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ORIGINAL ARTICLE

Hand/Peripheral Nerve

Is It the Surgery or the Block? Incidence, Risk Factors, and Outcome of Nerve Injury following Upper Extremity Surgery

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Background: Although numerous studies have addressed the topic of postoperative nerve injury, debate continues to exist on its exact incidence, risk factors, etiology, and functional outcome. The aim of this study is to investigate the incidence of nerve injury and to identify patient, anesthetic, and surgical factors pertaining to perioperative nerve injury. Also, long-term nerve injury outcomes were assessed in terms of functionality.

Methods: A total of 297 patients, scheduled for elective distal upper extremity surgery, were prospectively included. At various time points, patients were screened for new onset nerve injury by means of clinical examination and questionnaires (including the Quick Disabilities of the Arm, Shoulder and Hand functionality measure).

Results: New nerve injury was diagnosed in 14 patients [4.7% (95% CI, 2.8–7.8)], but no causative risk factors were identified. The exact origin of nerve injury is suspected to be surgical in 11 cases. At 4 years postoperatively, 5 of the 14 patients with nerve injury (36%) were still symptomatic and had reduced functionality relative to preoperative status.

Conclusions: This study demonstrates an incidence of all cause nerve injury of 4.7%. No specific patient, anesthetic, or surgical risk factors are identified and, importantly, patients who received regional anesthesia are not at more risk of nerve injury than those who received general anesthesia. The exact origin of nerve injury is very difficult to determine, but is suspected to be caused by direct surgical trauma in most cases. Four years following the nerve injury, approximately 40% of the patients with new onset nerve injury have reduced functionality. *(Plast Reconstr Surg Glob Open 2019;7:e2458; doi: 10.1097/GOX.0000000000002458; Published online 27 September 2019.)*

INTRODUCTION

Postoperative nerve injury can create high levels of anxiety for both patient and clinician.[1] Especially in distal upper extremity surgery, nerve injury is dreaded because of the serious consequences for affected patients.[2] Although numerous studies have addressed this topic, debate continues as to the exact incidence, etiology, and risk factors of nerve injury.[2–4] When presented with a patient with postoperative nerve injury, discussion frequently exists as to the cause of this injury, especially with patients who have undergone surgery under regional (plexus) anesthesia. Is the nerve injury a complication of the surgery or related to the block? To answer this question, the current prospective double-centered observational study was designed.

The primary endpoint of this study is the incidence of all cause new postoperative nerve injuries, in patients undergoing elective plastic surgery on the distal upper limb under both regional and/or general anesthesia. The secondary endpoint of this study is to identify patient, anesthetic, and surgical risk factors pertaining to per operative nerve injury. Third, long-term nerve injury outcomes were assessed in terms of functionality.

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METHODS

The current study was carried out by the Departments of Anesthesiology and Plastic Surgery of 2 hospitals: a large university hospital and a teaching hospital. Patients scheduled for elective upper extremity surgery between October 2012 and October 2013 were consecutively requested to enroll following their outpatient visits. All patients included in this study gave written informed consent and met the following inclusion criteria: 18 years and older and scheduled for elective surgery of the distal upper extremity by a fellowship trained hand surgeon. Nonelective surgery patients (eg, traumatic amputations) were excluded, as were patients with injury of more than one nerve. Single nerve disease, such as carpal and cubital tunnel syndrome, was not excluded. The local Medical Ethics Committee of both hospitals reviewed and approved this study (October 11, 2012, number 2012–327).

Preoperatively

Preoperatively, all patients completed a survey to screen for preexisting nerve injury. This survey included both questions on pain and abnormal sensation, and the validated Dutch language version of the Quick Disabilities of the Arm, Shoulder and Hand (Quick DASH) Outcome Measure [see appendix, Supplemental Digital Content 1, which displays the patient survey (Translated from Dutch), http://links.lww.com/PRSGO/B230]. The Quick DASH is constructed to measure motor and sensory function and symptoms in people with any or multiple musculoskeletal disorders of the upper limb.[5,6] It is an 11-item questionnaire scored in 2 components: the disability/symptom section (11 items, scored 1–5), and the optional high performance sport/music or work module (4 items, scored 1–5). The optional module is beyond the scope of this study because it is intended for athletes, performing artists, and other groups of workers whose jobs require high levels of physical performance. The values for the questions in the disability/symptom section can be transformed on to a 0%–100% functionality scale; with 0%–20% being normal, 20%–40% being mild disability, 40%–60% moderate disability, and 60%–80% severe disability.

In addition to the preoperative survey, a fellowship trained hand surgeon examined all patients in the outpatient clinic. Patients were subjected to a structured history-taking and extensive clinical examination to confirm the indication for surgery and to identify preexisting nerve injury. History taking consisted of assessment of the patient's chief presenting complaint (exacerbation/improvement/frequency/duration) and past and present medical conditions. Physical examination consisted of inspection, palpation, assessment of the range of motion, neurologic assessment (motor/sensory testing and bilateral comparison), and additional functional tests if applicable. Autonomic dysfunction was suspected in the presence of abnormal sweating, skin color, skin temperature, and/or hair growth. Patients with preexisting nerve injury were excluded from participation in this study.

Intraoperatively

The treating physicians were free to determine the treatment strategies for their patient with regard to the type of anesthesia and surgical technique. The actual general anesthesia technique and medications used were at the discretion of the anesthesiologist. In patients receiving brachial plexus anesthesia, the use of ultrasound, nerve stimulator, needle type and diameter, and other equipment necessary for block performance was left to the discretion of the anesthesiologist. Also, dose (mg/kg) and volume (mL) of local anesthetic used was determined by the treating physician. Bier block was performed using a double tourniquet, followed by injection of 30–40 mL prilocaine 1%. Additional analgesia and sedation used during block performance or surgery consisted of one or a combination of alfentanil, sufentanil, propofol, and midazolam. In all patients, postoperative medication included paracetamol plus a nonsteroidal anti-inflammatory drugs and/or tramadol, with morphine as rescue medication if needed during admission.

The hand surgeon decided on the type of surgery, additional individual intraoperative distal nerve blocks, and tourniquet use. Duration of tourniquet use is limited, where possible, to a maximum of 120 min and an inflation pressure of 130 mm Hg greater than the systolic blood pressure, with a maximum of 180 mm Hg. Intraoperatively, blocks were placed by the plastic hand surgeon, using either lidocaine, ropivacaine, or bupivacaine. Patients scheduled for local infiltration anesthesia alone were operated on without any input from the anesthesiologist.

Postoperatively

Postoperatively, data on nerve injury were collected at varying time points. As per standard postoperative care, the treating plastic hand surgeon reviewed all patients at 2 and 6 weeks postoperatively. As preoperatively, patients were subjected to a structured history-taking and extensive clinical examination to identify new onset nerve injury. Outpatient follow-up beyond 6 weeks postoperatively was left to the discretion of the treating plastic hand surgeon. Additionally, before the week 2 and week 6 outpatient review, all patients completed the same survey (including the Quick DASH) as they did preoperatively [see appendix, Supplemental Digital Content 1, which displays the patient survey (Translated from Dutch), http://links.lww.com/PRSGO/B230].

Outcome

Nerve injury following the operation was defined as a new onset of motor and/or sensory deficit, nonresolving paresthesia, pain, allodynia, dysesthesia, and/or any other neurologic deficits found on physical examination by the plastic hand surgeon. These symptoms had to be nonresolving and needed to be present at the 6-week outpatient review. Nerve injury included all types of injury as described by Seddon (neuropraxia, axonotmesis, and neurotmesis).[1] Nerve injury was diagnosed by careful clinical assessment of motor, sensory, and autonomic function. If additional information on a nerve injury was needed, neurophysiological testing (eg, referral to a neurologist for nerve conduction studies and electromyography) was

Table 1. Characteristics of Patients with and without New Nerve Injury

	No Nerve Injury (n = 283)	Nerve Injury (n = 14)	*P*
Male (n)	128 (45.2%)	3 (21.4%)	0.101
Female (n)	155 (54.8)	11 (78.6%)	
Age (years)	51.3 ± 16.0	50.5 ± 14.5	0.857
BMI (kg/m²)	25.0	24.6	0.452
(IQR)	(23.2 – 28.0)	(22.7 – 27.8)	
Diabetes mellitus (yes)	19 (6.7%)	0	1.000
ASA-classification*			0.509
ASA 1 (n)	127 (44.9%)	7 (50.0%)	
ASA 2 (n)	146 (51.6%)	6 (42.9%)	
ASA 3 (n)	10 (3.5%)	1 (7.1%)	

Data are presented as "valid percentage," "mean ± SD," and "median (IQR)."
*ASA-classification (class 1–6), according to The ASA classification system.
ASA, The American Society of Anesthesiologists; BMI, body mass index; IQR, interquartile range.

performed. Treatment of a suspected nerve injury was left to the discretion of the treating plastic hand surgeon.

At 4 years following surgery, all patients with new onset nerve injury were contacted, and completed the same survey on pain and sensory/motor function (including the Quick DASH) as they did preoperatively and at 2 and 6 weeks postoperatively [see appendix, Supplemental Digital Content 1, which displays the patient survey (Translated from Dutch), http://links.lww.com/PRSGO/B230].

Statistical Analysis

Continuous variables were tested for normality of the distribution and were presented as mean (± SD) or median (+ IQR). For continuous variables, an unpaired t-test and Mann–Whitney U test were applied as appropriate. For categorical variables, Fisher's exact test was used. The Wilson method was used for calculating the CI. A *P* value of 0.05 or less was considered statistically significant.

RESULTS

A total of 335 patients agreed to participate in this study. After excluding 38 patients with preexisting nerve injuries before surgery, a total of 297 patients were suitable for analysis. Four patients were included twice in this study, as they had two unrelated distal upper limb operations performed within the inclusion period. Patient characteristics and anesthesia/surgical details are summarized in Tables 1 and 2. Type of surgery performed is shown in Table 3. Following surgery, 14 of the 297 patients were identified with new onset nerve damage; detailed characteristics are shown in Table 4.

The incidence of new onset nerve injury is 4.7%, with a 95% CI of 2.8 to 7.8. No patient characteristics were found to be statistically significant risk factors for nerve injury, although 79% of the patients with nerve injury are female (Table 1). Regional anesthesia, including type of regional anesthesia technique, was not shown to be associated with a higher risk of nerve injury compared with general anesthesia (Table 2). A total of 5 of the 92 patients receiving general anesthesia and 9 of the 189 patients receiving regional anesthesia had new nerve injuries (Table 2). Procedural characteristics of the regional block placement (such as the use of ultrasound, nerve stimulator, paresthesia, and sedation) had no significant influence on the onset of nerve injury (Table 2). Surgical factors,

Table 2. Characteristics of Anesthesia Technique Used in Patients with and without New Nerve Injury

	Total	No Nerve Injury	Nerve Injury	*P*
Type of anesthesia (n)	297	283	14	
General anesthesia alone	92	87 (30.7%)	5 (35.7%)	0.933
Local anesthesia (surgeon)	16	16 (5.7%)	0	
Regional anesthesia:	189			
Regional block alone		146 (51.6%)	9 (64.3%)	
Regional block + general anesthesia (scheduled)		19 (6.7%)	0	
Regional block + general anesthesia (conversion)		15 (5.3%)	0	
Type of regional anesthesia (n)	189	180	9	
Non plexus blocks	40			0.452
Bier block		39 (21.6%)	1 (11.1%)	
Plexus blocks	149			
Pippa block		1 (0.6%)	0	
Vertical infraclavicular block		1 (0.6%)	0	
Interscalene block		3 (1.6%)	0	
Supraclavicular block		18 (10.0%)	3 (33.3%)	
Axillary plexus block		118 (65.6%)	5 (55.6%)	
Plexus blocks details (n)*	149	141	8	
Sole use of ultrasound (n)		32 (22.7%)	4 (50.0%)	0.097
Sole use of nerve stimulator (n)		15 (10.6%)	0	1.00
Combined use (n)		94 (66.7%)	4 (50.0%)	0.449
Threshold nerve stimulator ≤ 0.2mA, at 0.1ms		10	0	1.00
Paresthesia during block placement (yes)		9 (6.4%)	0	1.00
Sedation during block placement (yes)		88 (62.4%)	5 (62.5%)	1.00
Surgical details (n)	297	283	14	
Additional block by surgeon or anesthetist		61 (21.6%)	2 (14.3%)	0.314
Tourniquet use		274 (96.8%)	14 (100%)	1.00
Tourniquet pressure (mm Hg)		250	250	0.751
(IQR)		(220 – 250)	(223 – 260)	
Duration of tourniquet use (min)		45.0	41.0	0.694
(IQR)		(30 – 65)	(30.0 – 56.0)	

Data are presented as "valid percentage" or "median (IQR)."
*Ultrasound or nerve stimulator are never used in performing the Bier block or local anesthesia and are therefore left out.
IQR.

Table 3. Type of Surgery Details for Patients with and without New Nerve Injury

	No Nerve Injury (n = 283)	Nerve Injury (n = 14)	*P*
Arthrodesis/arthroplasty	34 (12.0%)	5 (35.7%)	0.456
Carpal tunnel syndrome	14 (4.9%)	1 (7.1%)	
Cubital tunnel syndrome	2 (0.7%)	0	
Dupuytren's contracture	80 (28.3%)	3 (21.4%)	
Finger-joint replacement	3 (1.1%)	0	
Ganglion cyst removal	13 (4.6%)	0	
Ligament repair surgery	16 (5.7%)	0	
Neuroma excision	4 (1.4%)	0	
Placement of osteosynthesis material	4 (1.4%)	1 (7.1%)	
Proximal row carpectomy	2 (0.7%)	0	
Quervain's release surgery	6 (2.1%)	1 (7.1%)	
Removal of osteosynthesis material	4 (1.4%)	0	
Tendon repair surgery	9 (3.2%)	0	
Tenolysis	2 (0.7%)	1 (7.1%)	
Trigger finger release	12 (4.2%)	0	
Ulnar nerve transposition	9 (3.2%)	0	
Wrist arthroscopy	19 (6.7%)	2 (14.3%)	
Miscellaneous	50 (17.7%)	0	

Data are presented as "valid percentage."

such as tourniquet use or type of surgery, were also not shown to be associated with nerve injury (Tables 2 and 3). A subanalysis on the type of surgery did not show a statistically significant difference in anesthesia technique used (including type of plexus block) for the various types of surgical procedures.

In terms of the etiology of the 14 identified nerve injuries, in 11 patients a surgical and in two patient an anesthetic origin was suspected. In one patient, the origin of nerve injury was inconclusive.

In those 11 patients with a suspected surgical cause of injury, nerve injury was clearly identified in one during surgical exploration (Table 4, no. 1). In four patients, no needles were ever placed perineurally; 3 patients received general anesthesia and 1 a Bier block, and no additional blocks were placed intraoperatively (Table 4). Thus, in these 4 patients, a surgical cause of the nerve injury was strongly suggested. In 6 of the remaining 11 patients, a surgical cause of injury was suspected given the location of the signs and symptoms diagnosed by the hand surgeon during postoperative outpatient follow-up.

In the two patients with a suspected anesthesia cause of injury, the affected nerve was not in the direct surgical field, and therefore, an anesthetic cause was suspected (Table 4, no. 12 and 13). These two patients received an axillary brachial plexus block before surgery.

Finally, in one patient, the distribution of nerve injury coincided with the surgical and anesthetic region, making distinction between these 2 factors impossible (Table 4, no. 14).

Quick DASH scores, obtained preoperatively and at 4 years following surgery, are shown in Table 4. Scores were obtained in 12 of the 14 patients with nerve injury; one patient deceased 5 weeks postoperatively of cardiac cause, and 1 patient was lost to follow up at 4 years postoperatively. Preoperative Quick DASH scores are compared with the scores at 4 years following surgery.

Five patients had an increase in Quick DASH scores; representing a decrease in functionality compared with preoperatively (Table 4). In 6 patients, scores were lower than before surgery, representing an improvement in functionality following surgery (Table 4). One patient had equal scores preoperatively and postoperatively, and thus no change in functionality over time (Table 4).

At 4 years following surgery, all 5 patients with a decrease in functionality reported abnormal sensations of the hand or forearm, as scored on the survey on pain and sensory/motor function [see appendix, Supplemental Digital Content 1, which displays the patient survey (Translated from Dutch), http://links.lww.com/PRSGO/B230].

DISCUSSION

Incidence of Nerve Injury

This study identifies an incidence of 4.7% for new onset nerve injury, which is within the range of that reported in the preexistent literature on peripheral nerve injury following distal upper extremity injury. Previous studies have reported incidences of 0.01%–14%.[2–4,7–9] However, data in many of these studies were collected retrospectively, by means of voluntary reported incidents, or by closed claims analysis and could therefore very well be an unrealistic representation of the real incidence of nerve injury.

Patient Risk Factors

Previously published studies have suggested that the patients most susceptible to perioperative nerve injury include male gender, the extremes of age and bodyweight, and patients at risk of vascular disease.[10,11] Interestingly, the current study does not match the gender expectations for nerve injury, with 79% of the patients with identified nerve injury being female. It has been reported that the very young, elderly, and underweight population have more superficial positioning of nerves, which are therefore more vulnerable to injury.[11] In the obese patient, it can be challenging to properly pad and protect the pressure points and therefore nerve injury due to external compression is possible.[11] The current study does not identify age or BMI as a risk factor, although admittedly, the study population does not include vast extremes in age and BMI. Hypertension, smoking, diabetes mellitus,

Table 4. Details of All 14 Patients with Nerve Injury

No.	Medical History	Surgery and Anesthesia Details	Tourniquet	Type of Nerve Injury and Details	Quick-DASH*
Suspected Surgical Origin of Nerve Injury					
1	PVD: negative/smoking: positive COPD arthrodesis CMC-2/3, with botulin injections for dystonia	Surgery: arthrodesis/arthroplasty Details: distal pole resection of the scaphoid for arthrosis Anesthesia: general anesthesia/no additional block	200 mm Hg 36 min	Signs: dysesthesia (first to thrid finger) EMG: none Origin: complication of the surgery (focal crush and neurotmesis median nerve on re-exploration)	Deceased 5 weeks postoperatively (cardiac cause)
2	PVD: negative/smoking: negative dupuytren's contracture (left fifth finger)	Surgery: dupuytren's contracture Details: open fasciotomy (left fifth finger) Anesthesia: ABPB/US and NS/no additional block	250 mm Hg 60 min	Signs: dysesthesia in the ulnar side of the fifth finger (UDN paresthesia) EMG: none Origin: related to surgery	0%–9% (Decreased functionality)
3	PVD: negative/smoking: positive hypertension COPD	Surgery: quervain's release surgery Details: decompression of the first extensor compartment and ganglion excision Anesthesia: SCBPB/US/no additional block	280 mm Hg 16 min	Signs: dysesthesia of two nerves in operative field (RSN paresthesia and LABCN neuropraxia) EMG: none Origin: related to surgery	56%–59% (Decreased functionality)
4	PVD: negative/smoking: negative arthrodesis for CMC-1 arthrosis	Surgery: arthrodesis/arthroplasty Details: resection of part of trapezoid for pain Anesthesia: SCBPB/US/no additional block	250 mm Hg 41 min	Signs: dysesthesia of the RSN (nerve in surgical field) EMG: none Origin: related to surgery	59%–59% (equal functionality)
5	PVD: negative/smoking: negative hypertension	Surgery: arthrodesis/arthroplasty Details: soft tissue interposition PRC with styloidectomy for arthrosis Anesthesia: general anesthesia/no additional block	260 mm Hg 40 min	Signs: signs of CRPS and dysesthesia of the RSN EMG: none Origin: related to surgery/not related to regional anesthesia	39%–52% (Decreased functionality)
6	PVD: negative/smoking: negative arthrodesis MTP-1, complicated by CPRS	Surgery: arthrodesis/arthroplasty Details: trapezial excision and LRTI for CMC-1 arthrosis Anesthesia: general anesthesia/no additional block	250 mm Hg 30 min	Signs: RSN allodynia in the direct operative field EMG: none Origin: related to surgery/not related to regional anesthesia	75%–41% (Increased functionality)
7	PVD: negative/smoking: negative right-sided carpal tunnel release, complicated by neuropraxia	Surgery: carpal tunnel syndrome Details: left-sided carpal tunnel release Anesthesia: bier block/no additional block	250 mm Hg 35 min	Signs: dysesthesia (fourth and fifth finger) EMG: none Origin: related to surgery/not related to regional anesthesia	39%–21% (Increased functionality)
8	PVD: negative/smoking: negative traumatic amputation of the distal part of the second finger, without neurological deficits	Surgery: miscellaneous Details: neurolysis of the lateral digital nerve for neuropathic pain (second finger) Anesthesia: general anesthesia/additional block base of digit 2	200 mm Hg 17 min	Signs: RDN paresthesia (first to third finger) EMG: no signs of carpal tunnel syndrome or medial nerve compression Origin: related to surgery/not related to regional anesthesia	23%–5% (Increased functionality)
9	PVD: negative/smoking: negative no relevant history	Surgery: miscellaneous Details: operative fixation of a middle phalanx fracture (fifth finger) Anesthesia: SCBPB/US/additional block ulnar nerve	230 mm Hg 45 min	Signs: dysesthesia (fifth finger) EMG: none Origin: related to surgery	34%–43% (Decreased functionality)
10	PVD: negative/smoking: negative carpal tunnel release	Surgery: arthrodesis/arthroplasty Details: arthroplasty for CMC-1 arthrosis Anesthesia: ABPB/US and NS/no additional block	260 mm Hg 135 min	Signs: dysesthesia (second to fifth finger), partly due to tight cast EMG: none Origin: related to surgery	50%–36% (Increased functionality)

(*Continued*)

Table 4. Continued

No.	Medical History	Surgery and Anesthesia Details	Tourniquet	Type of Nerve Injury and Details	Quick-DASH*
11	PVD: negative/smoking: negative hypertension prosthetic aortic valve and coronary artery stenting	Surgery: dupuytren's contracture Details: open fasciotomy (left second to fifth finger) Anesthesia: general anesthesia/no additional block	220 mm Hg 40 min	Signs: signs of CRPS and dysesthesia (second finger) EMG: none Origin: related to surgery/not related to regional anesthesia	14%–16% (Decreased functionality)
Suspected anesthetic origin of nerve injury					
12	PVD: negative/smoking: negative no relevant history	Surgery: wrist arthroscopy Details: arthroscopy for ulnar ligament pathology Anesthesia: ABPB/US and NS/no additional block	250 mm Hg 50 min	Signs: dysesthesia (first to fourth finger) EMG: none Origin: related to regional anesthesia/not related to surgery	Lost to follow-up
13	PVD: negative/smoking: negative hypertension sacral nerve stimulator for an overactive bladder	Surgery: wrist arthroscopy Details: arthroscopic hemitrapeziectomy for CMC-1 arthrosis Anesthesia: ABPB/US/no additional block	250 mm Hg 56 min	Signs: paresthesia (second to fourth finger), nerve not in the surgical field EMG: distal median nerve lesion Origin: related to regional anesthesia	68%–50% (Increased functionality)
Inconclusive origin of nerve injury					
14	PVD: negative/smoking: negative no relevant history	Surgery: dupuytren's contracture Details: open fasciotomy (left first and second finger) Anesthesia: ABPB/US and NS/no additional block	280 mm Hg 50 min	Signs: signs of CRPS and paresthesia (second and third finger) EMG: signs of carpal tunnel syndrome Origin: unknown/not related to regional anesthesia	21%–11% (Improved functionality)

*Quick DASH scores preoperatively, and at 4 years following surgery; with 0%–20% normal function 20–40% mild disability, 40%–60% moderate disability, 60%–80% severe disability.
ABPB, axillary brachial plexus block; CMC, carpometacarpal joint; CRPS, complex regional pain syndrome; EMG, electromyography; LABCN, lateral antebrachial cutaneous nerve; MTP, metatarsophalangeal joint; NS, nerve stimulator; PVD, peripheral vascular diseases; RDN, radial digital nerve; RSN, radial sensory nerve; SCBPB, supraclavicular brachial plexus block; UDN, ulnar digital nerve; US, ultrasound.

and peripheral vascular diseases are all conditions that may affect neural blood flow and may thus predispose to nerve injury.[1,2,10,12,13] However, none of these conditions are found to be a risk factor in our study population.

Anesthesia Risk Factors

The current study does not show a higher risk of nerve injury with regional or local anesthesia compared with general anesthesia. This is in accordance with findings in a large retrospective cohort study on postoperative complications in 10,646 patients following hand surgery.[4] An incidence of <0.1% for nerve injury under all types of anesthesia techniques is reported, and regional anesthesia is found to be associated with a significantly lower risk of postoperative complications in comparison to general anesthesia.[4]

Although controversial, elicitation of paresthesia during the block placement procedure is often linked to intraneural injection and subsequently nerve injury.[10,15] However, there is no relationship between paresthesia and postoperative nerve injury in the current study.

Surgical Risk Factors

Obviously, direct intraoperative surgical trauma is an important surgical risk factor for nerve injury, as the risk of complications (including nerve injury) is imbedded in all surgical interventions. Other recognized surgical risk factors include tourniquet use and neuropathy due to improper patient positioning.[10,16,17] The incidence of "tourniquet paralysis" is estimated on 1 in 8,000 operations.[16,17] Tourniquet use, including inflation pressure and duration of use, is not found to be a factor in nerve injury in the current study. Also, extremes in patient positioning during surgery may result in traction and stretch of individual nerves or the brachial plexus.[12] Positioning in our study population is standard, with the arm extended to an angle of 45–90 degrees and padding of the elbow if appropriate. Intraoperative arm movement, to gain access to the operation field, was under direct supervision of the hand surgeon.

Etiology of Nerve Injury

In terms of the origin of the 14 identified nerve injuries in the current study, a surgical cause was suspected in 11 patients and an anesthetic origin in 2. In 1 patient, the origin of nerve injury was inconclusive.

The majority of nerve injuries in the current study are suspected to be surgical. A definitive surgical etiology is identified in only one patient. In 4 patients, no form of regional anesthesia was conducted, suggesting a nonanesthesia origin of nerve injury. In the remaining other 13 patients, the origin of injury was deducted on the basis of clinical examination and/or electromyography; illustrating the difficulties in uncovering the exact etiology. Also, the role of patient's susceptibility for nerve injury remains unclear in these 14 patients.

Long-term Functional Outcome

An important finding in this study is that 4 years following surgery, 5 of the 14 patients with nerve injury had a decrease in functionality on the basis of the Quick DASH scores. Studies on long-term outcome report that most intraoperative nerve injuries are limited in severity and fully resolve with time.[1,9] This is in contrast to the findings in the current study, in which approximately 40% of the patients with nerve injury have a decrease in functionality compared with preoperatively.

The Strength/Limitations

A major strength of this study is the intense cooperation between the departments of Plastic Surgery and Anesthesiology in making a thorough effort to determine the exact incidence, risk factors, and etiology of postoperative nerve injury. Obviously, in many cases, it is extremely difficult to be 100% certain on the origin of nerve injury. However, we believe that the design of this prospective observational study made it possible to study all factors involved in new onset nerve injury. This is unlike previous studies on this topic, which often limited to retrospective and/or based on voluntary reported incidents of nerve injury.

A further strength of the current study is long period of follow-up. Functionality at 4 years following the occurrence of nerve injury, measured with a validated functionality questionnaire, is compared with preoperative functioning.

A limitation of the current study is the small sample size, with a wide variability in the types of surgical procedures, types of regional anesthesia techniques, choice of local anesthetic, and nerve localization methods. The design of the current study was primarily observational and the foremost aim was to investigate the incidence of all new onset nerve injuries following various forms of anesthesia techniques. Therefore, no power calculation was performed before conducting our investigation. Due to the small sample size and the low incidence of nerve injury, further analysis of etiologic factors of nerve injury was conducted on only 14 patients. We chose to study a pragmatic cohort of patients undergoing distal upper extremity surgery, and therefore, the present conclusions should be interpreted accordingly.

CONCLUSIONS

This prospective double-centered observational study demonstrates an incidence of all cause nerve injury of 4.7% following distal upper extremity surgery. No specific patient, anesthetic, or surgical risk factors are identified and, importantly, patients who received regional anesthesia are not at more risk of nerve injury than those who received general anesthesia. The exact origin of nerve injury is very difficult to determine, but in most cases, the injury is suspected to be caused by direct surgical trauma. Four years following the nerve injury, approximately 40% of the patients with new onset nerve injury have reduced functionality. Thus, when presented with a patient with a new onset postoperative nerve injury, the exact etiology is often unclear and, unfortunately, functional recovery is not seen in all patients.

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