RADIAL NERVE INJURY TREATMENT BY SINGLE INCISION TECHNIQUE USING TENDON TRANSFER

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ABSTRACT

Background: Radial nerve injury may be the consequence of a complex humerus fracture, direct nerve trauma, compressive neuropathies, neuritis. Tendon transfers to restore function in radial nerve palsy are among the best and most predictable transfers in the upper extremity.

Aim of the study: The aim of this study was using modified jones technique tendon transfer for radial nerve injury through single incision and evaluates its functional and aesthetic outcomes.

Patients and methods: prospective analysis, A total of 18 patients of isolated radial nerve injury (17 men and 1 woman) with a mean age of 30 years (range, 22–40 years) underwent tendon transfer after failed nerve reconstruction or because nerve reconstruction was contraindicated. The exclusion criterion was radial nerve dysfunction resulting from brachial plexus injury. The standardized follow-up focused on the extent of motion determined through the neutral zero method with active and passive range of motion of wrist, MCP joints and finger joints were recorded. Functional results were assessed using a quick DASH scoring system. Patient satisfaction assessment with a two simple questions, first is, if he was satisfied or not and the second was, his agreement to do the same procedure to his other limb if it gained the same injury or not ,with explanation, were done.

Results: After surgical treatment, the average ranges of wrist movement were as follows: mean extension was 56° ±5°, which was 85% of the maximum mobility of the opposite side. Mean flexion was 57° ±5°, equivalent to 75% of the maximum degree of movement of the healthy side. Radial deviation was 17° ±5°, and ulnar deviation was 55° ±5°. The mean finger extension during wrist extension was 75° ±5° and was almost similar in the wrist neutral position at 75° ± 5°. The mean palmar abduction of the thumb was 41°±5°, which was 80% of the maximum mobility of the opposite side. All our patients were satisfied with procedure with no refusal to do same operation if they had same injury to his healthy limb. Only one postoperative complication is encountered.

Conclusion: Our results are comparable with results of recently published studies in respect to range of motion, grip power strength and functional outcomes for whom used same as our transfer combination and superior for who used other combinations, but regarding to cosmetic satisfaction of the patient, our recently introduced approach with a 10 cm single radial, dorsal, linear incision when compared to that of other procedures is superior.

Key words: Radial Nerve Injury, Tendon Transfer.
I. INTRODUCTION:

The radial nerve exits the brachial plexus from the posterior cord with contributions from C5, C6, C7, C8, and T1, traveling dorsal to the axillary artery and vein and closely abutting the shaft of the humerus near the spiral groove. [1]

It is the most frequently injured nerve in the upper extremity, especially in patients with multiple injuries. [2]

Radial nerve injury may be the consequence of a complex humerus fracture, direct nerve trauma, compressive neuropathies, neuritis, or (rarely) from malignant tumor, and considered one of the most debilitating injury affecting function in the hand because of impairment of grasp. These injuries are not uncommon in our society resulting in poor quality of living, dependency & loss of livelihood.

The most prominent features of this injury are loss of wrist extension, metacarpophalangeal joints (MCPJ) extension and a combination of thumb extension and abduction. [2]

More than 70% of RNP cases will recover conservatively. [3] Conservative treatment consists of the patient wearing a brace and undergoing rehabilitation. The aim of rehabilitation is to maintain the passive motion of various joints and to limit the risk of adhesions [4].

Alternative reconstructive options are preferable for injuries affecting the radial nerve that are very proximal, have extensive zones of injury, or present in a delayed fashion. Nerve transfers are an alternative method of restoring radial nerve function. Typically, expendable branches of the median nerve are used, and a variety of donor and recipient nerve combinations have been described. [5]

Tendon transfers are also an alternative method and it has been used for over a century to restore function after radial nerve injury or paralysis with good results. Innumerable tendon transfers have been described to treat radial nerve palsy, and all have their advocates who have shown commendable results. Almost all tendon transfer techniques use multiple incisions producing multiple surgical scars over the forearm except the technique this study focused on using Flexor carpi radialis, Palmaris longus and Pronator teres through the same surgical incision, and this study evaluates its functional and aesthetic outcomes.

We aimed at this study to use modified Jones technique tendon transfer for radial nerve injury through single incision and evaluates its functional and aesthetic outcomes.

II. PATIENTS AND METHODS:

2.1. In prospective analysis, A total of 18 patients of isolated radial nerve injury (17 men and 1 woman) with a mean age of 30 years (range, 22–40 years) underwent tendon transfer after failed nerve reconstruction or because nerve reconstruction was contraindicated. The exclusion criterion was radial nerve dysfunction resulting from brachial plexus injury. They were collected from Orthopedic Department Zagazig University hospital after obtaining the approval of the institutional review board (IRB) of Zagazig University.

2.2. A consent form approved by the committee of human rights in research in Zagazig University was obtained from each participant before the study initiation.

2.3. The patients who met the inclusion criteria and were suitable candidates for the study have been subjected to:

1- History taking and Clinical examination:

- Personal data: (name, sex, age, date of birth, special habits of medical importance, residency, occupation, telephone number and handedness)

- Age: The mean age of the patient population was 30 years. Our youngest patient was 22 years old and the oldest was 40 years.

- Sex: 17 patients were males and 1 patient was female.

- All our patients are right-handed.
• History of previous related operation and precise examination of its results are recorded.

2-Mode and date of trauma:
• In 10 cases, the cause of the initial radial nerve injury was a humeral shaft fracture; in 5 cases, the cause was a gunshot injury; and in 3 cases, the cause was an iatrogenic injury during surgical procedures in arm. Table (1) shows Causes of Injury in descending order of occurrence.
• Time of surgery following intial trauma was recorded.

Table 1: Etiological classification of radia nerve injury

<table>
<thead>
<tr>
<th>Cause of injury</th>
<th>Number of cases</th>
</tr>
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<tbody>
<tr>
<td>humeral shaft fracture</td>
<td>10</td>
</tr>
<tr>
<td>Gunshot injuries</td>
<td>5</td>
</tr>
<tr>
<td>Iatrogenic caused lesion</td>
<td>3</td>
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3-Clinical examination:
• A detailed examination of the injured extremity looking for scars, joint mobility, muscle power and any possible nerve recovery.
• The median, ulnar, and radial nerves was evaluated by examining finger and wrist motion looking for any associated injuries.
• Function of all possible donor muscles was estimated using the common clinical classification: M0–M5. This classification was easy to apply for the different muscle groups of the forearm.
• Hand grip strength of contralateral side using Jamar dynamometer (Jamar Hydraulic Hand Dynamometer; Sammons Preston Patterson Medical Products, Inc., Bolingbrook, IL).
• Active and passive range of motion of wrist, MCP joints and finger joints were recorded.
• A vascular examination was also performed. This examination included feeling distal pulses, feeling for thrills, or listening for bruits especially in penetrating injuries.

4-Investigations:
1 Routine immediate preoperative labs included: complete blood picture, kidney profile, liver profile, random blood sugar, and (PT, PC, INR).
2 EMG and NCS studies:
• A baseline examination, whenever possible was done 3 to 4 weeks after the traumatic injury to allow Wallerian degeneration to occur and the electrodiagnostic study to reflect the nerve injury.
• Whenever possible, a follow-up study was performed at 3 then 6 months after the initial study to assess for recovery.

B: Surgical Technique
For all tendon transfer procedures, critical components of the procedure include intraoperative confirmation of the ROM of all joints will be used and confirmation of appropriate donor muscles selection. With the patient supine after application of tourniquet, a 10 cm long incision is first marked over the radial aspect of the forearm (Figs. 5-1 and 2) extending distally from the middle third, distal third junction to 1 cm proximal to the radial styloid and. All the tendons required for the transfer are explored and identified through the same incision (Figs. 5-3 and 4). By good retraction of the wound proximally, Pronator teres muscle is raised from its insertion with a 4 cm sleeve of periosteum.
FIG 1. The surgical incision: The vertical limb of the incision extends from the mid third-lower third junction on the radial aspect of the forearm and ends 1 cm proximal to the radial styloid. The oblique limb extends dorsally toward the Lister tubercle to enable access to the extensor pollicis longus.

FIG 2.A. Surgical incision on the skin surface. B. Postoperative wound closure with subcuticular sutures

The pronator teres tendon is passed subcutaneously around the radial border of the forearm, superficial to the brachioradialis and extensor carpi radialis longus to reach the musculotendinous junction of extensor carpi radialis brevis muscle. The palmaris longus and the flexor carpi radialis tendons are identified and transected at the level of the wrist. Both tendons are identified at a higher level through the same incision and pulled up proximally.

The flexor carpi radialis tendon is passed around the radial border of the forearm to reach the extensor digitorum communis tendons at the lower third of the forearm. Extensor pollicis longus tendon is divided at the musculotendinous junction and rerouted to the radial side of Lister tubercle. Now the tendon anastamosis are carried out one by one tension is in maximum degree of desired range and as far distal as the donor tendon allow using end to side maneuver in both extensor of wrist and fingers while end to end with PL to EPL. Pronator teres is sutured to the extensor carpi radialis brevis tendon, followed by suturing of flexor carpi radialis tendon to extensor digitorum communis tendons, and finally, the palmaris longus tendon is sutured to the extensor pollicis longus tendon.
All sutures are made with 3-0 or 4-0 polypropylene with 5/8 rounded tip needles. In 2 cases where the palmaris longus tendon was absent, we used the flexor digitorum superficialis of the long finger. The wound is closed with subcuticular sutures after obtaining hemostasis after tourniquet deflation.

C-Postoperative management protocol:

All patients are given an above elbow plaster holding the wrist in 30-40 degrees of dorsiflexion, metacarpophalangeal and PIP joints in full extension, and the thumb in maximum radial abduction and extension. This position is maintained for a period of 2 weeks followed by freeing the PIP joints to move and continue the slab for more 2 weeks then another 2 weeks with the wrist in neutral position and freeing the MCP joints to move, then supervised exercise program after slab was discarded. A below elbow night splint is used for another 3 weeks maintaining the same position. With all above maneuver care must be taken to encourage joint mobility of shoulder and elbow as well.

The standardized follow-up focused on the extent of motion determined through the neutral zero method with active and passive range of motion of wrist, MCP joints and finger joints were recorded.

(Fig 5-5). In addition, we measured grip strength using a Jamardynamometer (Jamar Hydraulic Hand Dynamometer; Sammons Preston Patterson Medical Products,Inc., Bolingbrook, IL) with reference to contralateral side grip strength and to standardized scores (fig 5-5 and 6). In addition, we evaluated:

- The scar regarding its appearance, adherence, width, elevation, flexibility and presence of signs of infection is done.
- Path of transferred tendons is also examined for adhesions, tenderness and any crepitations.
- Functional results were assessed using a quick DASH scoring system.
- Patient satisfaction assessment with a two simple questions, first is, if he is satisfied or not and the second is, his agreement to do the same procedure to his other limb if it gained the same injury or not ,with explanation, were done.
  - Wrist flexion 0-90 degrees.
  - Wrist extension 0-70 degrees.
  - Wrist abduction 0-25 degrees.
  - Wrist adduction 0-65 degrees.
  - MCP flexion 0-90 degrees.
  - MCP extension 0-30 degrees.
  - Interphalangeal proximal (PIP) joints of fingers flexion 0-120 degrees.
  - PIP extension 120-0 degrees.
  - Interphalangeal distal (DIP) joint of fingers flexion 0-80 degrees.
  - DIP extension 80-0 degrees.
  - Metacarpophalangeal joint of thumb abduction 0-50 degrees.
  - MCP of thumb adduction 40-0 degrees.
  - MCP of thumb flexion 0-70 degrees.
  - MCP of thumb extension 60-0 degrees.
  - Interphalangeal joint of thumb flexion 0-90 degrees.
  - Interphalangeal joint of thumb extension 90-0 degrees.

Fig 4 Normal wrist and hand joints range of motion.

III. RESULTS:
All patients achieved a mean pronation of 80°±10° and a mean supination of 70°±10°, which amounts to 12% restriction compared with the contralateral healthy hand. After surgical treatment, the average ranges of wrist movement were as follows: mean extension was 56°±5°, which was 85% of the maximum mobility of the opposite side. Mean flexion was 57°±5°, equivalent to 75% of the maximum degree of movement of the healthy side. Radial deviation was 17°±5°, and ulnar deviation was 55°±5°. The mean finger extension during wrist extension was 75°±5° and was almost similar in the wrist neutral position at 75°±5°. The mean palmar abduction of the thumb was 41°±5°, which was 80% of the maximum mobility of the opposite side (Figure 5).

We evaluated hand grip strength using a Jamar dynamometer. On average, the operated hand had grip strength of 25±2 kg; the average of the healthy opposite side was 37±2 kg. After their tendon transfer, 14 patients still continue their previous carrier, 4 were unemployed changing their carrier from being heavy manual workers to lighter work to satisfy their new functions (Figure 6).

Regarding scar assessment we were not encountered any case of infection, scar adhesions or abnormally shaped scars (Figure 2.B)
All our patients were satisfied with procedure with no refusal to do same operation if they had same injury to his healthy limb even with the patient who developed the SRN neuroma, sure after its excision. Only one postoperative complication is encountered, which is superficial radial nerve neuroma which developed to the patient after 5 months from tendon transfer surgery and 11 months from initial attempt of radial nerve repair which is probably due to SRN injury during exploration of PT muscle at upper part of the wound, and this annoying complication required another small operation to excise the neuroma.

![Graph showing range of motion and mean grip strength](image.png)

**Fig 5:** Range of motion postoperatively between both sides.

**Fig 6:** Mean Grip Strength

### IV. DISCUSSION:

The first decision to make in a patient with established radial nerve palsy is whether to attempt late repair of the nerve or to restore lost function with tendon transfers. Obviously the time since injury is a critical factor, but late repair of the radial nerve within the first year after initial injury can produce reasonably good results at least in part because the nerve is almost entirely motor and the motor branches are often reasonably close to the site of injury. As a general rule, if the prognosis for return after nerve repair is poor, it would appear prudent to forego an attempt to repair and proceed directly to tendon transfers [6, 7].

Tendon transfers to restore function in radial nerve palsy are among the best and most predictable transfers in the upper extremity, but, as pointed out by Riordan, “in muscle tendon surgery there is very little hope that errors in technique can be overcome by local adaptation. The success or failure of an operation depends upon the technical competence of the operator and his painstaking after-care.” Riordan also noted that “there is usually only one chance to obtain good restoration of function in such a paralyzed hand.” [8]
The appropriate time to perform transfers for radial nerve palsy is a somewhat controversial subject. As noted previously, several authors\([9, 10, 7]\) advocate only a limited transfer (PT to ECRB) almost immediately after injury to act as an internal splint and also to supplement any return in the reinnervated extensor muscles. Brown\([11]\) suggested that it is advisable to proceed with the full component of tendon transfers early when there is a questionable or poor prognosis from the nerve repair. For example, if there is a nerve gap of more than 4 cm or if there is a large wound or extensive scarring or skin loss over the nerve, he recommended ignoring the nerve and proceeding directly to the tendon transfers. Recently most of authors basically agree with Brown, as if the chances of nerve regeneration are poor, there is no point in waiting before doing the transfers. However, if a good repair of the nerve has been accomplished, it must to wait a sufficient period of time before considering transfer. That “sufficient time” is determined by using Seddon's figures for nerve regeneration (i.e., approximately 1 mm/day). This means that it may take as long as 5 or 6 months before one sees return in the most proximal muscles (BR and ECRL) after nerve repair in the middle third of the arm. The remaining muscles should return in orderly progression at the same rate of 1 mm/day\([12]\).

Jones is credited with being the major innovator of radial nerve transfers, and all the articles in the post–World War I era acknowledged his fundamental contributions. The “classic” Jones transfer has been quoted and misquoted so many times, however, in articles and texts that it is worthwhile to review his original articles to see exactly what he did advocate. Part of the confusion arises from the fact that Jones described at least two slightly different combinations of transfers, as outlined in fig 7-1.\([13, 14]\).

The only part of the classic Jones’ transfer that has become universally accepted is the use of the PT to provide active wrist extension; however, even this acceptance came relatively recently. This classic transfer has proved its value over the years and continues to be the procedure of choice. The choice of transfers he advised were as follows:

- PT transfer to ECRB and ECRL.
- FCU transfer to the EDC of the third, fourth, and fifth fingers.
- FCR transfer to the EPL, EDC of the index finger, and EIP.\([13, 14]\)

The recent acceptance of PT transfer came from that it offer the greatest number of advantages, because (1) its force (1.2 kg) is somewhat superior to that of the ECRB or the ECRL alone; (2) its excursion (5 cm) is slightly greater in extension of the wrist, making rehabilitation easy; and (3) the pronator quadratus, innervated by the median nerve, continues to ensure pronation of the forearm after the removal of the PT.\((4)\) the PT, inserted on the ECR tendons, keeps the same direction with the same obliquity and therefore continues to play a role in pronation of the forearm.\([15, 16, 77]\)

Despite the wide acceptance of PT as a donor muscle, the recipient muscle is still debatable, surgeons have recommended insertion of PT into both radial wrist extensors \([78]\). Others prefer insertion into only the ECRB, citing that this limits the excessive radial wrist deviation that occurs when the PT is inserted into both radial wrist extensors, especially if the FCU is used for digital extension. Brand has pointed out that the ECRB insertion still has a radial deviation moment and recommends one of two options to balance the wrist in extension. One option is to attach the PT into the ECRL and ECRB but to detach the ECRL from its usual insertion and reinset it into the base of the fourth metacarpal. The other option is to insert the PT into the ECRB and also create an ulnar-balancing yoke with the FCU and ECU. This is accomplished by transecting the ECU tendon at the musculotendinous junction and attaching the distal stump to the FCU tendon. In effect, the FCU muscle becomes the motor for the FCU and ECU.\([17]\)

But our experience in this study went in favour with using the ECRB as a recipient muscle because that The ECRL takes its origin at the supracondylar ridge of the humerus, it plays a role in elbow flexion and loses a part of its wrist action when the elbow is flexed. In contrast, the ECRB has its origin on the epicondyle and is not affected by the position of the elbow, all of its action is on the wrist. These two tendons are congruent along most of their length in the forearm, however, they diverge at the wrist level so that at their insertions the ECRL tendon is about 1.5 cm lateral to the ECRB. The moment arms for extension of the wrist are 16.30 mm for the ECRB and only 12.50 mm for the ECRL.\((Ketchum et al 1978)\)\([9]\) In the ECRL, the moment arm for elbow flexion and radial deviation is more important than that for wrist extension; the ECRL only becomes a wrist extensor after radial
deviation is balanced against the ulnar forces of the ECU which is paralyzed. Thus the two wrist extensors have very different moment arms of extension. The ECRB is the most effective extensor of the wrist.

Our results for finger extension despite the position of the wrist and for simplicity to get the FCR tendon from same single incision as we described, FCR transfer was in favour.

Another debate concerning different combination of repairs to restore an independent finger extension especially for index finger, several authors describe separate FDS tendons for EC to provide this independent movement, but with this sophisticated techniques and no great deference in function the simply described single transfer is advocated. [16, 15, 16, 18]

In our results also we found some independence of finger extension by rehabilitating the patient how to adjust his separate finger extension by releasing its anagonist part of FDS while increasing the tone in other parts of superficialis muscle creating independent movement sufficient for computer typing with one finger, which need only 10 degrees of other fingers extension to do a job.

Regarding the thumb, APL, the EPB, and the EPL muscles are theoretically an available recipient for transfer for doing extension, abduction, and retroposition of the thumb column. The APL causes abduction of the first metacarpal in the radial plane. Its action is synergistic to that of the ECU, which opposes radial deviation of the wrist when the thumb is abducted. As noted by Duchenne (1867), in the case of paralysis of the ECU, abduction of the first metacarpal cannot occur without also causing radial deviation of the hand. The EPB inserts more distally than the APL and runs parallel to it. It produces isolated extension of the proximal phalanx. The EPL, whose amplitude is much greater, has a different course, as it travels around Lister’s tubercle. It not only contributes to the extension of the thumb, but it also brings the first ray in adduction and retroposition. A solution is first described by Scuderi’s procedure (1949) [19], which consists of transferring the palmaris longus to the EPL, having rerouted the EPL tendon lateral to Lister’s tubercle to diminish adduction. In this manner, abduction and extension of the thumb are obtained with the strongest EPL. Tsuge [20] noted a relatively minor problem of bowstringing of the rerouted EPL tendon across the radial aspect of the wrist. He reported that this may be prevented by hooking the EPL around the insertion of the APL at the time of the tendon transfer. In our study we have not seen this problem and it’s not documented in results of any other study.

Setting the proper tension in the transfers is a somewhat tricky task but is very critical to the outcome of the operation. It is difficult to describe precisely how to adjust tension in tendon transfers, and a certain amount of experience is essential in being able to “feel” the proper tension. In general, however, one should probably err on the side of suturing extensor tendon transfers too tightly rather than too loosely because the extensors tend to stretch out with time. [17, 15, 16, 18]

The tendons must be tight enough to provide full extension of the wrist, fingers, and thumb, yet not too tight as to limit flexion of the digits. During the PT to ECRB transfer, it is agreed to be sutured with the PT in maximum tension and the wrist in moderate (45 degrees) extension. The FCR transfer is then sutured through the EDC tendons at a 45-degree angle just proximal to the dorsal retinaculum. Moberg and Nachemson [21] have suggested that better results can be achieved if 4 to 5 cm of inactivated EDC muscle-tendon is resected just proximal to the intended site of suture. Although other authors have not found this technique provide a more direct line of pull because the tendon juncture is end-to-end rather than end-to-side. [22]

Most authors [16, 21, 23] do not include the EDM in the transfer for fear of creating excessive tension in the small finger. They determine whether to include it by pulling on the EDC tendons with an Allis clamp (proximal to the intended site of juncture); if the small finger extends adequately, the EDM is not included, but if there is an extensor lag in the small finger (signifying an inadequate slip of EDC to the small finger). It is important to suture the FCU or FCR tendon into each EDC slip separately and to adjust the tension in the EDC tendons individually so that all four MP joints extend synchronously and evenly. 4-0 nonabsorbable suture, is generally preferred and the tension used in most of studies is with the wrist and MP joints in neutral (0 degrees) and the FCU or FCR under maximum tension, in contrast to our used tension, which is with wrist in 45 degrees of extension and with MPJ in neutral. A good assistant is very helpful at this point to aid in holding the tension while the tendons are sutured. PL is transferred to rerouted EPL to be made in the region of the anatomic snuffbox superficial to the dorsal retinaculum. The direction of the tendons is essentially in line with the first metacarpal. The generally agreed tension is with maximum tension on both the EPL and PL tendons as we used. And regarding the order of
transfer, restoring the wrist extension followed by finger extension followed by thumb tendons reconstruction is widely accepted.[13]

Possible problems regarding our technique include lack of proper independence of finger extension dorsal scar, skin necrosis of elevated flaps and lack of studies comparing tension of anastomosis.

Recently in 2020 another study in which Four patients underwent single incision modified Jones transfer for radial nerve palsy, three of the four patients had excellent and one had had good outcome based on the Bincaz score[24], based on Naalla[25]. but also, with insufficient data to compare to ours.

Also, regarding operative time, our procedure is of shorter period compared to other procedures carried by the same surgeon.

Also regarding the recently introduced technique which described by its authors as being the future replacement for nerve repair and will be a strong competitor for tendon transfer. Its results is still inferior to our results yet with more than 50% failure and further need for tendon transfer in addition to long period needed for recovery (9 months in the best situations) compared to tendon transfer (8 weeks) which force them to do an internal splint transfer in conjunction to their nerve transfer to improve their patient satisfaction. Also there is a need for more operations for the patients who not improved by nerve transfer with carrying the problem of week donor muscles denervated in previous procedure, so it is still not cost effective. In this issue, comparing our results to that of nerve transfer, a more studies are needed.[26, 27].

V. CONCLUSION:

Our final conclusion regarding the results, using our combination of tendon transfer as mentioned before, we have found that our results are comparable with results of recently published studies in respect to range of motion, grip power strength and functional outcomes for whom used same as our transfer combination and superior for those who used other combinations, but regarding to cosmetic satisfaction of the patient, our recently introduced approach with a 10 cm single radial, dorsal, linear incision when compared to that of other procedures is superior.

Conflict of Interest: No conflict of interest.

REFERENCES