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ORIGINAL RESEARCH

Pedicle Muscle Flap Coverage as an Adjunct to Internal Neurolysis of the Chronically Scarred Lower Extremity Nerve

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10 legs in 10 patients with tibial (7) or common peroneal (3) chronic neuritis were treated with microscopic internal Neurolysis and a Hemi local muscle flap. All patients in this series had a positive electrodiagnostic testing, diagnostic nerve block, intractable leg pain and numbness involving the common peroneal and tibial nerve prior to operation. Range of follow up from the procedure was from 13 to 27 months. All legs showed post-operative improvement. NCVs improved by an average of 5.51 m/s and Amplitudes by 7 m/v. VAS scores improved to 2.1/10 postoperatively. Photos were used in an attempt to illustrate the anatomical structure and viable options for neurolysis with a local muscle flap.

Keywords: pedicle muscle flap; internal neurolysis; scar tissue; neurolysis; nerve repair

Background

Since Learmonth (1933) [1], later Cannon and Love (1946) [2], described surgical decompression of the medial nerve in carpal tunnel, decompression techniques for lower extremity pathology have evolved into a popular treatment for various entrapment neuropathies [3]. This article will focus on two of the most common sites of compression in the lower extremity; the common peroneal nerve, which lies in direct contact with the fibular head and the tibial nerve, lying at the level at or above the flexor retinaculum on the medial aspect of the ankle.

As a surgeon performs increasing volumes of decompressions, the question of how best to achieve this while properly dealing with complications becomes increasingly important, especially in the face of lifelong morbidity associated with nerve injury. Consequently, the majority of patients who undergo decompressions under appropriately trained surgeons relate improved symptom relief with minimal complication [4, 5].

Treatment failures do occur, however. Wood et al noted a 12% complication rate with tarsal tunnel release, with dehiscence being the most common occurrence [6]. Actual failure rates have ranged from 4% to 56% [7, 8, 9, 10]. If such surgeries are not successful the risk of re-entrapment and chronic pain can be a devastating element to the patient's standard of living [12].

Nerve Scarring

In the instance of injury, Nerve "tethering" in the surgical scar is still the main cause of symptoms related to perineural fibrosis [12]. Such conditions can reduce the nerve gliding mechanism important for nerve function [11]. Scarring may also interfere with intraneural microcirculation by compressing the vessels, therefore inhibiting the blood flow within the nerve, inducing neural ischemia and degeneration [12, 14]. Such damaging conditions can lead to unforeseen outcomes after previous decompression surgery, such as compression, neurogenic pain and neuroma formation [13].

Internal Neurolysis with Local Muscle Flap

Since internal neurolysis alone has been shown to increase fascicular scarring, it has been advocated to cover the nerve below a soft vascularized bed [14]. The main goal is safe coverage with adequate padding of the nerve and, often more important, preventing the nerve from contacting the overlying skin. Various flaps, which include omentum, adipose, adipofascial and muscle have been performed in the literature to place over the nerve [15–17].

The application of muscle flaps can provide an extra benefit [18].

According to McKinnon et al. [19] interposing muscle between injured nerve and scar tissue is effective because

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terminal nerve stumps, containing less connective tissue, are covered by a cellular cap at the muscle/nerve interface.

Muscle coverage could provide a well vascularized and innervated environment that satisfies neuronal receptors and decreases neuronal growth factor release [20–21]. Additionally, muscle acts as an insulation surface between skin and tension forces that occur during the healing process. By limiting such mechanical irritation, improved longitudinal gliding of the nerve is promoted [21–22].

Kirikuta and colleagues [23] initially introduced the greater omentum as a treatment of radiating neuritis in brachial plexus repairs. The use of the abductor digiti minimi flap [24] and Palmaris Brevis Flap [25] have been advocated for additional cushioning and enhanced neovascularization for revisional carpal tunnel syndrome. However, to our knowledge very little investigation has been documented regarding muscle flap coverage for lower extremity revision neurolysis.

Methods

Population

Following an expedited institutional review board approval, Saint Joseph Hospital Protocol #2016-30, data was obtained through a retrospective medical record review of patients who underwent revisional internal neurolysis with application of a local muscle flap by a single surgeon at Amita Health Saint Joseph Hospital in Chicago, Illinois USA (AHSJHC). A total of 10 patients (8 males, 2 females) were identified for analysis. All were cleared preoperatively by their respective internist. The anesthesia department at the surgeon's institution provided perioperative management. The collection of identified data sets included the primary mechanism of injury, comorbidities, severity of symptoms at time of referral, preoperative and post-operative evaluations on Visual Analogue Scale (VAS) scores, nerve conduction velocity (NCV), and electromyography (EMG). Descriptive statistics (mean, standard deviation, etc.) were used for data analysis. All electrophysiological studies were performed by a trained peripheral neurologist. This paper has been reported in line with the PROCESS 2018 criteria [26].

Lateral Gastrocnemius Flap for Coverage of Common Peroneal Nerve: Surgical Procedure

The Initial incision extends from a point proximal and posterior to the fibular head, extending anterior and distally toward the anterior compartment of the leg and ending at a point anterolateral to the bony crest of the fibula (**Figure 1**).

The incision then courses distally over the peroneus longus (PL) muscle belly approximately 12 centimeters (cm). This incision is deepend bluntly through the subcutaneous tissue to the level of the superficial fascia, which is incised linearly to expose the muscle belly of the PL.

Decompression of the common peroneal nerve (CPN) at the level of the fibular neck is initiated by resection of a small portion of the superficial proximal myofascial aponeurosis of the PL (**Figure 2**). Transverse resection of the Proximal 1/3 of the p. longus muscle belly allows

Figure 1: Incision begins proximal superior to fibular head and Extends distal anterior toward the anterior compartment of the leg.

Figure 2: Resection of superficial proximal aponeurosis of the peroneus longus muscle.

exposure to the CPN without disrupting the origin of the muscle (**Figure 3**).

From posterior to anterior, a fasciotomy is performed at both the anterior and lateral compartments, beginning at the posterior fibula to the lateral aspect of the tibia and crossing the anterior intermuscular septum (AIS). Care should be taken to incise only the fascia in order to minimize muscular bleeding. Identify both the anterior and lateral compartments and incise the fascia of both compartments at their mid-portion from proximal to distal, approximately 3 cm in length (**Figure 4**).

Figure 3: Transverse resection of the proximal 1/3 of the peroneus longus muscle belly.

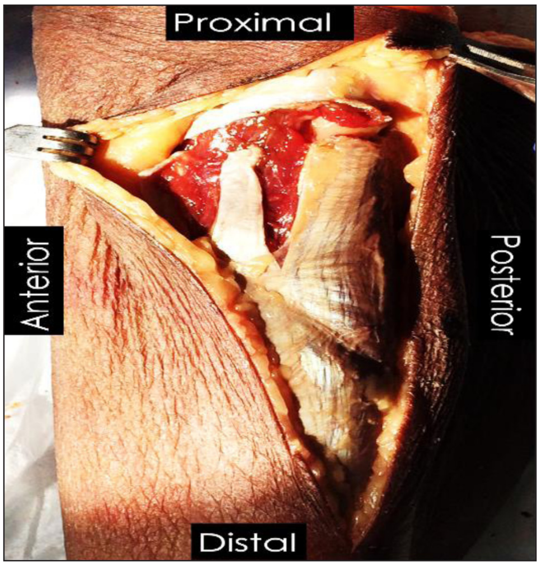

Figure 4: Fasciotomy of the proximal anterior compartment and lateral compartment.

Dissection is carried deep to the lateral compartment of the leg crossing the posterior intermuscular septum (PIS) to the border of the superficial posterior compartment of the leg to identify the lateral head of the gastrocnemius (**Figure 5**). The length and the width of the flap should be determined by the length of the defect and the required arc of rotation.

Identification and exposure of the of the CPN is performed distal to its division from the sciatic trunk crossing the PIS toward the head and neck of the fibula.

Internal neurolysis of the CPN is performed in order to divide the individual nerve branches of the superficial and deep peroneal nerves at the level of the fibular head and neck (**Figure 6**).

Figure 5: External Neurolysis of the CPN level of the proximal fibula under Peroneus Longus.

Figure 6: Neurolysis of the Common at Peroneal Nerve (CPN) is Performed.

The Author recommends application of nerve protector (**Figure 7**), either by autologous vein or allograft products, for barrier provision against external scar formation. The application of a nerve protector is necessary for additional protection against compressive forces [27–28].

Transection of the lateral hemi-gastrocnemius is performed by maintaining a vascularized pedicle proximally containing the sural artery (**Figure 8**). Because the gastrocnemius is a type I proximally based muscle flap, it is important to maintain the main perforator to vascularize the distal aspect of the flap [29]. Continuous visual inspection of the distal end of the muscle is evaluated at all times to ensure adequate bleeding of the transected area. It is important to avoid carrying the dissection of the pedicle deep into the popliteal fossa, thus preventing disruption of vascular inflow and minimizing disturbance of the neurovascular structures within.

The surgeon completes rotation of the proximal based lateral hemi-gastrocnemius flap with application over the fibular head (**Figure 9b**). The muscle is sutured distally to the fascia anterior and proximal to subcutaneous tissue in a 6, 9, 12 o'clock fashion, gently preventing migration or traction of the flap. Nevertheless, it is important to test knee range of motion at the time of flap inset to ensure a tension free flap.

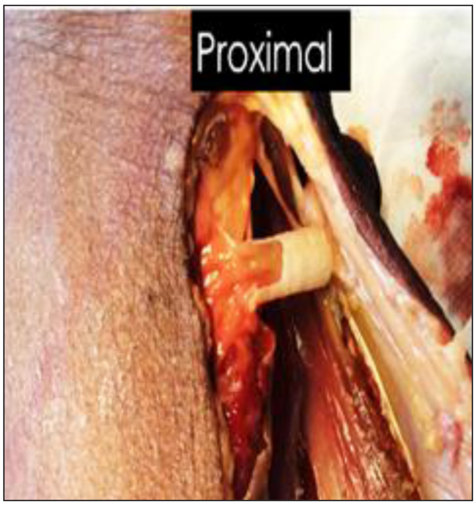

Figure 7: Nerve protectors are often applied for increased coverage.

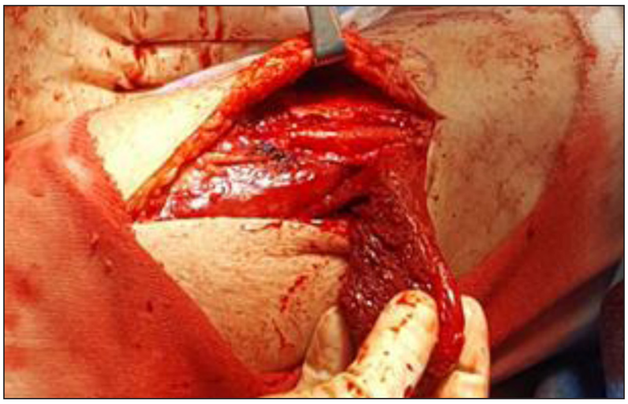

Figure 8: Transection of a proximally based lateral hemi-gastrocnemius muscle flap.

Deep tissues are closed with a non-absorbable synthetic suture and the skin is closed with skin staples. Full incisional drains are often protocol to prevent hematoma formation. Crossing vessel loops were also secured surrounding the incision to prevent tissue separation (**Figure 9a**).

Reverse Medial Soleus Muscle flap for Coverage of Tibial Nerve

The initial incision is marked by identifying the mid-portion of the posterior border of the tibia and the anterior border of the Achilles tendon. Dissection is carried over the superficial posterior compartment of the leg beginning at the posterior medial notch of the tibia, extending distally at the tarsal tunnel to fascia at the origin of the abductor hallucis (ABH). This dissection will allow adequate exposure to the superficial posterior compartment of the leg for a distally based medial hemi-soleus flap. A fasciotomy of the deep posterior compartment of the leg, proximal to the flexor retinaculum, is performed (**Figure 10**).

Transection of the fascia of the abductor hallucis (ABH), with release of the medial plantar nerve (MPN) and lateral

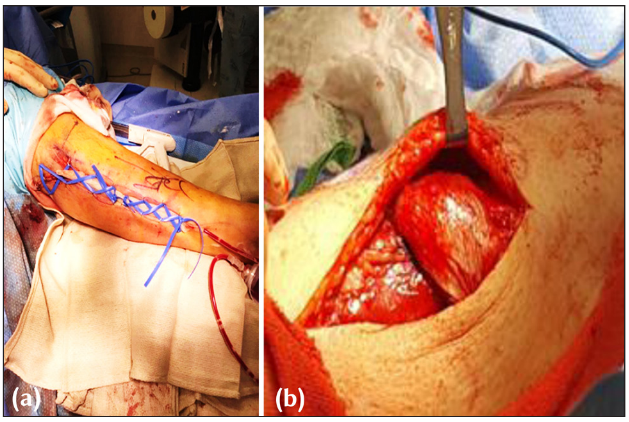

Figure 9: (a) Common peroneal nerve coverage by proximally based lateral hemi-gastrocnemius flap. **(b)** Criss Cross vessel loops are utilized to prevent tissue separation.

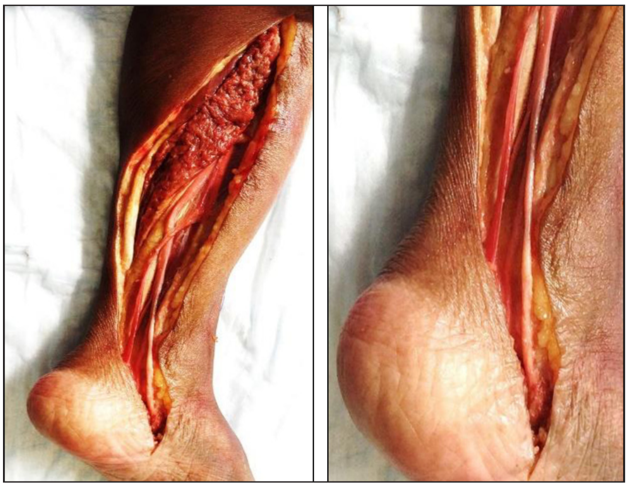

Figure 10: A fasciotomy of the deep posterior Compartment is performed in order to access the tibial nerve for neurolysis.

plantar nerve (LPN) from and fibrous attachment is performed, decompressing the tarsal tunnel and releasing the firm fascia Of the ABH and flexor digitorum brevis (FDB) (**Figure 10**). It is recommended by the primary surgeon that the tibial nerve be released circumferentially along the affected course to ensure appropriate gliding. If Intranueral fibrosis is noted (perhaps best visualized with a surgical microscope),internal neurolysis is performed. Commonly, additional protection over the area of neurolysis by autologous vein or collagen nerve protector is applied for coverage as it may prevent external scar formation [27–28] As the medial hemi-soleus is dissected, emphasis is placed on the need for at least two viable pedicles to the flap to prevent flap failure.

Flap perfusion is routinely performed with intra-operative doppler examination and visual inspection to ensure integral bleeding of the transected flap.

Other modes of imaging, such as fluorescent systems and dynamic infrared thermography, could perhaps be helpful in flap examination. As with the lateral gastrocnemius flap, ankle joint range of motion is tested to ensure limited tension. Should the flap appear at risk of compromise, a delayed inset technique may oftentimes be required for proper viability of the flap.

The proximal extension is based off need for coverage and arc of rotation but nevertheless is determined by viability of perforators distally (**Figure 11**). The pedicle of the flap extends from the distal aponeurosis of insertion of the soleus and the gastrocnemius (**Figure 12**). The tissues are re-approximated with a non-absorbable synthetic suture and skin with surgical staples. The surgical staples, along with the use of long incisional drains, are aimed at preventing hematoma formation. Is the primary surgeon's protocol to only remove the drains when less then 10ml of blood is collected.

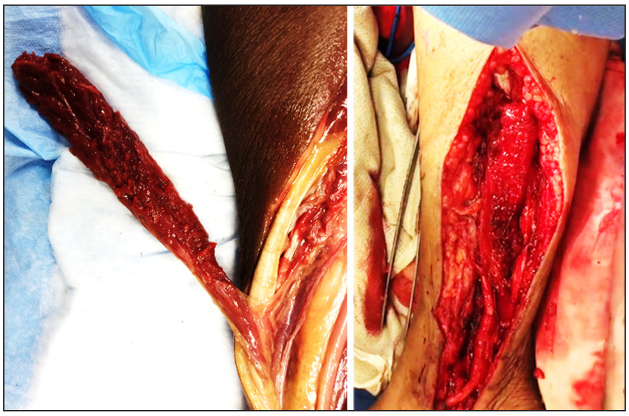

Figure 11: The length of the flap is determined by amount of coverage and arc of rotation.

Figure 12: Tibial nerve coverage by reverse medial soleus muscle flap.

Data Analysis

Data was entered into a spreadsheet and analyzed. Means and standard deviations were calculated for demographic data. The relationship between preoperative and postoperative pain was evaluated using the Visual Analog Scale (VAS) along with NCV and amplitudes.

Results

10 Patients (8 male/2 female) were included in the study. Average patient age at the time of surgery was 52 years old (ranges 37–64) (**Tables 1, 2**). Initial decompressions were attributed to foot and ankle sprain (n = 2), ankle fracture (n= 2) total knee arthroplasty (n = 1), and knee arthroscopy (n = 1). Preoperatively, all 10 patients had severe pain (VAS mean 8.5/10) with 2 patients experiencing 10/10 pain. After the revision surgery, the average pain (VAS) score was 2.1. NCV indicated improved conduction velocity (tibial nerve 27.25 m/s to 31.57 m/s; CPN 28 m/s to 36.33 m/s) and amplitude (Tibial 2.39 mv to 3.24 mv; CPN 1.23 m/v to 2 m/v). All patients resumed proper gait pattern with a return to activity levels of daily living demonstrated prior to injury. There were no infections or other adverse events. An average of 18-month follow-up, all patients showed no recurrence of symptoms.

Discussion

Traditional decompressions of the lower extremities have been very effective. Therefore, little is mentioned of surgical treatment for unrelieved tarsal tunnel syndrome or peroneal nerve compression. Some authors attribute recurrence to inadequate decompression of the fibrous attachments during primary surgery [30]. Additionally, in presence of a double crush syndrome, a nerve lesion exists proximally or distally along the path of the nerve [31]. All Cases in our series were failed primary release with no demonstrable evidence of a far-sighted lesion.

Vascularized soft tissue coverage seems to be an effective, but also complex, method of treatment for chronic painful nerve. Most articles in the literature confirm positive results after either pedicled or free tissue transfer for painful nerves. In the Lower Extremity, One major

Table 1: Tibial Nerve.

	Age	PMHx	Gender	Comorbid	NCV (m/s)		Amp (mv)		Vas Score		F/U
					Pre	Post	Pre	Post	Pre	Post	months
1 (T)	47	Hypertension	M	Ankle Sprain	35	38	3.0	3.5	8/10	3/10	17
2 (T)	39	Peptic Ulcer	M		37.6	39	2.5	3	9/10	2/10	13
3 (T)	62	Hypertension	M	Bi-Malleolar Ankle Fracture	32	35	2.7	3.2	9/10	1/10	21
4 (T)	58	Chronic Venous Insufficiency	M	Ankle Sprain	28.2	29	3.2	4.0	8/10	2/10	27
5 (T)	44	DM Type II	M		22	25	1.8	3	7/10	3/10	14
6 (T)	53		M	Ankle Fracture-Type A	17	25	1.5	3.0	10/10	2/10	21
7 (T)	64	Chronic Obstructive Pulmonary Disease	M		19	30	2.0	3.0	10/10	2/10	14
Mean +/−SD					Pre-27.25+/– Post-31.57+/–		Pre-2.39+/– Post-3.24+/–		Pre-8.71+/– Post-2.14+/–		

(T) = Tibia Nerve, above the flexor retinaculum.

Table 2: Common Peroneal Nerve.

	Age	Gender	PMHx	Comorbidities	NCV (m/s)		Amp (mv)		Vas Score		F/U
					Pre	Post	Pre	Post	Pre	Post	months
1(CPN)	63	F	DM Type II	Total Knee Arthroplasty	30	35	1.0	2.0	7/10	2/10	16
2(CPN)	49	F	DM Type II	Knee Arthroscopy	29	38	1.5	2	8/10	3/10	21
3(CPN)	37	M		ACL Reconstruction	25	36	1.2	2.0	9/10	1/10	18
Mean +/− SD	NA				Pre: 28 Post: 36.33		Pre: 1.23 Post: 2		Pre: 8 Post: 2 PreTotal: 8.5 Posttotal: 2.1		

(CPN) = Common Peroneal Nerve, below the head of the fibula. Both NCV (nerve conduction velocity) and Amp (amplitude) correspond to the particular segment where focal compression was identified.

advantage of these particular muscle groups (the Soleus and Gastrocnemius) is the proximity of the pedicle muscle to the surgeon's field. This excludes the need for a distant donor site or more lengthy incision. Additionally, no motor loss is created by using these particular muscle groups.

Local flaps, of course, do not come without obvious risks. Complications include hematoma formation, flap venous congestion, necrosis, wound dehiscence and infection. The choice of flap is also based on the ease of operative technique, patient positioning, ability to raise flap, reliability of flap perfusion and surgeon experience. Proper pre-operative imaging along with doppler examination with visual inspection are vital in determining flap viability. The use of long incision drains is our standard protocol for hematoma prevention.

Limitations of this case series include its retrospective nature, small sample size, and lack of a control group. Further investigation into the role of a muscle flap in revisional neurolysis are warranted to ensure adequate technique in a step-wise fashion. Although the literature confirms positive results after either pedicle or free tissue transfer for painful nerves, these techniques have been relegated to the mostly the forearm and hand levels [32–35].

Conclusion

Due to the risk of lifelong morbidity associated with nerve procedures, the efficacy of careful surgical technique and appropriate procedural selection is paramount. A thorough work-up prior to and a targeted complete release at the time of initial decompression surgery may prevent persistence and/or recurrence of symptoms. Knowledge of neuroanatomy, including function and pathology, are mandatory for diagnosis. Electrodiagnostic studies are used to confirm and localize the nerve injury, while also excluding other diagnoses such as the existence of more proximal lesions or systemically linked polyneuropathy disorders [36–37].

The present study suggests that the use of a local muscle flap as an adjunct to revisional neurolysis surgery can deliver promising results. The addition of vascularized tissue discourages scarring, while also improving compression between the incision and nerve as noted in the clinical outcomes, Improved VAS scores, nerve conduction velocity, amplitudes and return to normal activities in a shorter period were noted in our case series. While these results are encouraging, more research is desirable. Nevertheless, we found no other pre-existing publication describing the aforementioned procedures in the literature to date. We suggest that these local muscle flaps be considered a valuable adjunct for patients who have already undergone several pain treatment modalities without success in the presence of a scarred lower extremity nerve.

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- Dr. Edgardo Rodriguez-Collazo

Guarantor
Dr. Edgardo Rodriguez-Collazo.

Peer Review
This is a non-commissioned paper that has undergone external peer review according to journal policy.

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