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ORIGINAL ARTICLE

Hand/Peripheral Nerve

Characteristics of Iatrogenic Nerve Injury from Orthopedic Surgery Correlate with Time to Subspecialty Presentation

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Background: There is no current literature examining iatrogenic nerve injury resulting from orthopedic procedures across subspecialties and anatomic areas. This study uses a single peripheral nerve surgeon's experience to investigate the variable time to presentation of adult patients with iatrogenic nerve injury after orthopedic surgery.

Methods: A retrospective review of patients examined in Peripheral Nerve Clinic (PNC) from January 1, 2012, to April 1, 2018, at a single, private, university hospital was performed. Fifty-eight adult patients met inclusion criteria. Charts were reviewed to determine the index orthopedic procedure, peripheral nerve affected, clinical deficits, patient demographics, and time from injury to PNC presentation.

Results: The average patient age was 51.2 years, and the average time to PNC referral was 10.9 months after the procedure that resulted in nerve injury. The orthopedic procedures included fracture fixation (13), joint arthroplasty (10) knee arthroscopy and ligament reconstruction (9), mass excision (9), shoulder arthroscopy (7), irrigation and debridement (2), removal of deep hardware (2), tendon procedures (2), trigger digit release (2), nerve decompression (1), and release of exertional compartment syndrome (1). Time from injury to PNC presentation was substantially shorter for patients with upper extremity versus lower extremity deficits (5.9 months vs 19.8 months; $P = 0.0173$) and for patients with motor nerve involvement versus those with isolated sensory nerve injury (4.5 months vs 24.3 months; $P = 0.0164$).

Conclusions: Iatrogenic nerve injury is a risk across orthopedic subspecialties. Nerve injuries in the lower extremity and those with isolated sensory deficits have significantly delayed time to subspecialty presentation. *(Plast Reconstr Surg Glob Open 2020;8:e2678; doi: 10.1097/GOX.0000000000002678; Published online 17 March 2020.)*

INTRODUCTION

Iatrogenic nerve injury after orthopedic surgery has been discussed in the literature for specific procedures and anatomic areas. Peripheral nerve injury is not a common occurrence, but it is a reported complication of total joint arthroplasty,[1–4] arthroscopy,[5–10] and operative fixation of fractures.[11–17] Iatrogenic nerve injury has also been reported with mass excision,[18] tendon repair,[19,20] trigger digit release,[21–23] and nerve decompression.[16,24–26]

Peripheral nerve injury can result in isolated sensory or motor loss, or in a combined motor and sensory deficit. Treatment of motor nerve injury is particularly time-sensitive: peripheral nerve regeneration occurs at an approximate rate of one mm per day, and the regenerated nerve must reach the motor end plate before irreversible degeneration.[27] After irreversible muscle changes occur, nerve procedures are unable to restore clinically useful function. At this point, surgical options are limited to salvage operations such as tendon transfers, functional muscle transfer, and joint fusions. Although treatment of isolated sensory nerve injuries does not involve a race against muscle degeneration, it should also be performed in a timely manner. Surgical intervention for painful sensory neuromas improves DASH scores, decreases pain, improves depression, and enhances quality of life.[28,29]

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A single surgeon at our university's Peripheral Nerve Clinic (PNC) attracts referrals for peripheral nerve disorders. We have identified a subset of patients treated at the PNC who sustained iatrogenic injury from orthopedic procedures. In contrast to other published literature on iatrogenic nerve injury, this study looks at patients with iatrogenic nerve injury sustained in all anatomic areas following all nonspine, orthopedic procedures. The purpose of this study is to review the index intervention that resulted in nerve injury, examine characteristics of the injured nerves, and investigate the timing of patient presentation to PNC. The hypothesis of this paper is that both anatomic location (lower vs upper extremity) and type of nerve injured (isolated sensory vs nerves with motor involvement) correlate with a delayed patient presentation to PNC.

MATERIALS AND METHODS

After Institutional Review Board approval, a retrospective review was performed of the senior author's Peripheral Nerve Clinic (PNC) at a single, tertiary-referral university medical center. The PNC's patient database was used to identify patients who presented from January 1, 2012 to April 1, 2018. To be included in the study, an adult patient needed to have a normal preoperative neurologic exam and no history of peripheral nerve abnormality. A new, postoperative, peripheral nerve deficit needed to be documented after a nonspine, orthopedic procedure. Patients were excluded if they underwent fasciotomy in the setting of acute compartment syndrome, if they were diagnosed with Parsonage-Turner Syndrome, if the procedure involved purposeful resection of a peripheral nerve, or if the procedure of interest was performed to remove a nerve tumor.

Fifty-eight patients met inclusion criteria. Basic demographic information including patient age, gender, and body mass index (BMI) were collected. Charts were reviewed to record the procedure resulting in nerve deficit and clinical exam findings. Time from index surgery to PNC presentation was recorded.

Statistical analysis for time to presentation based on upper and lower extremity location, type of deficit (motor involvement vs sensory-only deficit), BMI, age, and gender was performed. First, a univariate analysis was performed to compare the time from injury to presentation for upper extremity compared to lower extremity patients. Regression analysis was performed to investigate the contribution of BMI, age, and gender. Fischer's exact test was used to determine if the type of deficit was a confounding factor in the difference for upper and lower extremity time to presentation. The Mann–Whitney nonparametric test was used to test the hypothesis of equal times for upper and lower extremity referral times. Second, a t test assuming unequal variances was performed to compare the time from injury to presentation for lesions with motor involvement versus those with sensory deficits only.

RESULTS

Overall Results

A total of 58 patients met inclusion criteria. Thirty-seven patients were women, 21 were men. At the time of clinic presentation, the average patient age was 51.2 (range: 21–90) and the average BMI was 29.6 (range: 19.5–56.4). Nineteen patients had a normal BMI (BMI < 25), 17 patients were overweight (BMI 25–29.9), and 22 were obese (BMI > 30). Of the 22 obese patients, 12 had class II obesity (BMI > 35).

The overall average time from the index procedure associated with iatrogenic injury to PNC presentation was 10.9 months. When categorizing the iatrogenic nerve injury, 37 suffered an upper extremity injury and 21 patients suffered a lower extremity injury. Thirty-five patients presented with a mixed motor and sensory neuropathy, 19 had an isolated sensory deficit, and 4 had an isolated motor deficit. The orthopedic procedures responsible for peripheral nerve injuries were fracture fixation in 13 patients, upper and lower extremity joint arthroplasty in 10, knee arthroscopy and ligament reconstruction in 9, mass excision in9, shoulder arthroscopy in 7, irrigation and debridement in 2, removal of deep hardware in 2, tendon procedures in 2, trigger digit release in 2, nerve decompression in 1, and release of exertional compartment syndrome in 1.

Results Categorized by Index Orthopedic Procedure

Fracture Fixation

Thirteen patients suffered an iatrogenic peripheral nerve injury during a fracture fixation procedure. These 13 consisted of 8 humerus fractures, 3 tibia fractures, 1 Monteggia fracture, and 1 clavicle fracture.

Of the 8 humerus fractures treated, 6 were diaphyseal, 1 was proximal with an associated glenoid fracture, and 1 was a mid-shaft nonunion that underwent fixation following unsuccessful nonoperative management. All underwent open reduction and internal fixation (ORIF). Unfortunately, the original approaches and use of nerve blocks were not consistently documented in the available charts. In every case, the radial nerve was affected. In the 1 patient with a proximal humerus and associated glenoid fracture, both the axillary and radial nerves were affected. The average time from injury with humerus ORIF to PNC referral was 3.7 months (range: day of surgery to 4.6 months).

Three patients treated for tibia fractures sustained an iatrogenic nerve injury. The average time to presentation was 6.3 months. In 2 cases, the peroneal nerve was affected. One procedure was an ORIF of a lateral plateau fracture, and the other was exchange nailing of a tibial nonunion. Both patients experienced complete motor and sensory palsy of the peroneal nerve. The third procedure was a tibial intermedullary nail. This patient developed a post-traumatic, sensory neuroma of the superficial peroneal nerve at the level of the distal interlock screws. The average time from injury with tibia fixation to PNC referral was 14.6 months (range: 4.2–31.4).

One patient sustained a radial nerve injury with motor and sensory symptoms during ORIF of a Monteggia fracture. The patient presented to clinic 3 months after the procedure. Another patient sustained a supraclavicular sensory nerve injury during clavicle fracture ORIF. The patient presented to clinic 36 months after the procedure.

Total Joint Arthroplasty (TJA)

Ten patients sustained iatrogenic nerve injury in joint replacement procedures: 5 with shoulder arthroplasty, 3 with elbow arthroplasty, and 2 with hip arthroplasty.

Upper Extremity TJA

The 5 shoulder arthroplasty patients sustained iatrogenic injury during total shoulder arthroplasty (TSA; 1), revision TSA complicated by an intraoperative humeral shaft fracture (1), reverse TSA (rTSA; 2), and revision rTSA (1). These patients sustained injuries to the axillary, musculocutaneous, radial, ulnar, and median nerves at the peripheral nerve and infraclavicular brachial plexus level. Four out of the 5 exhibited both motor and sensory deficits. The average time from injury to PNC presentation was 4.5 months (range: 2–7).

Three patients sustained iatrogenic nerve injury during total elbow arthroplasty (TEA): 2 were primary procedures and 1 was a revision. Both patients who underwent primary TEA presented with a dense ulnar nerve palsy. The patient who underwent revision TEA sustained a complete radial nerve palsy. The average time from injury to PNC presentation was 4.9 months (range: 1.5–10.8).

Lower Extremity TJA

Two patients sustained iatrogenic nerve injury following total hip arthroplasty via a posterolateral approach. One patient sustained an isolated, motor, and sensory peroneal palsy, and the second sustained a motor and sensory sciatic nerve palsy. The average time from injury to PNC presentation was 7.5 months (range: 4.5–10.4).

Knee Arthroscopy and Knee Ligament Reconstruction

Nine patients presented to our PNC with nerve injury from knee arthroscopy. The average time from injury to clinic presentation was 31.5 months (range: 0.5–143.6).

Seven patients underwent knee arthroscopy for a meniscectomy, an all-inside meniscus repair, or an ACL reconstruction. All 7 sustained an isolated sensory nerve injuries to a branch or branches of the saphenous nerve.

The 2 remaining patients who underwent knee arthroscopy sustained iatrogenic peroneal nerve injuries. One patient experienced isolated sensory deficits after arthroscopic resection of a painful ganglion at the base of the ACL with trephining of a partial medial meniscus tear. The second patient presented with a complete motor and sensory peroneal palsy after arthroscopic ACL reconstruction with open lateral collateral ligament and posterolateral corner reconstruction for a multiligamentous knee injury.

Mass Excision

Nine patients sustained iatrogenic nerve injury from mass excision. Six masses were removed from the upper extremity, and 3 from the lower extremity. Four patients experienced isolated sensory deficits, 2 patients experienced isolated motor deficits, and 3 suffered a combination of motor and sensory deficits. The overall average time to PNC presentation was 8.3 months (range: 2.4–20.1).

Six patients underwent removal of a soft tissue mass: 2 cysts, 3 lipomas, and 1 giant cell tumor (GCT) of tendon sheath. In 1 case, the palmar cutaneous nerve was injured following ganglion cyst removal from the volar wrist. In another case, the tibial nerve was injured after ganglion cyst removal from the tarsal tunnel (Fig. 1). In a third case, the sural nerve was injured after a lower extremity lipoma excision. In the fourth and fifth cases, the radial nerve and posterior interosseous nerve (PIN) were injured after upper extremity lipoma excisions. In the final case, a common digital nerve was injured during resection of GCT of the tendon sheath in the palm.

Three patients underwent removal of osseous lesions: 2 upper and 1 lower extremity. One was a bony metastasis of the humerus, while the other 2 were benign exostoses of the radius and the tibia. Injuries were to the radial nerve, posterior interosseous nerve, and peroneal nerve, respectively.

Shoulder Arthroscopy

Seven patients underwent shoulder arthroscopy and sustained an iatrogenic nerve injury. The average time from index procedure to PNC evaluation was 4 months (range: 0.2–9.6). Four patients sustained a single peripheral nerve injury; 3 experienced deficits in multiple nerve distributions. The axillary nerve was affected in 3 cases, the musculocutaneous in 2, the median in 2, the thoracodorsal in 1, and the phrenic in 1. Records from other hospitals were incomplete for 4 patients, and so it was not possible to definitively determine if a peripheral nerve block was performed at the time of arthroscopy in these 4 patients. However, nerve block administration was documented for the remaining 3 patients.

Irrigation and Debridement for Infection

Two patients suffered iatrogenic peripheral nerve injury following incision and drainage for infection of the elbow and the humerus. Both had multiple previous procedures for infection using the same approach before the intervention that resulted in injury. Both patients suffered complete radial nerve palsy. Average time to PNC presentation was 2.1 months (range: day of surgical injury to 4.2 months).

Fig. 1. Tibial neuroma in a patient who underwent cyst removal from the tarsal tunnel 13 months earlier. The patient's toes are to the upper right corner of the image and the leg is to the left-hand side of the image. The tibial nerve and neuroma are circled by the yellow vessel loop; distal nerve branches are tagged on blue backgrounds. After neuroma resection, size-matched allograft was used to reconstruct the tibial nerve from its healthy-appearing proximal end to distal branches. By 3 months postoperative, the patient had substantially decreased pain.

Removal of Hardware

Two patients suffered iatrogenic peripheral nerve injury following deep hardware removal. Both patients underwent hardware removal from the lower extremity: 1 from the talus and medial malleolus resulting in a sensory deficit of the tibial nerve and 1 from the tibial tubercle and distal femur, which resulted in a saphenous nerve deficit. Average time to PNC presentation was 15.5 months (range: 15–16.1).

Tendon Procedures

Two patients suffered iatrogenic nerve injury during tendon procedures: a distal biceps repair and a Strayer procedure. The distal biceps repair created a motor and sensory radial nerve deficit. The second patient experienced a combined motor and sensory tibial nerve deficit following a Strayer procedure. Average time to PNC presentation was 1.5 months (range: 1.3–1.7).

Trigger Finger Release

Two patients had digital nerve injuries following open A1 pulley release of the thumb. In both cases, the radial digital nerve was affected. Average time to PNC presentation was 8.25 months (range: 6.7–9.9).

Nerve Decompression

One patient presented after an intraoperative ulnar nerve laceration during cubital tunnel decompression. A mixed motor-sensory palsy was present. Delay to PNC presentation was 11.8 months.

Fasciotomy for Exertional Compartment Syndrome

One patient suffered a sensory-only, superficial peroneal nerve injury following a 2-incision, 4-compartment release for exertional compartment syndrome of the leg. Delay to PNC presentation was 18 months.

Results Categorized by Characteristics of Injured Nerve

Combined analysis of our adult PNC patients who sustained injury after an index orthopedic surgery reveals that time to presentation varies based on anatomic area affected. Patients with an upper extremity deficit (n = 37) presented at an average of 5.9 months after injury, while patients with a lower extremity deficit (n = 21) presented at an average of 19.8 months after injury (Fig. 2; $P = 0.0173$). Regression analysis shows that BMI

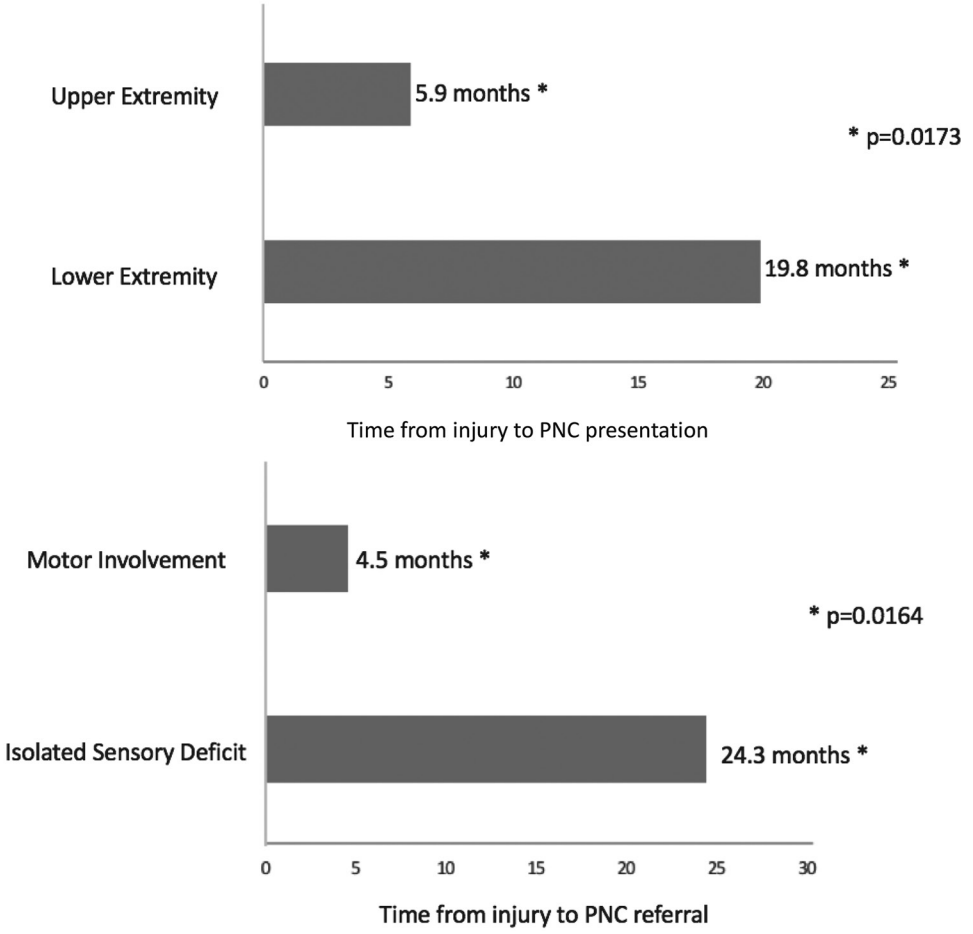

Fig. 2. Characteristics of iatrogenic nerve injury associated with time to presentation in our clinic. (Top) Time from iatrogenic injury to PNC referral is significantly longer ($P = 0.0173$) for patients with lower extremity deficits (19.8 months) when compared to referral time for those with upper extremity deficits (5.9 months). (Bottom) Time from iatrogenic injury to PNC referral is substantially longer ($P = 0.0164$) for patients with isolated sensory deficits (24.3 months) when compared to referral time for those with motor involvement as part of a pure motor deficit or a mixed motor and sensory deficit (4.5 months).

(r = –0.153, P = 0.251) and patient age (r = –0.219, P = 0.099) were not confounding variables. Gender composition between the 2 groups was similar (P = 0.783) and was also not a confounding factor. There was a higher proportion of patients with motor symptoms among those with upper extremity iatrogenic injury (85.5%) compared to those with lower extremity iatrogenic injury (33%). This difference between the upper and lower extremity groups is significant (P < 0.0001). However, the delayed time to presentation among patients with a lower extremity deficit remained significant in analyses accounting for the type of nerve deficit.

Analysis also reveals that patients with isolated sensory deficits present later than those with motor or combined motor-sensory deficits (Fig. 3). Patients with motor nerve involvement (n = 39) presented at an average of 4.5 months after injury, while patients with only sensory deficits (n = 19) presented at an average of 24.3 months after injury (p = 0.0164). The group of patients with sensory only deficits included a patient who presented very late at 143.6 months after injury. If this patient is excluded from the statistical analysis, a significant difference still remains in time to presentation between patients with motor involvement and those with only sensory symptoms (P = 0.020).

DISCUSSION

Iatrogenic peripheral nerve injury after orthopedic surgery is a debilitating complication that can overshadow the expected postoperative course. An overview of our PNC treatment algorithm for patients with new, postoperative neurologic deficits is presented. We advise prompt subspecialty referral if the primary surgeon is concerned about the nerve's structural integrity or if neurologic symptoms thought to be neuropraxia have not clinically improved or shown an advancing Tinel's sign by 6 weeks.

Our study found 2 characteristics of iatrogenic nerve injury correlated with significantly delayed presentation to our PNC: lower extremity location and isolated sensory deficits. The difference in time to presentation may reflect patients' ability to tolerate specific deficits or the likelihood of physician referral to a subspecialist. Studies have brought attention to the techniques and timing of motor nerve reconstruction, but there is also a smaller body of current literature supporting timely surgical intervention for sensory deficits and neuromas.[27–29] For post-traumatic sensory neuromas, our preferred technique begins with complete neuroma resection back to a level of healthy, normal nerve. This is followed by either sensory nerve reconstruction with allograft to distal branches or by coaptation of the proximal end to allograft, which connects the proximal stump to a healthy bed of nearby tissue in a so-called "bridge to nowhere."[29–32]

This study has limitations, including its retrospective design and single, specialized, tertiary clinic setting. Our study is also limited by the incomplete records from other hospitals precluding us from investigating the potential role of peripheral nerve blocks. Additionally, the referral

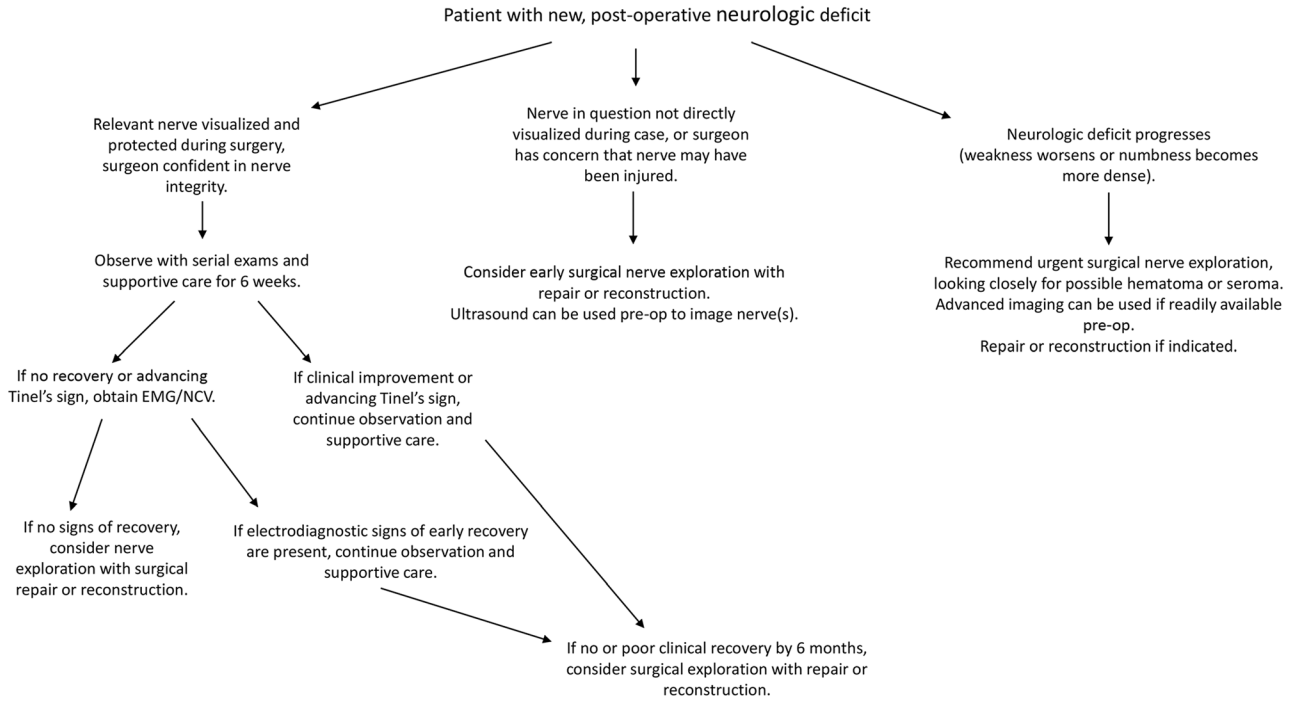

Fig. 3. Our algorithm for treating patients with new, postoperative neurologic deficits. A frank conversation with the operating surgeon is crucial in guiding initial management. Supportive care includes patient education, clinical reexamination every 2–3 weeks, and comanagement with a pain specialist if neuropathic pain is present. It also includes therapy and bracing, particularly for patients with a motor deficit to maximize current function and avoid contractures. Surgical nerve reconstruction involves a combination of nerve grafting with autograft, grafting with allograft, nerve transfers, and/or and distal nerve decompression as indicated by the nerve injured, the zone of injury, and the anatomic location.

source for patients was not consistently recorded in the chart. Our PNC is sometimes the second or later opinion. This contributes to delayed presentation, although we believe it is unlikely this unevenly contributed to delayed presentations for specific injury types. From our records, we were not able to definitively determine the cause – or causes – of delay in PNC presentation. Delays could be from surgeons not recognizing iatrogenic peripheral nerve injuries in a timely manner, surgeons recognizing neurologic deficit but choosing to delaying referral with the hope that nerve symptoms are from neuropraxia that will recover with observation, or surgeons pursuing non-surgical treatment modalities including therapy.

In conclusion, iatrogenic peripheral nerve injury occurs throughout orthopedic subspecialties. Our experience suggests that patients with lower extremity nerve injury and isolated sensory symptoms may be at risk for delayed subspecialty presentation. Surgeons are urged to consider a standardized care pathway and subspecialist referral for iatrogenic nerve injuries in all anatomic areas and for all nerve compositions.

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