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. Secondarily, 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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Overall risk of postoperative neural dysfunction after hand/wrist surgery

Because of the large variety of different hand and wrist procedures, it is difficult to quantify the risk involved in all types of surgery in this region of the body. Several reviews or large database studies have provided perspective on neurologic dysfunction after wrist and/or hand surgery. In a review article with 10,646 patients who underwent a number of different of hand/wrist procedures, Lipira *et al.* (2015) reported only 4 peripheral nerve injuries (0.04%).[2] In an overall evaluation of nerve injury related to compression, in both trauma and in surgery to the hand, Figus *et al.* (2007) reported 42 cases of adverse neurologic outcome from elective surgery, with most resulting from Dupuytren's contracture release.[3] Antoniadis *et al*. (2014) reviewed the causes of iatrogenic nerve injury; among 340 patients referred to their practice for surgical correction of nerve injury, 16.5% were the result of a surgical procedure. The most frequent site of surgical nerve injury was the wrist, with the median nerve most commonly injured.[4] In a similar analysis of iatrogenic nerve injuries, Kretchmer *et al*. (2004) assessed 191 patients with surgically-induced neuropathy and reported that 25 (13.1%) involved the median nerve after carpal tunnel release (CTR), osteosynthesis or ganglion surgery, and 13 (6.8%) involved the sensory branch of the radial nerve (SBRN), which was injured by Kirschner wire (K-wire) insertion, ganglion resection, tenolysis or removal of hardware.[5] In other studies of surgery-related nerve injury in the distal upper extremity, ulnar nerve injuries and digital injuries are also noted.[6]

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.[7] 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.[8,9] 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.[10] 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.[11] Overall, neurologic dysfunction has been reported in a range of 0 to 16.7% after wrist arthroplasty (Table 1),[9,10,12-20] with a mean incidence of 4.6% [95% CI 3.2-6.6%].

Wrist arthrodesis

Wrist fusion, or arthrodesis, is carried out to address a myriad of conditions that result in wrist instability or pain, including inflammatory, degenerative and traumatic etiologies. This was considered the intervention of choice for such maladies until the advent of wrist arthroplasty, and is still frequently performed for those in whom arthroplasty is not deemed appropriate. Arthrodesis may involve the entire wrist joint, or only a portion of it, in techniques such as scaphoid excision, four-corner fusion, scaphotrapezioid fusion and radiocarpal fusion.[19] Whether arthrodesis is total or limited to the radiocarpal or midcarpal regions, the goal is to provide relief of pain and preservation of as much function as possible, since mobility at the wrist is more important than the ability to exert force.[19,20] Nerve dysfunction in the aftermath of arthrodesis has been reported in 0-35% of cases,[21-36] though postoperative carpal tunnel syndrome from pressure on the median nerve may occur in 10-25%, accounting for a large proportion of these neurologic symptoms.[19,21,22] Among the studies noted, the mean incidence of nerve dysfunction was 9.7% [95% CI 7.8-12.1], with a range from 0 to 22.6%. Plate fixation has been associated with a higher risk of nerve injury than other types of arthrodesis in some studies[23] but not in others.[24] During this surgical procedure, the highest neurologic risk appears to be to the dorsal sensory branch of the ulnar nerve (DSBUN) and to the sensory branch of the radial nerve (SBRN).[20] In an anatomic investigation in cadavers, Mok *et al*. (2006) described the course of the DSBUN, SBRN and lateral antebrachial cutaneous nerves (LABCN), over the dorsum of the wrist and hand,[25] emphasizing the importance of caution with surgical incisions in this area. They also noted frequent dual innervation by the SBRN and DSBUN which may mitigate sensory loss after surgical procedures in this region.

Table 1. Neurologic complications reported in wrist arthroplasty.

Author	Design	Approach	N.	Rate/NI	Nerves	Perm	Anesthesia	Remarks
Murphy 2003 [10]	R	Universal vs Arthrodesis	27	3 (11.1)	Median	1	NS	CTS
Van Harlingen 2011 [12]	P	3rd Generation	32	3 (9.4)	Median, Ulnar	NS	NS	CTS, Ulnar N. sensory loss
Herzberg 2012 [13]	P	Remotion Prothesis	215	8 (3.7)	Median	NS	NS	CTS
Cooney 2012 [9]	R	Resection vs Resurfacing	46	0 (0)			Ax Block	
Gellman 1997 [14]	R	Volz Prothesis	14	0 (0)		NA	NS	
Nydick 2012 [15]	R	Maestro	23	0 (0)		NA	UE Block	
Gaspar 2016 [20]	R	Partial vs Total Arthroplasty	105	5 (4.9)	Median, ulnar	NS	NS	CTS, Guyon's canal syndrome
Dennis 1986 [16]	R	Volz Arthroplasty	30	4 (13.3)	Median	NS	NS	CTS
Takwale 2002 [17]	P	Biaxial Prothesis	66	0 (0)			NS	CTS
Rahimtoola 2003 [18]	P	RWS Prosthesis	27	3 (11.1)	Median	0	NS	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.[37] 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.[38] 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.[39] 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),[37-38,40-52] with a mean incidence of 3.6% [95% CI 2.4-5.3]. Portals 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.[40-44] In addition, mid-carpal portals are placed in close association to the distal, sensory portion of the posterior interosseous nerve.[43] 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 DSBUN.[45,46]

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.[53] 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).[53-76] 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.[54] The median nerve, and its palmar cutaneous branch (PCBMN), appear to be the most frequently affected with this surgical procedure.[55-57] 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.[58] 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).[59] 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%.[60] As with most surgically-associated neurologic complications, the great majority appear to be temporary.[58,61,62] 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.[63]

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.[77] 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.[78-81] Nerve dysfunction in the wake of surgical intervention is reported in a rather large range, from 0-22%,[82-84] 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.[85,86] 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).[78-119] Other nerves that may be affected include the PCBMN, ulnar nerve and LABCN, though these are much less common.[87] *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.[84]

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 2. Neurologic complications reported in wrist arthroscopy.

Author	Design	Approach	N.	Rate/NI	Nerves	Perm	Anesthesia	Remarks
Estrella 2007 [47]	P	TFCC Repair	35	6 (17.1)	Ulnar	1	NS	Sens. Disturb, DSBUN
Darlis 2005[48]	R	SL Ligament Repair	16	1 (6.3)	Median	0	NS	CTS
Nagle 1992 [37]	R	Dx, Staging and Therapeutic	84	0 (0)			AX 54, GA 30	
Hofmeister 2001[49]	P	Midcarpal and Radiocarpal ports	89	0 (0)			GA or Reg	
Trumble 1997 [50]	P	TFCC Repair	24	1 (4.2)	Ulnar	0	NS	Paresthesia of DSBUN
Grechenig 1999 [47]	P	Dx, Staging and Therapeutic	96	4 (4.2)	Ulnar Median	1	NS	Irritation of DSBUN Irritation of Median N.
Beredjiklian 2004 [38]	R	Dx, Therapeutic	211	4 (1.9)	Ulnar	0	Reg 52 GA 159	DSBUN and Ulnar Neurapraxia
Cobb 2011[51]	P	Resection Arthroplasty	35	5 (14.3)	Radial	0	NS	Paresthesia SBRN
Doi 1999 [52]	P/RCT	Arthroscopic *vs* Open Fracture repair	82	3 (3.7)	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.

LABCN and SBRN.[88,89] While some authors espouse *safe zones* based on surface and boney landmarks, others note that the variability of the course of such superficial nerves is too great to allow blind placement of fixation devices.[89] A *semi-open* technique, in which small incisions are made, with avoidance of any nerve branches found by inserted pins, may reduce such injuries.[90] The incidence of nerve dysfunction with percutaneous placement of external fixation devices or pins is comparable to that of open surgical management, ranging from 0.4-20%.[80,81] Surgery to correct distal ulnar fracture also poses risks to neurologic structures, particularly branches of the ulnar nerve, [91,92] but the median nerve may be compromised as well.[93]

Thumb carpometacarpal surgery

The thumb is used for most pinching and grasping functions of the hand, and therefore it is subject to significant degradation over time, resulting in osteoarthritis at the carpo-metacarpal (CMC) joint. Women have a greater predilection for degenerative arthritis at this joint than men.[120] Because many daily activities are markedly affected by the pain of arthritic changes at the CMC joint, surgical intervention is common. Surgical management of arthritis in the distal upper extremity is most frequently provided at this joint.[121] Either arthrodesis of the trapeziometacarpal (TMC) joint or one of several different types of arthroplasty may be applied to reduce pain and restore function. These include ligament reconstruction, metacarpal osteotomy, and trapezius excision, which may include soft-tissue interposition.[122] Because the incisions for thumb CMC arthroplasty or reconstruction are at the base of the thumb, the dissection is adjacent to the branches of both the SBRN and the LABCN.[25] The mean reported postoperative neurologic dysfunction rate is 7.9% [95% CI 6.6-9.3], with a range from 0% to 35.7 % (Table 5). The particularly high rate was reported by Mureau *et al*. (2001) in 24 patients who received tendon interposition arthroplasty.[120-139] Specific techniques to spare the SBRN have been reported to be successful in some series.[120]

Peripheral nerve blockade *versus* other types of anesthesia

We also sought to evaluate the impact of regional anesthesia procedures on the reported frequency of nerve issues, but this proved difficult. Among the 138 studies evaluated, only 17 of them reported the specific type of anesthesia. Six noted the use of peripheral nerve block (PNB), either as axillary block, *brachial plexus block*, or simply as *regional block*. Another 11 cited use of either general anesthesia (3), local anesthesia (6) or Bier block (2), none of which would likely cause an impact on a defined peripheral nerve. While we are able to summarize the incidence of injury with regional blocks [2.0% (1.0-3.9)] as well as the incidence with these three types of non-PNB anesthesia [0.14% (0.1-0.2)], the small numbers of studies could likely lead to inaccuracy. Many authors noted *regional or general* anesthesia without differentiating, in the results, which patients had received which type of anesthesia, with relation to postoperative neurologic complaints.

Table 3. Neurologic Complications Reported in Carpal Tunnel Release.

Author	Design	Approach	N.	Rate/NI	Nerves	Perm	Anesthesia	Remarks
Shinya 1995 [64]	P	ECTR, Single Portal	107	0 (0)		NA	NS	
Chow 1990 [61]	R	ECTR, Single Portal	142	1 (0.7)	Ulnar	0	NS	Temporary loss of interosseous muscle fxn
Brown 1993 [65]	P-RCT	Open vs ECTR	169	2 (1.2)	Digital, Ulnar	0	Regional	Digital N. contusion; Ulnar N. neurapraxia
Uchiyama 2007 [66]	P	ECTR, modified Chow technique	119	(1.2)	Median	0	Local	Mumbness, Weakness
Nagle 1996 [67]	P	ECTR Chow extra- versus transbursal	640	14 (2.2)	Median, Ulnar, Digital	NS	NS	Neurapraxia
Pajardi 2008 [60]	R	ECTR	12,702	6 (0.05)	Median Digital	NS	Local	Neuroma PCBMN "complete" digital
MacDonald 1978 [56]	R	Open	186	11 (5.9)	Median	NS	NS	PCBMN
Lichtman 1979 [68]	P	Open	100	2 (2)	Median	NS	Local	Neuroma PCBMN
Sennwald 1995[69]	P-RCT	ECTR vs Open	47	1 (2.1)	Digital	NS	Regional	Neurapraxia
Ferdinand 2002 [70]	P-RCT	ECTR vs Open	50	1 (2.0)	Median	NS	General	likely PCBMN injury
Agee 1995 [71]	P	ECTR	883	11 (1.2)	Median, Digital	1	AX, Bier, GA, Local	Abnormal Sensation
Muller 2000 [59]	P	ECTR	100	12 (12)	Ulnar, Digital	0	NS	Ulnar N. neuropraxia, Digital N. contusion
Agee 1992 [72]	P-RCT	ECTR vs Open	147	2 (1.4)	Ulnar	0	GA or Regional	Ulnar N. neuropraxia.
Saw 2003 [73]	P-RCT	ECTR vs Open	150	1 (0.7)	Median	0	Local	Transient Numbness Index Finger
Erdmann 1994 [53]	P-RCT	ECTR vs Open	105	1 (0.95)	Ulnar	0	NS	Paresthesia
Helm 2003 [74]	P-RCT	Knifelight vs Open	82	1 (1.2)	Median	0	Local	Numbness index finger
Jacobsen 1996 [75]	P-RCT	ECTR	32	3 (9.4)	Median	0	Bier	Numbness ring finger
Bhattacharya 2004 [76]	P-RCT	Knifelight *vs* Open	52	1 (1.9)	Median	0	Local	Palmar Numbness

ECTR denotes endoscopic carpal tunnel release; fxn 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[60] 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)			NS	
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 [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 Radial	NS	NS	Median N. neuropathy, SBRN
Tarallo 2013 [99]	R	Volar Plate	303	5 (1.7)	Median	NS	NS	CTS, Median N. neuropathy
Esenwein 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 Radial	1	Reg	CTS SBRN
Drobetz 2003 [102]	P	Volar Plate	50	1(2)	Median	NS	GA or BP block	CTS
Zyluk 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 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
Dennison 2007 [92]	R	Volar Plate, Radius plus Ulna	5	2(40)	Radial	0	NS	Paresthesis of SBRN
Egol 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 *vs* Nonoperative	258	27(10.5)	Median, Ulnar, Radial	NS	NS	CTS, Ulnar neurapraxia, SBRN
Abbaszadegan 1990 [108]	P-RCT	Ex Fix *vs* Cast	47	1(2.1)	Radial	0	Local or Bier	Sensory disturbance SBRN
Atroshi 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 Radial	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 Radial	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 Radial	1	NS	Median N. contusion SBRN injury
Howard 1989 [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
Casteleyn 1992 [119]	P-RCT	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 amalgum 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	
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 [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 Radial	NS	NS	Median N. neuropathy, SBRN
Tarallo 2013 [99]	R	Volar Plate	303	5 (1.7)	Median	NS	NS	CTS, Median N. neuropathy
Esenwein 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 Radial	1	Reg	CTS SBRN
Drobetz 2003 [102]	P	Volar Plate	50	1(2)	Median	NS	GA or BP block	CTS
Zyluk 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 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
Dennison 2007 [92]	R	Volar Plate, Radius plus Ulna	5	2(40)	Radial	0	NS	Paresthesis of SBRN
Egol 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 *vs* Nonoperative	258	27(10.5)	Median, Ulnar, Radial	NS	NS	CTS, Ulnar neurapraxia, SBRN
Abbaszadegan 1990 [108]	P-RCT	Ex Fix *vs* Cast	47	1(2.1)	Radial	0	Local or Bier	Sensory disturbance SBRN
Atroshi 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 Radial	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 Radial	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 Radial	1	NS	Median N. contusion SBRN injury
Howard 1989 [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
Casteleyn 1992 [119]	P-RCT	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.

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 forearm 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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