Neurologic complications in common wrist and hand surgical procedures

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Abstract

Nerve dysfunction after upper extremity orthopedic surgery is a recognized complication, and may result from a variety of different causes. Hand and wrist surgery require incisions and retraction that necessarily border on small peripheral nerves, which may be difficult to identify and protect with absolute certainty. This article reviews the rates and ranges of reported nerve dysfunction with respect to common surgical interventions for the distal upper extremity, including wrist arthroplasty, wrist arthrodesis, wrist arthroscopy, distal radius open reduction and internal fixation, carpal tunnel release, and thumb carpometacarpal surgery. A relatively large range of neurologic complications is reported, however many of the studies cited involve relatively small numbers of patients, and only rarely are neurologic complications included as primary outcome measures. Knowledge of these neurologic outcomes should help the surgeon to better counsel patients with regard to perioperative risk, as well as provide insight into workup and management of any adverse neurologic outcomes that may arise.

Introduction

Nerve dysfunction after upper extremity orthopedic surgery is a recognized complication. Neural complications may be the result of trauma or neurotoxicity during regional anesthesia. However, they may also be the sequelae of intraoperative injury such as compression from patient or retractor positioning, or a direct laceration during the procedure. Hand and wrist surgery require incisions and retraction that necessarily border on small peripheral nerves, which may be difficult to identify and protect with absolute certainty. The reported frequency of neurologic complications is likely to vary based on a myriad of factors, including the extent of follow up.

The purpose of this narrative review article is to summarize the incidence of nerve dysfunction for common surgical procedures of the forearm, wrist, and hand, as well as their purported mechanisms of injury, and the duration of symptoms, when reported. Outcomes are reported with respect to the type and location of the procedure, and the type of anesthetic utilized, if specified. Knowledge of these neurologic outcomes will help the surgeon to better counsel patients with regard to perioperative risk, as well as provide insight into workup and management of any adverse neurologic outcomes that may arise.

Materials and Methods

The authors conducted searches in MEDLINE and Cochrane Review databases,1 from 1975 to the present, for articles reporting neurologic outcomes and complications after common hand, wrist and forearm surgical procedures. The searches incorporated the following key words: hand, wrist, metacarpal, carpal, radius, ulna; arthroscopy, arthroplasty, arthrodesis, fixation, repair, replacement, surgery; nerve injury, neurologic, complications, neuropathy. References from applicable citations were evaluated manually for completeness, and were included if appropriate.

Our primary outcome is the mean incidence, as well as the range of reported incidence, of postoperative neurologic complaints in forearm and wrist surgery. Secondly, we evaluated the risk of nerve dysfunction for these procedures when the anesthetic type was specified as peripheral nerve blockade, versus other types of anesthesia. Studies considered acceptable for this report included large observational or cohort studies that provided the incidence of neurologic outcomes or injury, related to six commonly performed surgical procedure types for forearm and wrist pathology (wrist arthroplasty, wrist arthrodesis, wrist arthroscopy, carpal tunnel release, distal forearm fracture and thumb carpometacarpal joint surgery). Studies related to traumatic injury were included, as this makes up a significant portion of hand surgery cases. Case reports were excluded, as were reports specific to pediatric hand surgery. Several anatomic, cadaver-based articles are referenced in the text in order to provide perspective and help to elucidate the mechanism of injury of nerves in relationship to surgical incisions, though these did not factor into the determination of actual clinical risk of postoperative neurologic disorders. Nerve dysfunction was not a primary outcome for the great majority of the studies cited, given the scarcity of such investigations in the hand surgery literature. Instead, neurologic dysfunction was typically reported as a secondary outcome by the various investigators, among other complications encountered. The specifics of type of anesthesia, mechanism of injury and time to resolution are noted in the tables, when these were reported by the authors of the individual studies.

The mean incidence rates of neurologic dysfunction, along with 95% confidence intervals, are reported for each surgical type, as well as the range reported in the studies included. Confidence intervals were determined using an online calculator (www.Vassarstats.net).

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Key words: Wrist, hand, thumb, surgery, neurologic, complication, outcome.

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Wrist arthroplasty

Wrist arthroplasty is a procedure designed to relieve pain and preserve wrist motion in patients with pathology involving the entire wrist joint. It is an alternative to wrist arthrodesis, maintaining a greater degree of function. Arthroplasty helps to preserve quality of life for afflicted patients, and is indicated for treating destructive wrist joint pathology due to trauma, long-term overuse, or inflammatory processes. However, the long-term durability of arthroplasty remains limited compared to fusion, and this surgery is often confined to older patients and those who place fewer demands on the wrist. Wrist arthroplasty is often utilized for severe arthritis and intractable wrist pain, in situations in which arthrodesis may have previously been provided. It is not clear whether this more extensive procedure increases the risk of nerve injury. In some comparative studies, the likelihood of injury has been quite similar. In a systematic review of studies comparing wrist arthroplasty and wrist arthrodesis for rheumatoid arthritis, Cavaliere and Chung (2008) reported a similar incidence of overall complications, though major complications, requiring surgical correction (including median nerve compression) were more common with the various types of arthroplasty. Overall, neurologic dysfunction has been reported in a range of 0 to 16.7% after wrist arthroplasty (Table 1), with a mean incidence of 4.6%.

Table 1. Neurologic complications reported in wrist arthroplasty.

| Author          | Design               | Approach                   | N. | Rate/NI | Nerves | Perm | Anesthesia | Remarks           |
|-----------------|----------------------|----------------------------|----|---------|--------|------|------------|--------------------|
| Murphy 2003     | R                    | Universal vs Arthrodesis   | 27 | 3 (11.1) | Median | 1    | NS         | CTS                |
| Van Haringen    | P                    | 3rd Generation             | 32 | 3 (9.4) | Median, | UNS  | NS         | CTS, Ulnar N. sensory loss |
| Kretzner        | P                    | Remotion Prothesis         | 215| 8 (3.7) | Median | NS   | NS         | CTS                |
| Cooney 2012     | R                    | Resection vs Resurfacing   | 46 | 0 (0)   |        |      | Na         | Ax Block           |
| Gellman 1997    | R                    | Volar Prothesis            | 14 | 0 (0)   |        |      | Na         | NS                 |
| Nydick 2012     | R                    | Maestro                    | 23 | 0 (0)   |        |      | Na         | UE Block           |
| Gaspar 2016     | R                    | Partial vs Total Arthroplasty | 105 | 5 (4.9) | Median, | NS   | NS         | CTS, Guyon’s canal syndrome |
| Dennis 1986     | R                    | Volar Arthroplasty         | 30 | 4 (13.3)| Median | NS   | NS         | CTS                |
| Takwale 2002    | B                    | Bialar Prothesis           | 66 | 0 (0)   |        |      | NS         | CTS                |
| Rahimtoola 2003 | P                    | RWS Prosthesis             | 27 | 3 (11.1)| Median | 0    | 0          | CTS                |

Rate/NI denotes absolute number and (%) of reported nerve dysfunction; Perm denotes number of permanent injuries reported; R denotes retrospective; P denotes prospective; CTS denotes carpal tunnel syndrome; NA denotes not applicable; NS denotes not specified by authors.
Wrist arthroscopy

Wrist Arthroscopy has been utilized for over three decades, evolving from a primarily diagnostic method to an important therapeutic intervention for a large variety of wrist complaints. Indications include diagnosis of joint pathology, staging of the severity of wrist maladies, and surgical intervention. Specific disorders for which arthroscopy is indicated to evaluate and treat patients include tears of the triangular fibrocartilage complex (TFCC), articular fractures involving the distal radius or carpal bones, carpal instability, and arthritis of the wrist joint. Several different ports for wrist arthroscopy are typically placed; these are named/numbered in relationship to the extensor tendon compartments on the back of the wrist. Volar portals are also described, but are used less frequently.

Wrist arthroscopy provides a means for hand surgeons to address intra-articular pathology with a minimally invasive technique that allows for limited incision size and more rapid rehabilitation. Abnormal neurologic outcomes related to this arthroscopic technique are reported to be between 0 and 14% (Table 2), with a mean incidence of 3.6% [95% CI 2.4-5.3]. Ports on the radial aspect of the joint are in proximity to the dorsal sensory branch of the radial nerve, while those on the ulnar aspect are close to the dorsal branches of the ulnar nerve. In addition, mid-carpal portals are placed in close association to the distal, sensory portion of the posterior interosseous nerve. When arthroscopy is applied for repair of tears of the triangular fibrocartilage within the wrist joint, both internal-external and all-internal techniques can be associated with post-operative dysfunction of the DSBN.45,46

Table 2. Neurologic complications reported in wrist arthroscopy.

| Author          | Design | Approach                  | N. | Rate/Nl | Nerves | Perm | Anesthesia | Remarks          |
|-----------------|--------|--------------------------|----|---------|--------|------|------------|------------------|
| Estrella 2007   | P      | TFCC Repair              | 35 | 6       | Ulnar  | 1    | NS         | Sens. Disturb, DSBN |
| Darlis 2005     | R      | SL Ligament Repair       | 16 | 1       | Median | 0    | NS         | CTS              |
| Nagle 1992      | R      | Dx, Staging and Therapeutic | 84 | 0       | AX 54, GA 30 |
| Hofmeister 2001 | P      | Midcarpal and Radiocarpal ports | 89 | 0       | GA or Reg |
| Trumble 1997    | P      | TFCC Repair              | 24 | 1       | Ulnar  | 0    | NS         | Paresthesia of DSBN |
| Grecenig 1999   | P      | Dx, Staging and Therapeutic | 96 | 4       | Median | 1    | NS         | Irritation of DSBN |
| Beredjiklian 2004 | R     | Dx, Therapeutic         | 211 | 4       | Ulnar  | 0    | Reg 52, GA 159 | DSBN and Ulnar Neurapraxia |
| Cobb 2011       | P      | Resection Arthroplasty   | 35 | 5       | Radial | 0    | NS         | Paresthesia SBRN |
| Doi 1999        | P/RCT  | Arthroscopic vs Open Fracture repair | 82 | 3       | Median | NS    | NS         | CTS              |

TFCC denotes triangular fibrocartilage complex; SL denotes scapholunate; Dx denotes diagnosis; Sens. Denotes sensory; AX denotes axillary block; GA denotes general anesthesia; Reg denotes unspecified regional block; RCT denotes randomized controlled trial.

Carpal tunnel release

Carpal tunnel release (CTR) is one of the most frequently performed surgeries in the United States; it is estimated to affect up to 10% of those over 40 years of age. The release of the flexor retinaculum to reduce pressure on the median nerve may be conducted by either open or endoscopic carpal tunnel release (ECTR). With the use of the open or the endoscopic technique, postoperative neurologic symptoms occur in the range of 0 to 7.5% for open procedures, and 0 to 6.8% for endoscopic ones (Table 3). The mean reported incidence of nerve dysfunction after all types of CTR is 0.5% [95% CI 0.4-0.6]. Either type of CTR may result in dysfunction of the median, ulnar or digital nerves. The median nerve, and its palmar cutaneous branch (PCBMN), appear to be the most frequently affected with this surgical procedure. In direct comparisons of the open and the endoscopic techniques, the frequency of neurologic complications has been similar, with a higher likelihood of temporary dysfunction occurring with endoscopic surgery. In a meta-analysis of over 27,000 cases, Benson et al noted an overall rate of nerve injury of 1.58% for ECTR and 0.35% for open CTR. However, some authors have reported a significantly higher risk of nerve injury. Muller et al. (2000) noted 10 cases of ulnar neuropraxia along with 2 digital nerve injuries among 100 cases released endoscopically (Table 3). At the other extreme, in a retrospective analysis of 9,675 patients who underwent ECTR, Pajardi et al. (2008) reported only 6 injuries—a rate of 0.07%. As with most surgically-associated neurologic complications, the great majority appear to be temporary. In a study of cadaveric anatomy, Boughton et al. (2010) noted that open CTR with incision in the axis of the ring finger increases the risk to branches of the ulnar nerve.

Distal forearm fracture

Distal forearm fractures-usually involving the radius—are one of the most common traumatic injuries treated by orthopedists and represent the most common fracture of the upper extremity. The elderly are particularly at risk when falling on outstretched arms. Neurologic compromise is common, with either nonoperative or surgical therapy. Operative intervention may involve either open reduction with plates and screws, or placement of Kirschner wires or external fixators. The nerves which may be affected by such procedures vary with different management techniques. Nerve dysfunction in the wake of surgical intervention is reported in a rather large range, from 0-22%, with a mean of 5.8% [95% CI 5.2-8.8]. Dorsal plate fixation, as opposed to volar plating, may allow for a lower incidence of neurologic compromise.

Median nerve involvement, with acute or long-term development of carpal tunnel syndrome (CTS), is most commonly cited, followed by dysfunction of the SBRN (Table 4). Other nerves that may be affected include the PCBMN, ulnar nerve and LABCN, though these are much less common. Prophylactic CTR during operative fixation of distal radius fracture may reduce risk to the median nerve for patients who show evidence of nerve compromise acutely in the wake of the fracture.

Anatomic studies in cadavers emphasize the close proximity of the superficial nerves about the wrist to sites of placement of pins and K-wires, particularly the...
Table 3. Neurologic Complications Reported in Carpal Tunnel Release.

| Author         | Design     | Approach            | N.     | Rate/NI | Nerves         | Perm | Anesthesia | Remarks                      |
|----------------|------------|---------------------|--------|---------|----------------|------|------------|-----------------------------|
| Shinya 1995    | P          | ECTR, Single Portal | 107    | 0 (0)   | NA             | NS   | Regional   | Temporary loss of interosseous muscle fnx |
| Chow 1990      | R          | ECTR, Single Portal | 142    | 1 (0.7) | Ulnar          | 0    | Local      | Numbness index finger        |
| Brown 1993     | P-RCT      | Open vs ECTR        | 169    | 2 (1.2) | Digital, Ulnar | 0    | Regional   | Digital N. contusion; Ulnar N. neurapraxia |
| Uchiyama 2007  | P          | ECTR, modified Chow technique | 119    | 1 (2)   | Median         | 0    | Local      | Mumbness, Weakness           |
| Nagle 1996     | P          | ECTR extra- versus transbursal | 640    | 14 (2.2) | Median, Ulnar, Digital | NS   | Local      | Neurapraxia                 |
| Pajardi 2008   | R          | ECTR                | 12,702 | 6 (0.05) | Median, Digital | NS   | Local      | Neuroma PCBMN ‘complete’ digital |
| MacDonald 1978 | R          | Open                | 186    | 11 (5.9) | Median         | NS   | NS         | PCBMN                       |
| Lichtman 1979  | P          | Open                | 100    | 2 (2)   | Median         | NS   | Local      | Neuroma PCBMN               |
| Sennewald 1995 | P-RCT      | ECTR vs Open        | 47     | 1 (2.1) | Digital        | NS   | Regional   | Neurapraxia                 |
| Ferdinand 2002 | P-RCT      | ECTR vs Open        | 50     | 1 (2.0) | Median         | NS   | General    | likely PCBMN injury          |
| Agee 1995      | P          | ECTR                | 883    | 11 (1.2) | Median, Digital | 1    | AX, Bier, GA, Local | Abnormal Sensation |
| Muller 2000    | P          | ECTR                | 100    | 12 (12) | Ulnar, Digital | 0    | NS         | Ulnar N. neurapraxia, Digital N. contusion |
| Agee 1992      | P-RCT      | ECTR vs Open        | 147    | 2 (1.4) | Ulnar          | 0    | GA or Regional | Ulnar N. neurapraxia         |
| Saw 2003       | P-RCT      | ECTR vs Open        | 150    | 1 (0.7) | Median         | 0    | Local      | Transient Numbness Index Finger |
| Erdmann 1994   | P-RCT      | ECTR vs Open        | 105    | 1 (0.95) | Ulnar          | 0    | NS         | Paresthesia                 |
| Helm 2003      | P-RCT      | Kniefelight vs Open | 82     | 1 (1.2) | Median         | 0    | Local      | Numbness index finger       |
|Jacobsen 1996   | P-RCT      | ECTR                | 32     | 5 (9.4) | Median         | 0    | Bier       | Numbness ring finger        |
| Bhattacharya 2004 | P-RCT     | Kniefelight vs Open | 52     | 1 (1.9) | Median         | 0    | Local      | Palmar Numbness             |

ECTR denotes endoscopic carpal tunnel release; fn denotes function; PCBMN denotes palmar cutaneous branch of median nerve; local denotes local anesthesia; Bier denotes intravenous regional anesthesia.
Further, one large retrospective study of CTR markedly skewed the results or the non-regional group of studies, and with exclusion of this study, the likelihood of nerve dysfunction was essentially the same with or without regional anesthesia [2.0% (1.0-3.9) vs. 1.9% (1.1-3.1)].

### Discussion and Conclusions

Numerous surgical procedures exist to treat pathology at the distal forearm or wrist. Each approach carries a unique potential for neurologic dysfunction, varying with anatomy, mechanism and severity of injury. Nerve injury during wrist surgery can be related to regional anesthesia, positioning, or surgical factors. Understanding of both surgical-related and nerve block-related neurologic occurrences will aid in diagnosis. For example, after brachial plexus blockade, if a single peripheral nerve is injured, it is more likely to be related to a

### Table 4. Neurologic complications reported in distal forearm/wrist fracture.

| Author          | Design | Approach                   | N.  | Rate/NI | Nerves         | Perm | Anesthesia | Remarks                     |
|-----------------|--------|---------------------------|-----|---------|----------------|------|------------|-----------------------------|
| Lee 2003 [94]   | P      | Volar Plate               | 22  | 3 (13.6)| Radial         | 0    | NS         | numbness/SBRN               |
| Henry 2007 [84]| P      | Various Surgeries (pins, screws, plates) | 374 | 0 (0)  |                |      |            |                             |
| Knudsen 2014 [95]| R   | Volar Plate               | 165 | 12 (7.3)| Median         | NS   | NS         | CTS                         |
| Ho 2011 [96]    | R      | Volar Plate               | 282 | 24 (8.5)| Median         | 1    | NS         | CTS, Median N. neuropathy   |
| Rampoldi 2007 [87]| R | Volar Plate               | 90  | 1 (1.1) | Median         | 0    | Reg        | CTS                         |
| Vu 2011 [98]    | R      | Volar or Dorsal Plate     | 104 | 4 (3.9) | Median, Ulnar  | NS   | NS         | CTS, Ulnar entrapment       |
| Ruch 2006 [96]  | R      | Volar vs Dorsal Plate     | 34  | 2 (5.9) | Median         | NS   | NS         | Median N. neuropathy        |
| Richard 2011 [81]| R   | Ex Fix vs Volar Plate     | 115 | 11 (9.6)| Median, Radial | NS   | NS         | Median neuropathy; SBRN     |
| Tarallo 2013 [99]| R  | Volar Plate               | 303 | 5 (1.7) | Median         | NS   | NS         | CTS, Median N. neuropathy   |
| Eisenwein 2013 [77]| R | Volar Plate               | 665 | 22 (3.3) | Median         | NS   | NS         | CTS                         |
| Singh 2005 [100]| P     | K-wire                    | 40  | 3 (7.9) | Median, Ulnar  | 1    | Reg        | CTS, SBRN                   |
| Hoe 1997 [101]  | P      | ORIF Dorsal Plate         | 31  | 3 (9.7) | Median         | NS   | NS         | SBRN                        |
| Drobetz 2003 [102]| P | Volar Plate               | 50  | 1 (2)   | Median         | NS   | GA or BP block | CTS                       |
| Zylak 2011 [103]| P     | ORIF Dorsal Plate         | 115 | 1 (2)   | Median         | NS   | NS         | CTS                         |
| Chapman 1982 [80]| R  | Pins                      | 80  | 11 (15.8)| Median         | NS   | NS         | CTS, Ulnar N. paresthesias  |
| Arora 2007 [104]| P     | Volar Plate               | 114 | 3 (2.6) | Median         | NS   | GA or BP block | CTS                       |
| Biyani 1995 [93]| R     | ORIF or Ex Fix Radius plus Ulna | 19  | 2 (10.5)| Median         | 0    | NS         | CTS                         |
| Dennisson 2007 [92]| R | Volar Plate, Radius plus Ulna | 5   | 2 (40) | Radial         | 0    | NS         | Paresthesia of SBRN         |
| Eged 2010 [105]| R     | Case Control (Surgery vs Casting) | 90  | 6 (6.7) | Median         | 1    | NS         | CTS                         |
| Arora 2011 [106]| P     | Volar Plate nonoperative  | 73  | 1 (1.4) | Median         | NS   | BP block, GA or Local | CTS                       |
| Lattmann 2011 [107]| P | Volar Plate               | 245 | 11 (4.5)| Median         | NS   | NS         | CTS, Median N. irradiation  |
| Kukla 2003 [107]| P     | Bridging vs Nonbridging Ex Fix | 75  | 4 (5.5) | Median         | NS   | NS         | SBRN                        |
| Lutz 2014 [78]  | R      | ORIF vs Nonoperative      | 258 | 27 (10.5)| Median, Ulnar, Radial | NS | NS | CTS, Ulnar neuropaxia, SBRN |
| Abbasazadehn 2010 [108]| P  | Ex Fix vs Cas | 47  | 1 (2.1) | Radial         | 0    | Local or Bier | Sensory disturbance SBRN    |
| Aroshi 2006 [109]| P     | Ex Fix, Bridge vs Nonbridging | 38  | 1 (2.6) | Radial         | 0    | Reg or GA  | Numbness SBRN               |
| Webster 2005 [110]| P   | Ex Fix, 5 Pin vs 4 Pin    | 50  | 1 (2.0) | Median         | 0    | GA         | Paresthesia Thumb, Index, Long Finger |
| Sommerkamp 1994 [111]| P  | Ex Fix, Dynamic vs Static | 50  | 0 (0)  | Median         | Radial | 0 | GA or AX | Median N. dysfunction SBRN neuritis |
| Krishnan 2003 [112]| P   | Ex Fix, Dynamic vs Static | 60  | 3 (5.0) | Radial         | NS   | NS         | SBRN Irritation             |
| McQueen 1995 [113]| P     | ORIF, Ex Fix or casting   | 120 | 8 (6.7) | Median         | NS   | NS         | CTS, Neurapraxia SBRN       |
| Rodriguez-Merchan 1997 [114]| P   | Cast vs Pinning          | 40  | 1 (2.5) | Median         | 1    | Local, GA, or BP block | Median neuropathy |
| Stoffelen 1988 [115]| P   | Cast vs Pinning          | 98  | 8 (8.2) | Median         | 1    | NS         | Median N. contusion SBRN injury |
| Howard 1989 [116]| P     | Cast vs Pinning          | 50  | 10 (20) | Median, Ulnar  | NS   | NS         | Median and SBRN neuritis Ulnar N. compression |
| Home 1990 [117]| P     | Cast vs Pinning          | 29  | 4 (13.8)| Radial         | NS   | BP Block   | SBRN Irritation             |
| Lesnobile 1995 [118]| P  | Pin Fixation (two types) | 96  | 11 (11.5)| Radial         | 11   | GA or Regional | SBRN                        |
| Casteley 1992 [119]| P  | K-wire vs Rods           | 30  | 2 (6.7) | Median         | 0    | GA or Regional | CTS                         |

Ex fix denotes external fixation; ORIF denotes open reduction-internal fixation; BP block denotes unspecified brachial plexus block; comp denotes comparative (but nonrandomized) study.
surgical or positioning factor, rather than a nerve block etiology. A plexus injury would be more likely to be of nerve block etiology, but a positioning etiology should also be considered.

The current review offers insight into neurologic risk related to surgical factors for six common procedures performed by hand surgeons about the forearm, wrist, and hand. In our analysis, we found that the mean incidence of reported nerve dysfunction after these surgical procedures varied significantly with the type of procedure, from 0.5% for carpal tunnel release to 7.9% for thumb CMC surgery. As one would expect, the types of reported injuries were typically related to the sites of incision for these procedures. The overall mean incidence of expected nerve dysfunction for the amalgam of these procedures is relatively low, at 2.1% [2.0-2.3].

Table 5. Neurologic complications reported in Thumb CarpoMetacarpal Surgery.

| Author               | Design   | Approach                  | N.  | Rate/NI | Nerves         | Perm | Anesthesia | Remarks                              |
|----------------------|----------|---------------------------|-----|---------|----------------|------|-------------|--------------------------------------|
| Lee 2003 [94]        | P        | Volar Plate               | 22  | 3 (13.6)| Radial         | 0    | NS          | numbness/SBRN                        |
| Henry 2007 [84]      | P        | Various Surgeries (pins, screws, plates) | 374 | 0 (0)   |                |      | NS          |                                      |
| Knuusen 2014 [95]    | R        | Volar Plate               | 165 | 12 (7.3)| Median         | NS   | NS          | CTS                                  |
| Ho 2011 [96]         | R        | Volar Plate               | 282 | 24 (8.5)| Median         | 1    | NS          | CTS, Median N. neuropathy            |
| Rampoldi 2007 [97]   | R        | Volar Plate               | 90  | 1 (1.1) | Median         | 0    | Reg         | CTS                                  |
| Yu 2011 [98]         | R        | Volar vs Dorsal Plate     | 104 | 4 (3.9) | Median Ulnar   | NS   | NS          | CTS, Ulnar entrapment                |
| Ruch 2006 [86]       | R        | Volar vs Dorsal Plate     | 34  | 2 (5.9) | Median         | NS   | NS          | Median N. neuropathy                 |
| Richard 2011 [81]    | R        | Ex Fix vs Volar Plate     | 115 | 11 (9.6)| Median         | NS   | Median N. neuropathy, SBRN           |
| Tarallo 2013 [99]    | R        | Volar Plate               | 303 | 5 (1.7) | Median         | NS   | NS          | CTS, Median N. neuropathy            |
| Esbenweiss 2013 [77] | R        | Volar Plate               | 665 | 22 (3.3)| Median         | NS   | NS          | CTS                                  |
| Singh 2005 [100]     | P        | K-wire                    | 40  | 8 (20)  | Radial         | NS   | NS          | SBRN                                 |
| Hove 1997 [101]      | P        | ORIF Dorsal Plate         | 31  | 3 (9.7) | Median         | 1    | Reg         | CTS                                  |
| Droberz 2003 [102]   | P        | Volar Plate               | 50  | 1 (2)   | Median         | NS   | GA or BP block | CTS                                  |
| Zytk 2011 [103]      | P        | ORIF Dorsal Plate         | 101 | 9 (9)   | Median         | 5    | NS          | CTS                                  |
| Chapman 1982 [80]    | R        | Pins                      | 80  | 11 (13.8)| Median Ulnar   | NS   | NS          | CTS, Ulnar paresthesias              |
| Arora 2007 [104]     | P        | Volar Plate               | 114 | 3 (2.6) | Median         | NS   | GA or BP block | CTS                                  |
| Bujani 1995 [95]     | R        | ORIF or Ex Fix Radius plus Ulna | 19  | 2 (10.5)| Median         | 0    | NS          | CTS                                  |
| Dennison 2007 [92]   | R        | Volar Plate, Radius plus Ulna | 5   | 2 (40)  | Radial         | 0    | NS          | Paresthesia of SBRN                  |
| Ego 2010 [105]       | R        | Case Control (Surgery vs Casting) | 90  | 6 (6.7) | Median         | 1    | NS          | CTS                                  |
| Arora 2011 [106]     | P-RCT    | Volar Plate vs nonoperative | 73  | 1 (1.4) | Median         | NS   | BP block, GA or Local | CTS                                  |
| Lattmann 2011 [107]  | P        | Volar Plate               | 245 | 11 (4.5)| Median         | NS   | NS          | CTS, Median N. irritation            |
| Krukhaug 2009 [79]   | P-RCT    | Bridging vs Nonbridging Ex Fix | 75  | 4 (5.5) | Radial         | NS   | NS          | SBRN                                 |
| Lutz 2014 [78]       | R        | ORIF Nonoperative         | 258 | 27 (10.5)| Median, Ulnar, Radial | NS   | NS          | CTS, Ulnar neurapraxia, SBRN         |
| Abbassadegan 1990 [108]| P-RCT   | Ex Fix vs Cast            | 47  | 1 (2.1) | Radial         | 0    | Local or Bier | Sensory disturbance SBRN            |
| Atoshi 2006 [109]    | P-RCT    | Ex Fix, Bridge vs Nonbridging | 38  | 1 (2.6) | Radial         | 0    | Reg or GA   | Numbness SBRN                        |
| Werber 2003 [110]    | P-RCT    | Ex Fix, 5 Pin vs 4 Pin    | 50  | 1 (2.0) | Median         | 0    | GA          | Paresthesia Thumb, Index, Long Finger |
| Sommerkamp 1994 [111]| P-RCT    | Ex Fix, Dynamic vs Static | 50  | 10 (20) | Median         | 0    | GA or AX    | Median N. dysfunction SBRN neuritis |
| Krishnan 2003 [112]  | P-RCT    | Ex Fix, Dynamic vs Static | 60  | 3 (5.0) | Radial         | NS   | NS          | SBRN Irritation                      |
| McQueen 1995 [113]   | P-RCT    | ORIF, Ex Fix or casting   | 120 | 8 (6.7) | Median         | NS   | NS          | CTS, Neurapraxia SBRN                |
| Rodriguez-Merchan 1997 [114] | P-RCT | Cast vs Pinning | 40  | 1 (2.5) | Median         | 1    | Local, GA, or BP block | Median neuropathy                     |
| Stoffelen 1998 [115] | P-RCT    | Cast vs Pinning           | 98  | 8 (8.2) | Median         | 1    | NS          | Median N. contusion SBRN injury      |
| Howard 1998 [116]    | P-RCT    | Cast vs Pinning           | 50  | 10 (20) | Median, Radial, Ulnar | NS   | NS          | Median and SBRN neuritis Ulnar N. compression |
| Horne 1990 [117]     | P-RCT    | Cast vs Pinning           | 29  | 4 (13.8) | Radial         | NS   | BP Block    | SBRN Irritation                      |
| Lenoble 1995 [118]   | P-Comp   | Pin Fixation (two types)  | 96  | 11 (11.5)| Radial         | 11   | GA or Regional | SBRN                                 |
| Castellon 1992 [119] | P-RCT    | K-wire vs Ribs            | 30  | 2 (6.7) | Median         | 0    | GA or Regional | CTS                                  |

Ex Fix denotes external fixation; ORIF denotes open reduction-internal fixation; BP block denotes unspecified brachial plexus block; comp denotes comparative (but nonrandomized) study.
However, the considerable range of reported neurologic injury related to surgical intervention in the studies cited suggests that simple prediction of injury is difficult, as a myriad of patient and surgical factors provide variability in outcome. While we found that transient nerve dysfunction resulting from wrist and hand surgery is not rare, the likelihood of permanent nerve injury is small. In addition, the limited number of studies that specified the actual type of anesthetic used makes it difficult to make any definitive conclusions about the impact of this factor on reported nerve dysfunction.

This narrative review is limited by the nature of the literature itself: there are countless small studies and case series in the hand/wrist surgical literature, which defy comprehensive reporting in a single article. We sought to summarize a representative range of reported neurologic complications without citing every existing study; thus some degree of bias could exist in this narrative review. A further limitation is the manner in which neurologic compromise is described in this literature: it is frequently reported as a secondary outcome, making searches challenging and requiring considerable use of secondary and tertiary citations extracted manually from the investigations identified by search services. Finally, the retrospective nature of many of these studies may underestimate the presence of nerve injuries, which are more commonly identified when sought actively and in prospective fashion.

Understanding the patterns of iatrogenic nerve dysfunction associated with common foream and wrist and hand procedures is important for orthopedic and hand surgeons. This knowledge is also beneficial for anesthesiologists when planning the most appropriate regional techniques, and may assist in the diagnosis and guide therapy when neurologic complications arise. Although it may be impossible to determine the exact cause of neurologic compromise, knowing the most common presentation with respect to specific procedures may aid in overall patient care, and in obtaining informed consent for anesthetic and operative procedures.

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