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Original Research

Changes in Nerve Conduction Studies After Distal Radius Fracture Fixation Using a Volar Approach and Locked Plate

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Purpose: To determine whether there are changes in nerve conduction studies (NCS) of the median nerve after distal radius fracture (DRF) and to determine how operative fixation through a volar approach with a locking plate contributes to nerve conduction changes. We hypothesized that a considerable percentage of patients would have electrodiagnostic evidence of median neuropathy at the wrist after fracture, but fixation with a volar locked plate would not worsen the electrodiagnostic findings.
Methods: This was a prospective cohort study of 14 neurologically asymptomatic patients who underwent surgical treatment of an isolated DRF using a volar plate. All patients underwent surgery within 2 weeks of injury. On the day of surgery and at the 6-week follow-up, patients were clinically examined, *Quick*—Disabilities of the Arm, Shoulder, and Hand questionnaire was completed, and patients underwent NCS using a handheld device with the unaffected limb, which was used as a comparison. Preoperative and postoperative nerve function were compared with the unaffected limb as a baseline.
Results: Patients without symptoms after DRF had a 28% incidence of prolonged latencies compared with reference values for the device used. Distal sensory latencies of the median nerve were 3.64 ± 0.32 ms in the unaffected arm, 3.76 ± 0.70 ms before surgery, and 3.81 ± 0.52 ms after surgery. Distal motor latencies of the median nerve were 3.91 ± 0.59, 3.60 ± 0.68, and 3.88 ± 0.36 ms in respective arms and time points. *Quick*—Disabilities of the Arm, Shoulder, and Hand scores improved from 77 before surgery to 46 at 6 weeks.
Conclusions: Asymptomatic patients may satisfy nerve conduction criteria for median neuropathy at the wrist after DRF; however, open reduction and treatment with a volar locked plate has no significant effect on NCS findings.
Type of study/level of evidence: Prognostic II.

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Median neuropathy at the wrist (MNW) is a well-recognized condition that can occur as a result of distal radius fracture (DRF) or its treatment with a volar locking plate.[1] The injury-related entity is caused by nerve contusion and/or acute carpal tunnel syndrome (aCTS). Patients with a nerve contusion present with nonprogressive paresthesias in the median nerve distribution, which abate over time. In contrast, patients with aCTS present with progressively worsening paresthesias in the median nerve distribution. If a timely carpal tunnel release (CTR) is performed, patients can expect outcomes similar to those undergoing elective release.[1] Failure to identify and treat aCTS can lead to longstanding nerve dysfunction and disability.[2] The diagnosis and management are made based on clinical suspicion and physical examination, thus eliminating the role for nerve testing in the acute setting. The only published electrodiagnostic data after DRF demonstrate that 59% of

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patients with abnormal nerve conduction velocities are asymptomatic after closed treatment.[3]

Median neuropathy at the wrist is a common complication after DRF, although its incidence may mirror the general population.[4–7] Unlike aCTS, this usually develops several weeks to months after surgery, and it is unclear whether this is a result of surgery or a worsening compression that was present before injury. Surgical fixation is thought to contribute to median neuropathy by excessive retraction, fracture manipulation, and postsurgical changes to nerve milieu. As a preventative measure, some surgeons perform CTR in conjunction with open reduction internal fixation (ORIF) of distal radius fractures. However, prophylactic CTR has been associated with increased postoperative median nerve dysfunction[8,9] and its routine practice continues to be controversial.[10,11] To our knowledge, the results of nerve conduction testing after treatment of DRF with a volar locking plate have not been reported in the literature.

The increasing trend toward operative treatment of DRF, particularly with a volar locking plate,[6] underlines the importance of understanding its relationship to MNW. Our goal was to characterize nerve conduction changes as a result of open treatment of DRF using a volar locking plate. We hypothesized that a considerable number of patients would have some degree of MNW after DRF and that acute fixation with a volar locking plate would not significantly contribute to these changes.

Materials and Methods

This prospective cohort study was approved by the institutional review board at our institution. The study included consecutive patients with isolated DRF who underwent ORIF with a volar locking plate through a flexor carpi radialis approach. All included patients denied nerve-related symptoms before surgery. Patients were enrolled over an 8-month period at a single institution between January 2016 and August 2016. A power analysis of a paired data set with power set to 0.80, significance set to .05, and an effect size of 0.8 demonstrated the need for a sample size of 14 patients. Demographic data and fracture characteristics were collected. Patients were initially seen in the emergency department at a Level 1 trauma center and identified for eligibility at the initial outpatient evaluation before surgery. Patients who consented to ORIF were enrolled into the study. Patients aged of 18 to 75 years were included if they denied median nerve paresthesias and had normal 2-point discrimination (<6 mm). Patients were excluded if they had a concomitant injury, previous workup for nerve injury or neuropathy of either upper extremity, or a history of surgery to the neck or upper extremity. Patients were also excluded if they had an open fracture, a fracture treated by surgery more than 2 weeks after injury, or a systemic condition with potential effect on nerve function or healing (rheumatoid arthritis, diabetes mellitus, etc).

On the day of surgery, patients were clinically examined, completed a *Quick*—Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) questionnaire, and underwent nerve conduction studies (NCS) in an electrophysiology laboratory by a dedicated research assistant trained to use the ADVANCE-NCS handheld device (NeuroMetrix, Inc, Waltham, MA). The ADVANCE-NCS has been validated to detect carpal tunnel syndrome (CTS) with a median nerve distal sensory latency (mDSL) sensitivity of 91% to 100% with a specificity of 69% and a median nerve distal motor latency (mDML) sensitivity of 89% to 100% with a specificity of 94% to 95%.[12,13] We defined CTS as a result of fracture or surgery if (1) the mDSL or mDML was greater than the reference value of 3.4 or 4.4 ms, respectively; (2) there was a sensory median ulnar difference (MUD) of greater than 0.5 ms, or a motor MUD greater than 1.0 ms, because the MUD has been suggested to increase sensitivity for detection in asymptomatic patients[14,15]; or (3) the mDSL or mDML was 2 SD above the baseline value.[14] The operation was performed by 1 of 3 board-certified, fellowship-trained hand surgeons (J.R..F, R.J.G., or K.W.). Identical testing was repeated at the 6-week follow-up visit with the addition of NCS performed on the uninjured extremity, which was used as a baseline for comparison.

A 2-tailed Student *t* test was used to compare continuous variables, such as the changes in NCV among baseline, preoperative, and postoperative time points. Chi-square analysis was used to determine whether closed reduction before operative fixation or the number of fracture fragments affected the development of nerve conduction delays. Significance was set to $P < .05$.

Results

Nineteen patients who satisfied the study criteria initially presented after sustaining isolated DRF during the study period; 18 consented for enrollment into the study. Follow-up NCS testing was not performed in 4 patients (22%), who were considered lost to follow-up. Fourteen patients were included in the final cohort. There were 9 women and 5 men, average age of 54 years (range, 25–73 years). Nine patients sustained injuries to the dominant hand; the most common mechanism was fall onto an outstretched hand. Two patients had extra-articular fractures, 9 had 2-part intra-articular fractures, and 3 had 3 parts or greater. No patients reported numbness or tingling in the median nerve distribution, and all patients had a 2-point discrimination of 5 to 6 mm on the injured extremity before and after surgery. Six of the 14 patients underwent a closed reduction before surgery. Average time from injury to surgery was 9.8 days (range, 4–14 days). The remaining patient-specific data are shown in Table 1.

Seven of the 14 patients (50%) had median nerve conduction latencies consistent with MNW after injury, 3 (21%) of which demonstrated baseline subclinical CTS on the contralateral limb; thus, 4 (28%) were newly present changes in latencies compared with the control. These all resulted from prolongation of mDSL. No additional cases were identified using MUD, even after an increase to a 0.6-ms threshold to minimize false-positive MNW.[15] Three patients (21%) developed new conduction-defined CTS after surgical intervention, whereas 2 (14%) returned to normal. When we compared preoperative and postoperative mDSL and mDML with baseline values, we found no statistical difference. In addition, there was no statistically significant change in mDSL and mDML as a result of surgery. Tables 2 and 3 list nerve conduction findings for all patients; Table 4 shows *Quick*DASH scores before and after surgery.

Six of the 14 patients (43%) underwent preoperative closed reduction, which resulted in one new case of electrodiagnostic MNW before surgery (7%). Four patients who underwent closed reduction (67%) developed conduction latencies consistent with MNW after surgery, whereas only 50% of patients who did not undergo preoperative closed reduction had evidence of MNW after surgery, although this was not significant ($P = .533$). The number of fracture fragments compared with preoperative or postoperative MNW was not significant ($P = .800$ and .901, respectively).

Average *Quick*DASH score was 77 before surgery, which improved 31 points to 46 at the 6-week postoperative visit ($P < .001$). Surgical treatment demonstrated significant improvement in radiographic parameters with a postoperative volar tilt of $3.93^\circ \pm 5.08^\circ$ ($P < .001$), radial inclination of $20.00^\circ \pm 3.14^\circ$ ($P < .001$), and radial height of 9.93 ± 1.99 mm ($P < .001$).

Table 1
Demographic Data of Enrolled Patient Population*

Patient Demographics	
Age, y (range)	54.1 (25–73)
Gender, F	9 (64)
Mean comorbidities, n	0.93
Dominant hand	9 (64)
2-point discrimination < 6 mm	14 (100)
Low-energy	11 (79)
Preoperative closed reduction	6 (43)
Mean d to surgery	9.8
Postoperative CTR	0

* Discrete data are also expressed as a percentage of the total in parentheses.

Table 2
Median Nerve Distal Motor Latency

Patient ID	Age	Motor Baseline	Motor Before Surgery	Motor After Surgery	Change
1	48	5.71	4.44	4.26	−0.18
2	25	3.84	3.85	3.84	−0.01
3	64	3.93	4.32	3.84	−0.48
4	43	3.89	3.42	3.34	−0.08
5	70	3.91	3.61	3.91	0.3
6	53	4.14	3.71	4.14	0.43
7	65	3.39	1.72	3.39	1.67
8	58	3.48	3.94	4.12	0.18
9	35	3.86	3.32	3.95	0.63
10	20	3.21	2.94	3.14	0.2
11	66	3.44	3.75	4.06	0.31
12	69	3.99	3.39	4.1	0.71
13	73	4.16	4.16	4.39	0.23
14	69	3.82	3.82	3.8	−0.02
Mean	54.14	3.91	3.60	3.88	0.278
SD	17.46	0.59	0.68	0.36	0.510
P value			.074	.798	.062

Table 3
Median Nerve Distal Sensory Latency

Patient ID	Age	Sensory Baseline	Sensory Before Surgery	Sensory After Surgery	Change
1	48	4.14	5.37	4.79	−0.58
2	25	3.61	3.71	3.61	−0.1
3	64	3.61	3.81	3.22	−0.59
4	43	3.22	4	3.04	−0.96
5	70	3.42	3.32	3.42	0.1
6	53	4	3.42	4	0.58
7	65	3.42	2.45	3.42	0.97
8	58	3.71	4.69	4.2	-0.49
9	35	3.81	3.32	3.61	0.29
10	20	3.2	3.42	3.52	0.1
11	66	3.91	3.91	4.49	0.58
12	69	3.42	3.81	3.7	−0.11
13	73	4.1	4.2	4.51	0.31
14	69	3.32	3.22	3.79	0.57
Mean	54.14	3.64	3.76	3.81	0.048
SD	17.46	0.32	0.70	0.52	0.595
P value			.067	.446	.751

Discussion

There was no significant change in nerve conduction parameters from before to after surgical fixation with a volar locked plate, which suggests that the surgery itself has a minimal influence on nerve latencies. Although not definitive based on the small series, this suggests that changes in or the development of CTS symptoms in the future may not be related to the initial surgical treatment. Acute CTS after DRF is diagnosed and managed by a high index of clinical suspicion and physical examination, which explains why there is a paucity of electrodiagnostic data regarding this injury. In this study, we selected patients without CTS symptoms and compared their NCS after DRF and after fixation with a volar locking plate with the unaffected extremity, to determine their respective impact on median nerve conduction. This study provides prospectively collected data regarding the effect of a volar locking plate for DRF on median NCS immediately after surgery.

In this study, 50% of patients without subjective nerve symptoms had NCS that met criteria for MNW after DRF. After adjusting for the 21% (3 of 14) who had an increased mDSL in the unaffected limb at baseline, 28% of patients had new conduction-defined CTS compared with the baseline arm used. Alrawashdeh[15] demonstrated similar findings with a 15% prevalence of subclinical CTS after testing 130 healthy asymptomatic individuals with normal clinical exams. Stark[3] performed electrodiagnostic testing on 62 patients after closed treatment of DRF and found that 59% had abnormal NCS in the absence of symptoms. We do not think that nerve symptoms were underreported owing to pain, because testing was performed an average of 9.8 days after injury, minimizing the effect of acute pain as a distracting symptom.

A recent study by Bourque et al[16] examined electrophysiologic findings of 39 consecutive patients with DRF who were treated with cast immobilization. Although that study used a larger population than ours, it did not include patients who underwent surgical treatment and did not perform NCS for the first time until cast removal. The authors found that NCS parameters did not differ significantly between the unaffected wrist and the fractured wrist, which suggests that median nerve injury is not expected at the level of the carpal tunnel in most patients with DRF.

The prevalence of CTS in the general population has been reported to be 2.7% to 4.9% with a false-positive rate of 18% when relying solely on electrodiagnostic criteria.[4] Satake et al[7] performed a retrospective, multicenter review of 694 patients treated for DRF with a volar locking plate. The most common complication was CTS, with an incidence of 2.6% at a minimum 12-week follow-up. In another large retrospective cohort[17] of 1,511 patients who underwent surgical management of a DRF, the prevalence of CTS was 0.98% to 1.5%. Those patients were stratified as unreduced or reduced, respectively, at initial presentation. The incidence of CTS after surgical management of DRF is similar to the prevalence in the general population, although they have not been directly compared. When slit catheters were placed into the carpal tunnel of 10 patients after volar locking plate, the maximum pressure exceeded 40 mm Hg in only one patient, who did not exhibit symptoms of CTS. In addition, those authors found a downward trend of carpal canal pressures in all patients over the 24-hour monitoring period, and none developed CTS at 12 weeks.[18] Our findings suggest that surgical fixation with a volar locking plate does not cause median nerve dysfunction across the wrist at 6 weeks (Table 2). This finding was independent of whether a preoperative reduction was performed and regardless of the number of fracture fragments identified at the time of surgery. Our patients reported a 31-point improvement in *Quick*DASH score just 6 weeks after surgery, which surpasses the minimal clinically important difference for DRF of 25.8.[19]

There are obvious weaknesses to this study. The first is that it used a small population. In a post hoc power analysis, this study would require an enrollment of greater than 900 patients to support the difference in mDSL observed at $P < .05$ and a power of 80%. This would require a multicenter trial and considerable funding to verify a nerve conduction difference that may not be clinically significant. In addition, we did not perform electromyography owing to invasiveness and patient discomfort, which limits our ability to rule out differential causes of nerve compression.

Table 4
*Quick*DASH Scores

Patient ID	Preoperative *Quick*DASH	Postoperative *Quick*DASH	Change
1	79.5	72.7	6.8
2	61.4	22.5	38.9
3	72.7	79.5	−6.8
4	75	29.5	45.5
5	65.9	50	15.9
6	81.8	42.5	39.3
7	79.5	27.3	52.2
8	86.36	45.45	40.91
9	75	70.45	4.55
10	86.36	68.18	18.18
11	68.18	47.73	20.45
12	80	22.73	57.27
13	81.81	45.45	36.36
14	77.5	31.81	45.69
Mean	76.50	46.84	29.66
SD	7.39	19.34	19.64
P value			<.001

However, cervical radiculopathy and/or other more proximal etiologies would not be expected after DRF. Nerve conduction studies were carried out using an automated handheld testing device that used the manufacturer's suggested reference ranges, which were optimized for sensitivity and had a high false-positive rate. We acknowledge that NCS have a nontrivial false-positive rate (18.4%); however, they remain the reference standard for nerve evaluation.[4] We attempted to minimize this effect by using the unaffected contralateral upper extremity as a control. We recognize that the contralateral limb is not an ideal control group because subjects may or may not have had symmetric involvement of both wrists. However, because the patients included in this study are dependent on a fracture at a random time, it was impossible to obtain baseline measurements on previously asymptomatic arms in case there was a fracture in the future, and we thought this was the most viable alternative option.

Bodofsky et al[20] found increased mDSL and mDML in the unaffected limbs of patients with confirmed unilateral CTS compared with normal controls. Finally, we observed patients for only 6 weeks, although CTS after surgical fixation of DRF has been shown to occur between 6 and 23 weeks.[5,16,21] As a result, we are unable to determine whether there is a correlation between NCS values and patients who eventually develop CTS. However, the lack of notable change 6 weeks after surgery would suggest that the surgical insult itself does not cause median nerve dysfunction, because those changes should be present at 6 weeks if they result from surgery.

Asymptomatic patients after DRF had a 28% incidence of MNW of unknown clinical importance. These patients did not exhibit significant changes in NCS after surgical fixation of fractures using a volar locking plate. In the absence of major NCS changes at 6 weeks, we believe that nerve conduction changes did not lead to symptomatic postoperative CTS after volar locking plate fixation in the early postoperative period. We are unable to conclude whether these patients may require eventual release of the carpal tunnel as a result of the healing process, flexor tendon irritation, or malreduction. This information can be important when counseling patients or evaluating electrodiagnostic testing in the postoperative setting.

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