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Peripheral neuropathies after shoulder arthroscopy: a systematic review

Richard D.J. Smith, MD, DPhil[a,*], Casey L. Wright, MD[a], Brian Shaw, BS[b], Salman Bhai, MD[c], Abhiram R. Bhashyam, MD, MPP, PhD[a], Evan A. O'Donnell, MD[a]

[a]Department of Orthopaedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA
[b]Larner College of Medicine at The University of Vermont, Burlington, VT, USA
[c]Department of Neurology, UT Southwestern Medical Center, Dallas, TX, USA

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Purpose: Peripheral neuropathies after shoulder arthroscopy are rare, though likely under-reported. Many resolve spontaneously, but some patients are left with permanent neurological deficits. The purpose of this study was to review the literature to better characterize this patient population, diagnostic tests performed, the timing and type of surgical intervention, and report clinical outcomes.

Methods: A systematic literature review was performed. Articles in English were identified from PubMed, EMBASE, and CINAHL in August 2021. Article titles and abstracts were screened for relevance by two authors and discordant abstracts were resolved by the senior author. Data were subsequently extracted from the included articles.

Results: Seventeen articles were identified yielding a total of 91 patients. The average age was 53 ± 12 years, and most patients were male (72%). Rotator cuff repair (62%) was the most common procedure performed. A peripheral neuropathy was identified an average of 80 ± 81 days from the index procedure (range, 0-240 days). Most commonly, peripheral nerve injury presented as a mononeuropathy, with the median nerve (39%) and ulnar nerve (17%) affected predominantly. Seventeen percent of patients underwent a secondary surgery at an average of 232 ± 157 days after the index procedure. At the final follow-up, 55% of neuropathies had resolved, 14% partially improved, and 22% showed no clinical improvement. The most proposed etiologies were postoperative immobilization (29%) and intraoperative positioning (20%), but several possible etiologies have been suggested.

Conclusions: Peripheral neuropathies after arthroscopic shoulder procedures are rare. While most spontaneously resolve, up to 1 in 5 patients may have persistent neuropathic symptoms. A high index of suspicion should be maintained throughout the postoperative period. When neurologic deficits are identified, patients should undergo a thorough diagnostic workup and be referred to a subspecialist in a timely manner.

Utilization of arthroscopic shoulder procedures is increasing, with over 400,000 procedures performed in the United States alone each year.[15,16] In general, shoulder arthroscopy has a low complication rate with recent estimates reporting an overall complication rate of approximately 1%.[19] Neurologic injuries, albeit rare, constitute a potentially devastating complication. While appropriate focus has been placed on neurological injuries and their prevention from direct instrumentation of the surgical field, reports of distal neuropathies outside the surgical field have been infrequently reported in the orthopedic literature.

Neurologic injury after shoulder surgery has largely focused on open surgery, where surgical manipulation of and direct trauma to neurologic structures may result in injury. Notably, in total shoulder arthroplasty, authors have shown a non-insignificant rate of neurologic injury.[24] Recently, authors have described distal peripheral nerve (DPN) injury remote from the surgical field. A review conducted on patients undergoing shoulder arthroplasty or arthroscopic rotator cuff repair with recorded DPN injury postoperatively found cubital tunnel syndrome and carpal tunnel syndrome were the most common DPN injuries for each procedure, respectively.[40]

In the perioperative and postoperative management of arthroscopic surgery, there may be multiple etiologies of DPN injury. Arm

Institutional review board approval was not required for this study.

*Corresponding author: Richard D.J. Smith, MD, DPhil, Massachusetts General Hospital Department of Orthopedic Surgery, 55 Fruit Street, Boston, MA 02114, USA.
E-mail address: rsmith21@partners.org (R.D.J. Smith).

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position, compression sleeves, gravity-dependent edema from arthroscopic fluid, and fixed sling immobilization for an extended period could all contribute to distal nerve compression, especially with arthroscopic shoulder surgery.[40] While many neurologic deficits after shoulder surgery resolve spontaneously, the neurologic symptoms are worrisome to both surgeon and patient, and some patients even require further surgical intervention with variable long-term prognoses.[6,9,23,35]

Given the rarity of neuropathies after shoulder arthroscopy, published literature on the topic is mostly limited to case reports and small case series.[35,40] As such, the purpose of this study was to systematically review the literature to:

1. Summarize the patient population that develops a peripheral nerve injury after arthroscopic shoulder procedures.
2. Determine the diagnostic tests performed.
3. Describe the timing and type of surgical intervention.
4. Report the clinical outcomes.

Materials and methods

Study design

The design and reporting of this systematic review was concordant with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21] The search protocol was designed and registered with the PROSPERO database (CRD42021272915).

Study eligibility

All studies including randomized controlled trials, cohort, case-control, case series, and case reports were included for patients suffering a peripheral neuropathy after shoulder arthroscopy. Studies investigating adults (age > 17) undergoing shoulder arthroscopy were included. Articles were excluded if they were not written in English, if patients sustained an injury at the level of the brachial plexus, or if patients underwent any procedure in addition to shoulder arthroscopy.

Literature search

A search of literature in PubMed (1966-present), EMBASE (1947-present), and CINAHL (1981-present) was conducted in August 2021 via a comprehensive search strategy (see Supplementary Figure S1 for full search strategy). Manual screening was subsequently performed of selected article citation lists to determine if relevant articles were missed in the database search.

Study selection and data abstraction

Authors R.D.J.S. and B.S. independently screened relevant titles, abstracts, and full-text manuscripts for inclusion, and any disagreements were resolved by the senior author E.A.O. For example, some studies were included in the initial screen for having patients undergoing shoulder arthroscopy but were subsequently excluded for having a concurrent mini-open procedure. Data were obtained and organized using the Cochrane Handbook for Systematic Review recommendations on data extraction, and custom data tables were formed including information on patient demographics, diagnoses, procedure(s) performed, type of neuropathy, the nerve injured, diagnostic workup, postoperative management, and clinical outcomes (Fig. 1). Descriptive statistics were reported using Microsoft Excel (version 16.54; Microsoft Corporation, Redmond, WA, USA).

Risk of bias assessment

Given the absence of randomized trials, each study was critically appraised for quality of evidence according to the Methodological Index for Non-Randomized Studies (MINORS) tool.[37] The MINORS tool describes a 12-item assessment of methodological strength. Studies were scored from 0 to 2 on each criterion, with higher scores indicating high quality of evidence (Table VI).[37]

Data analysis

The primary outcomes measured in this review were the procedure associated with peripheral neuropathy, proposed etiology for the injury, management, and patient-reported outcome measures. Type of surgery, type of nerve injury (mononeuropathy vs. polyneuropathy), specific nerve injured, nerve-related surgery, and nerve recovery are reported by prevalence (%). Time to diagnosis was reported in days. Heterogeneity of the included studies precluded formal meta-analysis.

Results

Quality of studies

Based upon the MINORS criteria,[7] 5 studies were low quality,[9,31,34,35,39] 7 studies were moderate quality,[6,13,19,23,25,26,41] and 5 studies were high quality.[8,12,14,17,40]

Patient demographics

A total of 91 patients were identified from 17 manuscripts.[6,8,9,12,13,14,17,19,23,25,26,31,34,35,39,40,41] The average patient age was 53 ± 12 years, with 58 (64%) males, 25 (27%) females, and 8 (9%) of the patients the sex was not reported (Table I). The most common diagnosis was a rotator cuff tear in 76 (72%) patients, followed by a labral tear (including superior labrum anterior and posterior and Bankart tears) in 9 (9%) patients, and then rotator cuff impingement in 8 (8%) patients. Biceps tendonitis (N = 4, 4%), subacromial bursitis in (N = 3, 3%), acromioclavicular arthritis (N = 3, 3%), and deltoid strain in (N = 1, 1%) were less common diagnoses (Table I).

Procedure

The three most common arthroscopic shoulder procedures performed were rotator cuff repair in 75 (62%) patients, subacromial decompression in 19 (16%) patients, and rotator cuff débridement in 6 (5%) patients. Lateral positioning was used for 45 (49%) patients and the beach chair position was used for 36 (40%) patients. A preoperative interscalene block was used for 41 (45%) patients and not used for 2 (2%) patients. Additional information regarding the type of procedure, positioning, and whether a preoperative block was used can be found in Table II.

Identification and workup of postoperative peripheral neuropathy

The peripheral neuropathy was identified an average of 80 ± 81 days from the index procedure but ranged from 0 to 240 days. The three most common neuropathies identified involved the median (39%), ulnar (17%), and axillary nerves (14%). Most patients developed a mononeuropathy (N = 67, 74%). The neuropathy was most frequently identified using clinical exam alone in 63 (69%) patients. In addition to the clinical exam, nerve conduction study and electromyogram (NCS/EMG) were used for diagnostic testing in 12 (13%) patients, and NCS/EMG and brachial plexus magnetic resonance imaging were used in 1 (1%) patient. Additional information

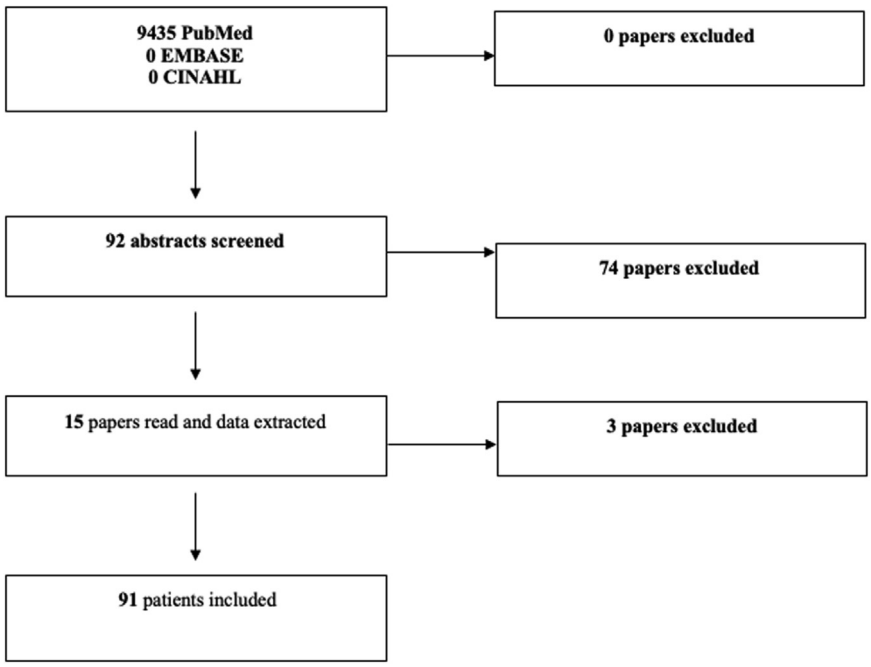

Figure 1 Flow diagram of patient identification.

Table I
Demographics.

	Patients
Age (years) ± SD*	53 ± 12
Sex†	
Male	58 (64%)
Female	25 (27%)
N/A	8 (9%)
Diagnoses‡	
Rotator cuff tear	76 (72%)
Labral tear (including SLAP and Bankart tears)	9 (9%)
Rotator cuff impingement	8 (8%)
Biceps tendonitis	4 (4%)
Subacromial bursitis	3 (3%)
Acromioclavicular arthritis	3 (3%)
Deltoid strain	1 (1%)
N/A	0 (0%)

SD, standard deviation; *SLAP*, superior labrum anterior and posterior.
*Age information was only available for 83 patients.
†Sex information was only available for 83 patients.
‡Patients can carry more than 1 diagnosis (total of 104 separate diagnoses).

Table II
Procedure information.

	Patients (%)
Procedure performed*	
Rotator cuff repair	75 (62)
Subacromial decompression	19 (16)
Rotator cuff débridement	6 (5)
Subacromial bursectomy	4 (3)
Labral repair (including SLAP and Bankart repairs)	4 (3)
Distal clavicle excision	3 (2)
Humeral head débridement	3 (2)
Biceps tenodesis	2 (2)
Biceps tenotomy	2 (2)
Posterior capsule release	2 (2)
Coracoacromial ligament release	1 (1)
N/A	0 (0)
Positioning†	
Lateral	45 (49)
Beach chair	36 (40)
N/A	10 (11)
Preoperative interscalene block used‡	
Yes	41 (45)
No	2 (2)
N/A	48 (53)

SLAP, superior labrum anterior and posterior.
*Multiple procedures may have been performed per patient.
†Positioning information was only available for 83 patients.
‡Interscalene block information was only available for 43 patients.

regarding the type of nerve involved, the number of nerves involved, and diagnostic studies can be found in Table III.

Postoperative management

Sixteen (17%) patients were managed with a secondary surgical intervention to treat the peripheral neuropathy. The second surgical intervention occurred on average 232 ± 157 days after the index arthroscopic shoulder procedure. Nerve decompression was the most common surgical intervention performed on 11 (12%) patients, followed by nerve transfer in 2 (2%) patients, and tenodesis in 2 (2%) patients. Sixty-seven (74%) patients were managed nonoperatively, and 8 (9%) patients had no data available regarding the precise postoperative management. Additional information regarding the management of the peripheral neuropathies and type of secondary surgical intervention can be found in Table IV.

Clinical outcomes and proposed etiologies

Patients had symptoms for an average of 252 ± 219 days after the index arthroscopic procedure (Table V). The mean timing of the final clinical follow-up was 333 ± 265 after the index procedure (Table V). By the time of the final clinical follow-up, 50 (55%) patients had complete resolution, 13 (14%) patients had partial improvement, and 20 (22%) patients had no improvement in their peripheral neuropathy (Table V). There was no information reported regarding symptoms at the final follow-up for 7 (8%) patients and 1 (1%) patient was lost to follow-up (Table V).

Table III
Neuropathy identification.

	Patients (%)
Nerve involved[*,†]	
Median	42 (39)
Ulnar	18 (17)
Axillary	15 (14)
N/A	14 (13)
Radial	12 (11)
Musculocutaneous	6 (6)
Number of different nerves involved[*]	
1	67 (74)
2	8 (9)
3	1 (1)
4	1 (1)
N/A	14 (15)
Diagnostics	
Clinical exam alone	63 (69)
Clinical exam and EMG	12 (13)
Clinical exam, EMG, and MRI brachial plexus	1 (1)
N/A	15 (17)

EMG, electromyogram; *MRI*, magnetic resonance imaging.
[*]Multiple nerves may have been affected in a single patient.
[†]If a branch of a major nerve was involved, it was reported under the major nerve.

Table IV
Postoperative management.

	Patients (%)
Management[*]	
Nonoperative	67 (74)
Operative	16 (17)
N/A	8 (9)
Surgical intervention performed[†]	
Nerve decompression	11 (12)
Tenodesis	2 (2)
Nerve transfer	2 (2)
Neurolysis	1 (1)
Nerve graft	1 (1)
Neuroma resection	1 (1)
Tendon transfer	1 (1)

[*]The management of timing of management was only available for 82 patients.
[†]Multiple surgical interventions may have been performed on the same patient.

All studies proposed multiple etiologies of the peripheral neuropathies, but none were able to determine the precise cause. The most frequently proposed etiology was postoperative immobilization in 52 (29%) patients, intraoperative positioning in 35 (20%) patients, and trauma from preoperative interscalene block in 30 (17%) patients (Table V). Other proposed etiologies included extravasation of arthroscopic fluid in 25 (14%) patients, intraoperative manipulation in 17 (10%) patients, and portal site placement in 11 (6%) patients. No etiology was proposed for 8 (4%) patients (Table V).

Discussion

This systematic review assessed peripheral nerve injury after shoulder arthroscopy including an analysis of the most affected nerves, the symptom duration, management, and outcomes. Though rare, patients who undergo shoulder arthroscopy may sustain an injury to one or multiple peripheral nerves. While most peripheral neuropathies after shoulder arthroscopy resolve within 1 year, approximately 1 in 10 patients will undergo a second surgery in the management of their symptoms, and 1 in 5 patients will have permanent neurological deficits.

Table V
Postoperative course.

	Patients (%)
Findings at the final follow-up[*]	
Resolved	50 (55)
Partial improvement	13 (14)
No improvement	20 (22)
N/A	7 (8)
Lost to follow-up	1 (1)
Proposed etiology[†,‡]	
Postoperative immobilization	52 (29)
Intraoperative positioning	35 (20)
Trauma from preoperative block	30 (17)
Arthroscopic fluid extravasation	25 (14)
Intraoperative manipulation	17 (10)
Portal site placement	11 (6)
N/A	8 (4)

[*]The findings at the final follow-up were only available for 83 patients, 1 patient was lost to follow-up.
[†]Proposed etiology was only available for 83 patients.
[‡]Multiple etiologies may have been proposed for each patient.

Neuropathy characteristics

The three most common neuropathies identified after shoulder arthroscopy were median, ulnar, and axillary neuropathies. A study by Pitman *et al*[25] recorded somatosensory evoked potentials (SEPs) for the musculocutaneous, ulnar, and either the median or radial nerves during shoulder arthroscopy. They noted abnormal SEPs of the musculocutaneous nerve in 100% (N = 20) of patients and in 50% (N = 10) of patients they noted variable combinations of median, ulnar, and radial nerve involvement. They noted abnormal SEPs in the musculocutaneous nerve in 16 patients immediately after initial joint distention with saline, which was relieved upon initiation of fluid outflow. They reported 40% of patients exhibited abnormal evoked potentials in their median and ulnar nerve during shoulder arthroscopy. Two patients (10%) had transient clinical neuropraxia postoperatively; one (5%) patient had a radial nerve palsy with wrist-drop and one (5%) had hypoesthesia in the musculocutaneous nerve, which resolved after 48 hours and 24 hours, respectively.[25]

Etiologies

While the precise cause of neuropathies associated with shoulder arthroscopy remains unclear, multiple etiologies have been proposed. In this study, the two most proposed etiologies were postoperative immobilization and intraoperative positioning. While the axillary nerve is closest to the arthroscopic field, located an average of 12 mm from the infraglenoid tubercle, the most common neuropathies found in this study were the ulnar and median nerves.[18] Furthermore, while direct peripheral nerve trauma has been described in labral repair,[20] labral repair only constituted 3% of the cases included. While not theoretically impossible, it is unlikely the neuropathies described in this study were from direct manipulation of the surgical field. Median and ulnar neuropathies are the most common compressive neuropathies in the general population, associated with carpal tunnel syndrome (incidence 1.73 cases per 1000 person-years)[27] and cubital tunnel syndrome (incidence 0.247 cases per 1000 person-years),[22] respectively. Some authors have noted that a likely etiology is that shoulder arthroscopy triggered the development of new or worsened symptoms in patients with pre-existing at-risk anatomy.[14]

Table VI
MINORS criteria.

Study	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	Total
Lefebvre *et al*[17]	1	2	2	1	0	2	2	2	2	0	0	1	15
Segmüller *et al*[31]	1	1	2	1	1	1	0	0	0	0	0	1	8
Martin *et al*[19]	1	1	2	2	2	0	0	2	0	0	0	2	12
Pope *et al*[26]	1	1	2	2	0	2	2	0	0	0	0	1	11
Pitman *et al*[25]	2	1	2	2	0	2	2	0	0	0	0	0	11
O'Neill *et al*[23]	1	1	2	2	0	2	2	0	0	0	0	1	11
Thomasson *et al*[40]	2	2	2	2	1	2	2	2	0	0	0	2	17
Sisco *et al*[35]	1	1	2	1	0	1	0	0	0	0	0	0	6
Steed *et al*[39]	1	1	2	1	1	1	0	1	0	0	0	0	8
Deslivia *et al*[9]	1	2	2	1	0	1	0	1	0	0	0	0	8
Carofino *et al*[8]	2	2	2	2	0	2	2	2	0	0	0	1	15
Bouacida *et al*[6]	1	1	2	1	0	2	2	0	0	0	0	0	9
Harada *et al*[12]	2	2	2	2	1	2	2	1	0	0	0	0	14
Harada *et al* [13]	2	2	2	1	1	1	0	1	0	0	0	1	11
Yung *et al*[41]	1	1	2	1	0	1	2	1	0	0	0	0	9
Horneff *et al*[14]	2	2	2	2	0	1	2	1	0	0	0	2	14
Singh *et al*[34]	1	1	2	1	0	0	0	1	0	0	0	0	6

MINORS, Methodological Index for Non-Randomized Studies.
1*. A clearly stated aim.
2*. Inclusion of consecutive patients.
3*. Prospective collection of data.
4*. Endpoint appropriate to the aim of the study.
5*. Unbiased assessment of the study endpoint.
6*. Follow-up period appropriate to the aim of the study.
7*. Loss to follow-up less than 5%.
8*. Prospective calculation of the study size.
9*. An adequate control group.
10*. Contemporary group.
11*. Baseline equivalent of groups.
12*. Adequate statistical analysis.

Shoulder arthroscopy utilizing the lateral decubitus position may cause peripheral nerve injury. Previous studies have reported up to 10% of patients developing a neuropathy associated with shoulder arthroscopy in the lateral decubitus position.[28] The traction used in the lateral decubitus position may affect blood supply to and conduction of the nerve.[10] Lateral decubitus positioning also uses a compressive forearm wrap, which can compress surrounding nerves.[9,40] Lateral positioning was utilized in 49% of patients in this study. Interestingly, the development of the beach chair position was, in part, to avoid the risks of neuropathy associated with lateral decubitus positioning and traction.[36,4] In this study, however, 40% of patients developed a neuropathy after shoulder arthroscopy in the beach chair position. This suggests that the beach chair position is not without risks and may indicate contribution from other factors.

Postoperative immobilization was the most proposed etiology for peripheral neuropathy in this study. While the use of a sling or shoulder immobilizer postoperatively may be necessary to allow for surgical repairs to heal, these devices are not without disadvantages. Sling and shoulder immobilizers have been shown to increase the intraneural pressure of nerves in the arm, particularly if the device is inappropriately sized.[40,14,3] Persistent elbow flexion causes increases in ulnar nerve pressure.[11,29] Furthermore, postoperative block may allow for peripheral compression to go unnoticed generating compressive nerve injury while the arm is insensate. While the orthopedic body almost innately intuits the risks of cast immobilization, sling immobilization may share analogous challenges.

Several studies cited trauma from a regional nerve block as a cause of peripheral neuropathy. In our study, 45% of patients received a preoperative interscalene block and only 2% did not. However, in 53% of the patients studied, information regarding block use was not reported. Neuropathy associated with regional anesthesia is thought to be associated with direct trauma, anesthetic toxicity, and compression from any hematoma that develops.[5] A study by Borgeat *et al*[1,7] in patients who received a regional nerve block prior to shoulder surgery found 14% of patients reported distal neuropathic symptoms 10 days after surgery and 0.9% had symptoms at 9 months.[2] Other studies, however, have suggested an even lower rate at approximately 0.03%.

Extravasation of arthroscopic fluid is another proposed etiology. Previous studies have reported both sensory and motor deficits after fluid extravasation was noted following shoulder arthroscopy.[25] It is thought that excess fluid within soft tissues can cause compression of surrounding nerves.[35] The dependent nature of the upper extremity means extravasated fluid will track distally with gravity, causing compression of nerves distant from the operative site. The use of postoperative immobilizers that keep the arm below the level of the heart may further contribute to this.[14] Our study reported a high rate of medial and ulnar neuropathies, which may result from fluid extravasation and dependent swelling, especially among patients with preexisting at-risk anatomy.[14]

While most patients who develop a peripheral neuropathy after shoulder arthroscopy will have complete symptomatic resolution, up to 36% will have only partial or no improvement. Furthermore, our study showed the average symptom duration was nearly 9 months (252 days). This aligns with previous studies which have suggested that recovery after nerve injury can take more than 1 year.[32] Peripheral nerves regenerate at a rate of approximately 1mm per day or 1 inch per month.[33] However, it is critical that the nerve reach the motor end plate before irreversible damage occurs in order to promote meaningful recovery.[17]

More than 1 in 6 patients with peripheral neuropathy after shoulder arthroscopy undergo a secondary surgical procedure. The challenging question is, when (if ever) should a secondary surgical intervention take place? Both from a diagnostic and therapeutic perspective, some authors suggest nerve exploration for patients with symptoms that do not resolve within 3-6 months.[35,38,30]

Conversely, our study includes patients who had symptoms for over 18 months, which fully resolved without surgical intervention.

Pope et al[26] suggest that in addition to clinical examination, NCS/EMG can be helpful to help delineate inflammatory neuritis from compressive neuropathies. Importantly, NCS/EMG can help localize the site of injury (specific nerve, motor and/or sensory fibers, compressive site or not), identify the presence of demyelinating or axonal injury, and the stage of denervation and/or reinnervation. Understanding these factors can aid in determining the need for surgery, and if necessary, the urgency of surgery, as well as if an underlying condition may be present (e.g., brachial plexopathy, hereditary neuropathy, cervical radiculopathy). Interestingly, only 13% of patients in our study underwent NCS/EMG evaluation of their neuropathy and only 1 patient (1%) underwent an magnetic resonance imaging. This demonstrates that adjunctive diagnostic tests, particularly NCS/EMG are being underutilized and should be part of the workup of a patient with a persistent neuropathy.

In our study, the neuropathy was identified on average 80 days after the index procedure. Lefebvre *et al*[17] reported that iatrogenic nerve injuries associated with orthopedic procedures were referred to a peripheral nerve clinic on average 10.9 months from the procedure which caused the injury. A paper by Shin *et al*[33] reports that delayed presentation (3-12 months after the index procedure) in patients with brachial plexus injuries resulted in poorer neurologic outcomes likely because irreversible nerve damage already occurred. The authors recommend the use of NCS/EMG, as well as prompt referral to a nerve specialist once a peripheral nerve injury is detected. Understanding which patients may benefit from subsequent surgical intervention and when is a topic that warrants further investigation.

Strengths and limitations

The primary strength of this study is that it represents the largest cohort of peripheral nerve injuries after shoulder arthroscopy.

There are several limitations of the study that should be considered. Firstly, the quality of some of the studies included is poor (Table VI). Secondly, given the study design of included studies, there are likely many patients who developed peripheral neuropathies that were either not identified or not published. Furthermore, the lack of standardized data reporting meant that we did not have complete data for every patient in the study.

Conclusion

In summary, peripheral neuropathies after shoulder arthroscopy are rare, though likely under-reported. Median and ulnar mononeuropathies are the most common. While most peripheral neuropathies resolve spontaneously over the course of 9 months, more than 1 in 6 patients will undergo a secondary surgery, and more than 1 in 5 patients may have permanent neurological deficits. In our opinion, for patients with a persistent complete or partial nerve deficit 6 weeks postoperatively, an EMG/NCS should be obtained to establish a baseline objective nerve assessment and the patient should be referred to a nerve specialist for comanagement.

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Supplementary data

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