Injury, Int. J. Care Injured 46 (2015) 671–675

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Comparative study of phrenic and intercostal nerve transfers for elbow flexion after global brachial plexus injury

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ARTICLE INFO

Article history:
Accepted 27 November 2014

Keywords:
Phrenic nerve
Intercostal nerve
Elbow flexion
Global brachial plexus injury

ABSTRACT

Background: Global brachial plexus injuries (BPIs) are devastating events frequently resulting in severe functional impairment. The widely used nerve transfer sources for elbow flexion in patients with global BPIs include intercostal and phrenic nerves.

Objective: The aim of this study was to compare phrenic and intercostal nerve transfers for elbow flexion after global BPI.

Methods: A retrospective review of 33 patients treated with phrenic and intercostal nerve transfer for elbow flexion in posttraumatic global root avulsion BPI was carried out. In the phrenic nerve transfer group, the phrenic nerve was transferred to the anterolateral bundle of the anterior division of the upper trunk (23 patients); in the intercostal nerve transfer group, three intercostal nerves were coapted to the anterolateral bundles of the musculocutaneous nerve. The British Medical Research Council (MRC) grading system, angle of elbow flexion, and electromyography (EMG) were used to evaluate the recovery of elbow flexion at least 3 years postoperatively.

Results: The efficiency of motor function in the phrenic nerve transfer group was 83%, while it was 70% in the intercostal nerve transfer group. The two groups were not statistically different in terms of the MRC grade ($p = 0.646$) and EMG results ($p = 0.646$). The outstanding rates of angle of elbow flexion were 48% and 40% in the phrenic and intercostal nerve transfer groups, respectively. There was no significant difference of outstanding rates in the angle of elbow flexion between the two groups.

Conclusion: Phrenic nerve transfer had a higher proportion of good prognosis for elbow flexion than intercostal nerve transfer, but the effective and outstanding rate had no significant difference for biceps reinnervation between the two groups according to MRC grading, angle of elbow flexion, and EMG.

Introduction

Global brachial plexus injuries (BPIs) are devastating events frequently resulting in severe functional impairment [1], which are usually very complex because of the involvement of spinal root avulsions from the spinal cord. Surgical treatment for BPIs has focused largely on motor and sensory recovery [2–4]. The primary goal in salvaging upper-extremity function in adult patients is the restoration of elbow flexion [5–7], because most actions of the upper limbs require elbow flexion to be complete in day-to-day activity. The treatments of global BPI to restore elbow flexion include nerve transfers and free functioning muscle transfer. Reports show that reinnervating the elbow flexor muscles is more effective than palliative tendon or muscle transfers [8]. In the subset of traumatic total BPI, the surgeon has limited available proximal donor nerves to control the multiple functions that are desirable for the shoulder, elbow, wrist, and hand [9]. The widely used nerve transfer sources for elbow flexion in patients with global BPIs include the intercostals [10–13], the phrenic nerve [14], the contralateral C7 [15], and the spinal accessory [16–18].

Intercostal nerve (ICN) transfers have become a mainstay treatment for reconstructing the brachial plexus since Seddon's initial description in 1963 [19] and the subsequent work of others [20–22]. In the study by Gu et al. [14], the phrenic nerve transfer for elbow flexion proved to be one of the optimal procedures in the treatment of BPIs. So far, phrenic nerve and ICN transfers are the main methods of repair for elbow flexion. In the present study, we analysed the results of 33 patients treated with these two types of phrenic nerve and ICN transfers to restore elbow flexion after global BPIs.

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http://dx.doi.org/10.1016/j.injury.2014.11.034
0020–1383/

Patients and methods

We carried out a retrospective review of 33 patients treated with phrenic nerve or ICN transfer for elbow flexion after posttraumatic global BPI at the Department of Hand Surgery, HuaShan Hospital. The inclusion criteria included global brachial plexus root avulsion, a minimum postoperative interval of >3 years, and phrenic nerve or ICN transfer to restore elbow flexion from 2004 to 2010. The exclusion criteria included diabetes, Volkmann contracture, fracture on the affected limb, rib fracture on the affected side, and brain trauma.

All of the patients were confirmed to have global root avulsion BPI by preoperative and intraoperative electromyography (EMG), physical examination, and especially by intraoperative exploration. They were placed in the supine position with the head turned towards the healthy side, and a supraclavicular incision was used for exploration. The brachial plexus was exposed and there was no nerve root in the intervertebral foramen.

Reconstruction methods

Phrenic nerve transfer

We exposed the phrenic nerve on the surface of the scalenus anterior and proved it normal by a nerve stimulator. The phrenic nerve was isolated to the costal end of the scalenus and was cut off distally. Then the anterolateral bundles of the anterior division of the upper trunk were exposed by a longitudinal epineurotomy, and the phrenic nerve was coapted to the anterolateral bundles of the anterior division of the upper trunk end to end using 8/0 nylon (Fig. 1). After the operation, a bracket was used to keep the head from turning to the contralateral side to avoid tension of the nerve coaption.

ICN transfer

A longitudinal incision along the midaxillary line was made, and the incision became a Z shape in the axilla. The ICNs of the third to sixth ribs were identified and dissected along their course. The ICNs were then passed through the serratus anterior muscle to the axilla.

A longitudinal medial arm incision was made to explorate the musculocutaneous nerve, which was identified and isolated long enough close to the lateral bundle. Then it was cut off close to the lateral bundle and led to one end of the ICNs in the axilla. Three ICNs were coapted to the anterolateral bundles of the musculocutaneous nerve end to end using 8/0 nylon (Fig. 2). After the operation, a chest girdle was used to avoid tension of the nerve coaption.

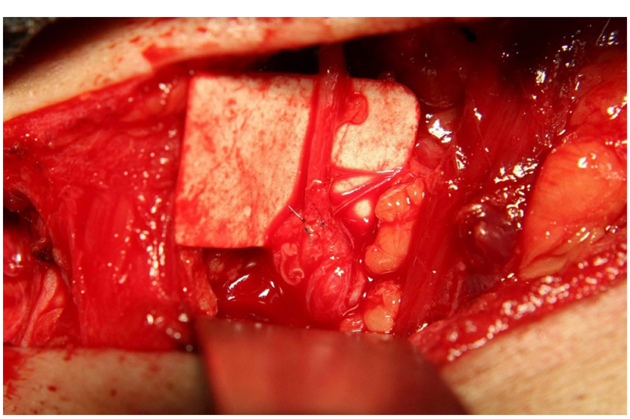

Fig. 1. The phrenic nerve was coapted to the anterolateral bundles of the anterior division of the upper trunk end to end using 8/0 nylon.

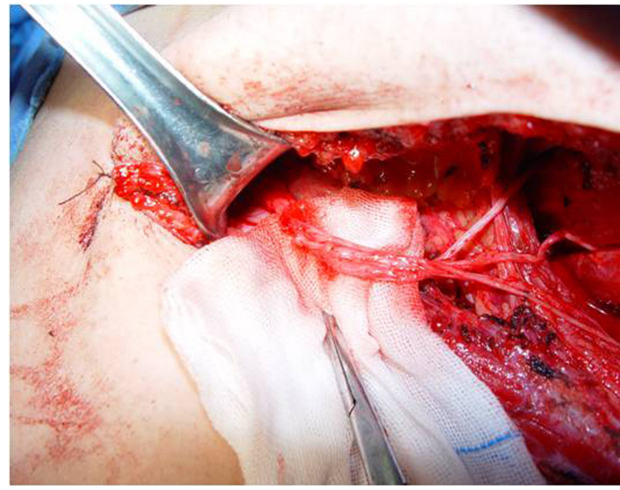

Fig. 2. Three intercostal nerves were coapted to the anterolateral bundles of the musculocutaneous nerve end to end using 8/0 nylon.

Postoperative rehabilitation

Physical therapy and electrostimulation therapy were started 4 weeks postoperatively. Patients were instructed to perform elbow flexion while taking a deep breath. Electrodes were placed on the supraclavicle and biceps muscle for phrenic nerve transfer, while they were placed on the lateral thoracic wall and biceps muscle for ICN transfer. Electrostimulation therapy could promote the growth of nerve axons by electric current.

Evaluation

The British Medical Research Council (MRC) grading system was used for evaluating elbow flexion strength. A return of muscle power of M3 or better was regarded as effective.

The angle of elbow flexion was used to evaluate the function of elbow flexion. An elbow flexion of $>120^\circ$ was regarded as an outstanding recovery of motor function.

We used electromyography (EMG) to evaluate the condition of nerve regeneration, which included a simple or a mixed phase, and newborn potential with little motor unit (MU) and no MU on the EMG screen. Normal muscle contraction could be recorded as a simple or a mixed phase, while newborn potential with little MU or no MU implied poor recovery.

Statistical analysis

Comparisons between the phrenic nerve and ICN transfer groups were performed using Fisher's exact test. The *p*-values were two-tailed and *p*-values <0.05 were considered significant. All analyses were performed using Statistical Package for Social Sciences (SPSS) 15.0 software.

Results

Among the 33 patients (Table 1), 23 patients underwent phrenic nerve transfer and 10 patients ICN transfer. In the phrenic nerve transfer group, 23 patients were all males except one female with a mean age of 27.4 years (range: 16–51) at the time of injury. The mean follow-up period was 4.9 years (range: 3–11 years). The delay in surgery ranged from 2 weeks to 13 months. In the ICN transfer group, there were 10 male patients and one female patient with a mean age of 24.5 years (range: 13–34) at the time of injury. For all patients, the time from injury to surgery was <6 months, and the mean follow-up period was 5.2 years (range: 3–9 years).