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Centro-Central Nerve Union in the Treatment of Amputation Stump Neuroma of the Upper Limb: Clinical Experience

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ABSTRACT

Among many methods of treatment of neuroma, one of the more successful is centro-central nerve union with an autologous nerve graft. The term centro-central anastomosis is used to describe the end-to-end connection across interposed nerve grafts between two nerve cords of central origin. Nine patients with symptomatic amputation stump neuromas (7 men and 2 women) with mean age 31.4 years underwent resection of the neuromas and end-to-end repair was performed between both proximal nerve stumps with autologus nerve grafts. Etiologies were amputation, laceration and gunshot injury. The affected nerves were median and ulnar nerves (N=2) and the palmar digital nerves (N=7). No patients have previously undergone surgery. Evaluation of the results was done subjectively and objectively by using the labored grading system. Follow-up averaged 13.7 months. Subjectively, after surgery using the labored grading system, about 77.5% of patients has experienced complete relief of pain with no interference with daily activities (excellent results), 11.2% of patients felt mild sensitivity to direct percussion at the site of nerve union, with slight interference but work is possible (good results). 11.2% of patient has not improved and the painful symptom recurred 2 months after surgery (bad results). Objectively for Tinel's sign at follow-up revealed no hyperesthesia, or pain in about 77.5% of patients, mild pain and hyperesthesia in 11.2% of patients, and moderate uncomfortable in 11.2% of patients. The results of centro-central nerve union are encouraging in the treatment of digital stump neuromas. It is consider an easy, reliable, not time consuming and no donor site morbidity.

INTRODUCTION

Terminal neuroma naturally results from transection of a peripheral nerve if the nerve ends are not reunited. According to Herndon, as many as 30% of all neuromas is painful often leading to severe functional impairment of an extremity or an amputation stump. Although 30% of neuromas cause pain, a fully reliable method of preventing or treating painful neuromas has not yet been found. This is reflected in the considerable number of reports on different treatment modalities for painful neuromas **[1]**.

Among many methods of treatment available, one of the more successful is centro-central nerve union with an autologous nerve graft. The term centro-central nerve union was used to describe the end-to-end connection across interposed nerve grafts between two nerve cords of central origin. The technique can also be applied for one nerve if it is split into two fascicles of equal size **[2]**.

Langley and Anderson observed that regenerating axons would not grow into endoneural tubes already occupied by axons and that two central nerves that are anastomosed do not have a functional reunion. Using nerve-to-nerve anastomosis to stop axonal regeneration was a theoretical possibility **[3]**.

Koch and coworkers compared the results of the clinical application of different surgical techniques in the treatment of painful neuroma in series involving at least 10 patients. They concluded that the technique of centro-central nerve coaptation via an interpositional nerve graft has given the best results among the studies **[4]** (Table 2).

All the above-mentioned results encourage us to use the centro-central nerve union with an interposed nerve graft in treatment of amputation stump neuromas of the upper limb. In this study, we present and evaluate our results with centro-central nerve union in treatment of nine cases of painful neuromas in the upper limb.

MATERIAL AND METHODS

Patient demographic data:

Nine patients with symptomatic amputation stump neuromas underwent resection of the neuromas and end-to-end union was performed between both proximal nerve stumps with autologus nerve graft. Seven patients were men, two were women. Patient age ranged from 18 to 45 years

(mean 31.4 years). Etiologies were amputation, laceration and gunshot injury. The affected nerves were median and ulnar nerves (N=2), and the palmar digital nerves (N=7). The duration of painful symptoms at the time of operation ranged from 3 to 9 months. Diagnosis of painful neuromas was based clinically on the presence of point of typical neuromatous pain, described as an electric shock, sometimes as spontaneous discharge and frequently elicited through any pressure or contact on the area corresponding to the stump of the sectioned nerve. Tinel's sign positive in all cases. No patients have previously undergone surgery.

Operative technique:

Preoperative marking of the point of neuromatous pain was carefully determined. Surgery was performed with the patient undergoing general anesthesia or regional nerve block, the patient in prone position, and using tourniquet control. In all cases, the neuromas were approached through the primary surgical incision. Exploration and identification of the typical amputation stump neuromas were done. The neuromas appear grossly as ovoid, firm mass at the proximal end of the amputated nerve stumps and adherent to the surrounding structures even to the periostium by fibrous tissues. After identification and mobilization of the neuromas, the neuromas and scar tissues were resected to healthy tissue to prevent new scar tissue formation in the proximal and distal nerve stumps. The next steps were mobilizing the nerve stump and transposing it to each other's. Using Microscopic magnification and microsurgical instruments an end-to-end repair was performed between both proximal nerve stumps using 9-0 Polypropylene (prolene) sutures (five to seven simple interrupted stitches). Complete sealing of the fascicles inside the perineurim was essential to prevent escape of the fascicles from in between the sutures (Our modification to this technique). One of the proximal nerve stumps was severed again at proximal level to providing about 6 to 9mm autologus nerve graft. Then a second end-to-end tension free repair was done (Fig. 1). Finally, the anastomsosis was buried in the surrounding muscle especially in patients who have amputation through the forearm or wrist. Closure of the incision in two layers was done using 4/0 Polyglactin (Vicryl) for subcutaneous layer and 3/0 Polypropylene (prolene) for the skin. The upper limb was immobilized for two weeks to prevent the disruption of the suture line. Systemic prophylactic antibiotic continued for five days, analgesic anti-inflammatory drugs for 3 dayes. All the excised neuromas were subjected to tissue diagnosis. Evaluations of the results were done subjectively and objectively by using the labored grading system **[5]**, which was summarized in the following criteria subjective pain (grade 1, non; grade 2, mild, no interference with daily activities; grade 3, moderate, work is possible but there is some limitation in the use of the extremity; grade 4, severe, cannot work or use extremity), subjective patient acceptance of surgery (grade 1, improved, no interference with daily activities; grade 2, improvement, slight interference but work is possible; grade 3, improvement, interference in daily activities, unable to work; grade 4, no change; grade 5, worse), and the results of physical examination for Tinel's sign, hyperesthesia, or pain on palpation (grade 1, none; grade 2, mild, slight tingle; grade 3, moderate, very uncomfortable; grade 4, severe). Minor complications were occurred such as, wound dehiscence, infection and improved with conservative treatment.

RESULTS

The follow-up period averaged 13.7 months (range 29-1 month). Subjectively, after surgery using the labored grading system, seven patients (77.6%) experienced complete relief of pain. These results were termed excellent. One patient (11.2%) felt mild sensitivity to direct percussion at the site of nerve union, without interference with daily activities. These results were assessed as good. In one patient (11.2%) painful symptom recurred 2 months after surgery, this was considered a bad result. We attributed this to disruption of the nerve union due to forcible extension of the finger post operative. The patient refuses further surgical treatment. Subjective patient acceptance of surgery, seven patients improved no interference with daily activities; one patient improved, slight interference but work is possible and one patient not improved. Objectively for Tinel's sign at follow-up revealed no hyperesthesia, or pain in 7 patients (77.6%), mild pain and hyperesthesia in 1 patient (11.2%), and moderate uncomfortable in 1 patient (11.2%) (Table 1).

Histopathology:

The neuromas appear grossly as ovoid, firm mass at the proximal end of the amputated nerve stumps and adherent to the surrounding structures even to the periostium by fibrous tissues. The average size of the neuromas were 7.2-10.1mm^2.

Light microscopic examination of all excised masses showed neuroma formation, which consists of a round to ovoid mass of haphazardly, arranged axons and spindle cells that were a mixture of Schwann cells and fibroblasts, without the parallel organization seen in normal nerve.

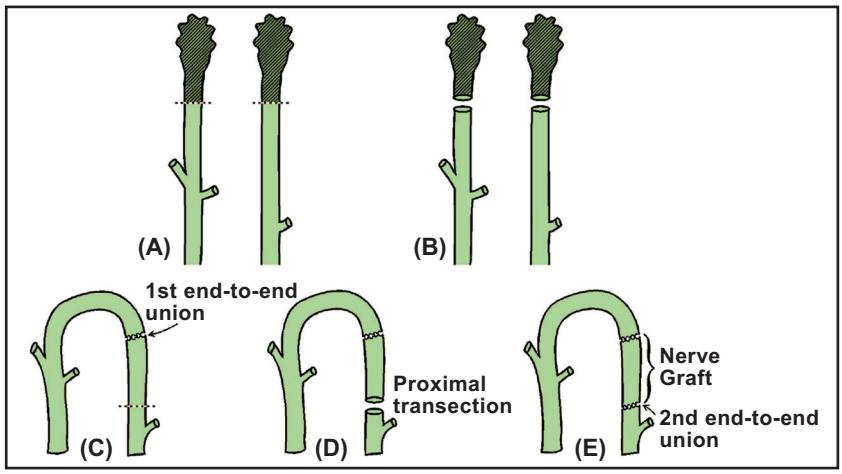

Fig. (1): Diagram illustrates the steps of Centro-central nerve union with an autologous nerve graft in bilateral digital nerves neuromas. (A&B) Exploration and excision of both digital nerves neuromas. (C) End-to-end repair was performed between both proximal nerve stumps. (D) Proximal transaction of one nerve. (E) Second end-to-end repair was completed.

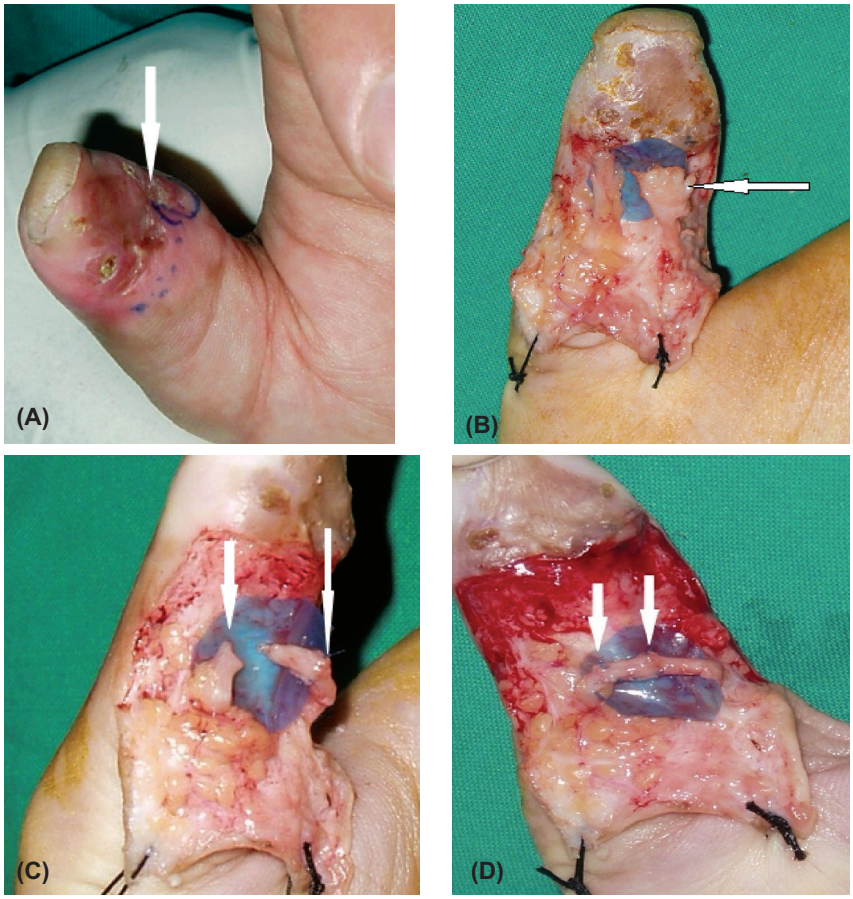

Fig. (2): (A) Preoperative view of 18 years old male patient after previous soft tissue injury to the distal phalanx of right thumb then previously reconstructed with full thickness skin graft (marking site of neuromatous pain with arrow). (B) Exposure of both digital nerves (C). Resection of the neurom and 1st tend-to-end nerve union was performed between the two proximal stumps of both digital nerves (right arrow) and proximal transaction of one nerve (left arrow). (D) Second end-to-end repair complete (interposed nerve graft between two arrows).

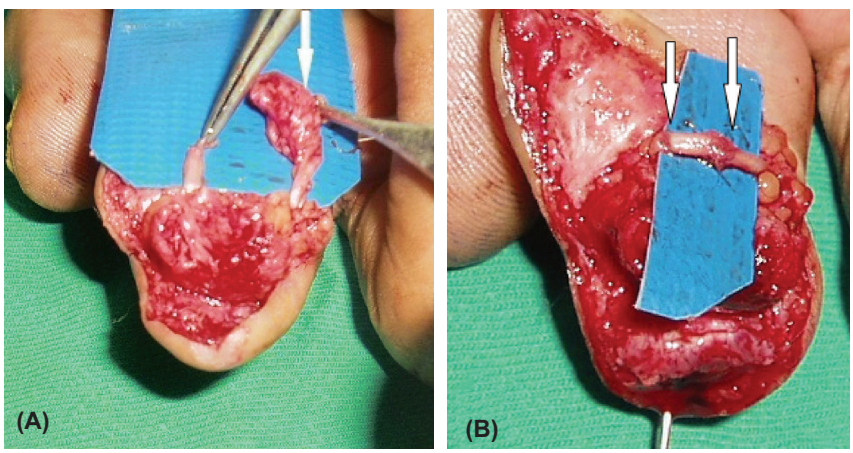

Fig. (3): (A) Exploration and exposure of both digital nerves in 35 years old male patient in right index finger amputated stump (neuroma at the arrow). (B) The centro-central nerve unions with interposed nerve graft completed (interposed nerve graft between two arrows).

Table (1): Results according to evaluation criteria.

	Subjective criteria									Objective criteria						
	Pain				Patient acceptance					Tinel's signs				Objective function		
	I	II	III	IV	I	II	III	IV	V	I	II	III	IV	I	II	III
Preoperative	8		1							8	1			8	1	
Postoperative	7	1		1	7	1		1		7	1	1		7	1	1

DISCUSSION

Symptomatic neuroma has been managed by numerous methods, till now there is no procedure that is completely and consistently successful in preventing neuroma formation [2]. Those methods divided into, non-operative and operative. The non-operative methods include desensitization with mechanical stimulation, transcutaneous electrical nerve stimulation [6] and Steroid injections. The operative methods are subdivided into, physical containment (Chemical treatment, ligation, cauterization, capping), physiological containment (nerve-to-nerve repair and grafting techniques) and translocation away from noxious stimuli (Excision and retraction, Implantation in muscle, bone or vein and En bloc translocation away from stimuli). The more successful treatment is physiologic containment, nerve-to-nerve repair, and grafting [2].

Gorkisch and Coworkers first described a technique of centro-central nerve union with autologous graft. Centro-central nerve repair is the coaptation of two nerve cords of central origin [7]. It also can be applied to one nerve if it is split into two fascicles of equal size that are joined with each other. The union of two proximal nerve stumps, by means of an interposed nerve graft to retard nerve growth, seems to be a physiological way of preventing neuroma formation. They also treated 30 patients with this procedure of centro-central nerve union with autologous graft. Except for one case, they reported no neuroma formation or complaints in the 4 years that had elapsed. The one failure was attributable to too early mobilization, leading to destruction of the anastomosis. Koch and Coworkers compared the results of the clinical application of different surgical techniques in the treatment of painful neuroma in series involving at least 10 patients. They concluded that the technique of centro-central nerve coaptation via an interpositional nerve graft has given the best results among the studies [4] (Table 2).

The question a raised now, what is the explanation of the presence of the autologus nerve graft in this technique?

Some authors believed that the newly formed axons under pressure in the area of the graft resulted in a reduction of protein production and the axoplasmic flow in the neuron and thus acted centrally to inhibit neuroma development [7]. Others theorized that the increased pressure created by the two proximal stumps pushing axoplasm toward one another and thus inhibiting central nerve cell protein production was logically. He also gave other plausible explanation, which involves the theory of "target-derived neurotrophic factors" (TDNF). This theory implies that structures distal to the cut nerve such as sensory receptors and/or muscles produce macromolecular proteins (TDNF) that stimulate and guide the regenerating proximal nerve stump to the correct end organ [21]. There is good experimental evidence to show that these factors exert their effect not only locally at the site of injury, but also on the central nerve cell body by retrograde axoplasmic transport. He further postulated that when one sutures the two nerve stumps together through a graft, they are effectively removing the proximal stump axons from the influence of their targets, in particular, the sensory nerve endings and receptors in the flaps covering the amputation stump. He also stated that the proximal stump axons avoided each other and interdigitated within the interpolated graft segment. This suggests that the advancing axons recognize each other's as "nontarget" structures. This technique works by isolating the proximal segment from the target derived neurotrophic factors (TDNF) and confining them in a non-target environment, which suppresses axon advancement, which could results in the cessation of regenerative efforts of the proximal stump axons. A study by Wood and Mudge, reported four patients who were treated with end-to-end anastomosis of median and ulnar nerves, and one patient who was treated with end-to-end anastomosis of the anterior interosseous and superficial radial nerve [22]. They reported an 80% to 90% success rate in reducing pain by direct primary coaptation of two proximal nerves without interposed nerve graft. They mentioned that the technique of inserting a nerve graft could result in a more successful treatment of neuroma than their

technique (direct primary coaptation of two proximal nerves without interposed nerve) which is helpful for patient who has amputation through the forearm or wrist.

A study by Belcher also showed successful inhibition of axon migration and reinnervation of skin and scar by centro-central nerve union **[23]**. They theorized that if a graft is not used, axon sprouts of fascicles could not penetrate into each other because endoneurial tubes are full and axons will penetrate into neighboring connective and scar tissue forming a neuroma.

This study was conducted up on nine patients; the results were encouraging, about 77.5% of patients have experienced complete relief of pain with no interference with daily activities (excellent results). One patient (11.2%) felt mild sensitivity to direct percussion at the site of nerve union, without interference with daily activities. These results were assessed as good. In one patient (11.2%) painful symptom recurred 2 months after surgery, this was considered a bad result. These results more or less coincide with the results of Gorkisch and Coworkers used this method in 30 patients with neuromas following hand-narrowing surgery, (97%) were neuroma free after the procedure **[7]**.

In addition, Kon and Bloem used the same method to treat neuromatous pain in the hand. In their series with 18 patients, they reported marked improvement in pain in all patients, although some patients continued to experience disability and limited function **[14]**.

Barbera and Albert-Pamplo showed good clinical results (100% pain free) after performing centro- central technique on painful neuromas in patients with lower extremity amputations. They had 21 of 22 patients who were free of their neuroma pain at an average of 15 months of follow-up. They confirmed this success by the absence of neuroma microscopically **[16]**. However, Laborde and associates using the same technique of end-to-end anastomosis with an interposing nerve graft. They reported poor results with this method (36% success) without proper explanation **[4]**.

Table (2): Clinical results of different surgical techniques in the treatment and prevention of painful neuroma in series of at least 10 patients (Koch et al. **[4]**).

Author	Year	Method	Number of Patients	Number of Neuroma	% of Good Results	Remark
Tupper & Booth **[8]**	1976	Simple excision		232	32.7	Primary hand neuromas
Herndon et al. **[9]**	1976	Nerve stump transposition into unscarred tissue	33	57	70	Hand neuromas
Swanson et al. **[10]**	1977	Silicone capping	18	38	83	Upper extremity neuromas
Laborde et al. **[5]**	1982	Simple excision partly nerve stump transposition into muscle	38		34	Hand neuromas
Mass et al. **[11]**	1984	Neuroma transposition into bone	15	20	70	Hand neuromas, no neuroma resection
Goldstein & Sturim **[12]**	1985	Nerve stump transposition into bone	11	23	64	Hand and forearm Neuromas
Dellor & Mackinnon **[13]**	1986	Nerve stump transposition into muscle	60	78	81	Upper extremity, 1 intercostal, 1 sural nerve neuromas
Kon & Bloem **[14]**	1987	Centro-central anastomosis	16	28	94	Finger neuromas
Martin & Fromm **[15]**	1989	Sealing of epineurium with adhesive	36	68	78	Upper and lower extremity neuromas
Barbera & Albert-Pamplo **[16]**	1993	Centro-central anastomosis	22	22	95	Sciatic and peroneal nerve neuromas in amputation stumps
Novak et al. **[17]**	1995	Nerve stump transposition into muscle	19	19	64	Lower extremity neuromas
Novak et al. **[18]**	1995	Nerve stump transposition into muscle	70	112	64	Upper extremity neuromas
Herbert & Filan **[19]**	1998	Nerve stump transposition into vein	14	14	86	Forearm and hand neuromas
Sood & Elliot **[20]**	1998	Nerve stump transposition into muscle	10	13	70	Hand and wrist neuromas

Conclusions:

The results of centro-central nerve union are encouraging in the treatment of digital stump neuromas. It is considered an easy, reliable, not time consuming, suitable for all nerves except monofasicular nerves and no donor site morbidity for harvesting a nerve graft. We recommend the application of this technique to all cases of digital stump neuromas especially the recurrent cases.

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