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Hand/Peripheral Nerve

Carpal Malalignment as a Predictor of Delayed Carpal Tunnel Syndrome after Colles' Fracture

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Background: The present study aimed to clarify whether carpal malalignment associated with distal radius malunion after Colles' fracture is involved in the onset of delayed carpal tunnel syndrome (DCTS) in elderly women.

Methods: This retrospective case–control study was conducted in 40 female patients with Colles' fracture treated with a cast, including 10 patients (mean age, 71.6 years) who developed DCTS from 6 weeks to 6 months after injury (DCTS group) and 30 patients (mean age, 73.4 years) without DCTS (control group). Radiological parameters, including the radiocapitate distance (RCD), volar prominence height (VPH), and volar tilt (VT) were measured. Relationships between the RCD and both the VPH and VT were examined, and the involvement of the RCD in the onset of DCTS was analyzed.

Results: The RCD showed strong correlations with both the VPH and VT. The mean RCD was significantly lower in the DCTS group than in the control group (−12.8 mm versus −8.4 mm). Logistic regression analysis showed involvement of the RCD in the onset of DCTS, and the threshold value according to receiver operating characteristic curve analysis was −9.9 mm, with an odds ratio of 21.

Conclusions: Dorsal displacement of the capitate due to Colles' fracture malunion is involved in DCTS accompanied with anatomical alteration of the carpal tunnel. When the center of the head of the capitate is located more than 1 cm dorsally behind the volar cortical line of the radius, careful follow-up should be performed as DCTS may occur within 6 months after injury. *(Plast Reconstr Surg Glob Open 2019;7:e2165; doi: 10.1097/GOX.0000000000002165; Published online 13 March 2019.)*

INTRODUCTION

Delayed carpal tunnel syndrome (DCTS) after Colles' fracture is the most common complication following conservative treatment involving a cast,[1] with an incidence rate of 0.5%–22%.[2] DCTS is considered to be associated with distal radius malunion, residual volarly displaced fragments, chronic inflammation and edema of the tenosynovium, prolonged limb immobilization in the Cotton–Loder position, and an encroaching callus.[3] Conservative treatment in elderly women with Colles' fracture is likely to result in malunion because of bone fragility. Distal radius malunion, especially excessive dorsal flexion of the distal radius, has been reported to be associated with DCTS in previous studies.[4–6] In addition, Aro et al.[5] suggested that carpal malalignment caused by distal radius malunion[7] may be involved in the onset of DCTS. A recent study[8] showed that carpal alignment is strongly influenced by displacement of the distal radius; however, no study has investigated the relationship between carpal malalignment and the onset of DCTS. As most patients with DCTS show symptomatic improvement with carpal tunnel release alone, an increase in carpal tunnel pressure and entrapment of the median nerve caused by anatomical alteration of the carpal tunnel[5,9,10] may be the pathomechanisms of DCTS. Therefore, we hypothesized that carpal malalignment, especially dorsal displacement of the capitate to the radius, caused by distal radius malunion after Colles' fracture results in anatomical alteration of the carpal tunnel, which is involved in the onset of DCTS. The aim of this study was to clarify whether dorsal displacement of the capitate due to Colles' fracture malunion is associated with the onset of DCTS up to 6 months after injury in elderly women.

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METHODS

This study was approved by the ethics committee at our hospital.

Patient Characteristics

This study evaluated 10 female patients (mean age, 71.6 years; age range, 63–84 years) who developed DCTS after Colles' fracture between 2011 and 2017. Of these patients, 7 had visited our hospital because of DCTS after conservative fracture treatment with a cast at other institutions. The mean period from injury to the onset of DCTS was 3.5 months (range, 6 weeks–6 months). All patients had paresthesia in the median nerve distribution of the injured hand and positive findings in neurological examinations, including the Tinel sign test and Phalen test, and 9 patients had nocturnal pain. The mean score of the CTS-6 assessment,[11] except of 2-point discrimination (not evaluated), of the injured hand was 19.3 (range, 16.5–21.5). In this study, we excluded patients with a history of carpal tunnel syndrome (CTS) on either the injured or uninjured hand (n = 2), those with transit symptoms of CTS at the time of injury (n = 2), those with CTS onset at cast application (n = 1), and those with concurrent symptoms of CTS on the uninjured side (n = 3). Additionally, we excluded patients with diabetes mellitus (n = 2), hypothyroidism (n = 1), and rheumatoid arthritis (n = 1) and patients receiving maintenance hemodialysis therapy (n = 2). For a case–control study design, 30 female patients (mean age, 73.4 years; age range, 60–86 years) who did not experience symptoms of CTS on both the injured and uninjured hands up to 6 months after injury were included as controls from among consecutive patients treated with a cast at our hospital. Carpal tunnel release was performed in 7 patients with DCTS, resulting in symptom relief; however, the other 3 patients did not desire to undergo surgery.

Radiological Assessment

Radiological parameters, including the radiocapitate distance (RCD), volar prominence height (VPH), and volar tilt (VT), were measured using lateral view radiographs at the time of onset of DCTS in the DCTS group and at 6 months after injury in the control group (Fig. 1). The RCD was defined as the distance between the center of the head of the capitate and the volar cortical line of the radial diaphysis, and the VPH was defined as the distance between the vertex of the volar prominence of the distal radial epiphysis and the volar cortical line of the radial diaphysis, according to a previous study.[8] The RCD was positive when the center of the head of the capitate was located on the volar side from the volar cortical line of the radial diaphysis and was negative when the center was located on the dorsal side.

Statistical Analysis

Correlations of the RCD with the VPH and VT were examined in all cases, and a predictive equation for the RCD according to the VPH and VT was prepared using stepwise multiple regression analysis. For each radiological parameter, the DCTS group was compared with the control group (Student's t test), and the odds ratio of each parameter was examined using univariate logistic regression analysis. In addition, the threshold value and the odds ratio for the RCD related to the onset of DCTS were determined using a receiver operating characteristic (ROC) curve, according to the Youden index. Multiple logistic regression analysis with the VPH and VT was performed as a subanalysis. Statistical significance was set at a $P < 0.05$.

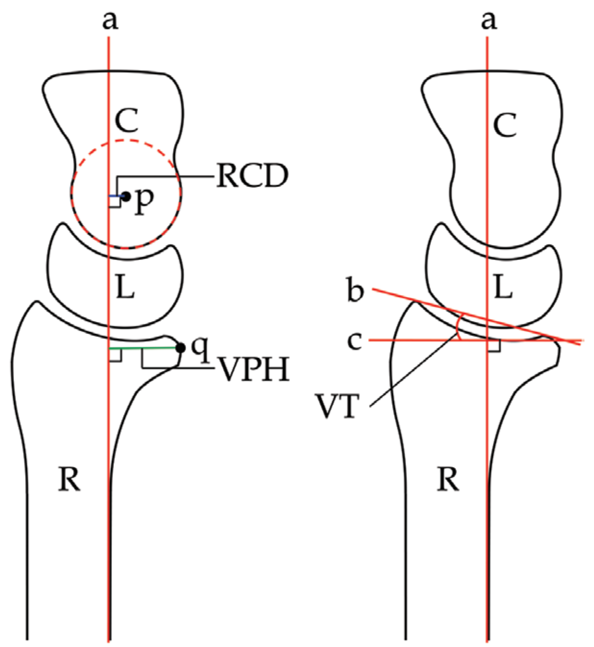

Fig. 1. Illustrations showing radiological parameters. RCD: the distance between point "p" and line "a." VPH: the distance between point "q" and line "a." VT: the angle between lines "b" and "c." C indicates capitate; L, lunate; R, radius.

RESULTS

Correlation between the Position of the Capitate and Displacement of the Distal Radius

The mean RCD, VPH, and VT values were −9.5 mm, 4.4 mm, and −13.6-degree angle, respectively. The RCD was significantly correlated with both the VPH and VT (Fig. 2). The prediction equation of the RCD with these parameters as independent variables in stepwise multiple regression analysis was $y = -9.973 + 0.790x_1 + 0.219x_2$ (where x_1 and x_2 represent the VPH and VT, respectively). In this equation, the coefficient of determination (R^2) was 0.878, and the P value for the regression coefficient was <0.001.

Comparisons of Radiological Parameters between the DCTS and Control Groups

Table 1 presents the mean values of age and radiological parameters, including the RCD, VPH, and VT, in the DCTS and control groups. There was no difference in age between the 2 groups. All radiological parameters were significantly lower in the DCTS group than in the control

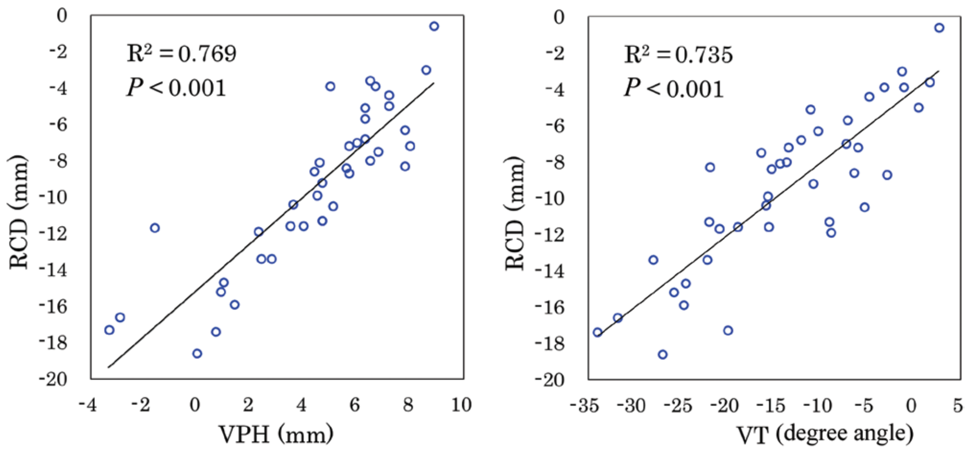

Fig. 2. Correlations between the RCD and parameters indicating distal radius malunion. A, Scatter diagram and regression line indicating the correlation between the RCD and VPH. B, Scatter diagram and regression line indicating the correlation between the RCD and VT.

Table 1. Comparison of Each Parameter between the DCTS Group and Control Group

	DCTS Group (n = 10)			Control Group (n = 30)			
Parameter	Mean	Range	SD	Mean	Range	SD	*P*
Age (y)	71.6	63 to 84	6.3	73.4	60 to 86	7.4	0.501
RCD (mm)	−12.8	−17.4 to −4.4	4.1	−8.4	−18.6 to −0.6	4.0	<0.005
VPH (mm)	1.7	−3.3 to 7.2	3.6	5.3	0.0 to 8.9	2.2	<0.001
VT (degree angle)	−20.5	−34.0 to −4.8	10.0	−11.3	−27.0 to 2.7	8.3	0.006

group. The statistical powers for the RCD, VPH, and VT in post hoc power analyses were 0.784, 0.897, and 0.755, respectively.

Univariate Analysis

The results of logistic regression analysis and the odds ratio of each parameter are presented in Table 2. The threshold value of the RCD according to the ROC curve was −9.9 mm (sensitivity, 0.9; specificity, 0.7; odds ratio, 21; 95% CI, 0.624–0.969; $P < 0.001$) (Fig. 3). The threshold values of the VPH and VT according to the ROC curve were 4.5 mm (sensitivity, 0.8; specificity, 0.733; odds ratio, 11; 95% CI, 0.626–0.977; $P < 0.01$) and −15.7-degree angle (sensitivity, 0.8; specificity, 0.733; odds ratio, 11; 95% CI, 0.560–0.954; $P = 0.01$), respectively.

Subanalysis by Multivariate Analysis

Multivariate logistic regression analysis showed that the VPH and VT were not significant factors of DCTS, as the 95% CIs included 1 (0.464–1.071 and 0.844–1.099, respectively).

Table 2. Results of Univariate Logistic Regression Analysis for Each Parameter

Parameter	Odds Ratio	95% CI	*P*
RCD	0.768	0.625–0.943	0.012
VPH	0.646	0.473–0.881	0.006
VT	0.887	0.805–0.977	0.015

For example, as the radiocapitate distance increases by 1 mm, the odds of DCTS onset increases 0.768 times.

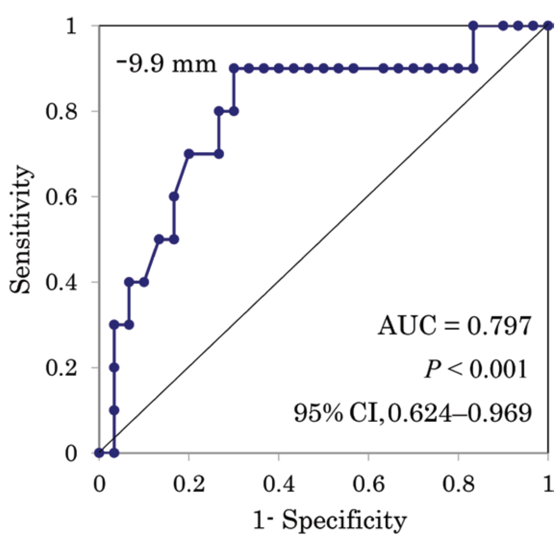

Fig. 3. ROC curve for RCD. AUC indicates area under the curve.

DISCUSSION

Depending on the time of onset, CTS after distal radius fracture is generally classified into 3 types, including an acute type that develops at the time of injury due to direct damage to the median nerve, a subacute type that develops from the time of reduction to several weeks after injury, and a delayed type that develops from months to years after injury. Itsubo et al.[6] analyzed the causes of CTS after distal radius fracture according to the pattern of onset and defined DCTS as CTS occurring >12 weeks after injury. In their study, the DCTS group included cases with CTS onset up to 25 years after injury; however, the causal relationship with distal radius fracture becomes ambiguous when there is a long period after injury. Therefore, in this study, we analyzed cases of DCTS that developed between 6 weeks and 6 months after injury.

With regard to the factors of DCTS, previous studies analyzing radiological parameters indicated an association with dorsal tilt (ie, negative VT) of the distal radius. Stewart et al.[4] reported that the VT was −12.6-degree angle in cases with DCTS, whereas it was −7.0-degree angle in cases without CTS. Kwasny et al.[10] mentioned that the risk of DCTS increased when the VT was less than −20-degree angle. Additionally, in the present study, the mean VT was significantly lower in the DCTS group than in the control group (−20.5-degree angle versus −11.3-degree angle). Although there is no report about the relationship between DCTS and dorsal displacement of the distal radius after Colles' fracture, the mean VPH was also significantly lower in the DCTS group than in the control group (1.7 mm versus 5.3 mm). However, the VT and VPH were not significant factors of DCTS in the multivariate logistic regression analysis. On the other hand, a previous study showed that the RCD was related to these parameters of the distal radius.[8] The present study also showed that the RCD was strongly correlated with the VPH and VT, and a prediction equation was prepared. The mean RCD was significantly lower in the DCTS group than in the control group (−12.8 mm versus −8.4 mm). In addition, the RCD was related with DCTS according to a logistic regression analysis. Furthermore, the ROC curve indicated that the threshold value for DCTS was −9.9 mm with an odds ratio of 21; therefore, the RCD was considered to be involved in the onset of DCTS.

Kwasny et al.[10] thought that median nerve entrapment is due to traction and pressure over the volar edge of the distal radius under the transverse carpal ligament (TCL) following distal radius malunion and reported that symptoms of CTS after Colles' fracture improved in 12 of 13 patients after opening wedge osteotomy of the radius alone without carpal tunnel release. This report suggested that an improvement in anatomical alteration of the carpal tunnel after corrective osteotomy of the distal radius caused a decrease in the carpal tunnel pressure. The present study also suggested that dorsal displacement of the capitate and the TCL associated with distal radius malunion caused anatomical alteration of the carpal tunnel. With regard to the pathomechanism of DCTS after Colles' fracture malunion, narrowing of the proximal entrance of the carpal tunnel due to dorsal displacement of the distal carpal row and the TCL causes entrapment of the median nerve, and further, the meandered flexor tendons increase the pressure under the TCL owing to repeated finger flexion motion (Fig. 4).

The present study had few limitations. First, the number of patients was small. Although the odds ratio (21) of the threshold value of the RCD according to the ROC curve was considered significantly high, the statistical power may not have been sufficient because of the small sample size. As it was difficult to analyze many cases of DCTS

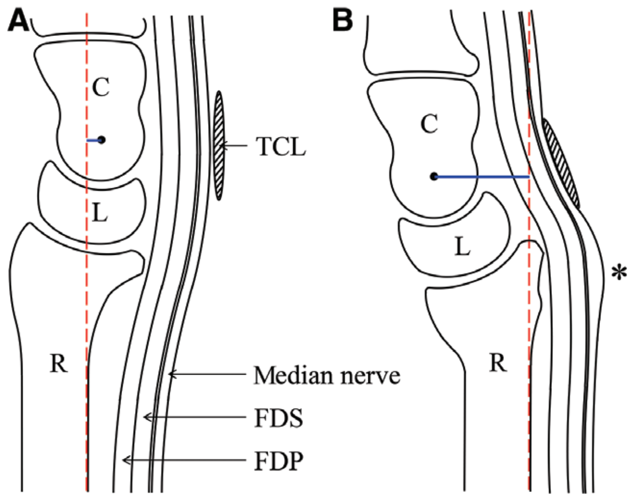

Fig. 4. Illustrations showing the relationships between carpal alignment and the anatomical positions of the flexor tendons, median nerve, and TCL. A, Normal wrist. B, Wrist showing Colles' fracture malunion with pseudoneuroma of the median nerve (*). FDP indicates flexor digitorum profundus; FDS, flexor digitorum superficialis; C, capitate; L, lunate; R, radius.

in our hospital alone, a multicenter study is required in the future. Second, the diagnosis of DCTS was based on only physical examination. Electrodiagnostic assessment was not performed in all cases. Although diagnosis was performed with careful observation of patients and with evoking tests, the accuracy of the diagnosis was unknown. Moreover, potential CTS patients might have been included in the control group. A case–control study based on a more accurate diagnosis is required. Third, anatomical alterations of the carpal tunnel were not confirmed. Magnetic resonance imaging or ultrasound imaging is helpful to visually confirm morphological changes of the carpal tunnel. The relationships between the change in the cross-sectional area at the inlet of the carpal tunnel and the changes in radiological parameters need to be studied in the future.

In conclusion, dorsal displacement of the capitate due to Colles' fracture malunion causes anatomical alterations of the carpal tunnel, which are involved in the onset of DCTS. When the center of the head of the capitate is located more than 1 cm dorsally behind the volar cortical line of the radius, DCTS may occur within 6 months after injury, and therefore, a sufficient follow-up with careful attention is required.

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REFERENCES

1. Cooney WP 3rd, Dobyns JH, Linscheid RL. Complications of Colles' fractures. *J Bone Joint Surg Am.* 1980;62:613–619.
2. Niver GE, Ilyas AM. Carpal tunnel syndrome after distal radius fracture. *Orthop Clin North Am.* 2012;43:521–527.

3. Bienek T, Kusz D, Cielinski L. Peripheral nerve compression neuropathy after fractures of the distal radius. *J Hand Surg Br*. 2006;31:256–260.
4. Stewart HD, Innes AR, Burke FD. The hand complications of Colles' fractures. *J Hand Surg Br*. 1985;10:103–106.
5. Aro H, Koivunen T, Katevuo K, et al. Late compression neuropathies after Colles' fractures. *Clin Orthop Relat Res*. 1988;233: 217–225.
6. Itsubo T, Hayashi M, Uchiyama S, et al. Differential onset patterns and causes of carpal tunnel syndrome after distal radius fracture: a retrospective study of 105 wrists. *J Orthop Sci*. 2010;15:518–523.
7. Taleisnik J, Watson HK. Midcarpal instability caused by malunited fractures of the distal radius. *J Hand Surg Am*. 1984;9:350–357.
8. Watanabe K. Carpal alignment in distal radius fractures following volar locking plate fixation. *J Hand Surg Glob Online*. 2019;1:10–14.
9. Lynch AC, Lipscomb PR. The carpal tunnel syndrome and Colles' fractures. *JAMA*. 1963;185:363–366.
10. Kwasny O, Fuchs M, Schabus R. Opening wedge osteotomy for malunion of the distal radius with neuropathy. 13 Cases followed for 6 (1-11) years. *Acta Orthop Scand*. 1994;65:207–208.
11. Graham B, Regehr G, Naglie G, et al. Development and validation of diagnostic criteria for carpal tunnel syndrome. *J Hand Surg Am*. 2006;31:919–924.