Surgical outcome of phrenic nerve transfer to the anterior division of the upper trunk in treating brachial plexus avulsion

Clinical article

ZHENG DONG, M.D., PH.D., CHENG-GANG ZHANG, M.D., PH.D., AND YU-DONG GU, M.D.

Department of Hand Surgery, Huashan Hospital, Fudan University Medical Center, Shanghai, China

Object. The purpose of this investigation was to study the surgical results of phrenic nerve transfer to the anterior division of the upper trunk of the brachial plexus.

Methods. Between 2002 and 2005, 40 patients received a phrenic nerve transfer to the anterior division of the upper trunk of the brachial plexus to restore elbow flexion. These cases were followed postoperatively for > 2 years, and the efficacy of the surgery and related factors were evaluated.

Results. The overall effective rate of this procedure was 82.5% (Medical Research Council Grade ≥ 3). The results show that for patients with surgical delay of > 1 year or prolongation of the latency of the preoperative phrenic nerve evoked potential > 20%, the recovery rates were 25 and 50%, respectively.

Conclusions. Phrenic nerve transfer to the anterior division of the upper trunk of the brachial plexus is a simple procedure that causes minor surgical trauma and yields good recovery of elbow flexion. It is suitable in patients with a relatively intact structure at the division level of the brachial plexus. (DOI: 10.3171/2009.4.JNS081064)

Key Words • phrenic nerve • brachial plexus • nerve transfer • neurotization • nerve injury

Phrenic nerve transfer to the anterior division of the upper trunk of the brachial plexus is one of the most frequently used surgical procedures in our clinic to restore elbow flexion in treating brachial plexus avulsion injury. We followed 40 consecutive patients who underwent this surgery between 2002 and 2005. The results are reported and evaluated.

Methods

Patient Population

Forty cases were included in this study. There were 35 male and 5 female patients, with injuries to 21 left and 19 right brachial plexuses. The mean age at operation was 31 years (range 14–59 years). The causes of the injuries were as follows: traffic accident (34 cases), machine traction injury (3), fall from heights (2), and explosion injury (1). The mean surgical delay was 4.6 months (range 34 days–21.5 months). The injury types included upper trunk injury (3 cases), upper and middle trunk injury (6), and total plexus injury (31). In all cases, bilateral phrenic nerve function was evaluated using preoperative EMG.

Operative Technique

After induction of general anesthesia, the patient was placed supine and a pillow was placed under the shoulder, with the head turned to the uninjured side. An incision ~ 8 cm long was made 2 cm parallel to and above the clavicle (Fig. 1). The brachial plexus was explored, with the anterior and posterior divisions of the upper trunk identified. The upper trunk was found to be avulsed during surgery. The preganglionic injury diagnosis was further confirmed by intraoperative EMG. A nerve transfer was indicated accordingly. The phrenic nerve was identified on the surface of the anterior scalenus muscle, and electrical stimulation elicited powerful contraction of the diaphragm, showing good function of the nerve, which was then divided as distally as possible. The upper trunk was dissected at the trunk-division level, and the proximal end of the phrenic nerve was transferred to the anterior division of the upper trunk directly and attached using 8-0 nylon sutures (Fig. 2). Other nerve transfers were performed simultaneously when appropriate; for example, accessory-to-suprascapular nerve transfer. The surgically treated upper limb was immobilized by a head-shoulder spica bandage for 4–6 weeks after the surgery.

Follow-Up and Statistical Analysis

The patients were scheduled to visit every 3 months postoperatively for consultation. The effectiveness of the treatment was analyzed using the logistics regression procedure (with age, surgical delay, prolongation rate of latency, and attenuation rate of amplitude as variants).
Results

For most patients, weak biceps contraction could be seen ~ 8–9 months after this surgery by initiating a breath, indicating the successful regeneration of the phrenic nerve into the biceps. The follow-up period was 28.2 months on average (range 10.5–47 months). Of these 40 patients, 33 recovered to ≥ MRC Grade 3 in biceps (82.5%), and in the other 7 cases (17.5%) the biceps strength reached MRC Grade 0–2.

Patient Age and Surgical Effectiveness

As shown in Table 1, among 40 patients there were 32 who were < 40 years of age, and 29 of them had biceps muscle strength recovery to ≥ MRC Grade 3 (90.6%), whereas for the rest of the older patients, only half of them recovered to ≥ MRC Grade 3.

TABLE 1: Patient age and surgical effectiveness

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>No. of Cases</th>
<th>Muscle Strength</th>
<th>Effective Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40</td>
<td>32</td>
<td>29</td>
<td>90.6</td>
</tr>
<tr>
<td>≥40</td>
<td>8</td>
<td>4</td>
<td>50.0</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>33</td>
<td>82.5</td>
</tr>
</tbody>
</table>

Surgical Delay and Effectiveness

As shown in Table 2, 32 patients underwent surgery within 6 months after their initial injury, and 29 of them had biceps strength recovery to ≥ MRC Grade 3 (90.6%). For the 4 patients who underwent surgery between 6 and 12 months after injury, in 3 of them the biceps recovered to ≥ MRC Grade 3 strength (75%). In contrast, for the other 4 patients, in whom operations were performed > 12 months after injury, only 1 had MRC Grade 3 recovery (25%).

Preoperative Phrenic Nerve Function and Surgical Effectiveness

In all cases, the amplitude and latency of the evoked potential of phrenic nerve were documented on both sides preoperatively (Table 3). The correlation between recov-
Phrenic nerve transfer to anterior upper trunk of brachial plexus

Discussion

After transection of the phrenic nerve, unilateral diaphragmatic paralysis was observed in all patients on plain chest radiographs, but no respiratory dysfunction was encountered in our series due to the compensation of the intact diaphragm. The safety of phrenic nerve transfer has been reported in previous literature in detail, by both our unit and by investigators at other centers, and therefore is not addressed in this paper. Close study needs to be done on these patients who attain elderly status to clarify whether pulmonary function will be affected in the long run by dividing the phrenic nerve. Such a study is now being performed in our unit on our early cases treated in the late 1970s, and the results will be published separately.

Based on our anatomical study of the topography of the motor branch of the biceps in musculocutaneous nerve, we advocate phrenic nerve transfer to the anterior division of the upper trunk to restore elbow flexion, and the overall effective recovery rate is 82.5%. Compared with phrenic-to-musculocutaneous nerve transfer, which shows similar efficacy, this procedure does not require a long nerve graft and simplifies the operation. Therefore it is recommended in the cases in which the structures at the division level of brachial plexus are relatively intact.

From the follow-up data it can be concluded that the outcome following this surgery is affected by surgical delay and the preoperative functioning of the phrenic nerve.

Conclusions

Phrenic nerve transfer to the anterior division of the upper trunk of the brachial plexus is a simple procedure that causes only minor surgical trauma and yields good recovery of elbow flexion. It is suitable for patients with relatively intact structures at the division level of the brachial plexus.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


TABLE 3: Preoperative EMG examination on bilateral phrenic nerve

<table>
<thead>
<tr>
<th>Side</th>
<th>No. of Cases</th>
<th>Latency (msec)</th>
<th>Amplitude (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>injured</td>
<td>40</td>
<td>7.57 ± 0.99</td>
<td>575.88 ± 227.46</td>
</tr>
<tr>
<td>healthy</td>
<td>40</td>
<td>6.89 ± 0.59</td>
<td>702.08 ± 211.43</td>
</tr>
</tbody>
</table>

* Values are presented as the means ± SDs.

TABLE 4: Prolongation of latency and effectiveness

<table>
<thead>
<tr>
<th>Prolongation of Latency</th>
<th>No. of Cases</th>
<th>Muscle Strength</th>
<th>Effective Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10%</td>
<td>25</td>
<td>23</td>
<td>92.0</td>
</tr>
<tr>
<td>10–20%</td>
<td>9</td>
<td>7</td>
<td>77.8</td>
</tr>
<tr>
<td>&gt;20%</td>
<td>6</td>
<td>3</td>
<td>50.0</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>33</td>
<td>82.5</td>
</tr>
</tbody>
</table>

TABLE 5: Attenuation of amplitude and surgical effectiveness

<table>
<thead>
<tr>
<th>Attenuation of Amplitude</th>
<th>No. of Cases</th>
<th>Muscle Strength</th>
<th>Effective Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10%</td>
<td>11</td>
<td>10</td>
<td>90.9</td>
</tr>
<tr>
<td>10–20%</td>
<td>10</td>
<td>8</td>
<td>80.0</td>
</tr>
<tr>
<td>&gt;20%</td>
<td>19</td>
<td>15</td>
<td>78.9</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>33</td>
<td>82.5</td>
</tr>
</tbody>
</table>

Because the results are usually not good for the patients treated at > 1 year after injury or for those with prolongation of latency of the phrenic nerve evoked potential > 20%, other procedures such as intercostal nerve transfer, Oberlin procedure, contralateral C7 nerve transfer, or free muscle transfer should therefore be considered in reanimating elbow flexion.

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Address correspondence to: Cheng-Gang Zhang, M.D., Ph.D., Department of Hand Surgery, Huashan Hospital, Fudan University Medical Center, Shanghai, 200040 China. email: cgzhang@swk.shmu.edu.cn.