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Effectiveness of intercostal nerves in restoration of elbow flexion in devastating brachial plexus injuries

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Abstract: In extensive lesions with root avulsions, intercostal nerves provide the source of motor axons to reanimate the elbow flexors. In long standing cases, nerve transfers are no longer effective. These patients can be rehabilitated with free functioning muscle transfers innervated by the intercostals nerves. Between September 2003 and February 2006, 48 patients with devastating brachial plexus injuries underwent intercostal nerve transfers. In 22 patients with complete palsy (C5 to T1) three intercostal nerves (3^{rd},4^{th} & 5^{th}) were directly sutured to the musculocutaneous nerve. Sixteen patients had C5, C6 and C7 injuries. In 12 of these patients all the three roots were avulsed. In the remaining four, C7 spinal nerve was adhered to the scar tissue and was treated by microneurolysis. In all patients three intercostal nerves were directly coapted with the musculocutaneous nerve. Ten patients, presenting one or more years after the injury underwent free functioning muscle transfer using gracilis muscle motored by two or three intercostal nerves. Results of nerve transfers were better in the partial injury group (16 patients) with 7 patients regaining MRC grade 4, and 5 patients MRC grade 3. Four patients could achieve only M2 grade. In the total group (22 patients) only four could restore MRC grade 4 function. Eight patients attained MRC grade 3 and four patients MRC grade 2. Six patients could not restore elbow flexion. In the late group (10 patients) free functioning muscle transfer restored MRC grade 4 elbow flexion in 1 patient and MRC grade 3 function in another 5 patients. In the remaining 4 patients muscle transfer was not successful. We conclude that direct coaptation of intercostal nerves to the musculocutaneous nerve is a viable option to restore elbow flexion in total plexus injuries. Intercostal nerves are also suitable motor donors for free functioning muscle transfers.

Keywords: brachial plexus injury, elbow flexion, intercostal nerve transfer.

INTRODUCTION

Devastating brachial plexus injuries present with severe functional impairment in the affected limb. Restoration of elbow flexion is the first goal as loss of this function leads to significant disability in patient's daily work. There is a general agreement that nerve transfers produces better results than muscle are tendon transfers. In severe traction avulsion injuries there is a paucity of potential donor nerves. In such situations, two or three intercostal nerves have been extensively used to reanimate the flail arm and most common acceptor nerve for this purpose has been the musculocutaneous nerve. Various studies[1,2,3,4,5] indicate the return of useful elbow flexion (MRC grade 3 or more) in as many as 88% of cases. Intercostal nerves are available in global brachial plexopathy and their use does not lead donor site morbidity of any significance.

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MATERIALS AND METHODS

Forty eight patients (47 males and 1 female), underwent intercostal nerve transfer to the musculocutaneous nerve in the period between September 2003 and February 2006. The average age was 23 years, with range of 4 years to 37 years. The injuries were caused by motor-bike accidents in 39 patients, falling from heights in 5 patients, pedestrian accidents in 3 patients and gunshot injury in one patient. Associated injuries included closed head injury in 7 patients, fracture of the clavicle in 5 patients fracture in ribs in 3 cases, fracture of the scapula in 2 patients, fracture of the humerus in two patients and fracture both bones leg in one patient. The average denervation period (the time between injury and nerve repair) was 4.5 months (range of 3 months to 7 months). Twenty two patients presented with flail limb suggesting a complete palsy. Exploration of these injuries revealed total root avulsions (C5 to T1) in 13 of the cases. In 5 patients, C5 and C6 roots were visibly intact but grossly fibrosed. Four patients had extensive fibrosis in C5 spinal nerve combined with avulsion of C6.

Sixteen patients had C5, C6 and C7 injuries. In 12 of these patients all the three roots were avulsed. In the remaining four, C7 spinal nerve was adhered to the scar tissue.

All patients in the series were subjected to intercostal – musculocutaneous neurotization. In the total group, three intercostal nerves (T3, T4 and T5) were transferred to the lateral part of musculocutaneous nerve in 19 patients (Figs 1-6). In remaining three of this group, one of the intercostals nerve was scarred at the fracture site in corresponding rib. Separation of nerve led to inadvertent division. Hence only two nerves (T3, T5 in two and T4, T5 in one) could be transferred in these cases. In the partial group there was no difficulty in transferring three intercostal nerves (T3, T4 and T5) to the musculocutaneous.

Fig 1: C5,C6 and C7 palsy

Fig 2: Wasting of shoulder and arm muscles

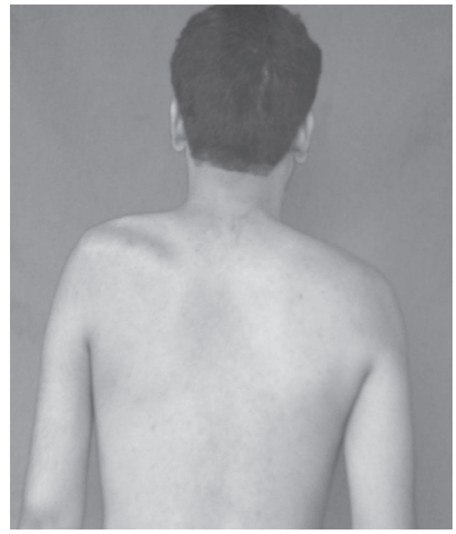

Fig 3: Wasting of deltoid, supraspinatus and infraspinatus muscles

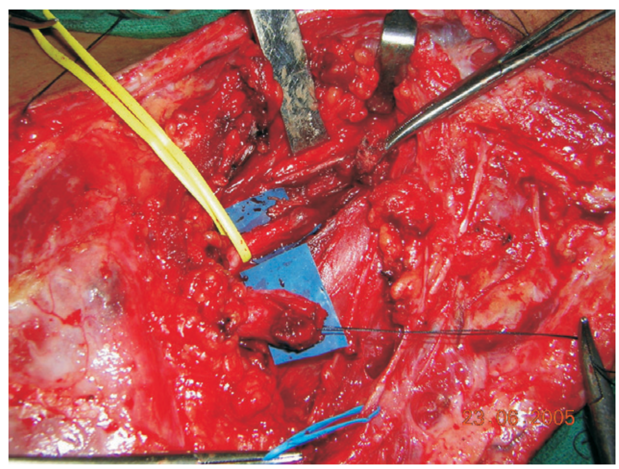

Fig 4: C5 and C6 roots are avulsed, C7 scarred

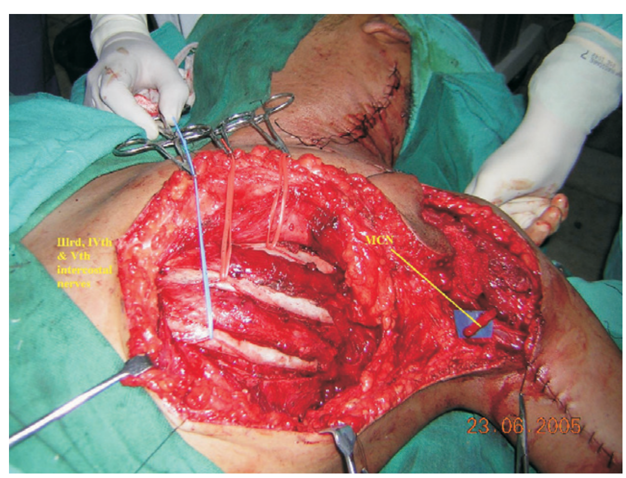

Fig 5: Dissection of T3,T4,T5 and musculocutaneous(MCN) nerves

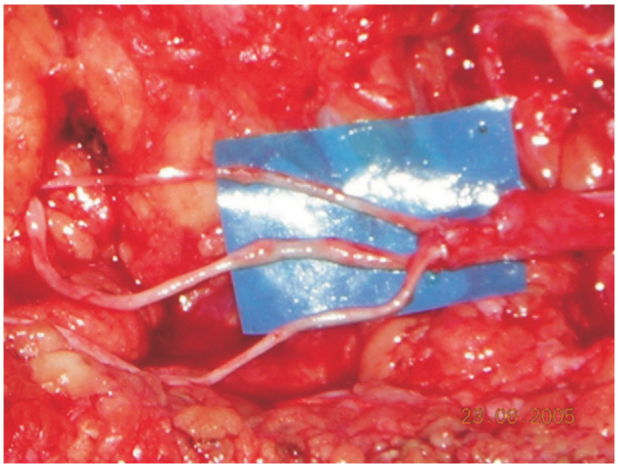

Fig 6: Coaptation of three intercostal nerves to MCN

Fig 7: Results in elbow flexion at 36 months follow up (for shoulder function spinal accessory nerve was

In all of these patients additional nerve transfers included; spinal accessory nerve to suprascapular nerve for shoulder reanimation (performed in 38 patients in nerve transfer group) and contralateral C7 transfer to median nerve for hand sensation and functions in 11 patients.

Patients with flail arms who presented late (2 years or more after injury or previously attempted but failed nerve repairs) were rehabilitated by transfer of gracilis from contralateral thigh on to the medial aspect of arm (Figs 8-11). Upper end of gracilis was fixed to the second or third rib and distal end was passed under the common flexor origin and sutured to the flexor digitorum profundus muscle. Microvascular anastomosis were made with the thoracodorsal vessels and two or three intercostal nerves innervated the transplanted muscle.

Fig 8: Flail left upper limb following gunshot injury

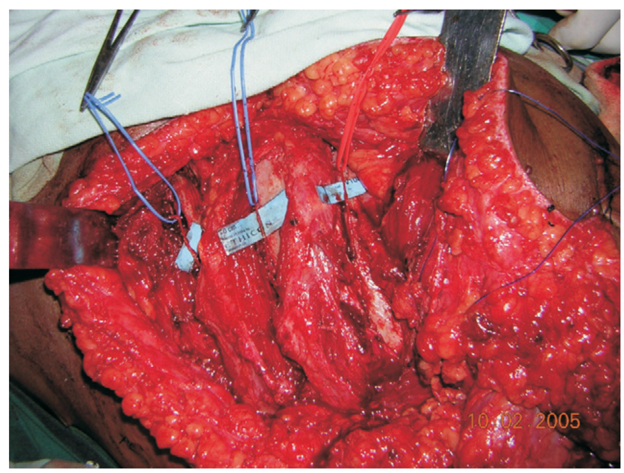

Fig 9: Dissection of T3,T4 and T5 intercostal nerves

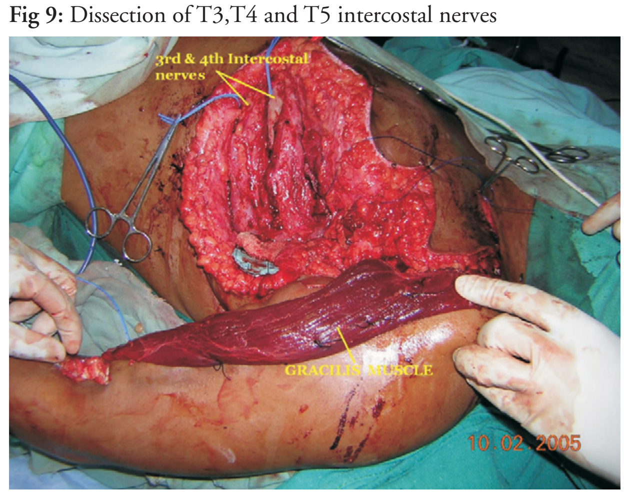

Fig 10: Free functioning muscle transfer (FFMT)using gracilis muscle

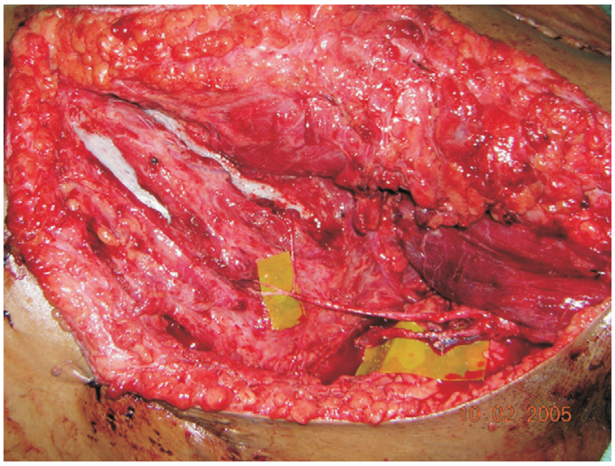

Fig 11: Intercostal nerves coapted with obturator nerve branch and microvascular nerve anastomoses performed

Postoperatively patients were subjected to passive physiotherapy and electrical stimulation till they regained M3 power. Final follow up was made 28 to 34 months after the repair.

RESULTS

Direct coaptation of intercostal nerves to the musculocutaneous nerve was possible in all cases after careful dissection of the nerves up to the parasternal region. In the total palsy group useful elbow flexion (MRC grade 3 or more) was regained in 54% of patients. Some of these patients also restored protective sensations in the distribution of lateral cutaneous nerve of forearm.

In the partial palsy group results were better, with 7 patients regaining MRC grade 4 elbow flexion (Fig 7) and 5 patients MRC grade 3. Hence useful functions were restored in 75% of patients in this group. Four patients restored M2 elbow flexion. One of these patients had developed hematoma in the chest and needed reexploration.Overall results were better in patients with three intercostal nerve transfers.

In the muscle transfer group one patient restored MRC grade 4 elbow flexion (Figs 12,13) whereas 5 patients could regain MRC grade 3 function. In the remaining 4 patients free functioning muscle transfer did not restore useful elbow flexion. None of the patients had donor nerve related problem (on pulmonary functions).

DISCUSSION

Use of intercostal nerves in the repair of devastating brachial plexus injuries was initially reported by Yoeman and Seddon[6]. Seddon[7] attempted a transfer between the intercostal and musculocutaneous nerve using an interposed ulnar nerve graft. Subsequently, several other workers reported their experience of intercostal – musculocutaneous nerve transfers with variable success[8,9,10,11,12]. Friedman et al[13] transferred three intercostal nerves directly to the musculocutaneous nerve

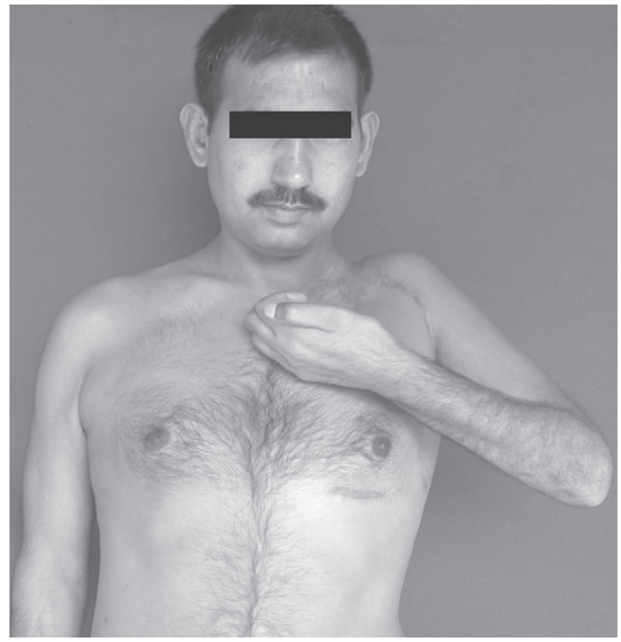

Fig 12: Restoration of elbow flexion with FFMT

Fig 13: Patient lifting 2 kg weight with elbow flexed at 26 months follow up

and achieved useful elbow flexion (MRC grade3 or more) in approximately 50% of the patients. So far best results have been reported by Kawabata et al[14] in birth related brachial plexus palsy. They could achieve MRC grade 4 power in 26 (84 %) of 31 patients in the age group 3 to 14 months (average age 5.8 months). They attribute this to a greater ability of the nervous system in infants to regenerate and adapt to new circumstances and a shorter distance between a neurorrhaphy site and the target muscle.

In intercostal –musculocutaneous neurotization certain points need elaboration; nerve transfer with or without a graft, number of intercostal nerves used and site of coaptation on to the musculocutaneous nerve. Friedman[13] interposed sural nerve grafts in two of sixteen cases and noted neither of the cases with interposed grafts resulted in useful elbow flexion. In the series reported by Kline et al [14], 57% of the patients attained useful elbow flexion after paravertebral sectioning of intercostals nerves and coaptation to the musculocutaneous nerve with sural nerve grafts.

In the Kawabata series[15], best results so far, two or three intercostal nerves were coapted directly to the musculocutaneous nerve. Most of the investigators at present prefer dissecting the intercostal nerves well distally along the rib to allow their easy transfer to the axilla and direct repair without sural nerve grafts. We also prefer this direct approach.

There is also a disagreement on the optimum number of intercostal nerve that should be transferred. Each intercostal nerve contains approximately 1200 to 1300 myelinated fibers[9], although there may be as few as 800. Only 40% are motor fibers in each intercostal nerve[16]. Compared to this, each musculocutaneous nerve contains about 6000 fibers, two-thirds of which are motor. Hence in ideal situations five intercostal nerves will be required to match the musculocutaneous nerve. However in practice only two or three intercostal nerves are used. It has been suggested that normal muscle force can be achieved with a minimum of 30% of the original motor neuron pool[17]. Chuang et al[18] compared the results of 2 versus 3 intercostal nerves in their series of 66 nerve transfers and found no significant differences between the two. Nagano[19] noticed that transfer of three intercostal nerves was no better than two.

Another point of concern is the site of coaptation in the musculocutaneous nerve. Chuang et al[18] suggested a plan for coaptation of three intercostal nerves to the musculocutaneous nerve. They felt that cut surface of the musculocutaneous nerve, though usually monofascicular, can be separated in to three sections. One large section in the central portion and two small sections on each side. The three central branches of the intercostal nerves are coapted to the central sections whereas the superficial lateral branches of the intercostals nerves are coapted to the smaller side sections. Chiarapattanakam et al[20] conducted a detailed anatomical study to define the internal topography of the motor fasciculi to the biceps, the brachialis and sensory fasciculi of the lateral cutaneous nerve of the forearm. They concluded that the groups of fasciculi of the nerve to the biceps, the nerve to the brachialis, and the lateral cutaneous nerve of the forearm were constantly located laterally to medially. The preferred site for coaptation of motor fibers was suggested to be the lateral half of musculocutaneous nerve. In our practice we have adopted this approach in the transfer of three intercostal nerves directly to the lateral half of musculocutaneous nerve. Free functioning muscle transfer innervated by intercostal nerves is a viable option for restoring elbow flexion and indicated as a secondary procedure in previously failed primary nerve repairs or when patients are presenting more than one year after injury. The largest series in this group is from Doi et al[21,22]. In the latest report of 67 patients with double free muscle transfer technique[23], mean active elbow flexion regained was 114° (range 70-145°).

CONCLUSIONS

Intercostal to musculocutaneous nerve transfer is a viable option of restoring elbow flexion in devastating brachial plexus injuries where most of the roots are avulsed and donor nerves are limited. Their use does not lead morbidity of any clinical significance.

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