Outcome after transfer of intercostal nerves to the nerve of triceps long head in 25 adult patients with total brachial plexus root avulsion injury

Clinical article

KaiMing Gao, M.D., Jie Lao, M.D., Xin Zhao, M.D., and YuDong Gu, M.D.
Department of Hand Surgery, HuaShan Hospital, Shanghai, China

Object. The intercostal nerves (ICNs) have been used to repair the triceps branch in some organizations in the world, but the reported results differ significantly. The effect of this procedure requires evaluation. Thus, this study aimed to evaluate the outcome of ICN transfer to the nerve of the long head of the triceps muscle and to determine the factors affecting the outcome of this procedure.

Methods. A retrospective review was conducted in 25 patients with global root avulsion brachial plexus injuries who underwent ICN transfer. The nerves of the long head of the triceps were the recipient nerves in all patients. The ICNs were used in 2 different ways: 2 ICNs were used as donor nerves in 18 patients, and 3 ICNs were used in 7 patients. The mean follow-up period was 5.6 years.

Results. The effective rate of motor recovery in the 25 patients was 56% for the function of the long head of the triceps. There was no significant difference in functional recovery between the patients with 2 or 3 ICN transfers. The outcome of this procedure was not altered if combined with phrenic nerve transfer to the biceps branch. Patients in whom surgery was delayed 6 months or less achieved better results.

Conclusions. The transfer of ICNs to the nerve of long head of the triceps is an effective procedure for treating global brachial plexus avulsion injuries, even if combined with phrenic nerve transfer to the biceps branch. Two ICNs appear to be sufficient for donation. The earlier the surgery is performed, the better are the results achieved.

(http://thejns.org/doi/abs/10.3171/2012.10.JNS12637)

Key Words • brachial plexus • intercostal nerve • follow-up • triceps branch • long head • peripheral nerve

Abbreviation used in this paper: ICN = intercostal nerve.
Intercostal nerves transfer to triceps branch

TABLE 1: Characteristics of 25 patients with global root avulsion brachial plexus injuries

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Cases/Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>23</td>
</tr>
<tr>
<td>female</td>
<td>2</td>
</tr>
<tr>
<td>side of injury</td>
<td></td>
</tr>
<tr>
<td>lt</td>
<td>11</td>
</tr>
<tr>
<td>rt</td>
<td>14</td>
</tr>
<tr>
<td>age at injury (yrs)</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>25.3</td>
</tr>
<tr>
<td>range</td>
<td>16–45</td>
</tr>
<tr>
<td>cause of injury</td>
<td></td>
</tr>
<tr>
<td>traffic accident</td>
<td>23</td>
</tr>
<tr>
<td>upper-limb traction injury</td>
<td>2</td>
</tr>
<tr>
<td>follow-up period (yrs)</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>5.6</td>
</tr>
<tr>
<td>range</td>
<td>3–8</td>
</tr>
<tr>
<td>posttraumatic period (mos)</td>
<td></td>
</tr>
<tr>
<td>≤6</td>
<td>15</td>
</tr>
<tr>
<td>&gt;6</td>
<td>10</td>
</tr>
</tbody>
</table>

these 95 patients, 61 had 2 ICNs transferred, and 34 had 3 ICNs transferred. Of the 95 patients, 43 agreed to participate in our study. Twenty-five patients were enrolled and 18 were excluded. The inclusion criteria included global root avulsion brachial plexus injury, a minimum postoperative interval of 3 years, an operation performed by the same surgeon, ICNs directly neurotized to the long head branch of the triceps, and the biceps branch was reconstructed with the phrenic nerve. The exclusion criteria included diabetes, Volkmann contracture (2 cases), fracture of the affected limb (humerus fracture, 3 cases; radius fracture, 2 cases; ulna fracture, 1 case), rib fracture (5 cases), brain trauma (2 cases), and nerve graft (2 cases).

All 25 patients were confirmed to have global root avulsion brachial plexus injury based on preoperative and intraoperative electromyography, physical examination, and intraoperative exploration. The right brachial plexus was involved in 14 patients and the left in 11 patients. Twenty-three of the patients were male and two were female. The mean age at the time of surgery was 25.3 years (range 16–45 years). The mean follow-up period was 5.6 years (range 3–8 years). Of the 25 patients, 15 underwent ICN transfer within 6 months of injury, and 10 patients had reconstructions later than 6 months after injury. The injuries were caused by traffic accidents in 23 patients and a machine (traction injury of the upper extremity) in 2 patients.

Evaluation

At the last office visit, the patients were asked to move their affected limbs actively, passively, and with resistance. The British Medical Research Council grading system was used for motor assessment, and electromyography examinations of all recipient nerves were also performed.

Intraoperative Findings of the Involved Brachial Plexus

All patients underwent supraclavicular exploration of the involved brachial plexus, as previously described. Total brachial plexus root avulsion injuries were confirmed in all cases.

Surgical Technique and Reconstruction Methods

Each patient was placed in the supine position with the affected upper extremity abducted on an arm table. The sterile field included the bilateral upper extremities, both sides of the neck up to the mandible, and the anterior and posterior chest to the midline. The surgery was performed under ×2.5 magnification.

A continuous thoracobrachial incision (Fig. 1) was made, Z-shaped in the axilla and longitudinal in the lateral chest and the arm. The thoracic part of the incision began at the inferior axilla and followed the curve of the anterior border of the latissimus dorsi muscle. The arm portion of the incision was made on the medial aspect of the arm.

The ICNs were exposed in the chest incision. The latissimus dorsi muscle was reflected, and the serratus anterior muscle was resected in the middle and reflected. The peristeum was detached and pulled downward to expose its posterior aspect, and the thin motor branch of the ICNs was identified. The split sensory branch was left intact. The third–sixth ICNs were most commonly used.

The radial nerve was located through the brachial and axillary approach. The nerve of the long head of the triceps was found at the level of the axilla and followed the long head branch of the triceps, and the biceps branch was reconstructed with the phrenic nerve. The exclusion criteria included diabetes, Volkmann contracture (2 cases), fracture of the affected limb (humerus fracture, 3 cases; radius fracture, 2 cases; ulna fracture, 1 case), rib fracture (5 cases), brain trauma (2 cases), and nerve graft (2 cases).

All 25 patients were confirmed to have global root avulsion brachial plexus injury based on preoperative and intraoperative electromyography, physical examination, and intraoperative exploration. The right brachial plexus was involved in 14 patients and the left in 11 patients. Twenty-three of the patients were male and two were female. The mean age at the time of surgery was 25.3 years (range 16–45 years). The mean follow-up period was 5.6 years (range 3–8 years). Of the 25 patients, 15 underwent ICN transfer within 6 months of injury, and 10 patients had reconstructions later than 6 months after injury. The injuries were caused by traffic accidents in 23 patients and a machine (traction injury of the upper extremity) in 2 patients.

Evaluation

At the last office visit, the patients were asked to move their affected limbs actively, passively, and with resistance. The British Medical Research Council grading system was used for motor assessment, and electromyography examinations of all recipient nerves were also performed.

Intraoperative Findings of the Involved Brachial Plexus

All patients underwent supraclavicular exploration of the involved brachial plexus, as previously described. Total brachial plexus root avulsion injuries were confirmed in all cases.

Surgical Technique and Reconstruction Methods

Each patient was placed in the supine position with the affected upper extremity abducted on an arm table. The sterile field included the bilateral upper extremities, both sides of the neck up to the mandible, and the anterior and posterior chest to the midline. The surgery was performed under ×2.5 magnification.

A continuous thoracobrachial incision (Fig. 1) was made, Z-shaped in the axilla and longitudinal in the lateral chest and the arm. The thoracic part of the incision began at the inferior axilla and followed the curve of the anterior border of the latissimus dorsi muscle. The arm portion of the incision was made on the medial aspect of the arm.

The ICNs were exposed in the chest incision. The latissimus dorsi muscle was reflected, and the serratus anterior muscle was resected in the middle and reflected. The peristeum was detached and pulled downward to expose its posterior aspect, and the thin motor branch of the ICNs was identified. The split sensory branch was left intact. The third–sixth ICNs were most commonly used.

The radial nerve was located through the brachial and axillary approach. The nerve of the long head of the triceps was found at the level of the latissimus dorsi tendon. The long head of the triceps branch was traced into the triceps for identification, and it was divided proximally to increase its length, facilitating a direct suture with the ICN with no tension (Fig. 2).

The ICNs were coapted with the long head triceps branch under ×4 magnification using 9-0 microsutures while the patient’s arm was in full abduction. In the current series, 2 ICNs were used as donors in 18 patients.

Fig. 1. A continuous thoracobrachial incision is made, in a Z-shaped pattern in the axilla and longitudinally in the lateral chest and the arm. The thoracic part of the incision starts from the inferior portion of the axilla and follows the curve of the anterior border of the latissimus dorsi muscle. The incision in the arm is made on the medial aspect.
(72%) and 3 ICNs were used in 7 patients (28%). The recipient nerve (target) for all patients was the nerve of the long head of the triceps. In addition to the long head triceps branch, the ICNs were also transferred to the axillary nerve or thoracodorsal nerve simultaneously.

**Postoperative Rehabilitation**

Postoperatively, the upper extremity was immobilized with the shoulder in full adduction and the elbow held at 90° of flexion for 4 weeks. Physiotherapy began at the 5th week postoperatively to prevent joint contractures. The patients were also asked to breathe deeply until they recovered active elbow extension.

**Statistical Analysis**

Comparisons between postoperative groups were performed using chi-square tests. Probability values were 2-tailed, and p values < 0.05 were considered significant. All analyses were performed using Stata 7.0 software (StataCorp).

**Results**

The follow-up period ranged from 3 to 8 years. No complications were found in any of the 25 patients. A grade of 3/5 or higher was regarded as an effective recovery of triceps function. The surgical results showed that the long head of the triceps recovered to Grade 3/5 or better in 14 patients, 2/5 in 6 patients, 1/5 in 4 patients, and 0/5 in 1 patient. The effective motor recovery rate was 56%.

Our population was divided into groups in terms of the number of donor ICNs and the duration of the post-traumatic period. Two ICNs were used in 18 patients and 3 ICNs in 7 patients. In the 2-ICN group, the long head of the triceps recovered to Grade 3/5 strength or more in 10 patients, 2/5 in 4 patients, 1/5 in 3 patients, and 0/5 in 1 patient; the effective recovery rate was 55.56%. In the 3-ICN group, the long head of the triceps recovered to Grade 3/5 strength or more in 4 patients, 2/5 in 2 patients, and 1/5 in 1 patient; the effective recovery rate was 57.14%. The results showed no statistically significant difference between the groups (p > 0.05, Table 2) in the motor function recovery of the long head of the triceps. Sample cases of ICN transfers and other nerves with repaired functional recovery are depicted in Figs. 3 and 4A.

**Discussion**

At present, the most successful method of restoring affected limb function in patients suffering total root avulsion brachial plexus injuries is nerve transfer. Shoulder function, elbow flexion, and wrist and finger function have been restored successfully using spinal accessory,1,22,23 intercostal,4,12–14 phrenic,4,7,11,18,24 and contralateral C-7 nerve transfers.2,5,10,21 Although El-Gammal and colleagues3 and Terzis and Kokkalis20 have reported successful results for flexion and extension in obstetric patients with brachial plexus palsy, the recovery of elbow extension has not been considered of much importance in total brachial plexus root avulsion injuries. However, we believe that active extension plays an important role in stabilizing the elbow, which can help with driving a car and pushing objects. Thus, in our department, the regular treatment plan is to use the accessory nerve for direct transfer to the suprascapular nerve, the phrenic nerve for

<table>
<thead>
<tr>
<th>No. of ICNs</th>
<th>Efficient</th>
<th>Not Efficient</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>total</td>
<td>14</td>
<td>11</td>
<td>25</td>
</tr>
</tbody>
</table>

* There was no statistically significant difference between the groups (p > 0.05).
Intercostal nerves transfer to triceps branch

![Fig. 4](image)

**Fig. 4.** Same patient as shown in Fig. 3. At the last office visit, which was 4 years and 8 months after his last surgery, the patient displayed excellent shoulder abduction and elbow extension and good finger flexion (A). Electromyography studies show a mixed phase recruitment (B) in the triceps but no recruitment (C) in the biceps when the patient extends his elbow.

direct transfer to the musculocutaneous nerve, the ICNs for direct transfer to the axillary nerve, and the nerve of the long head of the triceps and contralateral C-7 nerves for transfer to the median nerve bridged by the pedicled ulnar nerve. Jean-Noel Goubier et al.\(^2\) reported 81% effective recovery of the long head of the triceps after using 3 donor ICNs. However, the number of nerves for donation is extremely limited in cases of total brachial plexus root avulsion injury. Thus, we repaired the long head triceps branch by using only 2 ICNs. In the current study cohort, 2 ICNs were used in 18 patients, and 3 ICNs were used in 7 patients. The motor recovery efficiency of the long head of triceps was 55.56% in the former group and 57.14% in the latter group. There was no statistically significant difference between the groups. According to previously reported results, the number of nerve fibers in the ICN is relatively small, at approximately 500–700;\(^6\) however, we used all motor fibers to guarantee the quality of the donor. Therefore, 2 ICNs appear sufficient for donation to repair the long head branch of the triceps.

Goubier’s group\(^2\) reported two poor results because the surgeries were delayed over 6 months postinjury. In our research, 15 patients underwent surgery within 6 months of injury, and 10 patients underwent surgery later than 6 months after injury. According to the results shown in Table 3, the motor recovery efficiency of the first group (73.3% when ≤ 6 months) was significantly better than that of the second group (30% when > 6 months). For other nerve transfers, such as contralateral C-7 nerve transfer, Gu et al.\(^6\) and Chen et al.\(^2\) showed that a surgical delay of more than 1 year was an important unfavorable factor influencing outcomes. Thus, for ICN transfers, we emphasize the importance of performing the surgery within 6 months of injury.

The phrenic nerve and ICNs are similar in function, while the biceps and the triceps control antagonistic motion. Zheng et al.\(^6\) have reported poor recovery of triceps function after ICN transfer to the long head triceps branch together with phrenic nerve transfer to the musculocutaneous nerve. In their study, none of the 7 patients recovered M3 (Medical Research Council Grade 3) elbow extension. For this reason, they did not recommend transferring the ICNs to the triceps branch and instead suggested radial nerve transfer in conjunction with primary phrenic transfer to the musculocutaneous nerve. However, we observed different results in our current study. All 25 patients underwent phrenic nerve transfer to the musculocutaneous nerve together with ICN transfer to the long head of the triceps. The motor recovery efficiency was 88% in the biceps and 56% in the triceps. Electromyography showed no recruitment from the biceps when the patient extended his/her elbow (Fig. 4B and C). One possible reason may be that the cortical areas for the phrenic nerve and ICNs are independent and, thus, will not affect each other despite having similar functions. However, if the ICNs are used to repair the musculocutaneous nerve and the triceps branch simultaneously, the result might be entirely different. Thus, we believe that patients are able to regain effective triceps function through professional rehabilitation (bending elbow with deep inspiration and extending elbow with deep expiration) even when the ICN transfer is combined with a phrenic nerve transfer to the musculocutaneous nerve.

### Conclusions

Transfer of ICNs to the nerve of long head of the triceps is an effective procedure for treating global brachial plexus avulsion injuries, even if combined with phrenic nerve transfer to the biceps branch. Two ICNs appear to be sufficient for donation. The earlier after injury that the surgery is performed, the better are the results achieved in patients.

### Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.
Author contributions to the study and manuscript preparation include the following. Conception and design: Lao. Analysis and interpretation of data: Gao, Zhao. Drafting the article: Gao. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Lao. Study supervision: Gu.

References


K. Gao et al.


Please include this information when citing this paper: published online November 23, 2012; DOI: 10.3171/2012.10.JNS12637.

Address correspondence to: Jie Lao, M.D., Department of Hand Surgery, HuaShan Hospital, No. 12 WuLuMuQi Zhong Road, Shanghai, China. email: laojie633@hotmail.com.