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Special Article - Brachial Plexus Injury

Anatomical Feasibility of Pronator Quadratus to Deep Branch of the Ulnar Nerve Transfer: Is Tension-Free Anastomosis Always Achievable?

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Abstract

Introduction: Tension-free anastomosis during Pronator Quadratus Nerve (PQN) to Deep Branch of the Ulnar Nerve (DBUN) transfer is mandatory for good functional outcomes. The aim of this study was to assess the anatomical and surgical feasibility of a tension-free transfer between these nerves and to report a short clinical case series.

Materials and Methods: DBUN was identified in 20 formalin-fixed forearms and retrograde intra-neural dissection was performed under surgical microscope until this fascicle was no longer recognizable (point A) (10% acetic acid was used to ease the dissection). The intramuscular branching point of the PQN was identified (point B). Distances from pisiform to point A and point B were measured. Distance between points A and B was calculated by subtracting the previous measures. Five patients with T1 nerve-root or proximal ulnar nerve injuries underwent PQN to DBUN transfer, with an injury-surgery delay of 2-8 months and a minimum follow-up of 10 months.

Results: Distance from pisiform to points A and B was 72,6mm (41-101mm) and 60mm (43-83mm), respectively. Distance between points A and B was 12,5mm (-20 -48mm). Tension-free nerve transfer could be performed with satisfactory functional recovery (M3 or higher) in all the surgical patients.

Conclusion: Although PQN to DBUN tension-free transfer was anatomically feasible in 23 out of 25 cases, in 2 cadaveric upper limbs, the distance between both nerves might be a major limitation in achieving tension-free anastomosis.

Keywords: Ulnar nerve; Pronator quadratus nerve; Nerve transfer; Deep branch of the ulnar nerve

Introduction

Nerve transfers are surgical re-innervations of a denervated peripheral target (either muscle or skin) using axons from a healthy donor nerve. Usually not the whole donor nerve but one of its fascicles is used in the procedure, thus minimizing functional loss. Since the first publication by Lurje in 1948 [1] to treat brachial plexus traumatic injuries, nerve transfers in the upper limb have increased exponentially, essentially in the treatment of nerve palsies.

The objective of the termino-terminal anastomosis of the Pronator Quadratus Nerve (PQN) to the Deep Branch of the Ulnar Nerve (DBUN) is to minimize or even revert weakness of the intrinsic muscles of the hand after proximal Ulnar Nerve (UN) or T1 nerve-root injuries. This technique was first described by Wang and Zhu in 1997 [2] and Battiston and Lanzetta [3] published in 1999 the first clinical case series, with encouraging functional results. Brown et al. in 2009 detailed the surgical procedure step-by-step [4], while Barbour et al. in 2012 [5] proposed a modification of the original technique by performing a termino-lateral anastomosis of the PQN to the DBUN (supercharged end-to-side nerve transfer).

The aim of this study was to assess the anatomical and surgical feasibility of a tension-free anastomosis of the PQN to the DBUN.

Materials and Methods

Twenty formalin-fixed cadaveric upper extremities with no evidence of previous surgery or injuries were used. The DBUN was identified in the palm and retrograde intra-neural dissection was performed under surgical microscope (Olympus OME, 4-20x). Dissection was continued until DBUN could no longer be recognized from the other UN fascicles (Point A) (Figure 1). Ten percent acetic acid solution was applied to ease the dissection.

Next, the anterior interosseous neurovascular bundle was identified in the forearm and intramuscular dissection of the PQN was performed distally until it gave off its first muscular branch (Point B) (Figure 2).

Distance from the pisiform to point A and from the pisiform to point B were meassured in every case. Distance between point A and point B was calculated by subtracting the distance from the pisiform to point B to the distance from the pisiform to point A (Figure 3).

Five patients underwent PQN to DBUN transfer, 3 males and 2 females, aged 16-38 years-old. All the surgeries were performed

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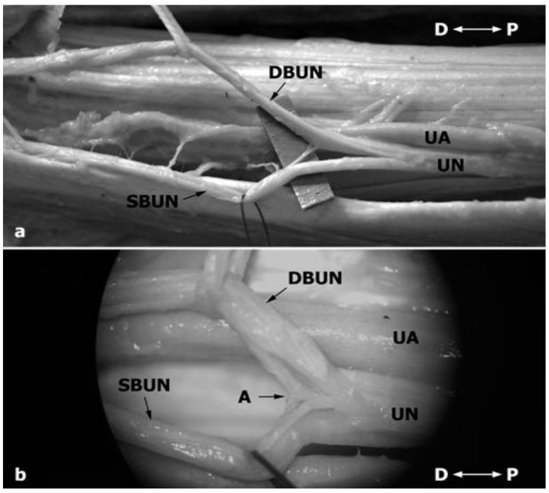

Figure 1: Distal branch of the ulnar nerve intraneural dissection.
a) Macroscopic view and b) Enlarged (8x) view of the most proximal intraneural segment of DBUN.
SBUN: Superficial Branch of the Ulnar Nerve; DBUN: Deep Branch of the Ulnar Nerve; UA: Ulnar Artery; UN: Ulnar Nerve; A: Point A; D: Distal; P: Proximal

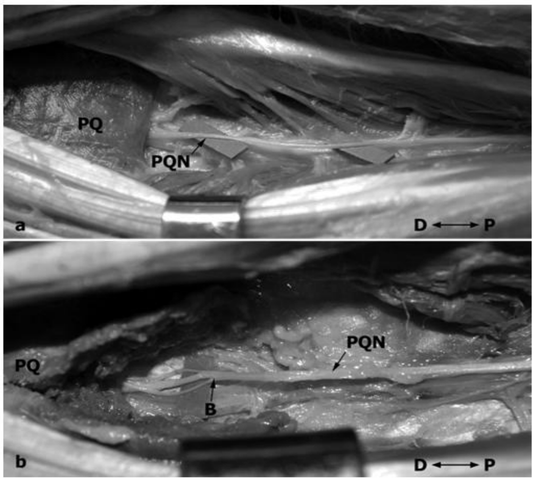

Figure 2: Pronator quadratus nerve dissection.
a) PQN entering the pronator quadratus muscle and b) Identification of the PQN branching point after intramuscular dissection.
PQ: Pronator Quadratus muscle; PQN: Pronator Quadratus Nerve; B: Point B; D: Distal; P: Proximal

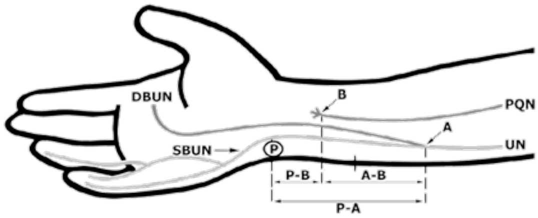

Figure 3: Measurements. Diagram shows measures taken after intraneural dissection of the DBUN was performed in a right forearm.
SBUN: Superficial Branch of the Ulnar Nerve; DBUN: Deep Branch of the Ulnar Nerve; UN: Ulnar Nerve; PQN: Pronator Quadratus Nerve; P: Pisiform; P-A: Distance from Pisiform to Point A; P-B: Distance from Pisiform to point B; A-B: Distance between point A and point B

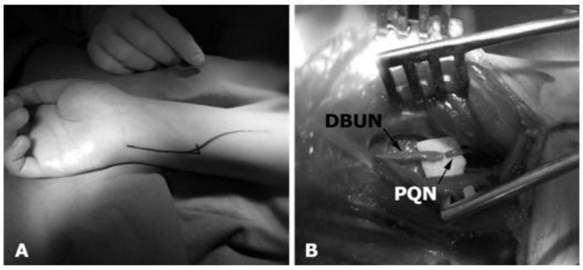

Figure 4: Surgical patient.
a) Long S-shaped incision to be performed and b) Nerve stumps preferred for termino-terminal anastomosis, showing tension-free has been achieved.
DBUN: Deep Branch of the Ulnar Nerve; UN: Ulnar Nerve; PQN: Pronator Quadratus Nerve.

by two of the authors (FM and SP). Causes conducting to surgery were: T1 nerve-root traumatic injury (3 cases); proximal ulnar nerve injury (1 case) and T1 nerve-root Schwanomma resection (1 case). All injuries occurred on the right upper limb. Time between injury and surgery was 2-8 months.

A long S-shaped incision was made in the distal forearm, starting in the ulnar canal and extending proximally up to 8cm (Figure 4). DBUN was identified distally and then a retrograde neurolysis was performed as far as it was necessary or possible. Anastomosis between both nerves was performed and clinical follow-up was continued for at least 10 months.

Results

Cadaveric upper extremities

Distance from pisiform to point A and from pisiform to point B was 73mm (41-101mm) and 60mm (43-83mm), respectively.

The calculated distance between points A and B was 13mm (-20-48mm). Negative results indicate that point A was distal to point B, with a gap between them.

Collected data is presented in Table 1.

Surgical patients

Tension-free anastomosis was achieved in the five patients

Table 1: Measures from cadaveric forearms.

	Forearm number																			
Distance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P-A (mm)	41	91	82	77	76	53	75	94	84	79	71	43	70	45	62	75	95	68	70	101
P-B (mm)	43	43	61	66	51	73	76	83	63	61	55	58	61	53	59	68	59	59	49	60
A-B (mm)	-2	48	21	11	25	-20	-1	11	21	18	16	-15	9	-8	3	7	36	9	21	41

P-A: Distance from pisiform to point A; P-B: Distance from pisiform to point B; A-B: calculated distance between point A and point B.

without interposing nerve grafts (Figure 4). In one of the patients, intramuscular dissection of the PQN was necessary in order to achieve a tension-free anastomosis.

All the patients showed satisfactory functional recovery (M3 or higher) after clinical follow-up.

Discussion

The UN is a terminal branch of the medial cord of the brachial plexus. It is originated in the axilla and descends through the arm and forearm, where it gives off branches to the Flexor Carpi Ulnaris (FCU) and the medial fascicles of the Flexor Digitorum Profundus (FDP). It then enters the palmar region and divides into two terminal branches: the superficial and deep branches. The latter is the main motor nerve of the hand, innervating all the interossei muscles, the hypothenar compartment muscles, the two medial lumbricals, the flexor pollicis brevis and the adductor pollicis.

Therefore, UN injuries determine severe functional and aesthetic sequels: clawing of the 4th and 5th fingers ("ulnar claw"), first finger metacarpophalangeal joint instability and grip and pinch weakness [6].

Time lapse between axonal injury and muscular re-innervation is one of the most important factors for successful functional outcomes following a nerve transfer. After denervation, muscles rapidly undergo atrophy, losing 60% of its mass and 90% of its strength as soon as the first month [7]. Axonal regeneration after nerve injuries occur at a speed of 1mm/day approximately [7], which explains the poor functional outcomes after direct repair of proximal ulnar nerve or T1 nerve-root injuries: 50% of patients will recover FCU and FDP strength, although only 5% will recover useful strength in the intrinsic hand muscles [6]. This led many surgeons to perform tendons transfers at the same time they repaired the nerve injury, while some authors have even questioned the relevance of such nerve repair [4].

In the recent past, proximal UN injuries sequels were treated by tendon transfers, which are currently considered secondary salvage procedures with, at best, limited results [7]. In such context, PQN transfer to the DBUN emerged as a very appealing treatment alternative for several reasons [8]:

1. The axon source is near the target muscles, considerably shortening denervation time and minimizing muscular degeneration. This becomes of special importance in cases of late surgery or large injuries [9].

2. The PQN is almost exclusively a motor nerve, with a minimal contingent of sensitive fibers, which minimizes the chances of sensitive fibers regenerating to the DBUN.

3. Although PQN is usually smaller in diameter and has less axons than the DBUN (900*vs*1200 approximately, respectively) [10] direct suture between the nerve stumps is feasible [2,6].

4. Despite a healthy donor nerve being sacrificed, in presence of a normal pronator teres muscle, section of the PQN has no major functional consequences in pronation [11].

5. Failure in the nerve transfer doesn't prevent from performing alternative procedures.

Although the number of patients is low, published clinical case series demonstrate good functional outcomes after PQN to DBUN transfer: Battiston and Lanzetta achieved intrinsic hand muscles strength recovery greater than or equal to M4 in 6 out of 7 patients (86% of success) [3], while Novak and MacKinnon in 2002 reported reinnervation of the hand intrinsic muscles with improvement in grip and pinch in all the 8 patients without pronation strength deficit [12]. In his series of 5 patients, Flores achieved a recovery of hand M4 strength in 3 patients and M3 in the other 2 patients [11]. These results are comparable to the functional outcomes obtained in the operated patients in our series.

One of the key points for nerve transfers success is performing a tension-free anastomosis with no interposed nerve grafts, which would slow down axon regeneration [7]. This forces the surgeon to cut the PQN as distal as possible, eventually performing intramuscular dissection, and to cut the DBUN as proximal as possible, in order to allow full wrist extension after the procedure.

Retrograde intra-neural dissection of the DBUN can be performed up to 4-6 cm proximal to the proximal edge of the pronator quadratus muscle [9], and small anastomotic fascicles between DBUN and SBUN can be sacrificed without major consequences. Likewise, PQN useful length can be extended 0.7-1.5 cm after intramuscular dissection. This allows tension-free nerve transfers in every patient without the need for nerve grafts, according to Mackinnon's group [7,10] and Weber [13].

In 15 out of 20 cadaveric upper extremities, point B was distal to point A, what would allow for nerve mobilization and tension-free suturing of the stumps. However, in the remaining 5 extremities (1, 6, 7, 12 and 14), point B was proximal to point A (negative distance between points A and B), which could lead to complications during nerve suturing.

Robert et al. in 2011 [14] demonstrated that tension-free anastomosis between PQN and DBUN could be achieved by using minor wrist joint flexion, even with distances of -10mm between nerve ends. This means that in cases 1, 7 and 14 of our cadaveric dissections, tension-free anastomosis would still be anatomically feasible.

Nevertheless, cadaveric extremities 6 and 12 showed a gap between PQN and DBUN ends of of -20 and -15mm respectively, which is larger than the feasibility-safe distance established by Robert et al. This represents a major technical issue, forcing the surgeon to use nerve grafts to achieve a tension-free anastomosis, with consequent limitation in axonal regeneration and increased failure chances.

To our knowledge, there is only one published paper which makes references to the possibility of the anatomical unfeasibility of a tension-free anastomosis between the PQN and the DBUN [3]. Lack of publications discussing this aspect of the procedure might be explained by publishing bias due to either journals or authors unwillingness to report negative results.

Despite being the largest published work on this subject, our paper has one major limitation which is the use of formalin-fixed cadaveric material. Formaldehyde determines tissue dehydration, which eventually modifies its mechanical properties, potentially affecting the intraneural dissection of the DBUN, and consequently, measurements and results.

Assessment of the anatomical feasibility of a tension-free anastomosis between the PQN and the DBUN should be one of the first steps in this procedure, in order to avoid futile sacrifice of the pronator quadratus muscle and to implement promt therapeutic alternatives. New studies, both surgical and anatomical, should be carried out in order to identify those patients in which the procedure would be unfeasible, and to compare the functional outcomes PQN to DBUN transfer with nerve graft interposition *vs* tendinous transfers.

Conclusion

Tension-free anastomosis was achieved in every surgical patient and was possible in most cadaveric upper extremities. However, there is a minor percentage of cases in which the distance between both nerves might preclude tension-free anastomosis.

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