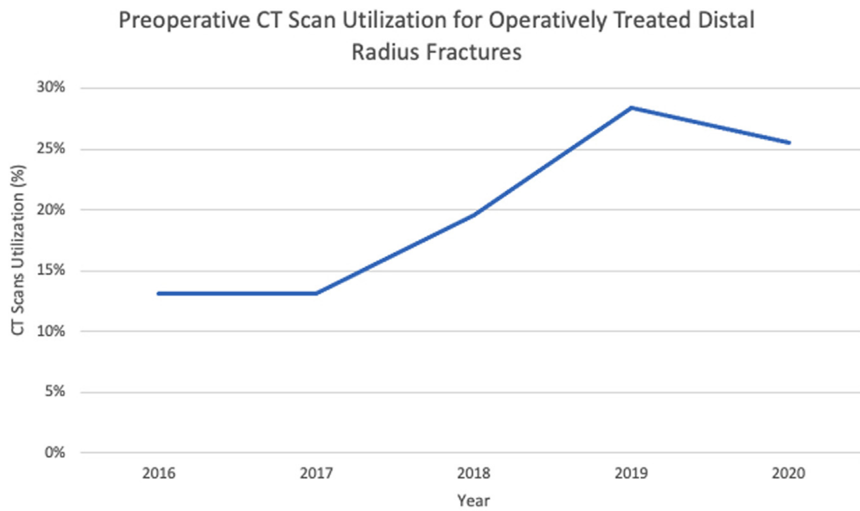

Figure. Graph depicting preoperative CT scan use during the course of the study period for operatively managed DRF (2016−2020).

was not associated with increased odds of having a preoperative CT scan, as noted in Table 4. However, specific to operatively treated OTA-C3 DRF, hand surgeons used a preoperative CT scan in 36 out of 120 cases (30%), whereas nonfellowship-trained hand surgeons used a preoperative CT scan in 22 out of 141 cases (16%), with statistically significant results ($P < .05$). There was a significantly decreased odds of having a CT scan among patients who received a VLP-only treatment (OR 0.46; 95% CI: 0.30, 0.69).

The Figure illustrates the increasing trend of preoperative CT scan utilization during the study period. In 2016, 14% of cases had a preoperative CT, whereas, in 2020, 26% of cases had a preoperative CT.

A post hoc power analysis was performed for the primary comparison (cases with a preoperative CT that underwent VLP fixation only versus those that underwent other forms of fixation). Given the sample size and proportions, the power for this study design was determined to be >99%.

Discussion

Preoperative CT scans were associated with increased use of fixation methods other than isolated VLP in the surgical management of DRF. The role of preoperative CT scans in surgical planning for DRF remains controversial. Katz et al[21] had four hand surgeons evaluate 15 DRFs and noted that CT scans influenced both the decision to proceed to surgery and the proposed surgical treatment plans. In contrast, Nascimento et al[18] had 17 surgeons with varying experience levels assess DRF imaging and found that although preoperative CT scan changed the OTA fracture classification, it did not change the proposed treatment plans for hand surgeons. Cases in our series that underwent dorsal bridge plating had a 3.49 (95% CI 1.15−10.61, $P < .05$) greater odds of having a preoperative CT scan than cases without a bridge plate. Our results suggest that in cases where CT scans are obtained, surgeons are more likely to use alternative fixation techniques other than an isolated VLP.

Other than the male sex, we identified no other patient demographic characteristics associated with increased use of preoperative CT scans, indicating that injury characteristics were likely the largest driver of CT utilization. In the adjusted logistic regression model, hand fellowship training was not associated with differing CT utilization, as hand surgeons were less likely to obtain preoperative CT scans than orthopedic trauma surgeons. However, when looking specifically at OTA-C3 patterns, hand surgeons were significantly more likely to use preoperative CT scans than their nonhand surgeon colleagues. The reasons for this finding are likely multifactorial. This may be, in part, because of referral patterns in our system, where some patients with complex injuries initially seen and managed in community settings are referred to treating hand surgeons at a centralized location.

Over the course of the study period, we found an overall increase in the use of preoperative CT scans in operatively treated DRFs. This finding is consistent with results from prior recent investigations that have similarly identified increases in CT utilization in upper-extremity fractures over time.[23,24] Furthermore, advanced imaging modalities (including CT scans) are increasingly used during emergency department visits related to fractures.[22] It remains uncertain if preoperative CT scans improve postoperative outcomes. In attempting to identify potential opportunities to reduce CT scan utilization, extra-articular fractures appeared to be a possible option. In our series, 19 out of 288 (7%) of OTA-A had a preoperative CT scan. However, Dahlen et al[15] assessed 35 extra-articular fractures based on plain radiographs and found that 57% had an intra-articular extension on a CT. Given their findings, the authors advocated increased use of advanced imagining for preoperative planning. Additionally, prior authors have also demonstrated that CT scans can more reliably quantify the articular gap and step-off compared to plain radiographs.[16] However, in this context, we believe preoperative CT scans should be reserved for cases where they are likely to result in a change in operative treatment type (such as an alternative fixation approach).

Our investigation had several limitations that need to be considered. It should be clearly stated that without knowing the treating surgeon's plan prior to reviewing the CT, these data were unable to determine causation with respect to alterations in treatment plans. Rather, we reported the association between preoperative advanced imaging and methods of fixation. Surgeons may find CT imaging beneficial when it reinforces a treatment decision instead of altering it. Furthermore, even if CT does not change the surgical approach or implant selection, it may impact screw or plate placement, which would not be accounted for with our retrospective design. Although our series included a large number of patients and 44 individual surgeons, these data were from a single health system, which may limit the generalizability of the results. In addition, we did not include patients that underwent nonsurgical management and also had CT scans. Understanding the associations between CT scan utilization and nonsurgical treatment should be the focus of future investigations. Although we reported the fixation approach chosen by the treating surgeon, we recognize that there are often multiple approaches that may be appropriate for a given fracture, with variations attributable to physician experience, training, and expertise with alternative fixation techniques. Although VLP was the most common method of fixation observed in our series, there is no clear consensus regarding the optimal fixation approach for DRF.[25−29] Given the retrospective nature of the study, we could not determine if the CT scans impacted treatment or fixation decisions based on the plain radiographs. It is possible that in cases where the treating surgeon was seen as a second opinion, decisions to order advanced imaging studies may have been made prior to the evaluation by the treating surgeon. In cases where CT scans were ordered by a provider in the emergency department, we were unable to determine whether this was performed independently or at the request of the treating physician.

In conclusion, these data indicate that both patient and fracture characteristics are associated with the use of a preoperative CT scan in cases of operatively treated DRF. Additionally, using a preoperative CT scan is associated with less conventional fixation approaches, as cases with a CT scan were more likely to use methods other than isolated VLP. As more efficient health care models are being developed, the costs and benefits must be carefully weighed against whether preoperative CT scans add value or improve outcomes in the treatment of DRFs.

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