ABSTRACT

Purpose: To show our results of median to radial nerve transfer in radial nerve injury.

Method: We transferred flexor digitorum superficialis (FDS) branch to long and ring finger to extensor carpi radialis brevis (ECRB) and flexor carpi radialis (FCR) branch to the posterior interosseous nerve (PIN) in 6 patients, who had presented to us with radial nerve injury. We followed all patients for 24 months and evaluated their functional outcome via Medical Research Council MRC grading and by measuring hand strength with JAMAR.

Results: All patients had M4+ wrist extension 9 months after surgery. By 12 months 5 patients had M4+ thumb and finger extension. All patients had independent finger movements by 15 months. Grip strength measurement was done in 4 patients. All of them had satisfactory grip strength post operatively.

Conclusion: Median to radial nerve transfer for management of radial nerve palsy provided reliable return of function for wrist and finger extension in our study. However more studies are required on this method.

Key words: Median nerve fascicles Nerve transfer Radial nerve injury Outcome.

INTRODUCTION

The incidence of peripheral nerve injury in trauma patients is 1.6%. The most commonly injured peripheral nerve is the radial nerve. Injury to the radial nerve can occur from fractures, surgical management for fractures, gunshot, nerve compression, as part of a brachial plexus injury or iatrogenic like injections.

Surgical options include neurolysis, end-to-end repair, nerve grafting, tendon transfer and the new option nerve transfer. Out of these the tendon transfer is still the gold standard as it’s easier to perform and has acceptable results. However as it requires postoperative immobilization, good physiotherapy, and motor re-education, the results are not always acceptable. A case series done by Dunnetetal on 49 cases showed that 80% patients had loss of endurance and 66% reported impaired coordination and dexterity. Other authors have reported lack of independent finger extension, and occasionally finger or wrist stiffness. The greatest functional loss after radial nerve palsy is not finger extension but instead loss of grip, which cannot be easily recreated by tendon transfer.

Several authors have already published their results of nerve transfers for radial nerve injuries. The first case report was published by Lowe et al in 2002. The first case series of 19 cases was published by Ray and Mackinnon in 2011. Another series of 6 patients was published recently by Lopez et al.

Here we present our experience for doing nerve transfers for the radial nerve. This includes transfer of FCR to PIN and transfer of one fascicle of FDS (going to long and ring fingers) for ECRB. This is similar to the technique described by Brown and Mackinnon except that we take just one branch of FDS and do not include any tendon transfers.
MATERIALS AND METHODS

All patients who presented with radial nerve injury were evaluated. An EMG/NCV (nerve conduction velocity) was done in all patients in whom there was no radial nerve function. Once it had been ascertained that the patients with radial nerve injury required surgery the patients were counseled regarding the procedure options. Since this was a new procedure, the pros and cons were discussed with the patient and family. Those opting for nerve transfer were then included in this study. After taking informed consent from the patients, videos and photographs were taken preoperatively. Videos were also made during surgery showing specifically the radial nerve, which was not working with nerve stimulation, and the specific median nerve fascicles, which were to be transferred. After surgery each patient was followed prospectively. Hand exercises involving synergistic hand movements were started 2 weeks post surgery. Patients were followed in clinic every 3 months for 2 years. Photographs were taken postoperatively every three months and videos were made one year after surgery. Four patients came regularly to clinic for follow-up. The fifth patient was from another city and he was called on his mobile at every three months and asked to come after every 6 months till 2 years. The sixth patient was from another country and we kept in touch with him through email and he would regularly send us his pictures. One year after his surgery he posted a video on YouTube showing his hand function. We also measured the grip strength of four of the patients one year after surgery by JAMAR.

Patient Population:

We reviewed six patients in this study who were operated for radial nerve injury; out of these five were male and one was female. All were right hand dominant. Four sustained injury to the left side and two to the right side. Causes of the injuries included road traffic accident in three cases, firearm injury in two cases and iatrogenic injury (injection in deltoid region) in one case.

Of the three road traffic accidents one had supracondylar fracture of humerus, one had mid humerus fracture and the third had fracture of surgical neck of humerus. Out of the two patients who had firearm injuries one had a mid-shaft humerus fracture and the other had injury to radial nerve below surgical neck of humerus. All presented to the clinic after variable time period of injury (1 month to 8 months). The median age was 26 years (range of 6-40 years). Median time for surgery since injury was 4 months (range of 2-8 months).

Surgical Method:

The surgery was performed without a tourniquet. Prior to the nerve transfer the radial nerve was explored and we only proceeded to nerve transfer if the radial nerve was irreparable primarily and the area was scarred or if the injury was high and there had been no return of function. The brachioradialis and the pronator teres were palpated and a lazy “S” incision was given over the volar aspect of the forearm between these two muscles extending from 1cm below the elbow to the junction of these muscles (figure 1).

Once the deep fascia was opened the brachial artery along with its branches was identified, dissected and shifted radially. The median nerve was found between pronator teres and the artery. The branch to FCR was identified on the ulnar side of the median nerve and its contraction checked with a stimulator. The next structure coming off the median nerve was the anterior interosseous nerve, which came off the radial side. Deep head of the pronator teres was then divided in a step lengthening fashion to dissect the FDS branches. The FDS branches were found on the ulnar side or undersurface of the median nerve. Once the FDS branches had been dissected they were separated and each branch checked separately with a nerve stimulator. Only the branch going to the long and ring finger was taken (figure 2 and figure 3).
The brachioradialis was then lifted and the SRN (superficial radial nerve) identified. It was then followed proximally till the main radial nerve. Here the PIN (posterior interosseous nerve) was identified going laterally into the supinator muscle. Between these two nerve a third nerve was present with its direction being similar to the SRN but above the Brachioradialis. This was the nerve to ECRB (Extensor carpi radialis brevis) (figure 4). If there was any confusion a small incision was given at the anatomical snuffbox, the SRN branches identified and moved to and fro to correctly identify SRN proximally. Nerve stimulators were then used to make sure that these nerves were not working. Both the PIN and the ECRB were then cut from their origins. The PIN was also released from the supinator fascia (by cutting the supinator fibres) so its direction was in a straight line towards the median nerve fascicles. Then the median nerve fascicles were cut making sure there is no shortage of length. FDS branch to long and ring finger was anastomosed to the ECRB and the FCR branch to the PIN (figure 5) using Prolene 8/0. This anastomosis was done over the brachial and radial artery or under the vessels depending on the length required. Deep fascia and skin were then closed. A soft dressing was done and the hand is placed in a sling before the patient was woken. After two weeks the patient was started on simple synergistic exercises which would include making a fist and then doing wrist extension and then flexing his wrist and opening of the fingers and thumb. This he could do by himself using his other hand or with the help of a family member. Patient was encouraged to do these exercises as many times per day as was possible.
RESULTS (table 1)
Post operatively the mean follow-up was 24 months. Post-operative assessment was done by MCR grading scale and JAMAR hand strength device. All patients were able to get M4+ wrist extension 9 months after surgery. The finger extension was M4+ in 5 patients but M4- in one patient (this was the patient operated at 8 months post injury). Thumb extension also was M4+ by 12 months in all patients. All patients had independent finger movements by 15 months.

We could only check the JAMAR grip strength in 4 patients. Out of these one patient had injury on the dominant hand. Her grip strength at one year was 45kgs in the operated dominant hand and 30 Kgs in the normal hand. The other 3 patients had injuries to the nondominant hand. Their strength ratio was 1.5 when comparing the noninjured dominant hand to the operated nondominant hand (Table 2).

<table>
<thead>
<tr>
<th>Patient</th>
<th>Right hand</th>
<th>Left hand</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 2</td>
<td>29 (Dominant)</td>
<td>18 (Injured)</td>
<td>1.6</td>
</tr>
<tr>
<td>Patient 4</td>
<td>34 (Dominant)</td>
<td>23 (Injured)</td>
<td>1.4</td>
</tr>
<tr>
<td>Patient 5</td>
<td>09 (Dominant)</td>
<td>06 (Injured)</td>
<td>1.5</td>
</tr>
<tr>
<td>Patient 6</td>
<td>45 (Dominant and injured)</td>
<td>30</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Case # 1 (patient 3) (figure 6a,b,c)
A 30 year old gentleman who was right hand dominant sustained a firearm injury to his right arm. This resulted in a fracture of midhumerus along with radial nerve injury and wrist drop. He underwent ORIF (open reduction and internal fixation) of his humerus just after the injury at another hospital. He presented to our clinic after 1.5 months after the initial injury with complaints of no recovery since the time of injury and with a note from the primary orthopedic surgeon saying radial nerve was severely damaged. Initial physical examination showed no radial

Table 1. Patient Demographics.

<table>
<thead>
<tr>
<th>Age/ Sex</th>
<th>Cause</th>
<th>Side</th>
<th>Level of injury</th>
<th>Treatment Of fracture</th>
<th>Time of surgery post injury (months)</th>
<th>Post op Function Wrist extension (MCR total 5)</th>
<th>Post op Finger and thumb extension (MCR total 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 40/M</td>
<td>RTA</td>
<td>L</td>
<td>Surgical neck of humerus</td>
<td>Conservative</td>
<td>6</td>
<td>Excellent 4+</td>
<td>Excellent 4+</td>
</tr>
<tr>
<td>2 18/M</td>
<td>Iatrogenic</td>
<td>L</td>
<td>Radial groove</td>
<td>-</td>
<td>8</td>
<td>Excellent 4+</td>
<td>Excellent 4-</td>
</tr>
<tr>
<td>3 30/M</td>
<td>Fire Arm</td>
<td>R</td>
<td>Mid humerus</td>
<td>Plating</td>
<td>2</td>
<td>Excellent 4+</td>
<td>Excellent 4+</td>
</tr>
<tr>
<td>4 27/M</td>
<td>Fire Arm</td>
<td>L</td>
<td>Below surgical neck of humerus</td>
<td>-</td>
<td>3</td>
<td>Excellent 4+</td>
<td>Excellent 4+</td>
</tr>
<tr>
<td>5 6/M</td>
<td>RTA</td>
<td>L</td>
<td>Supracondylar</td>
<td>K wire fixation</td>
<td>3</td>
<td>Excellent 4+</td>
<td>Excellent 4+</td>
</tr>
<tr>
<td>6 36/F</td>
<td>RTA</td>
<td>R</td>
<td>Midhumerus</td>
<td>Plating</td>
<td>3</td>
<td>Excellent 4+</td>
<td>Excellent 4+</td>
</tr>
</tbody>
</table>
nerve function. His mid arm wound was infected with MRSA (methicillin resistant staphylococcus aureus). An NCV was done which showed complete transection of his radial nerve. Orthopedic consult was taken. They decided to treat the patient with antibiotics only. Different options of reconstruction were discussed with the patient. This patient underwent nerve transfer two months after surgery.

This patient was from another country so we kept in touch via email. His wrist extension started coming back after 3 months, by 8 months he had good wrist extension. His finger extension started improving by 6 months and he had good finger and wrist extension by 12 months and independent finger movements by 15 months. The last thing to come back was ulnar deviation of his wrist. He has made a video and posted it on youtube detailing his hand function return.

**Case #2 (patient 6)(figure 7a,b,c)**

A 36 years old right hand dominant housewife presented 2 months post fracture fixation of right humerus after RTA. On examination she had complete wrist drop and no finger extension. She also had stiff fingers and was unable to make a full fist. Her NCV showed complete injury of the radial nerve. We initially put her on hand physiotherapy for a month. However there was no improvement and her fingers were still stiff after one month. We then discussed the different options with the patient and her husband. She underwent a radial nerve transfer 3 months after her injury. Her wrist extension started improving, after 4 months, function for 4 months. Her fingers started moving 7 months after surgery. After 9 months there was rapid recovery in the hand and by one year she had MRC4+ at both her wrist and fingers.
The success of proximal nerve transfers for brachial plexus has led surgeons to explore different nerve transfers for the distal injuries. For a nerve transfer to be successful the donor nerve should be an expendable nerve which has minimal morbidity, it should be close to the target organ, the transfer should be done within a certain period (maximum time 8-10 months post injury), the number of axons between the donor and recipient nerve should be a good size match and the transfer should be synergistic. While there is a size discrepancy between the nerves, good reinnervation is not a problem. A study by Totosy showed that a donor nerve should have at least 30% of nerve fibres of the recipient nerve. And Ukrit et al after doing 10 cadaveric dissections found that proximal FDS branch has about 35% of number of nerve fibers of the ECRB branch. Initially we were also worried due to the difference in the size of the nerves especially the difference between the FDS fascicle to long and ring fingers and the ECRB. Good functional recovery postoperatively relieved these fears. We did not use a tourniquet during the surgery. We were afraid that if dissection was prolonged the nerve stimulation of donor nerve branches would become problematic. And therefore while this increases the procedure time and one has to be very meticulous, there is no risk of tourniquet-induced ischemic neuropraxia. We always did nerve exploration prior to doing the nerve transfer. We only proceeded to nerve transfer if the nerve was damaged, not amenable to primary repair and the area was scarred or the nerve was damaged and the lesion was high. We tend to operate at 3 months if patients have presented early rather than wait longer. This is because we have had better results with nerve transfers when we have operated early. One patient whom we operated even earlier had a note by the primary orthopedic surgeon which stated that his nerve was damaged with a nerve gap. To date the tendon transfer for the radial nerve injury is the gold standard. However the nerve transfer has its own advantages:

1. Muscle reinnervation provides a more physiologic and adaptive solution. Therefore a more natural, functional reconstruction can be achieved.
2. Patients can get independent finger movements.
3. Patients with stiff hands do better with this procedure. This has been previously reported and we also found this in our patient with stiff hands.
4. The hand does not need to be kept in a plaster for several weeks. Infact we just do soft dressing but keep the hand in a sling and a wrist brace for two weeks and then start physiotherapy.
5. The physiotherapy for the nerve...
transfer is much easier as it is a synergistic transfer and good results can be achieved without significant motor reeducation. The patient could do the physiotherapy at home with another family member or even alone. We shifted to nerve transfers primarily because of patient noncompliance with physiotherapy after tendon transfer, as patients would not go to a physiotherapist.

The recovery time for the transfers also is important. Usually wrist extension starts coming by the third or fourth month. Initially patient is only able to extend the wrist after he makes a fist. This slowly improves and both wrist power and wrist independence become better over time. By 6-9 months all patients had grade 4+ wrist power. Wrist independence is complete by 9 months. The finger extensors start improving by the sixth month with their power coming back to at least M4 by 9-12 months. All our patients had nearly M4+ power at the wrist and 5 out of 6 had M4+ power at EDC and EPL. Only one patient did not get more than M4 at the fingers and this was patient number 2 who had surgery at 8 months post injury. By 15 months all patients could move their fingers independently.

We measured the grip strength for our patients at least one year after surgery (Table 2). We could only measure the grip strength in 4 of our patients. Three of these patients were right handed and had injury to the left hand. The average ratio of strength between the two hands was 1.5 in these three patients. It is expected that an injured hand will lose some power. The fourth patient was right handed and had injury to the same hand. Her grip strength was better in the injured hand then in the noninjured hand. Grip strength difference has been found to be statistically significant previously between dominant and nondominant hand. It has been suggested that the dominant hand is 10% stronger than the nondominant hand. There are few published studies about the nerve transfer for radial nerve injury. There have been two case series one by Ray and Mackinnon of 19 patients and the other Lopez et al in which there were 6 patients. In the first study the most common transfer was FCR to PIN and FDS to ECRB. They also had good to excellent results in most of their patients. Regarding the second study they transferred a branch from the PT to the ECRL and FCR to PIN. They also had good results with their transfers. Our results suggest that nerve transfers provide an acceptable alternate to tendon transfers. However our limitations include small number of patients and absence of control groups, which would include patients with tendon transfers, primary repairs or nerve grafts. Therefore this method can only be accepted as a norm once more studies with larger sample size have been published.

References:


