POST INCISIONAL NERVE ENTRAPMENTS OF THE LOWER EXTREMITY: A Treatment Protocol

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Iatrogenic nerve injuries of the lower extremity can be a result of many different types of trauma. These include tourniquet compression, improper positioning, bandage or cast pressure, or traumatic tissue-handling. However, post-incisional nerve entrapments can develop even with proper dissection techniques. Infection can cause post-inflammatory fibrosis which can increase the likelihood of peripheral entrapment neuropathy.[1]

TREATMENT

There are many treatment options, both conservative and surgical, for the entrapped nerve. Surgical methods should be attempted only after conservative methods have been exhausted.

CONSERVATIVE METHODS

Non-Invasive Techniques

Non-invasive techniques are initially attempted in order to minimize additional trauma to the nerve. Any direct, extrinsic, compression or tension aggravating the nerve trunk should be eliminated, and non-steroidal anti-inflammatory drug therapy should be initiated. Casting or splinting and non-weight bearing can prevent motion that may perpetuate local inflammation and nerve irritation.[1]

Capsaicin (.075%) or Zostrix (.025%) can be used to diminish the pain associated with nerve compression. Capsaicin or Zostrix-HP (non-prescription) is an alkaloid found in plants related to hot peppers. The mechanism of action is thought to act on nociceptive type C sensory neurons, which produce the neurotransmitter peptide substance P. These substances diminish substance P, which in turn decreases the transmission of painful impulses.[2,3]

The manufacturer recommends massaging the drug into the affected area of the skin three to four times daily, avoiding contact with damaged skin or mucous membranes. Adverse effects include severe burning and erythema at the application site. Therefore, the author suggests using an equal amount of 2% Xylocaine gel, in conjunction with Capsaicin, when applying to the skin. A second technique used by the author is to initially start the patient on Zostrix, and then after one to two months of treatment, advance to the stronger dosage of Capsaicin. Results from both Zostrix and Capsaicin are expected after a period of 6 to 8 weeks.

Breneman et al.[4] performed an uncontrolled trial in 12 patients with idiopathic trigeminal neuralgia. He reported that topically applied Capsaicin relieved or decreased pain in 10 patients. Four of those patients had subsequent relapses, but a second course of therapy succeeded in relieving or decreasing the pain.

Hydrocortisone phonophoresis used in conjunction with ultrasound is an additional non-invasive treatment alternative. Hydrocortisone

phonophoresis is a physical agent that uses an ultrasonic device to deliver topically administered medications into the subdermal tissues[5]. Hydrocortisone phonophoresis allows noninvasive and efficacious treatment. Phonophoresis can shorten rehabilitation time, increase range of motion, and decrease pain associated with sprains, strains, tendinitis, adhesions, fibrosed painful scar tissue, neuritides, and neuromas[6].

Hydrocortisone phonophoresis differs from that of conventional ultrasound application by the use of a conduction medium. Air is a poor conductor of ultrasound waves, therefore, a coupling agent is needed between the transducer and the skin. Standard ultrasonic gel is mixed with a 10% hydrocortisone solution. Phonophoresis is performed by maintaining constant movement of the transducer head, which is less likely to result in tissue burning. A dosage of 1.0 to 1.5 W/cm squared for 5 minutes is typically used. Pulse mode ultrasound application is preferred because it decreases the risk of thermal injury. This is especially important for applications overlying metallic implants and fixation devices[7,8]. Hydrocortisone phonophoresis should be limited to a maximum of 24 consecutive treatments. Another series of treatment may begin after a minimum of a 1 to 2 month rest period. This rest period is necessary to avoid potential injury to the collagen fibers of connective tissue[9].

Direct analgesic effects of ultrasound are believed to be caused by thermal effects on nerve fibers, specifically the C fibers[7,10]. Hydrocortisone is useful in treating inflammatory processes secondary to injury. Corticosteroids are believed to control the rate of cellular protein syntheses. Corticosteroids bind to receptors in the cytosol, and are then transported into the cell nucleus as macromolecular complexes[11,12]. At the chromosomal level, they alter gene expressions that have an effect on enzyme synthesis and activity, membrane permeability, transport processes, and cellular structure. This results in a variety of cellular responses, including anti-inflammatory and reparative effects[8].

Invasive Techniques

If noninvasive techniques are unsuccessful, invasive procedures such as local injections can be attempted to alleviate inflammation and pain due to tissue adhesions. Improperly performed injections can lead to severe injection injuries, causing greater pain, and further damage to the nerve. If the purpose of the injection is to release adhesions by separating tissue planes, one must be aware that injecting fluid around the nerve can lead to greater nerve compression if over-infiltration is performed. Therefore, one must inject a minimal amount of fluid around the nerve to delaminate the adherent tissues. If anti-inflammatory agents are being injected around the nerve, the physician should be extremely cautious of injection injuries.

Nerve injection injuries can have devastating effects, such as sensory and motor loss, and this has been well documented[13]. Therefore, many injection injuries can be avoided by paying careful attention to known surface anatomy and the anatomic position of underlying nerves. In order for peripheral nerve compromise to occur, the substance must be injected in an intrafascicular fashion.

Extra-fascicular injection of the same substance causes no nerve injury. Dexamethasone was the only agent that caused minimal damage even with intrafascicular injection[14]. Therefore if one has elected to inject tissue surrounding a peripheral nerve, a knowledge of the surface anatomy is critical, and most importantly, injection should never be carried out into the nerve itself. If a paresthesia is evoked when performing an injection, the needle should be immediately withdrawn until the paresthesia has subsided. When choosing between drugs with various toxicities, the least neurotoxic should be chosen. If when injecting the substance, the patient describes severe pain confined to a nerve distribution, the injection should be immediately discontinued.

SURGICAL TREATMENT

The exploration and possible repair of a nerve or decompression injuries due to incisional entrapments should be performed only after conservative measures have failed. However, certain conditions require immediate operative or therapeutic attention. These conditions include aneurysm or arteriovenous fistula compressing nerves, blood clot in a potentially tight space, (the popliteal space), or anterior compartment syndrome in the lower leg.

The ultimate postoperative intention, to alleviate pain or to reestablish function, will dictate which surgical procedure should be employed. Decompression techniques (external or internal neurolysis) or nerve transection (neurectomy) should be used if a sensory peripheral nerve is involved. Decompression techniques (external or internal neurolysis) should be used if a motor nerve is compressed. If compression is involved with a neuroma incontinuity, nerve grafting is the procedure of choice. It is not within the scope of this paper to describe nerve grafting techniques, therefore only the external neurolysis, internal neurolysis, and neurectomy procedures will be described.

External Neurolysis

External neurolysis is performed when a nerve is adhered to other structures or is embedded in scar tissue. Surgical release can be performed without excessive nerve manipulation. The nerve itself must be identified within normal tissue prior to location of the entrapped or fibrosed portion of the nerve. After normal non-adherent nerve tissue is identified, a vessel loop is placed around the nerve to gently retract and free the compressed portion of the nerve. The nerve itself should not be handled by any type of forceps, except for the external epineurium. This technique can be difficult to visualize unless magnification is used.

Tissue adherent to the nerve itself (adventitial tissue) is usually thickened and attached to the external layer of the nerve, the epifascicular epineurium. The internal layers of the epifascicular epineurium are usually spared in a external neurolysis. The adventitial tissue, bony fragments, fibrous tissue and other tissues that may be entrapping the nerve are removed.

Internal Neurolysis

Internal neurolysis is performed on a nerve which is entrapped in a fibrous bed of connective tissue. Fibrosis of the epineurium occurs at both the epifascicular and interfascicular levels. The perineurium may also be thickened, however, minimizing dissection of this highly vascular layer will preserve the nutrient supply to the nerve.

An operating microscope and microinstrumentation are used when performing an internal neurolysis. The degree of intraneural fibrosis can vary greatly from one portion of the nerve to another, therefore, the amount of the internal neurolysis to be performed will depend on the extent of the nerve injury. Intraneural neurolysis is continued until a regularly organized fascicular pattern is present, as evidenced by the perineurial markings on each fascicle[15].

Microsurgical instruments are used when performing an internal neurolysis[15]. Magnification loupes (3.5 power) may be utilized, however an operative microscope is suggested. A tourniquet is used to aid hemostasis and facilitate dissection. The extra-fascicular epineurium is incised and dissection is carried out until the fascicles are identified. A traction suture(s) is placed in the longitudinal incision of the epineurium to help stabilize the nerve and aid fascicular dissection. Intraneural fibrosis is identified and a fine pointed scissor is used to bluntly separate individual fascicles. Longitudinally oriented nutrient blood vessels are often encountered within the perineurium, and care is taken to avoid damaging these structures. In general, the amount of internal neurolysis to be performed corresponds with the length of nerve which has been compressed.

After the intraneural neurolysis is complete, the nerve is placed into the most optimal bed available. The nerve should lie in a well vascularized area, and not be placed adjacent to a skin incision. Steroids are not routinely infiltrated around the nerve after neurolysis[16].

If a nerve axon is severed and unable to reestablish continuity with its distal counterpart, a neuroma forms. This process begins at the proximal stump with the sprouting of axons and proliferation of Schwann cells. Fibroblastic proliferation often results when an interposed substance (blood clot, foreign body, necrotic debris) impedes axonal regeneration. The regenerating nerve fibers will then grow and branch in a haphazard fashion, and abundant irregular patterns of axons are created in an attempt to reach the distal nerve or end organ.

If scar formation has tightly capped the proximal nerve stump, the entrapped fibers grow in a circular manner within the scar, forming a whorl pattern of tissue. The proliferation of nerves which form these whorls is usually halted by overcrowding[17]. The quality of blood supply to the nerve stump does not appear to alter neuroma formation, but the presence of infection or a

foreign body, or repeated irritation from pressure or friction tends to increase the size[18,19].

If the scar tissue at the proximal stump is diffuse and radiates into surrounding tissues, so follows the growing axons and proliferating Schwann cells. The regenerating fibers haphazardly grow and branch, and abundant irregular ramifications of axons are created in their abortive attempt to reach their end organ[20].

Therefore, by changing the microenvironment of a nerve stump, the amount of axonal proliferation can be minimized, and the likelihood of a painful neuroma reduced. If the nerve stump is tightly capped, then the proliferation of axon fibers will be minimal. Another method of preventing painful stump neuroma formation is to transplant the free nerve end into bone or muscle[21,22]. If the nerve is to be buried in bone or soft tissue, dissection of the surrounding tissue must be carried proximally so that the nerve can be looped 180 degrees from its original orientation, far away from the original neuroma. If the nerve end is diffuse and identified radiating into surrounding tissues, a different approach must be performed to try to change the environment of the tissue surrounding the neuroma.

Authors[23] have described different capping techniques in an attempt to prevent regrowth of a cut nerve. However, it is this author's opinion that the combination of fibrin glue[24] and nerve tissue closure is the optimal method of repair.

Under a dissecting microscope, the nerve ends are identified and freed from surrounding tissue, to the level of normal appearing nerve. At this level the epineurium is cut and peeled proximally over the nerve fibers. The nerve is then transected shorter than the epineurium. The epineural sheath is retracted over the resected nerve end, and fibrin glue is placed within the epineural sleeve. The epineurium is reapproximated with 8-0 prolene to prevent regrowth of the nerve. This approach is used for nerve entrapments and recurrent neuromas of the forefoot and midfoot region. However, if the posterior tibial nerve, sural nerve, or intermediate dorsal cutaneous nerve of the ankle or leg is involved, a different approach must be considered. As described for the forefoot and midfoot region, an epineurial dissection is performed, however the perineurium surrounding each fascicle is identified. After cutting the nerve proximal to the level of the neuroma, fibrin glue can be used in conjunction with perineural closure using 10-0 prolene. Likewise, fibrin glue is used for closure of the epineurium, with 8-0 prolene. The fibrin clot creates a layer of resistance to the infiltration of fibroblasts. Complete resorption of the fibrin network occurs within six weeks and a layer of fibrous tissue remains. Using this technique results in a four layered closure of tissue over the nerve fibers, which helps to prevent regrowth of the nerve.

In both techniques described, using fibrin glue and tissue closure, the nerve is directed 180 degrees proximally in the leg, and buried in soft tissue. An angiocatheter apparatus is then used to infuse a decadron/marcaine solution for a period of 24-36 hours. This controls tissue edema and relieves the pain secondary to nerve manipulation.

Nerve entrapments must be evaluated and treated in a systematic manner. With the complexities associated with nerve surgery and the potential for further damage after surgical intervention, conservative methods must first be exhausted.

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