Acta Neurologica Belgica (2021) 121:119–124
https://doi.org/10.1007/s13760-020-01424-0

ORIGINAL ARTICLE

Iatrogenic nerve injuries: a potentially serious medical and medicolegal problem. About a series of 42 patients and review of the literature

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Received: 25 May 2020 / Accepted: 30 June 2020 / Published online: 11 July 2020

Abstract

Objective To analyze the management of iatrogenic nerve injuries (iNI) in 42 patients.

Methods Retrospective analysis of the charts.

Results The iNI occurred mostly during a surgical procedure ($n=39$), either on a nerve or plexus ($n=13$), on bone, joint, vessel or soft tissue ($n=24$) or because of malpositioning ($n=2$). The most commonly injured nerves were the brachial plexus, radial, sciatic, femoral, or peroneal nerves. 42.9% of the patients were referred later than 6 months. A neurological deficit was present in 37 patients and neuropathic pain in 17. Two patients were lost to follow-up. Conservative treatment was applied in 23 patients because of good spontaneous recovery or compensation or because of expected bad prognosis whatever the treatment. Surgical treatment was performed in 17 patients because of known nerve section ($n=2$), persistent neurological deficit ($n=12$) or invalidating neuropathic pain ($n=3$); nerve reconstruction with grafts ($n=8$) and neurolysis ($n=8$) were the most common procedures. Outcome was satisfactory in 50%. Potential reasons of poor outcome were a very proximal injury, placement of very long grafts, delayed referral and predominance of neuropathic pain. According to the literature delayed referral of iNI for treatment is frequent. We provide an illustrative case of a young girl operated on at 6.5 months for femoral nerve reconstruction with grafts while nerve section was obvious from the operative note and pathological tissue analysis. Litigation claims ($n=10$) resulted in malpractice ($n=2$) or therapeutic alea ($n=5$) (3 unavailable conclusions). i

Conclusions NI can result in considerable disability, pain and litigation. Optimal management is required.

Keywords Peripheral nerve · Iatrogenic injury · Nerve repair · Timing of surgery

Introduction

Nerves are at risk of injury during a medical or surgical procedure because of mal-positioning or from the different tools that are used. These iatrogenic nerve injuries (iNI) can lead to serious morbidity, including complete neurological deficit and/or severe neurogenic pain. Aside the medical problem, iNI are a source of medicolegal consequences.

iNI should be treated as any nerve injury, with early nerve repair if nerve section is likely or with attentist expectation if a lesion- in-continuity is suspected. Our personal experience and the literature review show a "non-optimal" management in a substantial proportion of patients, mostly because of delayed referral to a specialized center.

Patients and methods

We performed a retrospective review of the charts of iatrogenic nerve injuries referred to our department between January 2003 and February 2020. We analyzed the patients characteristics, the past medical history, the healthcare provider causing the nerve injury, the mechanisms of injury, its management by the practitioner, the interval date of injury/date of referral to us, the clinical and neurological examination at presentation to us, the results of radiological and electrophysiological studies, the proposed therapeutic attitude, the result of nerve surgical exploration when performed, the follow- up both concerning the neurological deficit and pain

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Table 1 Mechanisms of injury ($n=42$)

Injection/cannulation injury	
At buttock level	1
At elbow level	2
Traction from positioning (abducted arm)	2
Nerve fascicle or trunk section	
During nerve surgery	10
During non-nerve surgery	4
Traction/contusion from joint mobilization/use of retractors	20
Difficult dissection in scar tissue	2
Unknown	1

if present, the result of the medicolegal issue. For a satisfactory result, the patient needed to be well improved of pain and motor power had to improve to a British MRC grade of at least M4.

Results

The series includes 42 patients, 24 women and 18 men, aged from 5 to 79 years. The mechanisms of injury are listed in Table 1. Injection nerve injury occurred in three patients: a sciatic nerve injury from a buttock intramuscular (IM) injection caused both a severe neurological deficit involving mostly the peroneal division with foot drop and severe neurogenic pain. The second patient developed extremely severe neuropathic pain in the median nerve distribution following misplacement of an IV catheter at the elbow. A lateral antebrachial cutaneous nerve injury following IV puncture at the elbow caused neurogenic pain in the third patient.

Nerve injury at the brachial plexus level occurred in two patients because of arm positioning in uni- or bi-lateral abduction. The first patient had breast surgery and woke up with a severe deficit of the upper limb; the work up revealed a cervical rib. The second patient experienced a bilateral brachial plexus palsy following a body lift surgery. Both patients had a fast and complete recovery.

Nerve injury occurred in 37 patients during a surgical procedure, either on a nerve (13 patients) or on a joint, bone, vessel or soft tissue (24 patients) (Table 2). Among the 13 complicated nerve surgeries, 8 involved a benign nerve tumor removal, because of wrong preoperative diagnosis ("lump, ganglion…") or because of nerve fascicle sacrifice without electrophysiological study and/or without any reconstruction. We included three personal cases of postoperative deficit following resection of a large or giant schwannoma despite the use of intraoperative electrophysiology (illustrative case n° 1).

The largest group of iNI arose from nerve stretch, compression or section during a surgical procedure on a bone, joint, vessel or soft tissue at hip (5 patients), knee (3 patients), shoulder (3 patients), humerus (2 patients), cervical (2 patients) or other (9 patients) levels. The two cervical iNI were the typical spinal accessory injuries from a posterior cervical lymph node biopsy.

The orthopedic surgeon was the most frequent healthcare provider causing the iNI, as shown in Table 3.

Table 4 summarizes the injured nerve elements, involving the upper extremity in 23 patients and the lower extremity in 19. The brachial plexus, radial nerve, sciatic

Table 2 Surgical procedures causing iNI ($n=37$)

Nerve surgery	**13**
Benign nerve tumor removal	11
TOS surgery with costectomy	1
Cervical sympathectomy	1
Non nerve surgery	**24**
Hip orthopedic surgery	5
Knee orthopedic surgery	3
Shoulder orthopedic surgery	3
Humerus fracture surgery	2
Vascular surgery	5
Cervical lymph node biopsy	2
Deep lipoma resection	2
Other	2

Table 3 Healthcare provider involved in iNI ($n=42$)

Orthopedic surgeon	16
Vascular surgeon	8
Abdominal/general/plastic/maxillofacial surgeon	6
Neurosurgeon	5
Gynecologist	4
Nurse	3

Table 4 Injured nerve elements ($n=42$)

Upper extremity	**23**
Brachial plexus	13
Radial nerve	5
CN XI	2
Median nerve	2
Lateral antebrachial cutaneous nerve	1
Lower extremity	**19**
Sciatic nerve (peroneal > tibial)	6
Femoral nerve	5
Peroneal nerve	4
Tibial nerve	2
L5 + S1 roots	1
Obturator nerve	1

nerve, femoral nerve and peroneal nerve were injured in 13, 5, 6, 5 and 4 patients respectively.

Aside the three personal patients, the remaining 39 were referred to us within a few days (1 patient), 1 week to 3 months (12 patients), at 3–6 months (8 patients), at 6–12 months (6 patients), at 12–24 months (7 patients) or later than 2 years (5 patients). Our illustrative case n° 2 exemplifies a—possibly faulty- delayed referral.

At presentation to us, the patients suffered from a neurological deficit which was complete (30 patients) or partial (7 patients), and/or neuropathic pain (17 patients).

The patients underwent US imaging (5 patients), MRI (12 patients) and/or electrophysiological studies (36 patients).

Two patients were not followed up after the first consultation (1 radial nerve complete injury after humerus fracture instrumentation, 1 peroneal nerve complete injury after knee ligaments revision surgery).

Conservative treatment was applied in 23 patients: nine patients had good spontaneous recovery or developed compensation while bad prognosis was expected whatever the treatment in 11 patients because of old age, long delay before referral, very proximal injury, predominance of neuropathic pain. Some informed patients chose then not to go to surgery. No reconstructive surgery was judged indicated in our three patients operated on for nerve tumor resection based on the intraoperative final macroscopic appearance and electrophysiological analyses.

Surgical treatment was performed in 17 patients at 7 days to 41 months post-trauma. Indications were a known nerve sections (2 patients), a persistent neurological deficit (12 patients) or invalidating neurogenic pain (3 patients). Nerve reconstruction with grafts was performed in eight patients, using 2–6 cables which were 5–16 cm long. The injured nerve/ plexus was neurolysed in eight patients. The last patient had neuroma resection and suture of the infrapatellar branch of the saphenous nerve, with temporary good pain relief; she had subsequently neurectomy because of pain recurrence.

Three patients were lost to follow up while the follow-up is too short in one patient; the outcome at 6 months to 6 years was satisfactory in 18 of the remaining 36 patients (50%). Potential reasons of dissatisfactory outcome are detailed in Table 5. Among the 17 patients complaining of neuropathic pain at presentation to us, 9 had still invalidating pain at follow up; two patients had a neurostimulation trial or implantation at spinal cord level with bad result; a third patient with median nerve injury causing severe neurogenic pain during 10 years had excellent pain relief following peripheral nerve stimulation but committed suicide 3 months later.

Ten patients (23.8%) claimed malpractice (Table 6). The medicolegal issue is not known for two patients; a medical fault was recognized in two patients, will likely be decided in a third while five cases were concluded as a therapeutic alea.

Table 5 Analysis of dissatisfactory outcome following medical or surgical management ($n = 36$)

Dissatisfactory outcome in 10/22 conservatively treated patients	
No/poor improvement of neurological deficit	6
Neuropathic pain	5
Dissatisfactory outcome in 8/14 surgically treated patients	
Neuropathic pain	4
Long delay before surgery	2
Very proximal lesion	2
Very long grafts (> 10 cm)	2
No identified reasons	2

Discussion

Iatrogenic nerve injuries (iNI) are not rare. They comprised 17.4% of the surgically treated NI in the series published by Kretschmer et al. [1] in 2001 (126 iNI among 722 surgically treated traumas over a period of 9 years). The same rate of iNI (17.1%) is found in Kline's experience (262 iNI/1530 NI) [2]. iNI is becoming a much larger category of trauma in busy nerve centers nowadays than in the past. Some technological advances in surgery with the increased use of minimally invasive and endoscopic procedures may partly account for the increased incidence of iNI [3, 4]. One common cause of iNI (18%) in Rasulic's series [5] was carpal tunnel release.

The exact incidence of iNI is not easy to determine. New Zealand provides a national no-fault compensation scheme for treatment-related injuries claims [6]. During the year 2009, 313 iNI were documented among 5227 claims (6%) in this island of approximately 4.10^6 inhabitants. The commonest causes of iNI were mal-positioning, venipuncture, IV cannulation and hip arthroplasty. The nerves of the upper extremity were more commonly involved. A minority (11.6%) of patients were referred for surgical management.

Various mechanisms of iNI have been documented, including section, traction, compression, injection, heat, use of anticoagulation and radiation [6, 7]. iNI can occur in benign medical procedures done for diagnostic or therapeutic reasons. The most frequent non operative cause of iNI was cast application in Kretschmer's series [1]. High-thoracic restraints have even been reported to cause brachial plexus injury in psychiatric patients [8]. So-called minor operations, such as lymph node biopsy, lipoma resection, varicose vein procedure or even a simple venipuncture can lead to significant nerve damage. One of our patients developed severe median nerve neuropathic

Table 6 Medicolegal issues in ten patients (23.8%)

Malpractice
Delayed diagnosis of XI nerve palsy following reoperation for cervical lymph node biopsy
Femoral nerve section (misinterpreted as a ganglion) during inguinal hernia repair
Therapeutic alea
Tibial nerve rupture during knee arthroplasty
Brachial plexus (lower trunk) lesion during TOS surgery with costectomy
Femoral nerve lesion during hip surgery
Obturator nerve section during gynecological surgery for cancer
Saphenous nerve injury during knee arthroscopy
Unavailable conclusions
Sciatic (mostly peroneal) nerve lesion during hip arthroplasty
Median nerve lesion during fibroma resection in the axilla
L5–S1 nerve root injury during pelvic surgery

pain following misplacement of an intravenous catheter at the elbow. He obtained an excellent result thanks to spinal cord stimulation (SCS), which unfortunately had to be removed because of infection. A second SCS provided no relief. After a 10-year period of extreme suffering, the patient was referred to us. He obtained an excellent result thanks to peripheral nerve stimulation (PNS) on the median nerve at arm level, but committed suicide 3 months later. We published the case report in order to sensitize the medical and governmental communities about the large benefit of PNS in selected cases [9].

Systematic reviews of iNI have been published [3, 10]: the procedures at risk involve bone and joint surgery, lymph node biopsy in the neck posterior triangle, carpal tunnel release. Some nerves are particularly vulnerable to traction or compression, such as the cranial nerve (CN) XI, the sciatic nerve, the femoral nerve. In large-scale studies, 94% of CN XI lesions requiring treatment were iatrogenic, as were 60% of femoral nerve lesions and 25% of sciatic nerve lesions [10]. The brachial plexus was the most commonly involved element in our series. The brachial plexus and its terminal branches are at risk during orthopedic shoulder surgery [11–13]; another reason for iatrogenic brachial plexus injury is resection or biopsy of a nerve sheath tumor [12]. The patient should be informed that resection of a nerve tumor can lead to a at least transient postoperative deficit; intraoperative electrophysiology is of great help to make decisions about sacrificing or not, reconstructing or not fascicles embedded in the tumor. Transaxillary first rib resection was recognized in the past as risky for the brachial plexus [14]. First rib resection by the anterior approach is still a somewhat delicate procedure for the brachial plexus elements [15].

The sciatic and femoral nerves are at risk of stretch during hip surgery; they can be injured during abdominal surgery as well, when retracting in the deep pelvis [16]. Injection injuries mostly involve the sciatic nerve—or radial nerve—following a misplaced IM injection [17–19].

iNI should be managed as non iNI, with either early nerve repair if nerve section is likely or expectant attitude if a lesion-in-continuity is likely [7]. A long delay in referral is reported in many series: at least two thirds of the patients did not undergo surgery for the iNI within an optimal time interval in Kretschmer's series [1]. Our illustrative case n° 2 shows the need to send the patients to specialized centers as soon as possible. Some non-surgeon doctors have probably a poor idea of what harm a scalpel, or a retractor can do to a peripheral nerve; some treating physicians could put their head in the sand in front of an obvious severe NI. If nerve section is likely, there is no need for repeated electrophysiological studies. US and/or MRI can be useful adjuncts in doubtful cases. The peripheral nerve semiology should be entirely mastered by all medical students, doctors and surgeons. For example, a patient with a complete CN XI palsy can still shrug his shoulder by the compensatory action of the levator scapulae and other muscles. The patient's main complaint is weak shoulder abduction. We took care of two patients with CN XI palsy following lymph node biopsy in the posterior cervical triangle; one patient had early diagnosis and obtained an excellent result following neurolysis at 3.5 months post-injury; the other patient was diagnosed too late to benefit from surgery and had a bad result. Through proper and timely intervention, patients with CN XI NI achieve a favorable functional outcome [20]. Failure to make the diagnosis of an iNI and failure to treat the complication could be as much a cause for concern as the initial injury to the peripheral nerve [21].

Some iNI are benign and will recover rapidly and completely. This is the case for most positioning iNI, as reported by Winfree and Kline in 2005 [22]. On the other hand, iNI can be extremely severe involving nerve section or neurotmetic lesions. Nerve reconstruction by suture or grafts was

necessary in most published large series [1, 5, 12]. A lesion in discontinuity was found in 65.6% of the patients in Rasulic's series [5].

Contrarily to our series, the results of iNI management are rewarding in a significant percentage of patients—around 70%—following timely intervention in most published large series [1, 2, 5, 17, 20].

Our last point of discussion is about the medicolegal issue. In a very recent survey, an adverse event occurred in 3.4% of the surgical procedures (182/5365 surgeries), being related to a human error in 56.4% of cases [23]. Few published articles report the medicolegal consequences of iNI. Ten patients (23.8%) in our series did claim malpractice and this was recognized in 2 of them—a third case will likely be decided as such as well. The fault in the CN XI palsy in one of the patients was not the occurrence of the palsy but the delayed diagnosis that impaired the possibility of nerve repair. Looking to the charts, we found a "non-optimal" management in 6 of the remaining 32 patients, mostly when a nerve tumor had been misinterpreted as a ganglion or had been resected with complete fascicle/nerve sacrifice without any electrophysiological studies or reconstruction. A point commented by Dellon [21] is that the second surgeon and/or team should precisely document the preoperative status, the intraoperative findings if surgery is necessary and send specimens to pathology when indicated. Intraoperative pictures should be done. Indeed, it has been reported that the second, "good Samaritan" surgeon was blamed for the inflicted iNI.

In conclusion, prevention is of course the best treatment of iNI. All the healthcare providers should be aware of the optimal management when such a nerve injury does occur.

Illustrative case n° 1

This 20-year old right-handed patient was referred to us for a probable giant nerve sheath tumor of the radial nerve. He had developed a palpable mass at the external aspect of the right arm. At presentation to us 6 months later he complained of numbness and tingling radiating to the third and fourth digits. A Tinel sign was present on physical examination as well as a mild Abductor Pollicis Longus (APL) deficit. There was no sign of neurofibromatosis. The MRI (Fig. 1 top) showed a huge multiloculated mass of 13×4×3 cms; ultrasound examination confirmed that the radial nerve was embedded in the mass; the tumor was lightly hypermetabolic on FDG-PET scan. An ultrasound-guided percutaneous biopsy allowed the diagnosis of a benign nerve sheath tumor. Surgical resection was indicated for this giant symptomatic tumor in a very young patient. The informed consent was obtained. At surgery the tumor and distal radial nerve were exposed by an incision at the external aspect of the arm and proximal forearm; the upper pole of the tumor and proximal radial nerve were initially difficult to reach so that a second

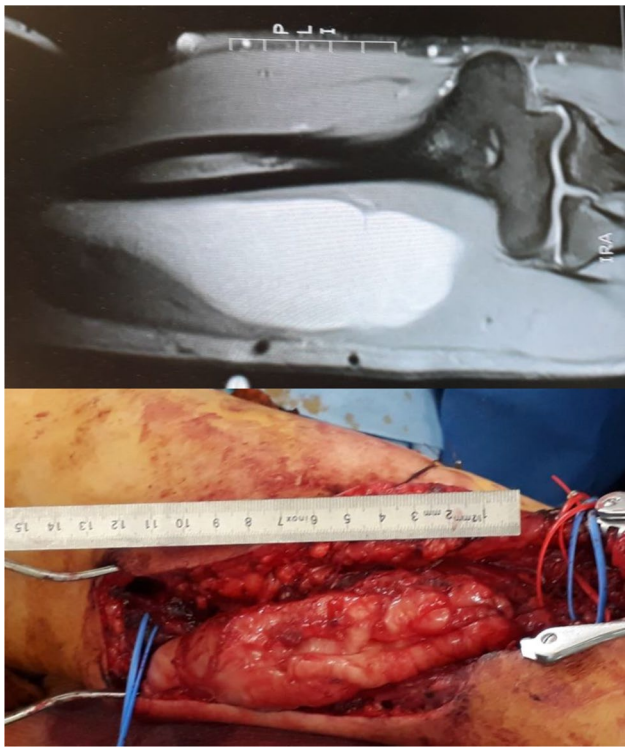

Fig. 1 MRI at arm and elbow level (top) and operative view (bottom) showing the huge tumor involving the radial nerve

incision was done at the inner aspect of the arm to expose the radial nerve down the retrohumeral course. Electrophysiology with stimulating and recording electrodes was used repeatedly. Using the microscope both poles of the tumor were exposed; the tumor capsule was incised; small fascicles completely embedded in the tumor, non-functional at the electrical analysis were sacrificed. Complete tumor resection by enucleation was achieved (Fig. 1 bottom). At final inspection 2 thirds of the radial nerve were in continuity between the two poles of resection; no fascicle reconstruction was feasible. Postoperatively the patient had paralysis of wrist extensors, Extensor Communis and APL. At 7.5 months the Tinel sign had progressed several cms distally while only the Extensor Carpi Ulnaris was showing weak activity.

Illustrative case n° 2

This 5-year old girl woke up from inguinal hernia repair with heavy pain in the thigh and quadriceps paralysis. She was allowed to leave the hospital after 2 days. A femoral nerve lesion was diagnosed, two electrophysiological studies being done. The patient was managed with physical therapy. She had to be reoperated 5 months after the first surgery, by another abdominal surgeon for recurrent inguinal hernia. The patient was referred to us at 6 months after the traumatizing surgery. She had complete quadriceps palsy. We

analyzed the first operative note: "no hernia, …, presence of a large ganglion which is dissected and sent for pathological examination". The pathological analysis demonstrated "no ganglion tissue but presence of numerous small nerve fascicles". We did explore the femoral nerve at inguinal and proximal thigh levels, which as expected was in complete discontinuity. We reconstructed the nerve with six 5-cm long grafts. The outcome at 4.5 years was good. We will never know whether a direct suture would have been feasible if early nerve repair had been done, with earlier and better recovery. The medicolegal issue concluded to malpractice.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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