




Recommendations for Patients with Complex Nerve Injuries during the COVID-19 Pandemic

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INTRODUCTION

The COVID-19 global pandemic has placed an unanticipated strain on healthcare systems and has dramatically influenced the manner in which physicians and allied health workers care for their patients. Delivery of care for patients with complex nerve injuries (CNIs) has the added challenges of time-sensitive surgical intervention, and the need for interdisciplinary care to optimize outcomes.¹ Requirements for physical distancing, closure of ambulatory care programs, and cancelation of elective surgeries have impacted the management of CNI. A radical rethink of healthcare delivery provision to patients with CNI during the pandemic is urgently needed. Furthermore, projections for the pandemic anticipate subsequent waves as well as future pandemics, highlighting the need to plan for further health system interruptions.²

This paper presents consensus recommendations for care of patients with CNI during the pandemic based on expert opinion from the Canadian Peripheral Nerve Research Collaborative, which is a group of neurologists, physiatrists, surgeons, occupational, and physiotherapists involved in CNI care. All complex nerve injury programs (CNIPs) across Canada are represented. CNIPs are comprised of medical, surgical, and rehabilitation specialists providing these services within a single clinical encounter.¹ We identify areas for change to the traditional care of CNI, with consideration for the protection of healthcare workers and patients, while providing timely and comprehensive care. The pandemic has also created an opportunity for innovation in all areas of interdisciplinary CNI care. We share preliminary insights regarding novel diagnostic, surgical, and rehabilitative approaches, with the understanding that they require rigorous evaluation to confirm effectiveness.

Patient Referral and Triage

The CNI population is broad and comprised of individuals with traumatic nerve injuries (e.g. brachial plexopathy), inflammatory

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nerve conditions (e.g. neuralgic amyotrophy), complex compression neuropathy (with secondary axonal loss), and nerve tumors. Individuals with spinal cord injury are also being evaluated through CNIPs for consideration for upper limb surgical interventions (e.g. nerve or tendon transfer),³ however, their care needs are different than the typical CNI patient and are outside the scope of this paper.

Functional recovery after CNI is dependent on timely evaluation and intervention. Patients with significant axon loss and limited clinical recovery are considered “urgent”, as surgery should be performed within 6 months or sooner (depending upon the distance to recipient’s muscle) to avoid irreversible muscle atrophy and degradation of motor endplates.⁴ Missing the window for surgical intervention can have life-long consequences to limb function;^{5,6} therefore, expedited referral and screening are of paramount importance. The challenge in identifying and triaging CNI patients for urgent assessment, evident before the pandemic, is now compounded by healthcare provision restrictions, including reduced clinic and surgical volumes. Furthermore, reduced availability of in-person assessments could result in delayed identification of CNI, as in-person sensorimotor physical examinations are often key to identifying neurological deficits (e.g. anterior shoulder dislocation resulting in axillary nerve palsy could be missed without in-person orthopedic follow-up).

Therefore, our strongest recommendation is an immediate referral of patients with CNI by primary treating physicians to their regional CNIP, through direct physician-to-physician communication to avoid delays. CNIPs must also establish a timely and responsive system of assessing and triaging referrals, allowing for multiple physicians to participate in this process where possible.

Virtual Care

The rapid adoption of virtual care in medicine has occurred to meet the unprecedented challenges of COVID-19⁷ and virtual visits should be implemented in the triage process to determine the requirement for, and urgency of, an in-person consultation. In addition, virtual assessments allow completion of the history and screening measures to minimize the time required in the clinic, involvement of family members who may not be permitted to attend an in-person visit, and facilitation of investigations. There are several factors specific to CNI requiring consideration: (1) video platforms are preferable to telephone, as video allows for a rudimentary physical examination to evaluate the continuity of major nerve branches and gauge recovery, (2) virtual consultations are appropriate for patients who do not have a time-sensitive nerve injury, for example, those with mild weakness, or who are rapidly improving, (3) CNI patients require close and frequent follow-up (typically every 3–6 months depending upon the stage of recovery). Many of these encounters can be performed virtually, including visits for titration of medication for pain or mood, reviewing the range of motion and strengthening exercises, and improving patient education.

However, where virtual care is not able to provide a thorough assessment of CNI, CNIPs will need to provide in-person assessments. A virtual assessment cannot substitute for the nuances of an in-person physical examination, such as evaluating for the Medical Research Council Grade 1 recovery. Therefore, if there is any concern about impediments to spontaneous or postoperative neurological recovery, or if injury characterization cannot be

Table 1: Triage recommendations: patients requiring an urgent “in-person” assessment

Patient characteristics
1. New, undifferentiated injury requiring an initial neurological examination and electrodiagnostic studies to determine the location and severity of injury.
2. Limited recovery, requiring electrodiagnostic testing, typically 3–5 months after injury.
3. Severe pain (e.g. nerve root avulsion) needing assessment for procedures such as dorsal root entry zone lesioning or infusion therapies.
4. In select cases, assessment of factors limiting recovery including: <ol style="list-style-type: none"> neuropathic pain, progressive worsening of ROM, compromised neurological function, or declining mental health (depression or anxiety). Other collateral injuries.
5. Patients requiring a time-sensitive surgical procedure, e.g. nerve repair or transfer in order to determine the optimal procedure and investigate potential donor nerves.
6. EMG to determine when nerve reinnervation has occurred, in order to initiate therapy to relearn the target movement, gain neurological control, and build strength and endurance of the newly re-innervated muscles.

EMG = electromyography; ROM = range of motion.

clearly defined virtual, we recommend that referring physicians and CNIPs have a low threshold for performing an in-person assessment. Our recommendations for those patients requiring urgent in-person assessment are presented in Table 1. For these patients, we recommend an interdisciplinary assessment where team members evaluate the patient during the same encounter, with one individual conducting the physical examination.

Infection Control

In order to provide safe, in-person visits, CNIPs must adhere to infection control measures according to prescribed public health recommendations with guidance from local hospital leadership.⁸ Consideration must be given to infection control in both clinical and surgical settings, with recommendations evolving with an improved understanding of COVID-19. For example, consensus is evolving on requirements for full personal protective equipment (PPE) use during surgery and CNI surgical teams may be sufficiently protected using droplet precautions only (thereby reducing PPE usage).⁹ We endorse the recent recommendations published by the American Association for Neuromuscular & Electrodiagnostic Medicine regarding general infection control measures for the resumption of routine electrodiagnostic testing.¹⁰ Infection control factors particularly germane to the evaluation and treatment of CNI are outlined in Table 2.

Neurophysiology and Other Testing

In order to prevent potential life-long loss of function, electrodiagnostic studies, including nerve conduction studies and needle electromyography (EMG), must be performed early in time-sensitive patients. EMG is a valuable tool in the initial diagnosis and prognostication of CNIs, as well as in helping to evaluate recovery and guide rehabilitation (Table 3).

EMG should be performed after changes are expected (~3 weeks after injury) due to Wallerian degeneration and repeated in a timeframe that allows surgical intervention before the

Table 2: Recommended infection control measures

<i>General measures</i>	<i>Clinical and electrodiagnostic visits</i>	<i>Surgical considerations</i>
Waiting room and treatment room occupancy to respect two-meter physical distancing.	The number of team members in contact with the patient should be minimized.	Consider perioperative testing of patients for COVID-19; droplet precautions for surgery likely sufficient.
Screening for COVID-19 exposure according to local institutional guidelines (online screening tools are readily available), prior to appointment and upon arrival.	Assessment/treatment of COVID-19-positive patients should be deferred until the patient is 14 days out from symptom onset, and is symptom free, and tests negative.	General anesthesia is an aerosol-generating procedure and requires the use of advanced PPE for the anesthesia and nursing teams during induction and extubation.
Healthcare teams are required to wear PPE, including a mask and gloves during patient interactions.	Whenever possible, disposable equipment should be used. All exposed non-disposable neurodiagnostic and therapy equipment should be sanitized between patients.	The surgical team must vacate the operating room for seven air cycles (typically 15–20 minutes depending on facility) during intubation and extubation to allow aerosolized virus particles to be cleared by air exchange. ¹⁷
Patients should wear a mask during healthcare encounters consistent with regional recommendations.	Escorts/caregivers should be present only if essential. The use of telephone-based translation services is recommended.	

PPE = personal protective equipment.

Table 3: Role of electrodiagnosis in management of complex nerve injuries

1. Establish diagnosis, localization, and severity of nerve injury.
2. For brachial plexopathies, assist in the determination of the presence of root avulsion.
3. Assess the health of both donor and recipient nerve/muscle pairs.
4. Estimate prognosis for recovery after nerve injury; the presence of significant numbers of voluntary motor units indicates (depending on timing) a favorable prognosis.
5. Assess progress after surgical intervention. The presence of new nascent motor unit potentials indicates timing is optimal to begin therapy to enhance cortical plasticity, using techniques such as teaching donor activation to drive target muscles.

Table 4: Recommendations for early medical management of CNI

<i>Early interventions</i>	i. Operative fixation of orthopedic injuries to allow early mobilization. ii. Positioning of the limb to minimize joint contractures and limb edema. iii. PT and OT to mobilize the injured limb with early passive ROM.
<i>Neuropathic pain management</i>	i. Multimodal approach utilizing exercise, TENS, central processing techniques, and psychological coping strategies, e.g. cognitive behavioral therapy. ii. Medications: often need combined treatment with medications at lowest effective doses.
<i>Assess mood and anxiety</i>	Use of screening tools such as the PHQ-9 and the GAD-7.
<i>Measures of global function</i>	Help identify patients who need more intensive intervention.

CNI = complex nerve injury; GAD-7 = Generalized Anxiety and Depression Scale-7; OT = occupational therapy; PHQ-9 = Patient Health Questionnaire-9; PT = physiotherapy; ROM = range of motion; TENS = transcutaneous electrical nerve stimulation.

window of recovery has started to close. EMG is also often indicated at several time points after surgery to look for evidence of reinnervation, which helps guide postoperative rehabilitation. The minimum number of key studies, including assessment of recovering muscle groups as well as possible donor nerves for nerve transfer surgery, should be performed to minimize time in the laboratory. If possible, the consultation and EMG procedure should be performed in the same clinic room to minimize points of contact for patients.

Other testing, including ultrasound and MRI, may be required in the evaluation of CNI, but should be limited to essential tests to limit exposure to the hospital environment.

Nonoperative Treatments

Many patients have suffered significant trauma and often have concomitant orthopedic and central neurological system injuries, which must be identified.¹¹ In addition to management of pain, range of motion and edema, psychological factors and social context need to be taken into account to optimize coping and global function. Table 4 outlines aspects of medical care that must continue despite the pandemic.

Virtual care with the patient and caregivers should facilitate these interventions, wherever possible. In selective circumstances, EMG biofeedback devices and orthoses can be purchased online with home delivery with direction provided virtually by the care provider. Challenges in care delivery during the pandemic highlight the need for excellent collaboration and communication between treating clinicians.

Surgical Considerations

The goal for surgical care is to treat in a timely manner with direct repair, nerve graft, or nerve transfer where appropriate, despite the challenges of the COVID-19 pandemic. In the pandemic context, there are several systemic factors that may impact treatment, including access to surgical resources and risk of perioperative exposure of the surgical team to COVID-19. Therefore, if early reconstruction does not occur due to time delay or other factors, and irreversible loss of motor endplates occurs, secondary reconstructive options such as tendon transfers (or more elaborate reconstructions such as free functioning muscle transfers) may be required at a later time point to enhance

function. However, it is strongly encouraged to manage these patients with primary nerve reconstruction, wherever possible.

Preoperative COVID-19 testing is subject to recommendations from regional public health authorities, disease prevalence within the population, and availability of testing resources. Various strategies exist including screening questionnaires and assessments to stratify risk of disease, which informs whether a test is performed. Alternatively, some advocate for testing all surgical patients due to perioperative morbidity and mortality in asymptomatic patients with COVID-19.^{12,13} Overall, we suggest a low threshold for preoperative COVID-19 testing given the risk to patient and healthcare team. If testing positive, then patients are delayed at least 2 weeks or until asymptomatic, which is expected to have minimal impact on their nerve reconstruction.

The majority of patients requiring reconstructive nerve surgery procedures are young, with limited comorbidities and thus may be treated as outpatients.¹⁴ Therefore, nerve surgery creates a modest impact on hospital resources. Furthermore, many procedures can be completed under regional anesthesia, which obviates the need for airway-related PPE use.¹⁵ It is recommended that nerve surgery be completed under regional anesthesia, where possible.

To mitigate perioperative infectious risk, we provide an example of how the surgical suite environment can be modified. This model – referred to as the surgical procedure rooms and developed at St. Paul’s Hospital, in Vancouver, British Columbia – uses an isolated site in the hospital that has adjacent operating room suites, with a neighboring patient care area that provides space for anesthetic care. This model optimizes patient flow through the surgical care pathway by increasing the number of patients being treated per day. Ideally, cases should be less than 2 hours in length. When longer cases are booked, patients who can have their surgery completed under local anesthetic (e.g. carpal tunnel release), can be treated between regional block cases to help the flow in the preoperative and postoperative area.

Pediatric Peripheral Nerve Surgery

The principles guiding the management of CNI in children during the pandemic are similar to that in adults, with a few unique considerations. The two main populations are brachial plexus birth injury (BPBI; most common) and traumatic nerve injuries.

Worldwide experience suggests that COVID-19 infection is less frequent in children, and pediatric cases requiring ICU admission or ventilatory support are rare.¹⁶ Each pediatric patient, however, is attended by a parent which needs to be considered when configuring hospital spaces.

Assessment of CNI in young children can be difficult, and in-person assessment by an interdisciplinary team of surgeons and therapists with pediatric expertise is recommended.

For infants with BPBI, we recommend minimizing in-person assessments to the key time points within the first year of life where decisions regarding the necessity of a primary surgery are made (typically at 3, 6, and/or 9 months of age).¹⁷ Virtual therapy consultations can be utilized between the in-person assessments to monitor progress and adherence to therapy regimens, as well as to continue caregiver education regarding BPBI. CNI to older children follows the same principles as that of an adult.

If the decision to operate has been made and all necessary investigations are completed, nerve reconstruction should be

completed as soon as possible. For BPBI, this time window should be within 3 weeks of the decision. Other traumatic nerve injuries in children would follow similar guidelines for adults.

The risks of general anesthesia in the presence of a respiratory infection (which are common in the pediatric population) must be carefully considered against the potential detrimental effects of deferring the nerve repair; decision-making should include the surgeon, anesthetist, and patient caregivers. Given the time sensitivity of brachial plexus reconstruction in infants with BPBI, we recommend deferring the operation by a minimum of 2 weeks following a milder upper respiratory tract infection (URTI), and 6 weeks for any severe URTI or lower respiratory tract infection. The same principles would be followed in an infant or child with active COVID-19 infection.¹⁸

Rehabilitation

After nerve injury, there are immediate changes in the peripheral and central nervous system, which continue through reinnervation and recovery.¹⁹ Extensive rehabilitation after nerve injury is required to achieve optimal outcome and function.

Postoperative rehabilitation is typically performed through “hands-on” sessions with a therapist utilizing modalities including exercises, dynamic-assist orthosis, biofeedback, and neuromuscular stimulation. Early intervention focuses on maintaining range of motion, control of edema and pain. Following nerve transfer surgery, rehabilitation is directed towards sensory and motor cortical remapping to facilitate optimal recruitment of the new neural connections.²⁰ Patients are taught to activate the donor nerve in combination with recipient muscle function. Following reinnervation, rehabilitation focuses on motor re-education to learn how to correctly recruit the newly re-innervated muscle. Depending on the stage of recovery, visits (in-person or virtual) with a therapist may occur weekly to monthly. During the pandemic, this process may be compromised. We advocate for virtual therapy visits when possible, with the understanding that in-person sessions are required to fabricate resting and dynamic-assist orthoses, provide instruction on biofeedback machines and tactile reinforcement of desired motor patterns for exercise.

Research and Education

The pandemic has impacted research in the fields of nerve injury and repair, with delays affecting multiple steps of the research process. These include cancellation of grant competitions and delays in reviewers’ comments. Funding is being diverted to COVID-19-related research, reducing resources available for other areas. Carrying out research projects is hindered by the inability to obtain ethics approval and forced closure or limited operation of research labs. The pandemic has had an adverse impact on participant recruitment, protocol adherence, treatment outcomes, meeting grant deliverables, and allowing research trainees to complete thesis projects on time.

While traditional research endeavors have been interrupted, the pandemic has led to the development of innovative service delivery strategies for CNI patients, presenting novel research opportunities. These innovations now require a systematic evaluation and create novel opportunities for future scholarly activity. Described above, telehealth tools lend themselves well to remote consults, but using them to their full potential will require systematic development and validation to improve features and

Table 5: Recommendations for future planning*Recommendations for administration:*

- recognize the time-sensitive nature of this patient population.
- Develop an ethical strategy for triage based on urgency, rather than time of referral.
- Secure resources required for patient assessment, including disposable items for electrodiagnostic testing (electrodes, markers, and tape measures) and PPE.
- Dedicate clinical and surgical resources for CNI patients.

Recommendations for an interdisciplinary approach:

- develop a team approach to patients with CNI allowing a “one-stop shop”, with only one point of contact to the healthcare system.
- Recommended team members: electrodiagnostics (neurologist or physiatrist), peripheral nerve surgeons, and allied health professionals, e.g. occupational therapists, physical therapists, pain specialists, psychologists, and social workers.

Recommendations for increased operating room efficiency:

- eliminate traditional “summer slowdown” periods.
- Extend the length of OR days.
- Perform urgent surgery during nontraditional times such as evenings and weekends.
- Swing rooms: incorporation of adjacent block rooms with a separate pre-anesthetic area called “swing rooms”. Upper extremity blocks are performed by anesthesia in the pre-anesthetic area while surgeons alternate between two operating rooms.
- Organize teams of peripheral nerve surgeons to maximize throughput of patients requiring surgical care and have care providers on backup in the event of illness.

CNI = complex nerve injury; PPE = personal protective equipment.

functionality. The creation of a standardized “virtual neurologic examination”, electronic administration of patient questionnaires, online education modules, and evaluation of patient experience with telemedicine are areas ripe for study.

Education for CNI has been affected by reduced clinic volumes which compromise trainees’ opportunity to acquire hands-on experiences and skills. The cancelation of in-person seminars further compounds the situation by reducing the opportunity for mentoring and didactic teaching. We recommend the systematic development of a coordinated program to deliver didactic teaching for trainees throughout the country. One example is the Canadian Plastic Surgery National Grand Rounds, created by the Canadian Royal College Plastic Surgery Specialty Committee, and is administered nationally to all residents and consultants each week via a virtual platform. Finally, restrictions on travel and the need for physical distancing also mean that future medical conferences may need to shift from in-person meeting to a virtual format, thereby changing how scientific knowledge is disseminated.

Future Directions

Addressing and responding to challenges experienced during the pandemic may help to guide responses to similar scenarios in the future. In the context of CNI, we recommend first tackling the most urgent issues that will have an immediate impact on quality of care for patients with CNI, including expanding and validating the capabilities of communication tools and virtual platforms. The next priority is to improve or optimize the delivery of interdisciplinary care so as to minimize the risk of exposure. In this regard, expanding the capabilities of digital tools to provide a

richer array of clinical information and time /expense associated with travel for rural patients, would be worthwhile efforts. The lessons learned from the pandemic have been valuable in highlighting the need for a widespread integrated approach for future healthcare delivery.

As CNIPs start to “re-open”, they must have a plan in place to prioritize and manage the backlog of patients impacted by the sudden, unanticipated halt to clinical care. In addition, programs must be cognizant of the potential for a second wave of the pandemic, potentially necessitating a similar shutdown of services affecting peripheral nerve patients. Table 5 highlights recommendations for future planning when these services do open.

CONCLUSION

Significant permanent morbidity will occur in patients who experience delays in CNI surgery and rehabilitation. A number of simple strategies can be introduced to facilitate ongoing neurologic assessment, surgical care, and rehabilitation of CNI and reduce the impact on hospital capacity and PPE supplies. Implementation of an interdisciplinary model and inclusion of virtual health care are key factors in providing safe and effective treatment of patients with CNI during a serious pandemic, such as COVID-19.

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All the authors contributed their clinical expertise to prove recommendations.

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