Original article

Triceps motor branch transfer for isolated axillary nerve injury: Outcomes in 9 patients

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A B S T R A C T

Introduction: Triceps motor branch transfer has been used for more than ten years to restore deltoid function after axillary nerve injury. However, there have been few reports of the outcome of this procedure in isolated axillary nerve injury.

Hypothesis: Triceps motor branch transfer could be an effective method to restore deltoid function for patients with isolated axillary nerve injury.

Materials and methods: Nine patients who underwent triceps motor branch transfer for treatment of isolated axillary nerve injury were followed up for at least 22 months. Shoulder abduction was assessed for all patients. The DASH outcome questionnaire was completed by every patient. Electrophysiological study was performed on 7 patients.

Results: All patients regained ≥ 90° (mean, 137°) shoulder abduction. Mean DASH score decreased from 35.2 before surgery to 13.1 at the last follow-up. There was no noticeable weakness of elbow extension in any patient.

Discussion: Triceps motor branch transfer provided good results and may be a feasible alternative to nerve grafting for the treatment of complete isolated axillary nerve injury.

Type of study: IV, retrospective cohort study.

1. Introduction

Deltoid paralysis caused by axillary nerve injury can severely impair shoulder abduction and affect the daily life of patients. When there is a long defect in the nerve, the ends cannot be sutured together without tension, and nerve grafting has been considered the best option to achieve satisfactory results [1–4].

Triceps motor branch transfer (i.e., transfer of the branch of the radial nerve innervating the long head of the triceps to the anterior branch of the axillary nerve), which was first described by Leechavengyongs et al. in 2003 for the treatment of upper brachial plexus injuries [5,6], has become an important approach for the treatment of deltoid paralysis. Over the past decade, it has demonstrated good curative effects both in adults and children, with most patients achieving ≥ M3 deltoid strength and ≥ 90° shoulder abduction [6–11]. Triceps motor branch transfer can also be an effective method to restore deltoid function for patients with isolated axillary nerve injury. However, there have been few reports of the outcome of this procedure in isolated axillary nerve injury, because isolated axillary injury is infrequent.

The purpose of the study was to assess the outcome of triceps motor branch transfer for isolated axillary nerve injury. Our hypothesis was that triceps motor branch transfer could be an effective method to restore deltoid function.

2. Materials and methods

This study was approved by the Medical Ethics Committee of Huashan Hospital.

2.1. Patients

In this study, isolated axillary nerve injury was defined as axillary nerve injury without any other peripheral nerve injury. The inclusion criteria were completely isolated axillary nerve injury, and performance of transfer of the triceps motor branch to the axillary nerve. According to our electronic medical records system, 12 patients met the inclusion criteria. Nine patients (7 males and 2 females) were finally included, because 3 patients could not be contacted.

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Table 1
Characteristics of the patients.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender/age (y)</th>
<th>BMI</th>
<th>Injury mode</th>
<th>Affected side</th>
<th>Time to surgery (mo)</th>
<th>Follow-up (mo)</th>
<th>Associated injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/56</td>
<td>23.7</td>
<td>Blunt trauma</td>
<td>L</td>
<td>3</td>
<td>37</td>
<td>Rotator cuff injury</td>
</tr>
<tr>
<td>2</td>
<td>M/45</td>
<td>23.7</td>
<td>Fall</td>
<td>R</td>
<td>5</td>
<td>50</td>
<td>Rotator cuff injury</td>
</tr>
<tr>
<td>3</td>
<td>F/54</td>
<td>23.9</td>
<td>Blunt trauma</td>
<td>R</td>
<td>6</td>
<td>36</td>
<td>Soft tissue contusion</td>
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<tr>
<td>4</td>
<td>M/44</td>
<td>20.1</td>
<td>Car accident</td>
<td>L</td>
<td>5</td>
<td>48</td>
<td>Cervical instability</td>
</tr>
<tr>
<td>5</td>
<td>M/23</td>
<td>23.9</td>
<td>Sport injury</td>
<td>R</td>
<td>4</td>
<td>44</td>
<td>Shoulder dislocation</td>
</tr>
<tr>
<td>6</td>
<td>M/28</td>
<td>27.8</td>
<td>Motorcycle</td>
<td>L</td>
<td>4</td>
<td>22</td>
<td>Humeral fracture</td>
</tr>
<tr>
<td>7</td>
<td>M/25</td>
<td>24.5</td>
<td>Bicycle</td>
<td>R</td>
<td>12</td>
<td>38</td>
<td>Shoulder dislocation</td>
</tr>
<tr>
<td>8</td>
<td>M/39</td>
<td>19.0</td>
<td>Crush injury</td>
<td>L</td>
<td>8</td>
<td>40</td>
<td>Rupture of spleen; rib fracture</td>
</tr>
<tr>
<td>9</td>
<td>M/26</td>
<td>24.2</td>
<td>Motorcycle</td>
<td>L</td>
<td>3</td>
<td>39</td>
<td>Skin contusion</td>
</tr>
</tbody>
</table>

y: year; BMI: body mass index; mo: month; F: female; M: male; L: left; R: right.

Table 2
Shoulder abduction range and DASH score.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Shoulder abduction (preoperative)</th>
<th>Shoulder abduction (postoperative)*</th>
<th>DASH score (preoperative)</th>
<th>DASH score (postoperative)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20°</td>
<td>90°</td>
<td>43.1</td>
<td>27.6</td>
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<tr>
<td>2</td>
<td>30°</td>
<td>100°</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>3</td>
<td>60°</td>
<td>150°</td>
<td>34.5</td>
<td>14.7</td>
</tr>
<tr>
<td>4</td>
<td>75°</td>
<td>160°</td>
<td>27.5</td>
<td>2.5</td>
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<tr>
<td>5</td>
<td>70°</td>
<td>170°</td>
<td>30.1</td>
<td>1.7</td>
</tr>
<tr>
<td>6</td>
<td>55°</td>
<td>110°</td>
<td>28.3</td>
<td>21.7</td>
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<tr>
<td>7</td>
<td>65°</td>
<td>130°</td>
<td>40.8</td>
<td>19.2</td>
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<tr>
<td>8</td>
<td>60°</td>
<td>160°</td>
<td>31.7</td>
<td>3.3</td>
</tr>
<tr>
<td>9</td>
<td>65°</td>
<td>160°</td>
<td>30.8</td>
<td>2.5</td>
</tr>
</tbody>
</table>

DASH: Disability of the Arm, Shoulder and Hand.

* Shoulder abduction or DASH score at the last follow-up.

From 2010 to 2014, the 9 patients with isolated axillary nerve injury underwent triceps motor branch transfer in our department (Table 1). The mean age was 37.8 years (range, 23–56 years). The injury was on the left side in 5 patients and on the right side in 4 patients; all patients were right-handed. The mean interval from injury to surgery was 5.5 months (range, 3–12 months); in 7 patients the interval was ≤ 6 months.

2.2. Preoperative diagnosis

The diagnosis of complete axillary nerve injury was established by physical examinations and electrophysiological studies. Other associated injuries, such as rotator cuff injury or humeral fracture, were present in all cases (Table 1), and were treated before triceps motor branch transfer. As Table 2 shows, mean shoulder abduction before triceps motor branch transfer was 55° (range, 25°–75°).

2.3. Surgical techniques

All surgeries were performed under general anesthesia, with the patient in the supine position.

2.3.1. Infraclavicular axillary nerve exploration

A standard infraclavicular brachial plexus exploration incision (10 cm long) was carried out, extending from the clavicular level to the axilla. Skin and subcutaneous tissue were dissected, and the deltopectoral groove was exposed. The pectoralis major and pectoralis minor were separated to expose the brachial plexus. In all patients, long defects were present in the axillary nerve, with the cut ends wrapped in scar tissues. On electromyography (EMG), no compound muscle action potential (CMAP) was recorded on the deltoid when the proximal axillary nerve was stimulated, and no somatosensory evoked potential (SEP) was recorded when the distal stump was stimulated. Since the axillary nerve was completely ruptured and could not be directly sutured without tension, triceps motor branch transfer was performed on all patients, according to the treatment options explained to patients before surgery.

2.3.2. Triceps motor branch transfer

An incision was made along the posterior edge of the deltoid. The skin and subcutaneous tissue were dissected, and the quadrilateral and triangular spaces were exposed. The axillary nerve was identified in the quadrilateral space. After confirming that the nerve was ruptured and could not be coapted directly, the anterior branch innervating the deltoid was identified, intraneurally dissected, and transected as proximally as possible. Then, the radial nerve was identified at the triangular space, and the branch to the long head of the triceps was identified and cut at its insertion into the muscle. After confirming that the length of the branch to the long head of triceps and that of the anterior branch of the axillary nerve was sufficient for tension-free coaptation, the nerve ends were sutured under binocular loupe with 9-0 nylon sutures. The affected arm was immobilized for 4 weeks after surgery.

2.4. Follow-up evaluation

Shoulder abduction was recorded pre- and postoperatively. Before surgery and at the last follow-up, all patients completed the Disability of the Arm, Shoulder and Hand (DASH) outcome questionnaire. All questionnaires were filled out and scored according to the guidelines on the website The DASH OUTCOME MEASURE (http://www.dash.iwh.on.ca/).

Electrophysiological study was performed on 7 patients postoperatively, focusing on the latency and amplitude of the CMAP recorded on the deltoid when the triceps motor branch–axillary nerve was stimulated via the skin. Two patients (patient 1 and patient 8) refused electrophysiological study because they were not willing to bear the pain caused by the insertion of the EMG needle.

Triceps function was evaluated by physical examination.

2.5. Statistical analysis

Wilcoxon test was used to compare pre- and postoperative shoulder abduction degrees and DASH scores. The relationship
between outcome versus age, body mass index (BMI) and injury-to-surgery time was assessed by regression analysis. The statistical significance threshold was set at \( P < 0.05 \). The influence of the gender, side of injury, injury type and duration of follow-up were also taken into consideration, but were not analyzed statistically because of the small sample size.

3. Results

Patients were followed up for at least 22 months (range, 22–50; mean, 39 months). Table 2 shows the outcomes of the 9 patients.

No notable weakness of elbow extension or any other complication was observed in any patient. In 7 patients, EMG showed that the deltoids were reinnervated by the third postoperative month. Subsequent EMG showed progressive reinnervation, as demonstrated by decreasing latency and increasing amplitude of CMAP.

Mean shoulder abduction was \( 137^\circ \) (range, \( 90^\circ – 170^\circ \)) at the last follow-up, significantly higher than the preoperative value \( (P < 0.001) \). Abduction increased with time: for example, patient 5 recovered \( 100^\circ \) abduction only one year after surgery; at 18 months, abduction had recovered to \( 140^\circ \), and 2 years postoperatively he achieved \( 170^\circ \) abduction (Fig. 1).

Mean DASH score was 35.2 (range, 27.5–50) before surgery, and significantly decreased to 13.1 (range, 1.7–27.6) at the last follow-up \( (P < 0.001) \).

No correlation was found between shoulder abduction or DASH score and age, BMI or injury-to-surgery time.

4. Discussion

Axillary nerve injury is the leading cause of deltoid paralysis, which seriously affects shoulder abduction. Shoulder abduction plays an important role in upper limb function, and without it the hand is also incapacitated to some extent. Therefore, great importance is given to the restoration of shoulder abduction after axillary nerve injury. When the injured axillary nerve cannot be sutured without tension because of a long defect, nerve grafting is the main treatment method used and has shown good results [1–4]. Triceps motor branch transfer, first reported by Leechavengvongs et al., is an alternative method for treating axillary nerve injury, and many surgeons have adopted it because of its advantages. For instance, the triceps motor branch is close to the distal stump of the axillary nerve, and therefore less time is needed postoperatively for nerve regeneration. Another advantage is that triceps motor branch transfer can bypass the scarred injured zone, which could otherwise affect the recovery of the axillary nerve [6,12]. Nerve transfer is also more acceptable than nerve grafting, because it avoids the need for a second incision to harvest the nerve graft. Most importantly, triceps motor branch transfer has shown encouraging efficacy. According to some reports, most cases regained \( \geq 90^\circ \) shoulder abduction [6–11].

Our study demonstrated satisfactory results in abduction range. The study hypothesis was confirmed. It should be noted that it is difficult to quantify deltoid strength, given that shoulder abduction is the synergistic effect of the supraspinatus and the deltoid. Therefore, we did not use deltoid strength as an evaluation index. The concept of shoulder strength may be helpful to describe the compound strength of related muscles [13], although we did not use it in this article. As a supplementary criterion, we used the DASH outcome questionnaire, a comprehensive scale including the patient’s daily life, mental state and social relations. The DASH score reflected the overall benefit that this surgery brought to patients. In this study, the DASH score decreased significantly by follow-up: i.e., surgery clearly improved patients’ quality of life.

Factors affecting the outcome were also studied. Age, injury-to-surgery time and body mass index (BMI) correlated with the result. Concretely, younger patients with shorter injury-to-surgery time and lower BMI generally demonstrated better recovery [11]. However, the study failed to find a consistent relationship. Patients 1, 6 and 7 had relatively poorer recovery, which could be partly attributed to the fact that they were older, had higher BMI, and longer injury-to-surgery time. However, no statistical association could be established, probably because of the small size and homogeneity of our study sample, which included only 9 patients, with the majority having normal BMI (18.8–25) and an injury-to-surgery time of \( \leq 6 \) months. In addition, the short distance between the triceps motor branch and the deltoid may also weaken the influence of injury-to-surgery time, because much reinnervation time was saved.

He et al. also reported that the duration of follow-up is a predictor of outcome after peripheral nerve repair [14]. This suggests that an adequate follow-up period is necessary for correct assessment of the final outcome of nerve repair. Most studies had only 1 year’s follow-up; in our experience, this may be not enough to assess the results of triceps motor branch transfer. In the present study, most patients had achieved maximal recovery by around 18 months.
This study had several limitations. First, it was a retrospective study from a single center. Large multicenter prospective studies are necessary to draw definite conclusions regarding the value of the procedure. Second, the sample size was very small, which may weaken the statistical power. And third, in the absence of a control group, comparison of nerve transfer and nerve grafting is difficult.

5. Conclusions

Triceps motor branch transfer shows good efficacy and could be a feasible alternative to nerve grafting for the treatment of complete axillary nerve injury. It causes less operative trauma and has many advantages.

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Disclosure of interest

The authors declare that they have no competing interest.

References