Evidence-Based Approach to Timing of Nerve Surgery

A Review

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Abstract: Events causing acute stress to the health care system, such as the COVID-19 pandemic, place clinical decisions under increased scrutiny. The priority and timing of surgical procedures are critically evaluated under these conditions, yet the optimal timing of procedures is a key consideration in any clinical setting. There is currently no single article consolidating a large body of current evidence on timing of nerve surgery. MEDLINE and EMBASE databases were systematically reviewed for clinical data on nerve repair and reconstruction to define the current understanding of timing and other factors affecting outcomes. Special attention was given to sensory, mixed/motor, nerve compression syndromes, and nerve pain. The data presented in this review may assist surgeons in making sound, evidence-based clinical decisions regarding timing of nerve surgery.

Key Words: nerve surgery, timing, nerve repair, timing nerve surgery, timing nerve repair, delayed nerve repair, immediate nerve repair, nerve timing, nerve timing outcomes, delayed surgery nerve outcomes, acute versus delayed nerve repair, timing nerve decompression, acute nerve surgery, acute nerve repair, coronavirus, COVID-19

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The circumstances created by the COVID-19 pandemic have shed light on a number of unanswered questions, particularly with regard to the acuity of conditions and urgency of surgical procedures. In the context of nerve surgery, the need for expedited decisions has revealed a lack of consolidated evidence, as there is currently no published article presenting clinical data on timing considerations of nerve surgery across a wide variety of injury patterns. Surgery remains necessary for many patients, even amid resource diversion, and all procedures exist within a timing hierarchy. An evidence-based approach is needed to adequately distinguish the relative acuity of different conditions, particularly within broad (and often misunderstood) categories such as “elective” surgery, which is frequently conflated with “optional.”

Published recommendations not created or endorsed by expert subspecialty groups are often vague and fail to address the nuances of clinical decision making (Tables 1, 2; Fig. 1). Overly simplified

**TABLE 1. Orthopaedic surgery case triage**

| Emergent—within 6 h |
|-------------------|
| • Compartment syndrome |
| • Open fracture |
| • Joint dislocations |
| • Fracture-dislocations |
| • Dysvascular limb/ex fix |
| • Traumatic amp/replant |
| • Septic joint |
| • Abscess |
| • Cauda Equina syndrome |

| Urgent—within 24–48 h |
|---------------------|
| • Hip and femur fractures |
| • Pelvis and acetabulum fractures |
| • Long bone (femur, tibia, humerus) fractures |
| • Multiple fractures |
| • Unstable spine fractures or progressive neurologic deficits |

| Acute—within 7 d |
|-----------------|
| • Fractures in general |
| • Hand/UE |
| • Ankle/tibial plateau, etc |
| • Spine fractures without gross |
| • Instability/cord compromise or neurologic symptoms |
| • Multiligamentous knee dislocation (s/p initial stabilization [ex fix] if necessary) |

| Semi-elective |
|---------------|
| • Incarcerated meniscus |
| • Biceps tear/tendon repairs |
| • Nerve transection |

| Elective |
|----------|
| • Total joint replacement (hip/knee/shoulder/ankle) |
| • Degenerative spine without cord/neurologic compromise |
| • Nonunion without hardware compromise/unstable extremity |
| • Degenerative hand/foot/ankle |
| • Isolated knee ligament/ meniscus etc |
| • Hardware removal |

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ex fix, external fixation; s/p, status post; UE, upper extremity.
algorithms will do little to assist surgeons and may even give a false sense of security when further deliberation is warranted. Physicians should always operate by best practices aligned with current evidence. A misstep in clinical judgment can leave patients and surgeons vulnerable to poor outcomes. A condensed view of the relevant data could as- sist physicians advocating for patients’ timely treatment. The following review may ultimately serve as a resource to positively impact outcomes involving both neurons and nonneuronal cells is initiated2,3 (Fig. 2). In- fluential changes increase blood-nerve barrier permeability, activating Schwann cells and macrophages.4 Nerve injuries present with varying degrees of involvement, which often dictate treatment and expected outcomes (Table 4). In less severe injuries, natural processes are often successful in regenerating the injured portion of a nerve, and full functional recovery may be achieved without interven- tion.5 However, with more severe injury, prolonged neuronal input defi- ciency distal to the site of injury can significantly reduce the regenerative success of nerves.4,5,8

### DELAYED TREATMENT OF INJURED NERVES

When peripheral nerves are injured, a coordinated response involving both neurons and nonneuronal cells is initiated2,3 (Fig. 2). Inflammatory changes increase blood-nerve barrier permeability, activating Schwann cells and macrophages.4 Nerve injuries present with varying degrees of involvement, which often dictate treatment and expected outcomes (Table 4). In less severe injuries, natural processes are often successful in regenerating the injured portion of a nerve, and full functional recovery may be achieved without intervention.5 However, with more severe injury, prolonged neuronal input deficiency distal to the site of injury can significantly reduce the regenerative success of nerves.4,5,8

### METHODS

The authors performed a systematic review of the MEDLINE and EMBASE databases using a comprehensive combination of keywords and search algorithm according to PRISMA guidelines. The literature search focused on clinical evidence-based data on nerve repair and reconstruction and was undertaken to define the current understanding of nerve repair timing and outcomes. Particular emphasis was made evaluating sensory, mixed/motor, nerve compression syndromes, and nerve pain. Search terms are listed in Table 3.
In large nerve defects with greater regeneration times, denervated distal targets may not be successfully regenerated. In the distal stump of a severed nerve, endoneurial tubes progressively and permanently shrink in diameter, and Schwann cells lose their capacity to support axonal growth when left transected (Figs. 2, 3). Target sensory and motor end-organs deteriorate irreversibly over time. Another cause for suboptimal recovery in peripheral nerve injury is upstream degeneration. When nerve injuries are incurred, neuronal cell death commences in the dorsal root ganglia (distal sensory nerve injuries) and/or the spinal motor neurons (proximal nerve injuries, eg, brachial plexus). Cortical changes are known to develop in cases of prolonged neuronal deficiency, and neural plasticity should be considered when making decisions related to timing of intervention.

Peripheral nerve injuries are known to result in poor sensory and/or motor function if left untreated. Significant declines in postoperative function and chronic pain may lead to long-term disabilities for patients who do not receive timely operative treatment. This could impact more than patient outcomes, as both proximal and distal nerve injuries may contribute to high costs, lost work or medical disabilities, increased pharmacologic dependencies and expenses, and substantial lost function. In a study of 66 median and/or ulnar nerve lesions, Dumont and Alnot found that the time from injury to repair was the most significant prognostic factor in functional nerve recovery. Multiple reports in the literature describe the negative implications of delayed repair on sensory and motor outcomes in a variety of injury patterns, with one study indicating the critical window lies within 3 months. Considering the implications of prolonged nervous deficiency, timing is critical for treatment algorithms involving the peripheral nerves.

SENSORY VERSUS MOTOR NERVES
Clinical data indicate that sensory nerves may be less affected by prolonged denervation than motor nerves (Table 6). However, the histologic response to prolonged denervation seems to be amplified for sensory when compared with motor nerves. The recovery of mixed motor nerves degrades dramatically over time, as repairs delayed more than 1 month exhibit significant functional declines. This is especially pronounced in motor outcomes, as the functional loss is even more amplified the longer the muscle is denervated because the end-target organ (eg, muscle supplied by an injured nerve) may not regenerate.

In a systematic review of 270 mixed nerve injuries (150 ulnar, 75 median, 45 radial), good to excellent sensory recovery (scoring scales in

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**FIGURE 1.** Treatment algorithm for elective cases currently in use by some centers. Piedmont Healthcare System, Georgia.
Delayed treatment of injured nerves

Table 7) occurred in 90.9% of immediate repairs (<24 hours from time of injury), 58.3% with a delay of <1 month, 73.3% with a delay of 1 to 3 months, and 46.2% with a delay of ≥3 months (Table 8). Although aggregate data show declines at monthly intervals, individual studies have reported increments as small as 14 days for progressive functional decline.4,54,58-65

In the same group, good to excellent motor recovery was achieved in 85.7% of immediate repairs, 80.0% with a delay of <1 month, 71.9% with a delay of 1 to 3 months, 52.9% with a delay of 3 to 6 months, and 25.0% with a delay of ≥6 months (Table 8). For each month of delay to repair, there was a significant decrease in the odds of good-excellent motor recovery (odds ratio, 0.93; 95% confidence interval [CI], 0.90–0.97; P < 0.01).22 In one study of 260 radial and posterior interosseous nerves, 49% of nerves repaired within 14 days achieved good-excellent results, whereas only 28% of late repairs (mean, 190 days; range, 15–440 days) produced good-excellent outcomes.58 One study involving 82 musculocutaneous nerve injuries reported 78% (21/27) good-excellent results when repaired within 14 days and 62% (34/55) when performed >14 days after injury.54

When making decisions for timing of nerve procedures, it is critical to use a multifactorial approach. The trends described previously are broad and do not account for variables such as gap length, mechanism of injury, proximal versus distal location, and other considerations to be discussed in later sections, which may have a compound negative effect on delayed repairs (Tables 6, 8).

Take-Home Messages

Sensory-Only

Sensory-only nerve injuries should be considered acutely (within 14 days of injury) when possible to prevent painful neuroma formation. Once a neuroma occurs, it becomes an additional task to overcome the psychological impairment and, in some instances, narcotic dependency in order to return patients to a healthy return to functional activities. In cases where the initial presentation is delayed, it is suggested to repair within 14 days of clinical presentation if the injury occurred <6 months prior. After 6 months, reconstruction may still be undertaken but with consideration for possible adjunctive techniques to optimize outcomes based on individual prognostic factors.

Functional sensory return is not as time sensitive as muscle reinnervation. Although sooner is better, evidence points to functional sensory return being achievable for several years after complete transaction, yet the quality of such delayed recovery might remain less predictable. Additional preoperative factors that should be considered in sensory-only timing decisions include age, the mechanism of injury, gap length, and reinnervation potential.
Mixed/Motor

For mixed/motor nerve injuries, immediate repair (within 24 hours of injury) is suggested when possible. In cases where the initial presentation is delayed, it is suggested to repair within 14 days of clinical presentation if the injury occurred <6 months prior. After 6 months, a multifactorial approach including but not limited to nerve grafting, nerve transfer, and/or tendon transfer may be necessary to restore function.

Motor endplate degradation may limit the amount of time available for any functional motor return. Typically, efforts should be taken to provide axons to the muscle endplate no later than 1 year after complete transections.95,96 Because of the slow rate (~1 mm/d) and unidirectional nature (neuronal outgrowth only occurs distally from proximal end), irreversible motor endplate degradation has been observed as early as 12 months after injury.3,95,96 Additional preoperative factors that

TABLE 4. Classifications of Nerve Injuries

| Degree of Nerve Injury | Definition of Nerve Injury | Prognosis | Tinel Sign | Surgical Intervention |
|------------------------|----------------------------|-----------|------------|-----------------------|
| First (neurapraxia)    | Segmental demyelination; Axonal continuity maintained; endoneurium, perineurium and epineurium, intact | Favorable | None | None, distal decompression |
| Second (axonotmesis)   | Discontinuity of axon and myelin; endoneurium, perineurium, and epineurium intact | Favorable | Present, progressive | None, distal decompression, supercharge procedure |
| Third                  | Discontinuity of axon, myelin and endoneurium; perineurium and epineurium intact | Favorable | Present, progressive | None, distal decompression, supercharge procedure |
| Fourth                 | Only the epineurium remains intact | Unfavorable | Present; no progression | Nerve repair, graft, transfer |
| Fifth (neurotmesis)    | Complete nerve transection | Unfavorable | Present; no progression | Nerve repair, graft, transfer |
| Sixth                  | Mixed injury pattern | Variable | Variable | All options may be appropriate |

Table adapted from Moore et al.5
should be considered in mixed nerves include the following: age, nerve injured, level of injury, concomitant vessel or tendon injuries, and gap length (Table 8).  

**DIGITAL NERVES**

Digital nerve injuries are a unique subset of sensory nerve injuries and should be considered independently with respect to timing of operative intervention. Although digital nerves primarily supply sensation to the hand, abnormal sensory outcomes have been shown to have an effect on motor function. Patients with good active range of motion may not use the affected digit because of the lack of sensation or pain with movement, resulting in lasting stiffness and/or weakness. Pain secondary to symptomatic neuroma formation has been shown to interfere with rehabilitation and functional outcomes, especially in the thumb and index finger, as both are critical for normal pinch and grip function. A time to repair of <15 days has been associated with significantly improved sensory outcomes (Table 9). Another study including 254 digital nerve repairs reported significantly improved outcomes in repairs performed within 3 months of injury.  

**Take-Home Messages**

For digital nerves, acute repair (within 14 days of injury) is suggested when possible. In cases where the initial presentation is delayed, repair is suggested within 3 months after injury to prevent painful neuroma formation. Once a neuroma occurs, it becomes an additional task to overcome the psychological impairment and, in some instances, narcotic dependency in order to return patients to a healthy return to functional activities. After 3 months, reconstruction may still be undertaken but with consideration for possible adjunctive techniques to optimize outcomes based on individual prognostic factors.

**TABLE 5.** Comparison of Patient-Reported Outcomes in Untreated Peripheral Nerve Injuries (Novak et al27) Versus Those Having Undergone Operative Interventions

| | SF-36 Scores | DASH/QuickDASH Scores |
|---|---|---|
| | Physical Function | Role Limit to Physical Health | Role Limit to Emotional Problems | Energy/Fatigue | Emotional Well-Being | Social Function |
| | Mean ± SD | 60.0 ± 23.0 | 23.0 ± 33.0 | 45.0 ± 43.0 | 49.0 ± 24.0 | 58.0 ± 23.0 | 57.0 ± 30.0 |
| Novak et al27 >6 mo after injury without operative intervention (n = 57) | | | | | | |
| Lequint et al23 (n = 30): ulnar nerve transposition | | | | | | |
| Domeshek et al23 (n = 19): upper extremity nerve decompression and/or transposition | | | | | | |
| Ido et al24 (n = 52): ulnar nerve transposition | | | | | | |
| Guse and Moran25 (n = 54): upper extremity neuroma excision, transposition, or nerve repair (43 traumatic injuries) | | | | | | |

**FIGURE 3.** Effect of Schwann cell insufficiency on distal nerve segments after prolonged discontinuity. 

**TABLE 6.** Effect of nerve function and injury characteristics on functional outcomes after nerve repair.
TABLE 6. Outcomes of Sensory-Only Peripheral Nerve Repairs

| Predictor       | Group               | Satisfactory Recovery (Good-Excellent) Sensory Recovery |
|-----------------|---------------------|-------------------------------------------------------|
| Age             | ≤16 y               | 100% (7/7)                                             |
|                 | 16–25 y             | 75.0% (24/32)                                          |
|                 | 26–40 y             | 88.5% (23/26)                                          |
|                 | >40 y               | 75.0% (18/24)                                          |
| Total (n)       | n = 89              |                                                       |
| Univariate odds ratio (95% CI): | per year | P = 0.31 |
| Sex             | Male                | 67.4% (29/43)                                          |
|                 | Female              | 95.5% (21/22)                                          |
| Total (n)       | n = 65              |                                                       |
| Univariate odds ratio (95% CI): | female vs male | P = 0.03 |
| Nerve           | Digital             | 80.7% (71/88)                                          |
|                 | Total (n)           | n = 88                                                |
| Graft length    | No graft            | 100% (2/2)                                             |
|                 | ≤30 mm              | 76.2% (45/54)                                          |
|                 | 30–50 mm            | 33.3% (2/6)                                            |
|                 | >50 mm              | 33.3% (1/3)                                            |
| Total (n)       | n = 65              |                                                       |
| Univariate odds ratio (95% CI): | per month | P < 0.01 |
| Delay           | No delay (<24 h)    | 78.6% (33/42)                                          |
|                 | 1–30 d              | 75.0% (3/4)                                            |
|                 | 1–3 mo              | 100% (5/5)                                             |
|                 | 3–6 mo              | 84.6% (1/13)                                           |
|                 | 6–12 mo             | 75.0% (3/4)                                            |
|                 | >12 mo              | 100% (2/2)                                             |
| Total (n)       | n = 70              |                                                       |
| Univariate odds ratio (95% CI): | per month | P = 0.64 |

Table adapted from He et al.32

sensory-only nerves include gap length, ability to identify proximal and distal stumps, and concomitant vessel or tendon injuries (Table 6).32

ACUTE NERVE COMPRESSION/DYSFUNCTION

In cases of acute compressive neuropathy, prompt diagnosis is particularly important because symptoms and functional outcomes deteriorate more quickly due to severe ischemic conditions and/or intraneural scarring.125 Acute compressive neuropathy in the ulnar nerve is rare, with the majority of cases occurring in Guyon’s canal secondary to ganglion cyst.125–128 Although early decompression has been recommended, the literature lacks algorithms for timing of intervention.126–129

Treatment algorithms have been described in the literature for acute median nerve compression, which is frequently associated with distal radius fractures.130–134 In healthy patients, carpal tunnel pressure has been reported from 5 to 14 mm Hg. Although carpal tunnel pressure has been reported from 12 to 43 mm Hg in patients with chronic carpal tunnel syndrome, acute cases may be elevated between 40 and 60 mm Hg.129,135 Although the exact threshold for irreversible damage is unknown, the literature has indicated that irreversible damage may be incurred at pressures as low as 30 mm Hg.129

Given the amplified sequelae of acute compression, pressure measurements may be taken after 2 hours of nonsurgical intervention (eg, elevation or dressing release) using a wick catheter or STIC device.131 The current literature on compartment syndrome indicates delayed intervention may lead to additional operations and/or permanent ischemic nerve damage.136 Although it is difficult to pinpoint the delay time because the exact time of onset is often not known, earlier intervention has been associated with significantly improved functional recovery.123,137–141

In a study of 22 patients, 68% of those treated within 12 hours recovered normal function, compared with only 8% in patients treated >12 hours from time of onset.136,138 Nerve conduction velocity returned to normal if compartment release was performed within 4 hours.138,142 Of note, patient age seems to play a role in functional outcomes of compartment release. In a review of 39 pediatric cases with a mean time to diagnosis of 48 hours, 54% returned to normal function.142 Another review reported that 85% of pediatric patients achieved full functional recovery when treated within a mean of 24.5 hours after the onset of symptoms.131,143

Frequently, patients present with postsurgical nerve dysfunction such as radial nerve palsy after open reduction and internal fixation of humeral fractures,144,145 peroneal and/or saphenous nerve palsy after knee ligament reconstruction and/or dislocation,146–149 or ulnar nerve complications after medial or collateral ligament reconstruction of the elbow.150–153 The literature addressing timing in these contexts is highly variable.144,145,147,150,151 Generally, symptom severity and duration are thought to be indicators of potential for spontaneous recovery or need for operative intervention. Although the literature lacks consensus recommendations, close monitoring of nerve symptoms is recommended in the early postoperative period (up to 12 weeks).144,145,147,150,151

Take-Home Messages

In the case of posttraumatic compressive neuropathy, if symptoms persist and/or elevated pressure remains in the affected tunnel/canal at 2 hours after injury, exploration with possible release should be considered.32

TABLE 7. Sensory and Range of Motion Recovery Scoring Scales

| Mackinnon-Dellon Scale (modified from British Medical Research Council Score of Sensory Recovery) |
|---------------------------------------------------------------|
| S0 (failure): absence of sensibility in the autonomous area of the nerve |
| S1 (poor): recovery of deep cutaneous pain and tactile sensibility |
| S1+ (poor): recovery of superficial pain sensibility |
| S2 (poor): recovery of some degree of superficial cutaneous pain and tactile sensibility |
| S2+ (poor): as in s2, but with overresponse |
| S3 (poor): return of pain and tactile sensibility with disappearance of over response, s2PD >15 mm, m2PD >7 mm |
| S3+ (good): return of sensibility as in s3 with some recovery of 2-point discrimination: s2PD, 7–15 mm; m2PD, 4–7 mm |
| S4 (excellent): complete recovery: s2PD, 2–6 mm; m2PD, 2–3 mm |

| ASH classification of total active motion (TAM) recovery |
|--------------------------------------------------------|
| Excellent: TAM equal to normal side |
| Good: TAM >75% of normal side |
| Fair: TAM >50% of normal side |
| Poor: TAM <50% of normal side |
be considered within 8 hours of symptom onset. Although the literature indicates that long-term changes may develop within this time window, clinical symptoms must be evaluated on a case-by-case basis. Given the lack of consensus and high-quality data, published timing recommendations should be included as one part of the clinical decision-making process rather than a sole determining factor.

In cases of compressive neuropathy secondary to cyst formation, decompression should be considered within 3 months of symptom onset if the patient's symptoms are minimal and nonprogressive. If symptoms progress rapidly and/or the patient has already incurred significant functional deficits, decompression may be performed acutely.

When treating injuries frequently associated with posttraumatic compressive neuropathy, the potential for compression should be considered when planning initial treatment. For example, in distal radius fractures, different fixation methods have been linked to varying rates of posttraumatic carpal tunnel syndrome.

Given the high variability of postsurgical neuropaxia, even in similar injury/repair patterns, patients with neuropathic symptoms should be closely monitored in the first several weeks postoperatively. At approximately 6 weeks, nerve conduction study (NCS) and electromyography (EMG) may further clarify etiology and serve as a baseline for future comparison if symptoms persist. At this time, surgeons may decide to schedule surgery or continue observation with a possible second NCS/EMG at 12 weeks. Although some have questioned the sensitivity of electrophysiologic testing in chronic carpal tunnel syndrome, the same studies show that symptom severity is significantly associated with positive NCS findings. In cases of acute, traumatic, or postsurgical compression, compartment pressure is often elevated above typical chronic compression values, indicating that NCS/EMG may have greater utility for monitoring suspected neuropathy in acute compression.

Ultimately, multiple modalities must be considered (eg, patient complaints, physical examination, NCS/EMG, radiological studies, and

### Table 8. Outcomes of Mixed Motor Peripheral Nerve Repairs

| Predictor     | Group | Satisfactory (Good-Excellent) Sensory Recovery | Satisfactory (Good-Excellent) Motor Recovery |
|---------------|-------|----------------------------------------------|--------------------------------------------|
| **Age**       | <16 y | 60.9% (56/92)                                | 66.7% (54/81)                               |
|               | 16–25 y | 64.7% (44/68)                               | 63.6% (35/55)                              |
|               | 26–40 y | 57.8% (38/66)                               | 60.4% (32/53)                              |
|               | >40 y | 40.9% (18/44)                               | 47.6% (20/42)                              |
| Total (n)     |       | n = 270                                      | n = 231                                     |
| Univariate odds ratio per year (95% CI) | 0.98 (0.96–0.99), P = 0.02 | 0.97 (0.96–0.99), P = 0.02 |
| **Sex**       | Male  | 51.0% (77/151)                               | 55.8% (72/129)                             |
|               | Female | 61.4% (35/57)                               | 73.5% (36/49)                              |
| Total (n)     |       | n = 208                                      | n = 178                                     |
| Univariate odds ratio (95% CI), female vs male | 1.53 (0.82–2.85), P = 0.18 | 2.19 (1.06–4.52), P = 0.03 |
| **Nerve**     | Ulnar | 52.7% (79/150)                               | 47.5% (56/118)                             |
|               | Median | 57.3% (43/75)                               | 75.0% (39/52)                              |
|               | Radial | 75.6% (34/45)                               | 75.4% (46/61)                              |
| Total (n)     |       | n = 270                                      | n = 231                                     |
| Univariate odds ratio (95% CI), median vs radial, ulnar vs radial | 0.44 (0.19–0.99), P < 0.05 | 0.98 (0.42–2.30), P > 0.05 |
|               | 0.36 (0.17–0.76), P < 0.05 | 0.30 (0.15–0.59), P < 0.05 |
| **Graft length** | No graft | 59.4% (63/106) | 73.8% (59/80) |
|               | ≤30 mm | 53.8% (14/26)                               | 48.0% (12/25)                              |
|               | 30–50 mm | 39.3% (11/28) | 28.9% (11/38) |
|               | >50 mm | 18.2% (4/22)                               | 64.9% (37/57)                              |
| Total (n)     |       | n = 182                                      | n = 200                                     |
| Univariate odds ratio (95% CI), graft used vs none | 0.48 (0.28–0.82), P = 0.01 | 0.40 (0.22–0.73), P < 0.01 |
|               | 0.91 (0.83–0.99), P = 0.04 | 0.93 (0.84–1.03), P = 0.15 |
| **Delay**     | No delay (<24 h) | 10/11 (90.9%) | 6/7 (85.7%) |
|               | 1–30 d | 21/36 (58.3%)                               | 56/70 (80.0%)                              |
|               | 1–3 mo | 22/30 (73.3%)                               | 23/32 (71.9%)                              |
|               | 3–6 mo | 17/39 (43.6%)                               | 18/34 (52.9%)                              |
|               | 6–12 mo | 11/24 (45.8%) | 5/21 (23.8%) |
|               | >12 mo | 25/52 (48.1%)                               | 10/39 (25.6%)                              |
| Total (n)     |       | n = 192                                      | n = 203                                     |
| Odds ratio per month (95% CI) | 1.00 (0.99–1.01), P = 0.73 | 0.93 (0.90–0.97), P < 0.01 |

Table adapted from He et al.32
nerve blocks) with serial measures to determine the appropriate course of treatment and/or assess recovery.

**CHRONIC NERVE COMPRESSION**

Compressive neuropathies vary in severity beginning with deterioration of the blood-nerve barrier, followed by subperineurial edema and demyelination, and ending in axonal loss.\(^{154}\) Although mild cases involving dynamic ischemia may be improved with nonoperative treatment such as therapy, activity modifications, or bracing, patients with a long history of compression may progress to axonal loss.\(^{154}\) Severity can be confirmed by serial EMG and NCS.\(^{157}\) Given the progressive nature of severe compression neuropathy,\(^{157}\) operative intervention is indicated, and early intervention is preferred to avoid further changes in sensation and/or motor weakness and atrophy.

Both duration and severity of symptoms have been shown to impact pain, sensation, and functional outcomes in carpal and cubital tunnel decompression procedures\(^{158,159}\). Masud et al\(^{157}\) reported that normal grip strength was not achieved in carpal tunnel procedures performed on patients with symptom duration >6 months. At preoperative symptom duration >12 months, patients in this cohort were more likely to have persisting night pain and a lower rate of return to activities. These findings are consistent with the findings by Eisenhardt et al\(^{163}\) in a similar patient population. In a 12-year study of 14,722 patients with carpal tunnel release, Hawksins et al\(^{166}\) suggested that these effects are likely due to the progressive nature of long-term compressive neuropathy.

Although published reports are variable, revision decompression has shown to provide comparable benefits in many outcome dimensions (Tables 13, 14).\(^{158} – 175,177,178,181–183,186,188–192\) Differences in revision decompression outcomes have not been associated with duration of symptoms in the literature.\(^{200}\) However, severity of symptoms has been identified as a correlating factor and should be taken into account if recurrent symptoms are rapidly progressing.\(^{201,202}\)

**Take-Home Messages**

In cases of chronic compressive neuropathy, the role of nerve surgery is to address the cause of ongoing symptoms (eg, a peripheral injury that has led to central sensitization). Multiple assessment methods are recommended to evaluate the status of a symptomatic nerve and determine the potential benefit of surgical intervention.

If operative intervention is indicated, it is suggested that nerve decompression procedures be optimally performed within 3 to 6 months of onset of symptoms. If functional deficits, pain, or atrophy are rapidly progressing, acute intervention should be considered. Revision decompression procedures may be planned with considerations for symptom severity speed of symptom progression. Additional preoperative factors that should be considered include the following: age, muscle atrophy, grip strength, electrophysiological severity, tobacco use, body mass index, anemia, depression, chronic lung disease, and inflammatory arthritis (Tables 10–12).\(^{158,160,161}\)

**BLUNT TRAUMA AND GUNSHOT WOUNDS**

In cases of blunt trauma or gunshot wounds, a wait time of 2 to 3 weeks for zone of injury demarcation may be recommended for peripheral nerve repair.\(^{5}\) During the time between injury and potential operative intervention, serial physical examinations may be accompanied by EMG and NCS.\(^{203}\) Once the extent of injury has been determined, treatment should be initiated as early as possible to avoid long-term nervous insufficiency.

### TABLE 9. Outcomes of Digital Nerve Repair With Varying Delay Times

| Author(s) | Mean Time to Repair in Days | Primary Repair | Nerve Graft | Synthetic Conduit | Vein Conduit | Muscle/Muscle-in-Vein s2PD Mean, mm | m2PD Mean, mm | SWMT Mean |  |
|-----------|-----------------------------|----------------|-------------|------------------|-------------|-------------------------------------|---------------|-----------|
| McFarlane and Mayer\(^{100}\) | 170.8 | 13 |  |  |  |  |  |  |  |  |
| Hirasawa et al\(^{101}\) | 186.1 | 10 | 4 |  |  |  |  |  |  |  |
| Sullivan\(^{102}\) | 41.02 | 42 |  |  |  |  |  |  |  |  |
| Walton et al\(^{103}\) | 61 | 115 |  |  |  |  |  |  |  |  |
| Rose et al\(^{104}\) | 256.2 |  |  |  |  |  |  |  |  |  |
| Pereira et al\(^{105}\) | 42.7 | 24 |  |  |  |  |  |  |  |  |
| Tang et al\(^{106}\) |  | 16 | 12 | 9.4 |  |  |  |  |  |  |
| Segalman et al\(^{107}\) | 19 |  |  |  |  |  |  |  |  |  |
| Battiston et al\(^{108}\) | 112.85 | 18 | 13 | 9.1 |  |  |  |  |  |  |
| Vipond et al\(^{108}\) | 1 |  |  |  |  |  |  |  |  |  |
| Lohmeyer et al\(^{109}\) | 115.9 | 12 |  |  |  |  |  |  |  |  |
| Marcocci and Vigasio\(^{110}\) |  |  |  |  |  |  |  |  |  |  |
| Taras et al\(^{111}\) | 6 | 22 | 18 | 10.7 | 9.2 |  |  |  |  |  |
| Rinker and Lain\(^{112}\) | 3 | 36 | 32 | 8.4 | 6.8 |  |  |  |  |  |
| Laveaux et al\(^{113}\) | 1 |  | 11 | 11 |  |  |  |  |  |  |
| Chen et al\(^{114}\) | 24 | 26 |  |  |  |  |  |  |  |  |
| Taras et al\(^{115}\) | 29 | 18 |  |  |  |  |  |  |  |  |
| Stang et al\(^{116}\) | 28 |  |  |  |  |  |  |  |  |  |
| Pilanci et al\(^{117}\) | 55.8 | 12 |  |  |  |  |  |  |  |  |
| He et al\(^{118}\) | 23.7 | 100 |  |  |  |  |  |  |  |  |
| Kim et al\(^{119}\) |  |  |  |  |  |  |  |  |  |  |
| Rinker et al\(^{120}\) | 13 | 37 |  |  |  |  |  |  |  |  |
| Wong et al\(^{121}\) |  | 93 |  |  |  |  |  |  |  |  |
| Fakin et al\(^{122}\) | 5 | 81 |  |  |  |  |  |  |  |  |
| Klein et al\(^{123}\) |  |  |  |  |  |  |  |  |  |  |

Table adapted from Kim et al.\(^{97}\)
| Variables | Change Score in SSS | Change Score in FSS | Satisfaction |
|-----------|-------------------|-------------------|--------------|
| Age       | $r = -0.196$      | $r = 0.226$       | $r = -0.193$ |
|           | $P = 0.016$       | $P = 0.005$       | $P = 0.017$  |
| Grip strength | $r = 0.020$   | $r = 0.063$      | $r = 0.655$  |
|           | $P = 0.805$       | $P = 0.284$       | $P < 0.001$  |
| Thenar muscle atrophy | $z = -3.084$     | $z = -1.072$      | $z = -1.561$ |
|           | $P = 0.002$       | $P = 0.284$       | $P = 0.119$  |
| Duration of symptom | $\chi^2 = 8.093$ | $\chi^2 = 2.638$ | $\chi^2 = 0.725$ |
|           | $P = 0.017$       | $P = 0.267$       | $P = 0.696$  |
| Electrophysiological severity | $\chi^2 = 99.786$ | $\chi^2 = 2.927$ | $\chi^2 = 2.69$ |
|           | $P < 0.001$       | $P = 0.231$       | $P = 0.260$  |
| Involved side | $z = -0.359$    | $z = -0.594$      | $z = -0.178$ |
| Phalen test | $z = -1.066$     | $z = -1.766$      | $z = -0.371$ |
|           | $P = 0.719$       | $P = 0.552$       | $P = 0.859$  |
| Previous carpal injection | $z = 3.881$  | $z = 7.50$        | $z = 3.861$  |
|           | $P = 0.275$       | $P = 0.067$       | $P = 0.277$  |
| Sex       | $z = -0.458$      | $z = -1.243$      | $z = -0.638$ |
|           | $P = 0.647$       | $P = 0.214$       | $P = 0.524$  |
| BMI       | $r = 0.037$       | $r = 0.044$       | $r = -0.006$ |
|           | $P = 0.186$       | $P = 0.31$        | $P = 0.937$  |
| Smoking   | $z = -0.497$      | $z = -0.067$      | $z = -0.497$ |
|           | $P = 0.619$       | $P = 0.947$       | $P = 0.619$  |
| Hypothyroidism | $z = -1.306$  | $z = -0.145$      | $z = -0.057$ |
|           | $P = 0.192$       | $P = 0.885$       | $P = 0.955$  |
| Tinel test | $z = -0.859$     | $z = -0.531$      | $z = -0.423$ |
| Durkan test | $z = -1.385$    | $z = -0.790$      | $z = -0.130$ |
| EMG abnormality | $z = -0.381$ | $z = -0.627$      | $z = -0.415$ |
| Monofilament test | $\chi^2 = 0.604$ | $\chi^2 = 4.705$ | $\chi^2 = 4.780$ |

BMI, body mass index; FSS, Functional Status Scale; SSS, Symptom Severity Scale.

Table adapted from Alimohammadi et al.159
If the zone of injury is clearly established, immediate exploration may be warranted. In these cases, the decision to explore immediately or wait is ultimately subject to clinical judgment and individual patient/injury characteristics. When the zone of injury is unclear, a wait time of 2 to 3 weeks is recommended.

Although penetrating wounds have historically been treated via delayed exploration, there is no clear consensus for optimal timing of exploration and repair.34,204 Advocates of early exploration point to improved outcomes, especially if suicidal ideation is present.209,212 Although a variety of treatment options are currently used for pain secondary to neuroma formation, most are focused on treatment of symptoms. Nonsurgical or symptomatic treatments are often unsuccessful, as they fail to address the root cause of pain.210,211 When pain persists despite reasonable treatment via symptomatic modalities, surgical intervention targeting the source of the pain is indicated.209,214

### Take-Home Messages

If chronic pain persists 3 to 6 months after nerve injury, it is recommended that surgical exploration/treatment be electively scheduled, with patient goals and rate of symptom progression taken into consideration. Although the literature is unclear regarding exact timing,

| Variable | Odds Ratio | 95% CI | P  |
|----------|------------|--------|----|
| Age <65 y | 2.08       | 1.52–2.85 | <0.001 |
| Tobacco use | 1.65       | 1.31–2.07 | <0.001 |
| Body mass index, kg/m² | 1.52 | 1.18–1.94 | <0.001 |
| ≥40 (obesity) | 1.53 | 1.16–2.01 | 0.002 |
| Male sex | 1.32       | 1.07–1.63 | 0.008 |

### Take-Home Messages

If chronic pain persists 3 to 6 months after nerve injury, it is recommended that surgical exploration/treatment be electively scheduled, with patient goals and rate of symptom progression taken into consideration. Although the literature is unclear regarding exact timing,
increased duration of symptoms has been associated with unfavorable outcomes.  

If a patient presents with uncontrolled pain that is severe, progressing, or incapacitating despite nonoperative management, acute exploration/intervention should be considered. Ultimately, intervention must be determined using clinical judgment for each patient regardless of whether pain has persisted for 3 months.

ADDITIONAL REPAIR CONSIDERATIONS

In addition to timing of repair, factors may play a role in both planning the operative case and the repair methodology used. Availability of personal protective equipment, sterile surgical supplies, anesthesia supplies, and staffing will influence the ability to achieve appropriate timing in nerve repair. Exposure risks for the both the clinical team and patient should also be taken into consideration. Ultimately, intervention must be determined using clinical judgment for each patient regardless of whether pain has persisted for 3 months.

Injuries include direct suture, autograft, allograft, conduit, or nerve transfer (Fig. 4). In addition to clinical outcomes data, additional factors should be considered for each approach, including:
1. Ability to achieve a tension-free repair
2. Operative time required for each repair approach
3. Ability to reduce anesthesia acuity and duration
   a. For example, although local regional anesthesia and monitored anesthesia care carry less risk of airway irritation, they may increase aerosol production (and viral spread in the present scenario) compared with tracheal intubation or laryngeal mask airway. Patient risk and the risk of viral spread should be discussed with an anesthesiologist.
4. Management of nerve gap (Fig. 4)
5. Ability to reduce resource utilization by performing a single surgery versus staged reconstruction
   a. For example, although local regional anesthesia and monitored anesthesia care carry less risk of airway irritation, they may increase aerosol production (and viral spread in the present scenario) compared with tracheal intubation or laryngeal mask airway. Patient risk and the risk of viral spread should be discussed with an anesthesiologist.
6. Management plan for concomitant injuries/procedures
7. Extent and timing of rehabilitative plan
8. Proximity to a tertiary referral center and/or available transportation

Each of these factors plays a role in resource utilization, ability to schedule the procedure, and exposure risk to the patient and clinical teams. Patient desires may not always align with scientific evidence.
| Study                                      | No. of Hands | Method/Follow-Up                  | Resolved or Improved, n (%) | Complications and Patient-Reported Outcomes |
|-------------------------------------------|--------------|----------------------------------|-----------------------------|-------------------------------------------|
| **Recurrent or persistent CTS**           |              |                                  |                             |                                           |
| Endoscopic revision CTR                   |              |                                  |                             |                                           |
| Tech and Tan165                           | 9            | Endoscopic revision             | 9 (100)                     | 0 complications                           |
| Retrospective                            |              | 24-mo avg follow-up             |                             | PRO: NR                                   |
| Luria et al166                           | 41           | Endoscopic revision             | 37 (90)                     | 0 complications                           |
| IV Prospective                           |              | 12-mo follow-up (all)           |                             | PRO: NR                                   |
| **Open revision CTR and neurolysis**      |              |                                  |                             |                                           |
| Total                                     | 50           |                                  | 46 (92)                     | Complications: NR                         |
| Wadstroem and Nigst168                   | 33           | External neurolysis             | 28 (85)                     | PRO: NR                                   |
| IV Retrospective                         |              | 24-mo avg follow-up             |                             |                                           |
| Langloh and Linscheid167                 | 33           | External and internal          | 12 (60)                     | 1 superficial wound infection             |
| Retrospective                            |              | neurolysis                      |                             | PRO: NR                                   |
|                            |              | 31-mo avg follow-up             |                             |                                           |
| O'Malley et al169                        | 20           | External neurolysis             | 29 (83)                     | Complications: NR                         |
| Retrospective                            |              | 23.5-mo avg follow-up           |                             | PRO: NR                                   |
| Chang and Dellon170                      | 35           | External and internal          | 87 (66)                     | 9 delayed wound healing                   |
| Retrospective                            |              | neurolysis                      |                             | 4 postoperative infections                |
|                            |              | 11-y avg follow-up              |                             | 3 RSD                                     |
| Cobb et al171                           | 131          | External and internal          | 87 (66)                     | Mean DASH 29 at follow-up                 |
| Retrospective                            |              | neurolysis                      |                             | 20 (6%) complications                     |
|                            |              | 23.5-mo avg follow-up           |                             |                                           |
| Duclos and Sokolow172                    | 13           | External neurolysis             | 12 (92)                     | NA                                        |
| IV Retrospective                         |              | 27.5-mo avg follow-up           |                             |                                           |
| Hulsizer et al173                        | 30           | External neurolysis             | 18 (60)                     | Complications: NR                         |
| Retrospective                            |              | 30-mo avg follow-up             |                             | PRO: NR                                   |
| Forman et al174                          | 22           | External neurolysis             | 21 (95)                     | 2 scar tenderness and stiffness           |
| Retrospective                            |              | 19-mo avg follow-up             |                             | PRO: NR                                   |
| Beck et al178                           | 28           | External neurolysis             | 23 (82)                     | Complications: NR                         |
| III Retrospective                        |              | 12-mo avg follow-up             |                             | Mean DASH 29 at follow-up                 |
|                            |              |                                 |                             | 20 (6%) complications                     |
| Total                                     | 339          |                                  | 252 (74)                    |                                           |
| Vein wrap                                |              |                                  |                             | 1 transient venous insufficiency          |
| Sotereanos et al6                        | 6            | Saphenous vein wrap             | 6 (100)                     | PRO: NR                                   |
| Retrospective                            |              | 18-mo avg follow-up             |                             |                                           |
| Sotereanos and Xu77                      |              |                                 |                             |                                           |
| Varitimidis et al178                     | 15           | Saphenous vein wrap             | 15 (100)                    | 1 transient local swelling at leg         |
| Retrospective                            |              | 43-mo avg follow-up             |                             | PRO: NR                                   |
| Synthetic wrap                           |              |                                 |                             | 2 (10%) complications, transient         |
| Total                                     | 21           |                                 |                             |                                           |
| Soltani et al179                         | 9            | Collagen synthetic wrap         | 8 (89)                      | Complications: NR                         |
| Retrospective                            |              | 13.7-mo avg follow-up           |                             | PRO: NR                                   |
| Kokkalis et al180                        | 2            | Collagen synthetic wrap         | 2 (100)                     | 0 complications                           |
| Retrospective                            |              | 19-mo avg follow-up             |                             | PRO: NR                                   |
| Kokkalis et al181                        | 10           | Collagen synthetic wrap         | 10 (100)                    | 0 complications                           |
| Retrospective                            |              | 24-mo avg follow-up             |                             | PRO: NR                                   |
| Total                                     | 21           |                                 | 21 (95)                     | 0 (0%) complications                      |
| Study                        | Level of Evidence | No. of Hands | Method/Follow-Up | Resolved or Improved, n (%) | Complications and Patient-Reported Outcomes                                      |
|-----------------------------|-------------------|--------------|------------------|-----------------------------|----------------------------------------------------------------------------------|
| **Recurrent or persistent CTS** |                   |              |                  |                             |                                                                                  |
| Hypothenar fat flap         |                   |              |                  |                             |                                                                                  |
| Strickland et al<sup>182</sup> | IV Retrospective  | 62           | Hypothenar fat flap (62) + internal neurolysis (7) 33-mo avg follow-up | 55 (89) | 1 ulnar digital nerve paresthesias 1 hypothenar numbness 1 superficial cellulitis Mean RTW 37 wk (work comp) Mean RTW 12 wk (nonwork comp) |
| Giampa et al<sup>183</sup>  | IV Retrospective  | 9            | Hypothenar fat flap | 8 (89) | 2 scar pain and edema, transient 2D DASH 100% RTW |
| Mathoulin et al<sup>184</sup> | IV Retrospective  | 45           | Hypothenar fat flap 45-mo median follow-up | 43 (96) | 2D DASH Complications: NR PRO: NR |
| Craft et al<sup>185</sup>   | IV Retrospective  | 28           | Hypothenar fat flap 10.5-mo avg follow-up | 26 (93) | 2D DASH Complications: NR PRO: NR |
| Stutz et al<sup>186</sup>   | III Retrospective comparative | 11 | Hypothenar fat flap 11-mo avg follow-up | 8 (73) | 2 hypertrophic scar DASH 31 at follow-up |
| Fusetti et al<sup>187</sup> | IV Retrospective  | 20           | Hypothenar fat flap 6-mo minimum follow-up | 18 (90) | 16 two-point discrimination resolved to normal DASH improved significantly in all patients |
| Karthik et al<sup>188</sup> | IV Retrospective  | 27           | Hypothenar fat flap 22-mo avg follow-up | 24 (89) | 2D DASH Complications: NR PRO: NR |
| Wichelhaus et al<sup>189</sup> | IV Retrospective  | 18           | Hypothenar fat flap 22-mo avg follow-up | 16 (89) | 2 hypertrophic scar DASH 42.2 to 17.6 (P < 0.01) |
| Athlani and Haloua<sup>190</sup> | IV Prospective    | 34           | Hypothenar fat flap 24-mo minimum follow-up in 13 patients | 34 (100) | 2D DASH VAS decreased from 6.4 to 1.4 (P < 0.05) Grip strength improved from 72% to 86% of the contralateral side (P < 0.05) QuickDASH 60.7 to 19.8 (P < 0.05) |
| **Total**                   |                   | 254          |                  | 232 (91) | 9 (4%) complications                                                                 |
| **Synovial flap**           |                   |              |                  |                             |                                                                                  |
| Wulle<sup>191</sup>         | IV Retrospective  | 27           | Synovial flap Follow-up range 1 mo to 14 y | 25 (93) | NA                                                                                  |
| Stutz et al<sup>186</sup>   | III Retrospective comparative | 16  | Synovial flap 11-mo avg follow-up | 9 (56)  | 1 delayed wound healing DASH 37 at follow-up |
| Murthy et al<sup>192</sup>  | IV Retrospective  | 45           | Synovial flap 11-mo avg follow-up | 43 (96) | 1 scar pain PRO: NR |
| **Total**                   |                   | 88           |                  | 77 (88) | 2 (2%) complications                                                                |
| Study | Methodology | N | Procedures |
|-------|-------------|---|------------|
| Strasberg et al | IV | 45 | External and internal neurolysis, Median nerve release forearm, Ulnar nerve submuscular transposition, Median nerve repair, Common dig nerve graft, Abductor muscle flap, 31-mo avg follow-up |
| Varitimidis et al | IV | 24 | External neurolysis alone, Hypothenar flap, Saphenous vein wrap, Neurotomy and hypothenar flap, 19-mo avg follow-up |
| Jones et al | IV | 55 | External neurolysis, Epineurectomy, Synovial or hypothenar flap, Reverse radial forearm flap, Minimum 1 year follow-up, Avg follow-up NR |
| Zieske et al | III | 97 | Persistent (42), Recurrent (19), New (36) |
| Djerbi et al | IV | 38 | Neurolysis, Hypothenar fat flap, Pronator quadratus flap, Synovial flap, Vein wrap, Silicone sheet, 51-mo avg follow-up |
| Total | | 162 | 119 (73) |

*P < 0.01.

Avg, average; CTR, carpal tunnel release; CTS, carpal tunnel syndrome; CTSFSS, Carpal Tunnel Syndrome Functional Status Score; CTSSS, Carpal Tunnel Syndrome Symptom Severity Score; DASH, Disabilities of the Arm, Shoulder, and Hand Score; NA, not available; NR, not reported; PRO, patient self-reported outcomes, validated outcomes include DASH, PRWE; RSD, reflex sympathetic dystrophy (ie, chronic regional pain syndrome); RTA, return to recreational activities; RTW, return to work; UWSS, University of Washington patient satisfaction score; VAS, visual analog scale.

Table adapted from Lauder et al.
### FIGURE 4. Management of peripheral nerve transection.

### TABLE 15. Medically Necessary, Time-Sensitive Procedures

| Procedure Factors | 1 | 2 | 3 | 4 | 5 | Score (1–5) |
|-------------------|---|---|---|---|---|-------------|
| OR time, min      | <30 | 30–60 | 60–120 | 120–180 | ≥180 |           |
| Estimated length of stay | Outpatient | 23 h | 24–48 h | ≤3 d | >4 d |           |
| Postoperative ICU need, % | Very unlikely | <5 | 5–10 | 10–25 | ≥25 |           |
| Anticipated blood loss, cc | <100 | 100–250 | 250–500 | 500–750 | ≥75 |           |
| Surgical team size | 1 | 2 | 3 | 4 | >4 |           |
| Intubation probability | 51% | 1%–5% | 5%–10% | 10%–25% | ≥25% |           |
| Surgical site     | None of the following | Abdominopelvic MIS surgery | Abdominopelvic open surgery, infraumbilical | Abdominopelvic open surgery, supraumbilical | OHNS/upper GI/thoracic |           |
| Disease factors   | 1 | 2 | 3 | 4 | >4 | Score (1–5) |
| Nonoperative treatment option effectiveness | None available | Available, <40% as effective as surgery | Available, 40%–60% as effective as surgery | Available, 60%–95% as effective as surgery | Available, equally effective |           |
| Nonoperative treatment option resource/exposure risk | Significantly worse/ not applicable | Somewhat worse | Equivalent | Somewhat better | Significantly better |           |
| Impact of 2-wk delay in disease outcome | Significantly worse | Worse | Moderately worse | Slightly worse | No worse |           |
| Impact of 2-wk Delay in surgical difficulty/risk | Significantly worse | Worse | Moderately worse | Slightly worse | No worse |           |
| Impact of 6-wk delay in disease outcome | Significantly worse | Worse | Moderately worse | Slightly worse | No worse |           |
| Impact of 6-wk delay in surgical difficulty/risk | Significantly worse | Worse | Moderately worse | Slightly worse | No worse |           |
| Patient factors   | 1 | 2 | 3 | 4 | 5 | Score (1–5) |
| Age, y            | <20 | 20–40 | 40–50 | 50–65 | >65 |           |
| Lung disease (asthma, COPD, CF1) | None | None | Minimal (rare inhaler) | Mild/Moderate (no CPAP) | >Minimal |           |
| Obstructive sleep apnea | Not present | Not present | Mild (≤51 med) | Moderate (2 meds) | On CPAP |           |
| CV disease (HTN, CHF, CAD) | None | None | Mild (≤51 med) | Moderate (PO meds only) | >Moderate (insulin) |           |
| Diabetes          | None | None | Mild (≥51 med) | Moderate | Severe |           |
| Immunosuppression | None, asymptomatic | None, asymptomatic | Yes | Yes | Yes |           |
| ILI3 Sx's (fever, cough, sore throat, body aches, diarrhea) | None | None | Yes | Yes | Yes |           |
| Exposure to known COVID-19–positive person in the past 14 d | No | Possibly | Possibly | Possibly | Yes |           |

Each row is scored, and all scores are added to produce a cumulative score (range, 21–105). A higher total score is associated with poorer perioperative outcomes, increased COVID-19 transmission, and/or increased hospital resource requirements.

CAD, coronary artery disease; CHF, congestive heart failure; CV, cardiovascular; COPD, chronic obstructive pulmonary disease; HTN, hypertension; ICU, intensive care unit.

Table adapted from Prachand et al.1
for optimal timing. In practice, decisions are made by engaging patients in an informed discussion of near- and long-term goals of recovery, as well as how these may be affected by different treatment options. Developing a shared understanding of the factors listed previously is crucial when creating a management plan and determining appropriate repair methods.

**DISCUSSION**

Appropriate timing of repair is a key consideration for the management of patients with nerve injuries. Injuries to peripheral nerves initiate a series of regenerative and degenerative processes. When these processes fail to proceed in a synchronous, organized manner, neuroma formation and/or nervous deficiency may occur, both of which are progressive in nature. Untreated nerve injuries can result in serial remodeling in the sensorimotor, frontoparietal, and executive control networks. Postinjury neuropathic pain has been linked to adverse cortical changes and psychosocial factors such as pain catastrophizing. Successful nerve procedures can improve or eliminate neuropathic pain symptoms as well as restore connectivity in the brain's sensorimotor and salience networks. Timely intervention may reduce the risk of patients progressing to dependence on narcotics or neuromodulators.

As a critical component of the nerve treatment algorithm, the issue of timing must be addressed to optimize outcomes. A concise view of relevant clinical data may assist physicians making decisions and advocating for the appropriate timing of intervention for patients. Although most of the existing recommendations are too broad to be useful in a clinical setting with high variability between cases, Prachand et al. recently proposed a scoring system that integrates procedure, disease, and patient factors to justify the scheduling of MeNTS Possible Score Ranges for Common Nerve Procedures

| Procedure Factors | Sharp Laceration of Digital Nerve | Ulnar Elbow (MM) | Carpal Tunnel | Neura |  |
|-------------------|----------------------------------|-----------------|--------------|-------|---|
| OR time           | 1–2                              | 2–3             | 1            | 2     |  |
| Estimated length of stay | 1 | 1 | 1 | 1 |  |
| Postoperative ICU need | 1 | 1 | 1 | 1 |  |
| Anticipated blood loss | 1 | 1 | 1 | 1 |  |
| Surgical team size | 4 | 4 | 4 | 4 |  |
| Intubation probability | 1 | 1 | 1 | 1 |  |
| Surgical site | 1 | 1 | 1 | 1 |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
| Patient factors |  |
| OR time |  |
| Estimated length of stay |  |
| Postoperative ICU need |  |
| Anticipated blood loss |  |
| Surgical team size |  |
| Intubation probability |  |
| Surgical site |  |
| Disease factors |  |
| Nonoperative treatment, pain medication | 2 | 1 | 2 | 2 |  |
| Nonoperative treatment, pain medication | 5 | 1 | 5 | 5 |  |
| Impact of 2-wk delay | 3 | 3 | 5 | 3 |  |
| Impact of 2-wk delay | 2 | 2 | 5 | 5 |  |
| Impact of 6-wk delay | 2 | 1 | 4 | 3 |  |
| Impact of 6-wk delay | 2 | 2 | 5 | 5 |  |
| Score (+ possible scores from factors below) | 27 (+8 → 40) | 22 (+8 → 40) | 36 (+8 → 40) | 34 (+8 → 40) |  |
In the case of the COVID-19 pandemic, the initial response of many institutions was to cancel or reschedule all "elective" surgeries. Unfortunately, many nerve surgeries must be performed within a critical time window to avoid permanent sensory and/or functional deficits. Postponing these serious but nonemergency cases can result in rescheduled procedures performed in a more unfavorable environment if ideal conditions do not materialize within the time frame for effective operative intervention. In routine practice conditions, procedures are often delayed because of inopportune surrounding circumstances such as patients' work or social commitments. When planning surgery with patients, the appropriate data must be used to weigh potential risks of delaying treatment.

Crisis scenarios can be a catalyst but are not the focus of discussions surrounding optimal treatment algorithms. Timing decisions are always critical to patient outcomes and are made by surgeons daily, regardless of external circumstances. Although the current literature remains limited in many situations, the authors believe this review serves as a suitably condensed resource to allow surgeons to make educated assessments for individual patients with any type of nerve pathology. Although further investigation will be necessary to parse out nuances in clinical decision making, the authors believe that these data will allow physicians to better advocate for patients regarding the timing of nerve procedures and may ultimately lead to more optimal outcomes.

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