Neurotization as an alternative for restoring finger and wrist extension

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Object. In cases of irreparable injuries to the radial nerve or in cases in which nerves are repaired with little anticipation of restoration of function, tendon transfers are widely used. In this study, the authors searched for a more natural alternative for selectively restoring function, with the aid of a motor nerve transfer.

Methods. Ten arms from five cadavers were used in the study. The posterior interosseous nerve and the median nerve together with their motor branches were exposed in the proximal forearm. The possibility of posterior interosseous nerve neurotization via the median nerve through its motor branches leading to the pronator teres, flexor pollicis longus, flexor digitorum profundus, and pronator quadratus muscles was investigated. The lengths of the nerves from points of divergence and their widths were measured using calipers, and the means with standard deviations of all nerves were calculated.

Motor branches to the pronator teres, flexor pollicis longus, and pronator quadratus muscles were found to be suitable for neurotization of the posterior interosseous nerve at different levels and in various combinations. The motor nerve extending to the flexor digitorum profundus muscle was too short to use for transfer.

Conclusions. These results offer a suitable alternative to tendon transfer for restoring finger and wrist extension in cases of irreversible radial palsy. The second step would be clinical verification in appropriate cases.

KEY WORDS • median nerve • neurotization • posterior interosseous nerve

Loss of radial nerve function in the hand creates a significant disability. Patients have great difficulty in grasping objects and, more importantly, loss of active wrist stabilization impairs power grip. In cases of low radial nerve palsy, the extensor carpi radialis brevis, digital extensor, abductor pollicis longus, and extensor pollicis brevis muscles are paralyzed, whereas the extensor carpi radialis longus and brachioradialis muscles are spared.2,4,8,12

Tendon transfers, in which the wrist flexors, superficial finger flexors, palmaris longus, and pronator teres are used to restore function in cases of radial nerve palsy, are among the best and most predictable transfers in the upper extremity.1 However, errors in procedure cannot be overcome by local adaptation, and there is usually only one chance to obtain good restoration of function. In addition, functional loss of one or more intact tendons leads to greater morbidity in the case.

The aim of this study was to find an alternative way of restoring lost function in cases of radial nerve palsy, resorting to tendon transfer only as the last choice. Selective neurotization of a motor nerve by another motor nerve was considered as a possible solution. The median nerve, with its proximity to the posterior interosseous nerve, appeared to be a viable option.

Materials and Methods

Ten arms from five cadavers were used in the study. The radial nerve and its terminal motor (posterior interosseous nerve) and sensory branches; the motor branches of the posterior interosseous nerve extending to the extensor carpi radialis brevis, supinator, extensor carpi ulnaris, extensor digiti quinti proprius, extensor digitorum communis, abductor pollicis longus, and extensor pollicis longus and brevis muscles; and the median nerve with its motor branches extending to the pronator teres, flexor pollicis longus, flexor digitorum profundus, and pronator quadratus muscles (anterior interosseous nerve) were exposed in the proximal forearm (Fig. 1). The widths and lengths of the nerves were measured using calipers, and the means and standard deviations were calculated. Afterward, the possibility of neurotization of the posterior interosseous nerve and its branches, via the median nerve and its branches, was evaluated by taking into account the suitability of their relative widths and lengths for surgically created nerve communication (Fig. 2).

Results

The results of our measurements are summarized in Table 1. The length of the branch leading to the pronator teres muscle was suitable for neurotization of the portion of the posterior interosseous nerve located before the origin of the branch extending to the extensor carpi radialis brevis muscle, or for neurotization of the branch extending...
to the extensor carpi radialis brevis muscle itself, only if these sections were separated from their origins and placed beside the branch leading to the pronator teres muscle to perform an end-to-end surgically created nerve communication (Fig. 3 upper left). The width of the branch leading to the pronator teres muscle only matched well with the branch extending to the extensor carpi radialis brevis muscle.

The branch leading to the flexor pollicis longus muscle was sufficiently long to be placed beside the branch to the extensor carpi radialis brevis muscle, the portion of the posterior interosseous nerve located after the branch coursing to extensor carpi radialis brevis muscle, or the portion of the posterior interosseous nerve before the origin of the branch to the extensor carpi radialis brevis muscle, if it was separated from its origin (Fig. 3 upper right). Its width was suitable for neurotization of the branch leading to the extensor carpi radialis brevis muscle.

The branch leading to the flexor digitorum profundus muscle was too short to use for neurotization.

The length of the branch extending to the pronator quadratus muscle was suitable for neurotization of the portions of the posterior interosseous nerve located both before and after it has given origin to the branch to the extensor carpi radialis brevis, the branch to the extensor carpi radialis brevis itself, and the portion of the posterior interosseous nerve located after its exit from the supinator muscle (Fig. 3 lower left and right). Its width was suitable for the branch extending to the extensor carpi radialis brevis muscle and the portion of the posterior interosseous nerve located after the branch leading to the extensor carpi ulnaris muscle.

When nerves extending to the flexor pollicis longus and pronator quadratus muscles were considered together for neurotization of a single nerve, their widths were sufficient for neurotization of the posterior interosseous nerve both before and after it has given origin to the branch to the extensor carpi radialis brevis. The branches leading to pronator teres and pronator quadratus muscles, or the branches leading to the pronator teres, pronator quadratus, and flexor pollicis longus muscles could be considered together for neurotization of the posterior interosseous nerve before it has given origin to the branch to the extensor carpi radialis brevis.

**Discussion**

The radial nerve, a continuation of the posterior cord of the brachial plexus, consists of fibers from C-6, C-7, and C-8, and, sometimes, T-1. It is primarily a motor nerve that innervates the triceps muscle, the supinator muscle, and the extensors of the wrist and thumb. This nerve is injured most often by fractures of the humeral shaft. Gunshot wounds are the second most common cause of radial nerve injury. Lacerations of the arm and proximal forearm, injection injuries, prolonged local pressure, and compression neuropathies are other causes.8,12

After repairs are made to the radial nerve, the prognosis for regeneration is more favorable than for any other major nerve in the upper extremity, first, because it is pre-
Nerve transfer for radial palsy

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**TABLE 1**

<table>
<thead>
<tr>
<th>Nerve†</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT</td>
<td>21 ± 1.02</td>
<td>1.7 ± 0.08</td>
</tr>
<tr>
<td>FL</td>
<td>35 ± 1.90</td>
<td>1.6 ± 0.14</td>
</tr>
<tr>
<td>FP</td>
<td>20 ± 1.20</td>
<td>1.4 ± 0.12</td>
</tr>
<tr>
<td>PQ</td>
<td>114 ± 5.80</td>
<td>1.5 ± 0.18</td>
</tr>
<tr>
<td>PINbecrb</td>
<td>14 ± 0.82</td>
<td>3.2 ± 0.19</td>
</tr>
<tr>
<td>ECRB</td>
<td>28 ± 1.60</td>
<td>1.7 ± 0.07</td>
</tr>
<tr>
<td>PINbs</td>
<td>35 ± 1.90</td>
<td>2.7 ± 0.18</td>
</tr>
<tr>
<td>PINasbb</td>
<td>7 ± 0.30</td>
<td>2.2 ± 0.17</td>
</tr>
<tr>
<td>PINaecu</td>
<td>8 ± 0.40</td>
<td>1.8 ± 0.09</td>
</tr>
</tbody>
</table>

* Values are expressed as the means ± standard deviation.
† Motor branches extending to the PT (pronator teres), FL (flexor pollicis longus), FP (flexor digitorum profundus), PQ (pronator quadratus), PINbecrb (portion of the posterior interosseous nerve located before divergence of the motor branch to the extensor carpi radialis brevis muscle), ECRB (extensor carpi radialis brevis), PINbs (portion of the posterior interosseous nerve located before its entrance into the supinator muscle), PINasbb (portion of the posterior interosseous nerve located after its exit from the supinator muscle, but before it sends off motor branches), PINaecu (portion of the posterior interosseous nerve located after it sends off a motor branch to the extensor carpi ulnaris).

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dominantly a motor nerve and, second, because the muscles it innervates are not involved in the finer movements of the fingers and hand. However, gaps in the radial nerve are closed less easily than those in the ulnar and median nerves. Thus, injuries with large defects require grafting and this, in turn, reduces the chance of success. Patients with combined injuries with large amounts of scar tissue around the nerve also have poor prognoses. Although multiple tendon transfers provide good functional results in these cases, they do not address the problem directly. In addition, it is necessary to obtain good results during the first operation, because local adaptation is not possible. On the other hand, neurotization of the posterior interosseous nerve offers a more natural solution, addressing the problem directly. Neurotization, or nerve transfer, in cases of brachial plexus injury is a well established and gradually evolving method. Nerve transfer performed using one or two fascicles of the ulnar nerve leading to the motor branch of the biceps muscle to provide elbow flexion in brachial plexus injury has also been reported. However, there are only a few studies in which neurotization in peripheral nerve injuries is a focus.  

One of the prerequisites to perform neurotization is that the function to be gained must be greater than the function to be lost. In this study, the branch leading to the pronator quadratus muscle was the most suitable donor because of its length. It could easily reach the posterior interosseous nerve proximal to the origin of the branch extending to the extensor carpi radialis brevis muscle. However, its width is approximately half that of the posterior interosseous nerve and, thus, it is suitable only to neurotize the portion of the posterior interosseous nerve located after or before the origin of the branch to the extensor carpi radialis brevis muscle, in combination with the branch leading to the flexor pollicis longus and/or pronator teres muscles. In addition, it can be used for transfer to the portion of the posterior interosseous nerve located after its exit from the supinator muscle. The loss of function of the pronator quadratus muscle, which occurs when the anterior interosseous nerve is used for transfer to the posterior interosseous nerve, does not constitute a major problem because it is easily compensated for by the pronator teres and secondary pronator muscles. The branch extending to the flexor pollicis longus muscle is a long nerve and can be placed beside the branch leading to the extensor carpi radialis brevis muscle with which its width also matches, to perform a surgically created nerve communication. If the branch leading to the flexor pollicis longus muscle is used for neurotization, interphalangeal flexion will be lost in the thumb. This joint has a secondary role in thumb motions, but there will be a need nevertheless to stabilize the joint by arthrodesis, tenodesis, or tendon transfer.
The pronator teres is the most frequently transferred muscle to restore wrist extension. Its loss is also easily compensated for by the pronator quadratus and secondary pronator muscles. However, the branch leading to the pronator teres cannot be transferred directly to either the posterior interosseous nerve or the branch leading to the extensor carpi radialis brevis muscle because of its short length. Its width only allows neurotization of the branch to the extensor carpi radialis brevis, or neurotization of the posterior interosseous nerve before the origin of the branch to the extensor carpi radialis brevis in combination with the branch to the flexor pollicis longus and/or the branch to the pronator quadratus, when the branch to the extensor carpi radialis brevis or the posterior interosseous nerve has been cut from its origin and placed beside it. When the results are assessed from a functional aspect in cases in which there is intact wrist function, the best choice is neurotization of the posterior interosseous nerve after the origin of the extensor carpi ulnaris muscle, by the branch to the pronator quadratus muscle. The advantages include the following: the short distance from the point of nerve repair to the targeted muscles, unimportant loss of function from excision of the pronator quadratus muscle, and the possibility of restoring all finger extensions and thumb abduction with the use of a single nerve. In the case of a tendon transfer at least two tendons must be used to restore thumb and finger extension. The first tendon leads to one of the two flexor muscles of the wrist, the flexor carpi ulnaris or the flexor carpi radialis, which are associated with the potential complication of wrist deviation toward the untouched tendon. As a donor nerve for neurotization, the branch leading to the pronator quadratus muscle produces negligible functional loss compared with the transfer of tendons for the same task in cases of posterior interosseous nerve or low radial nerve palsy. In addition, nothing is lost by using neurotization because the same tendons will still be available for transfer, if neurotization fails.

The transfer of the branch leading to either the pronator teres or the flexor pollicis longus muscle to the branch leading to the extensor carpi radialis brevis muscle to restore wrist extension can be performed simultaneously with the transfer of the branch leading to the pronator quadratus muscle to the posterior interosseous nerve after the origin of the branch to the extensor carpi ulnaris muscle for complete restoration of function in radial nerve palsy. Tendons frequently used for lost wrist extension are one of the superficial finger flexors or the pronator teres. Using a finger flexor inevitably weakens the flexion power of that finger. Nevertheless, it will be ready for transfer if our proposed nerve, the branch leading to the pronator teres muscle, fails to restore wrist extension after transfer to the branch leading to the extensor carpi radialis brevis muscle. Nerve transfers proximal to the supinator muscle must pass a long distance to reach the targeted muscles, and thus it seems better to use this level only for neurotization of the branch leading to the extensor carpi radialis brevis muscle in cases of lost wrist extension.

This transfer also meets another necessary criterion for neurotization, which proposes motor–sensory differentiation and selective restoration of sensory or motor function. Unless the patient has a painful neuroma, the sensory por-

References