Treatment Protocol for Peripheral Nerve Dysfunction of the Lower Extremity: A Systematic Approach

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Statement of Purpose

Peripheral nerve injuries and subsequent chronic pain are a common and challenging problem faced by the lower extremity reconstructive surgeon.[1-3] These cases often result in psychological debilitations, opioid dependence, or proximal amputation. Nerve injuries, first defined by Seddon include three main types based on their anatomical zone of injury; neuropraxia, axonotmesis, and neurotmesis. Sunderland, further described nerve injuries as five different degrees.[3] These two classification systems can be combined and simplified into three types of injuries as shown in the chart below. Several techniques in the literature have been described in the management of nerve injuries. Surgical intervention is comprised of two procedural groups, passive/ablative and active/reconstructive. Passive/ablative procedures are comprised of neurectomies, excision and implantation, as well as nerve relocation with grafting.[4-6] A recent trend in preference of reconstructive procedures such as nerve transposition with relocation, autologous/allograft reconstruction and targeted muscle reinnervation (TMR) is currently being reported in the literature.[4-9] Despite this, the literature reflects a paucity in the systematic approach for surgical intervention of peripheral nerve injuries. Here we describe our novel surgical algorithm incorporating these approaches based on zone of injury in the treatment of lower extremity neuritis.

Methodology

This protocol provides surgeons with a guide to understand and treat peripheral nerve injuries of the lower extremity. We discuss basic principles and patient work-up. Additionally, we highlight treatments based on the zone of injury and specific nerve affected.

Nerve Injury	Traits	NCV Findings
Type I	Myelin Disruption	Normal Amplitudes
Type II	Axonal Degloving (Neuroma-in-continuity)	Decreased Amplitudes
Type III	End Neuroma	Absent amplitudes

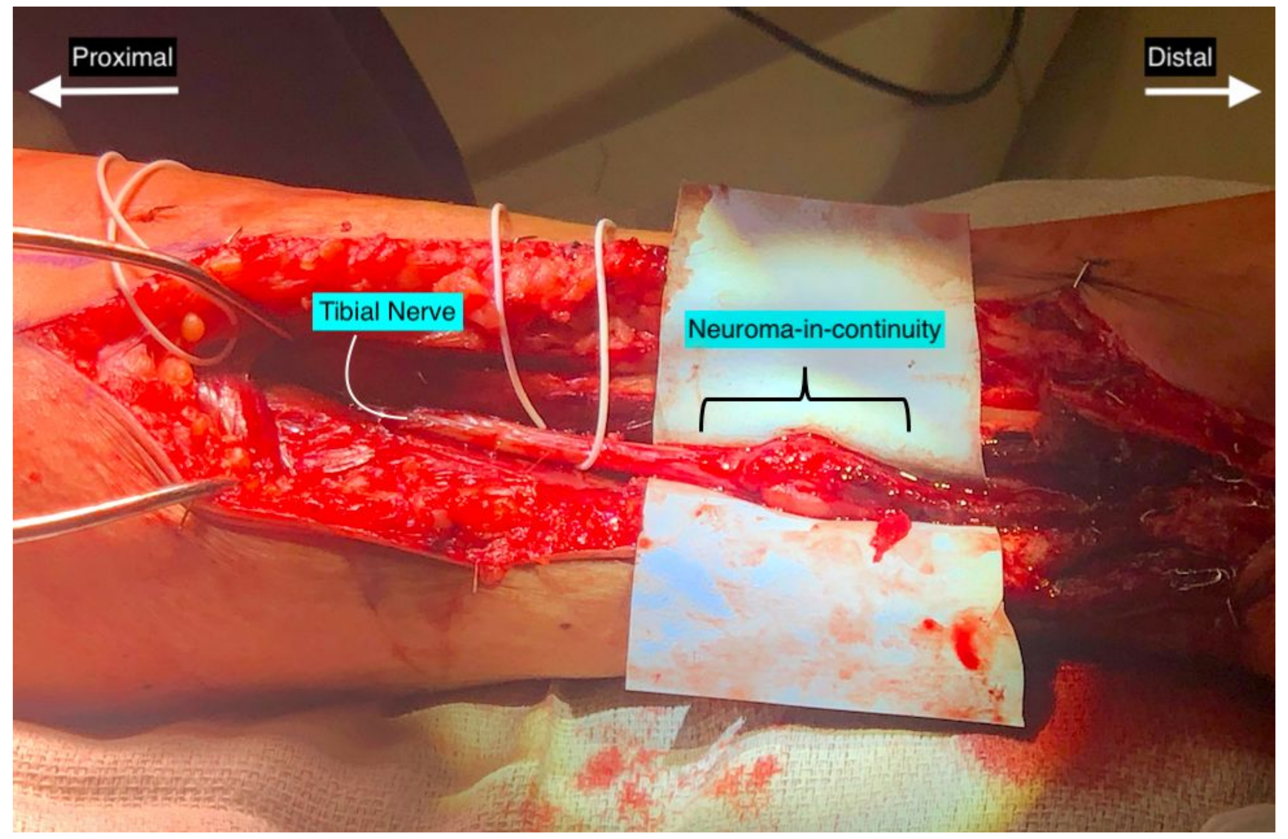

Figure 1: Intraoperative photo of Seddon Type II (Neuroma-in-continuity) injury of Tibial Nerve.

Declaration of Conflicting Interests:
Dr. Rodriguez-Collazo is a consultant for Orthofix, Integra, Isto Biologics and Axogen. The authors declare no potential conflicts of interest with respect to the research and/or authorship of this article.

Procedures/Results

Nerve Injury

Type I: Neuropraxia
- Compressive Trauma
- Amplitude: Normal past ZOI
  Velocity: Temporary block in conduction
  Myelin: Disrupted
  Axons: Intact
- Treatment Options
  - Internal Neurolysis
  - Decompression
  - Peri-Neurolysis
  - External Neurolysis

Type II: Axonotmesis "Neuroma-in-continuity"
- Amplitude: Decreased past ZOI
  Velocity: Decreased past ZOI
  Myelin: Disrupted
  Axons: Internal degloving
- Treatment Options
- Neurectomy
  - <5mm Defect → Conduit Assisted Nerve Coaptation
  - 5-70 mm Defect → Conduit Assisted Allograft Repair
  - >70 mm Defect → Conduit Assisted Autograft Repair

Type III: Neurotmesis "End Neuroma"
- Amplitude: Absent past ZOI
  Velocity: Absent past ZOI
  Myelin: Disrupted
  Axons: Disrupted
- Treatment Options
  - Transection <6 Months w/Available Distal Nerve Segment → (to defect pathway above: <5mm / 5-70 mm / >70 mm Defect)
  - Transection >6 Months w/out Available Distal Nerve Segment
    - TMR
    - Neuro-osteodesis
    - Neuromyodesis
    - TNI

Analysis & Discussion

Peripheral nerve injuries and subsequent chronic pain are a common and challenging problem faced by the lower extremity reconstructive surgeon. Seddon's and Sunderland's classifications of nerve injuries can be classified into three main types in combinationation with NCV/EMG studies.[1] Patients with significant nerve injuries are at increased risk of functional deficits, socioeconomic debilitation and narcotic abuse.[1-3] As such, finding reproducible, durable procedures to treat these pathologies is paramount. Eberlin and Ducic reported of two surgical procedural groups, passive/ablative and active/reconstructive.[4] Ablative procedures while more commonly performed, often result in a recurrence of symptoms as it does not appropriately address the pathologic process. As a result, there has been a recent trend in reconstructive procedures has been described in the plastics and neurosurgical literature.

The surgical algorithm shown here, provides the lower extremity surgeon a systematic approach to peripheral nerve injuries based on type of nerve injury as well as the zone of injury.

Type I injuries, usually due to a compressive structure or force are typically treated by decompressing the nerve and removing the deforming structure. Type II injuries, or neuroma-incontinuity involve insult to both the myelin as well as the axon. As a result, EMG/NCV velocity is normal proximal to the zone of injury, but the amplitudes are absent distally. The neuroma is therefore resected, the treatment from there is dependant on the resultant defect. It is in our experience that a defect <5mm is most effectively treated with a conduit assisted nerve coaptation between nerve endings. Defects 5mm to 70mm utilize an allograft that bridges the gap with conduits on both coaptation points. Finally defects greater 70mm require a conduit assisted autograft repair. Treatments for Type III injuries, or more commonly known as end-neuromas are dependant on duration as well as availability of distal nerve segment. If the distal nerve segment is available then our treatment algorithm follows the same path as type II nerve injuries. If the distal nerve segment is not available then neuromyodesis or neuro-osteodesis may be performed. Due to the possibility of recurrence of the neuroma, Target muscle innervation and nerve transfer are starting to be more commonly performed with good results.

This protocol demonstrates the utility of a systematic algorithmic approach for treatment of peripheral nerve injuries and serves as a comprehensive resource to assist in limb salvage. Utilizing this framework, the lower extremity surgeon can more readily incorporate this skillset into their armamentarium.

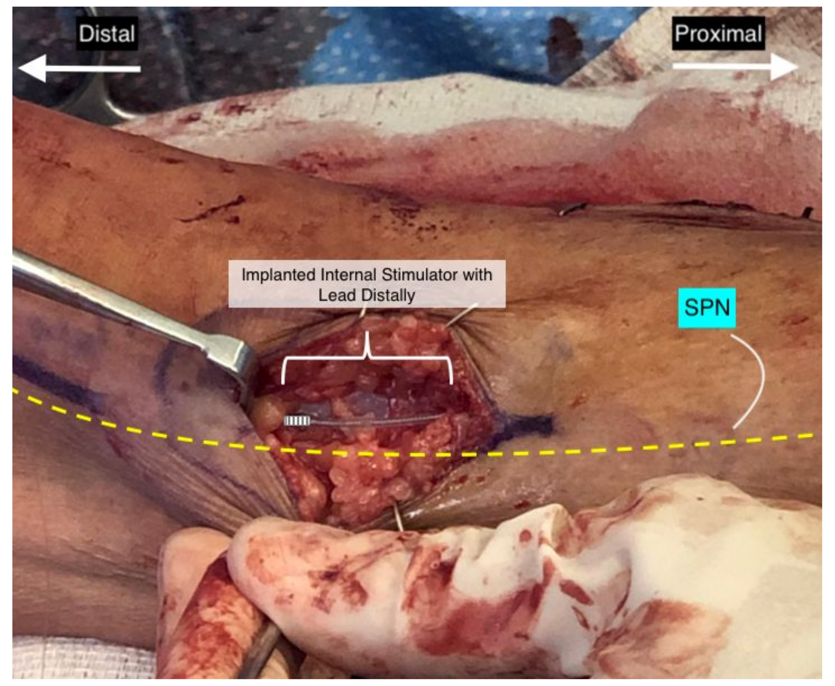

Figure 2: Implantation of Internal Nerve Stimulator at SPN. Note lead is in close proximity to nerve; however, is not in direct contact.

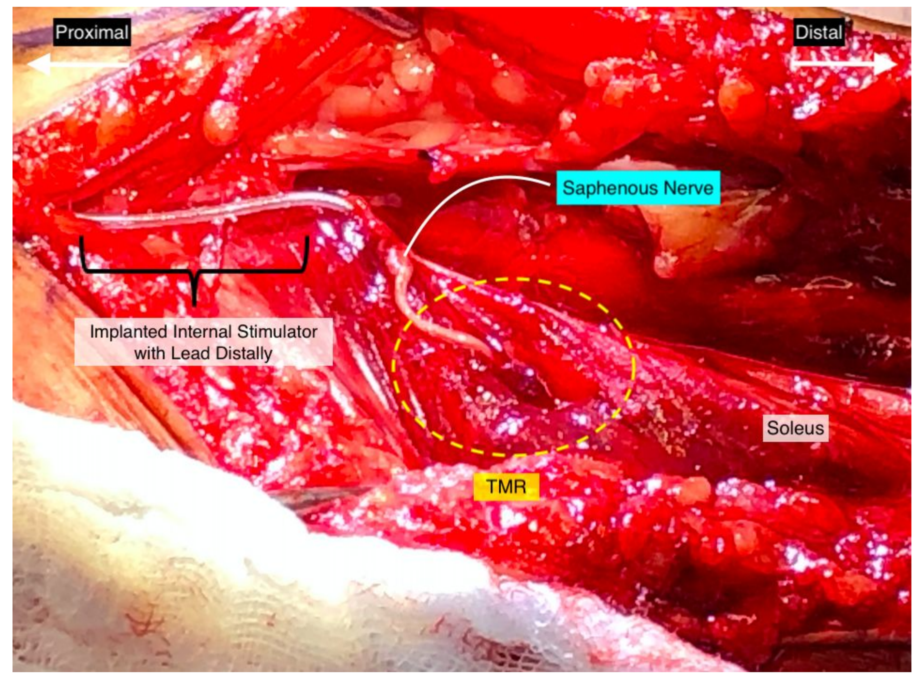

Figure 3: Saphenous Nerve to Soleus Muscle Target Muscle Reimplantation

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