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Direct transfer of C7 pectoral fascicles to the suprascapular nerve in C5/C6 brachial plexus palsies: an anatomical study

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Abstract

We investigated a technique to reconstruct the suprascapular nerve in patients with C5/C6 brachial plexus palsies, using pectoral fascicles from the ipsilateral C7 root. Using a supraclavicular approach in eight cadavers, the suprascapular nerve was placed side by side with an anterior quadrant fascicle from the C7 root. Several criteria were assessed, including the fascicle length, the overlap between the two nerves and their respective diameters. The mean length of the C7 fascicles was 19.3 mm, with a mean overlap of 4.7 mm. The suprascapular nerve and the C7 fascicles had mean diameters of 2.2 mm and 2.1 mm, respectively. Pectoral fascicles from C7 seem to be an option for reconstruction of the suprascapular nerve in C5/C6 palsies. Clinical studies will be required to establish the potential limitations of this transfer, especially in cases with complex lesions of the suprascapular nerve.

Keywords

Brachial plexus palsy, C7 root, direct nerve transfer, pectoral fascicle, suprascapular nerve

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Introduction

After a stretching brachial plexus injury (BPI), post-traumatic deficits are limited to the territory of the C5 and C6 roots in approximately 15% of patients (Kim et al., 2004). In this group, functional impairments most commonly involve shoulder elevation and external rotation, as well as elbow flexion (Spinner et al., 2011; Tung and Moore, 2015). When the preoperative delay is less than 6 to 12 months, all deficits may be addressed simultaneously using nerve reconstruction procedures: the three primary targets are the suprascapular nerve (SSN), the axillary nerve and the musculocutaneous nerve (Bertelli and Ghizoni, 2004).

Nerve transfers are appropriate for SSN reinnervation, with the spinal accessory nerve (SAN) being the most commonly used donor (Merrell et al., 2001). Despite satisfactory outcomes reported by many authors, there are two inherent shortcomings of this transfer. First, significant differences of axonal counts have been reported between the two nerves (Pruksakorn et al., 2007; Vathana et al., 2007), which may lead postoperatively to insufficient action in the spinati muscles and limited functional outcomes, especially for external rotation of the shoulder (Bertelli and Ghizoni, 2007; Terzis and Kostas, 2006). Second, partial impairment of the trapezius muscle reduces the available options that may be used to restore shoulder function in cases with failure of nerve surgery (Atlan et al., 2012; Elhassan et al., 2014; Oberlin et al., 2009).

The medial and lateral pectoral nerves are well established as donors of pure motor nerves in BPI reconstruction (Spinner et al., 2011; Tung and Moore,

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2015). Satisfactory outcomes have been reported after their use for the reinnervation of several targets, including the musculocutaneous nerve, the axillary nerve, the SAN or the long thoracic nerve (Brandt and Mackinnon, 1993; Maldonado and Spinner, 2017; Ray et al., 2011, 2012; Yin et al., 2012).

The use of partial transfer of the ipsilateral C7 root to reconstruct the brachial plexus has been described (Tung and Moore, 2015; Yin et al., 2012). The purpose of this anatomical study was to demonstrate the feasibility of transferring pectoral fascicles from the ipsilateral C7 root to the SSN using a supraclavicular approach and to outline the technicalities of such a transfer.

Methods

Eight fresh-frozen cadaveric hemi-torsos were obtained by our institutional anatomical bequest programme, including four right and four left sides. The mean age of the donors (five men, three women) was 79 years (SD 12; range 52 to 92). Before dissection, the specimens were thawed overnight at room temperature.

A V-shaped supraclavicular approach was used, with a longitudinal incision following the posterior border of the sternocleidomastoid muscle and extended distally with a horizontal incision following the superior border of the clavicle to the midclavicular area. The platysma muscle was opened and the cervical fat pad was mobilized, along with the cutaneous branches of the superficial cervical plexus and the external jugular vein. The omohyoid muscle was then identified, cut and retracted, as well as the transverse cervical vessels, so that the upper trunk of the brachial plexus could be accessed. Once the upper trunk was located, the C5 and C6 roots along with the SSN were identified proximally and distally, respectively. Then, following the anterior and middle scalene muscles inferiorly and posteriorly, the C7 root was identified from its origin and followed to its exit from the posterior cervical triangle under the clavicle. The lower trunk was finally exposed along with the subclavicular artery (Figure 1).

Once all the trunks and the SSN were identified, intraneural dissection was carried out under microscope magnification. First, the SSN was dissected from the upper trunk as proximal as possible, and cut proximally. Then, based on previous descriptions of the fascicular anatomy of the C7 root (Lee, 2007; Tung and Moore, 2015; Yin et al., 2012), a single fascicle from the anterior quadrant of the C7 root, assumed to correspond to one of the pectoral fascicles, was isolated (Figure 2). This fascicle was identified proximally at the root level and cut distally once

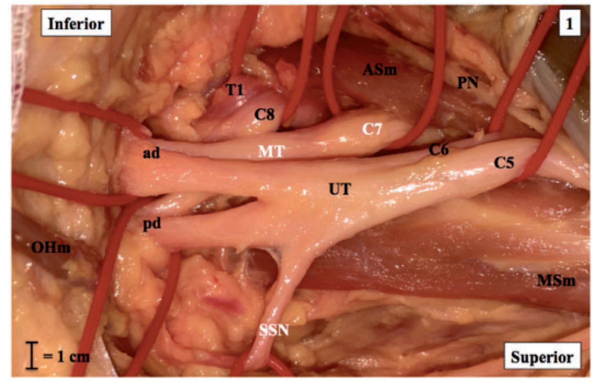

Figure 1. Anatomical dissection of the supraclavicular brachial plexus, left side.
SSN: suprascapular nerve; PN: phrenic nerve; C/T: cervical/thoracic roots; UT: upper trunk; MT: middle trunk; ad/pd: anterior/posterior divisions; OHm: omohyoid muscle; ASm/MSm: anterior/middle scalene muscles.

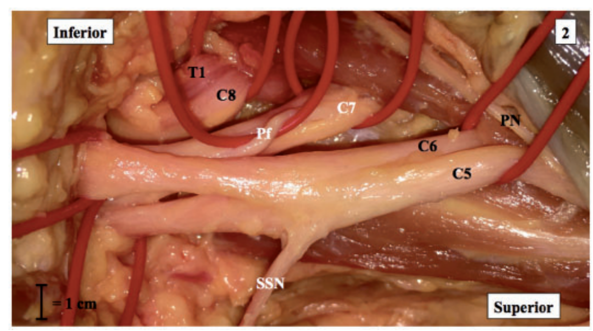

Figure 2. Anatomical intraneural microdissection of the pectoral fascicle, isolated from the C7 root anterior quadrant, left side.
SSN: suprascapular nerve; Pf: pectoral fascicle; PN: phrenic nerve; C/T: cervical/thoracic roots.

the formation of the plexus between the middle trunk fascicles and/or the clavicle prevented any further dissection. The C7 fascicle and the SSN were placed over the upper trunk to simulate an end-to-end epi-perineural suture (Figure 3). It was unnecessary to divide the clavicle or use an infraclavicular extension of the dissection to obtain sufficient nerve length.

Under microscope magnification using a slide calliper with an accuracy of 0.1 mm (ABS Series 500, Mitutoyo, Kawasaki, Japan), different measurements were made, including the diameters of the two stumps, the length of the C7 fascicle that was harvested, the length of the proximal part of the SSN that was dissected from the upper trunk and the overlap that could be obtained once the two stumps were placed side by side without tension.

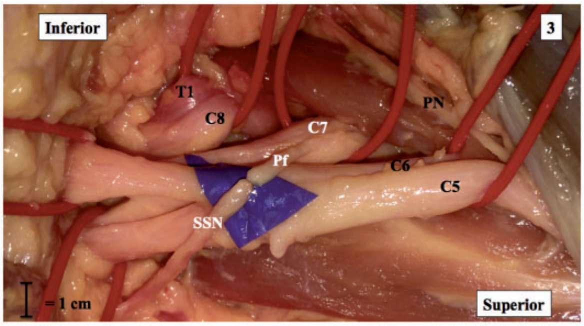

Figure 3. Anatomical direct transfer of the C7 pectoral fascicle (Pf) to the suprascapular nerve (SSN), left side. Pf: pectoral fascicle; PN: phrenic nerve; C/T: cervical/thoracic roots.

Results

The mean overlap was 4.7 mm (range 2.2 to 7.1). The mean length of the harvested C7 fascicle was 19.3 mm (range 14 to 25) and the mean length of the proximal part of the SSN isolated from the upper trunk was 2.5 mm (range 0.9 to 3.4). The mean diameter of the SSN and C7 fascicle stumps were 2.2 mm (range 1.9 to 2.7) and 2.1 mm (range 1.8 to 2.6), respectively. No significant anatomical variations were noted.

Discussion

Since the pectoral nerves are well established motor donors in BPI reconstruction, their anatomical characteristics and several potential recipients have been described (Aszmann et al., 2000; David et al., 2010; Lee, 2007; Maldonado and Spinner, 2017; Ray et al., 2011, 2012; Yin et al., 2012).

Selecting C7 pectoral fascicles for SSN reconstruction in C5/C6 BPI seems an appropriate option for several reasons. The first would be anatomical consistency and accessibility. Lee (2007) showed in an anatomical study of 30 brachial plexus specimens that pectoral fascicles from the C7 root were consistent and had the largest mean diameters compared with those from the other roots (i.e. 1.6 mm (SD 0.35), after removal of epiperineurium). At the trunk level, Aszmann et al. (2000) described their location to be consistently anterior, in a study of 29 dissections. Using an anterior cervical approach, the anterior quadrant of the root and/or the trunk is the first to be exposed, thus limiting intraneural dissection and subsequently decreasing the risk of damaging the C7 root. Our study was based on previous anatomical studies, assuming that the pectoral fascicles of the C7 root were located in its anterior quadrant (Lee, 2007; Yin et al., 2012). In clinical practice, intraoperative assessment with neurostimulation would be mandatory before harvesting to confirm these anatomical presumptions.

Based on the anatomical features, the expendability of C7 pectoral fascicles within the brachial plexus can be understood (David et al., 2010). Many authors have reported the clinical use of pectoral fascicles as donors in BPI reconstruction, without significant postoperative deficits (Maldonado and Spinner, 2017; Ray et al., 2011and 2012; Songcharoen et al., 2001; Wang et al., 2012; Yin et al., 2012). By harvesting a single C7 motor fascicle as we describe, the risk of a postoperative deficit appears to be low.

Another theoretical advantage of this procedure would be the size of the donor and its number of myelinated axons. We found that the diameter of the proximal SSN was properly matched with a single C7 anterior fascicle in terms of macroscopic diameter. Moreover, pectoral fascicles are intraplexal and pure motor nerves, which usually have more myelinated axons than extraplexal motor nerves (Terzis and Kostas, 2006; Tung and Moore, 2015). We did not carry out a histomorphological analysis in this study. However, Aszmann et al. (2000) described a large number of myelinated axons in the deep branch of the middle pectoral nerve coming from the C7 root (i.e. 1784 (SD 445)), whereas for the distal SAN, Vathana et al. (2007) reported smaller numbers (i.e. 817 (SD 140)).

Regarding the length of the donor, we established that a tensionless suture could be obtained with the use of a supraclavicular approach alone. However, complex SSN lesions might be a limitation for this transfer; these include a very distally translated origin of the SSN (e.g. in C5/C6 ruptures or avulsion), multilevel SSN lesions or an upper trunk neuroma including the SSN origin. In such cases, considering the great consistency of these fascicles within the infraclavicular plexus (Aszmann et al., 2000), a complementary infraclavicular approach could be used to allow a more extensive fascicular dissection at the level of the cords, or an interposition neural graft could be added between the C7 fascicle and the SSN.

Finally, the main benefit of this technique is that it avoids any harvesting of the SAN. Although satisfactory results have been reported for this transfer, poor outcomes have also occurred (Bertelli and Ghizoni, 2007, 2016; Terzis and Kostas, 2006). Terzis and Kostas (2006) also identified a difference in reinnervation between the spinati muscles after SSN reconstruction, with 79% good to excellent results for the supraspinatus against 55% for the infraspinatus, indicating that external rotation of the shoulder might be difficult to restore in such patients.

Choosing the SAN as a donor to improve shoulder motion in partial plexus palsies is questionable, considering the risk of subsequent scapular dyskinesia (Atlan et al., 2012; Oberlin et al., 2009). Also, if primary nerve surgery is unsuccessful, additional palliative surgery may be necessary, such as a lower trapezius tendon transfer to the infraspinatus to improve shoulder external rotation, or glenohumeral arthrodesis (Atlan et al., 2012; Elhassan et al., 2014). The lower trapezius transfer would be contraindicated after previous harvesting of the SAN and even the outcomes of shoulder fusion might be affected (Oberlin et al., 2009).

In conclusion, a direct transfer of a C7 pectoral fascicle to the SSN is anatomically feasible and appears to be a suitable and straightforward option in C5/C6 BPI. However, clinical studies will be required to assess the functional outcomes that may be expected after such procedure and to identify the potential limitations of this transfer, especially in cases with complex SSN lesions.

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