Neural interconnections between the nerves of the upper limb and surgical implications

A review

Marios Loukas, M.D., Ph.D.,1 Nicole Abel, M.D.,1 R. Shane Tubbs, M.S., P.A.-C., Ph.D.,2 Petru Matuzs, M.D., Ph.D.,3 Anna Zurada, M.D., Ph.D.,4 and Aaron A. Cohen-Gadol, M.D., M.Sc.5

1Department of Anatomical Sciences, School of Medicine, St. George’s University, Grenada, West Indies; 2Pediatric Neurosurgery, Children’s Hospital, Birmingham, Alabama; 3Department of Anatomy, University of Medicine and Pharmacy Victor Babes, Timisoara, Romania; 4Department of Anatomy, Medical Faculty, University of Warmia and Mazuria in Olsztyn, Poland; and 5Clarian Neuroscience, Goodman-Campbell Brain and Spine, and Department of Neurosurgery, Indianapolis, Indiana

The knowledge of neural interconnections between adjacent nerves of the upper limb is important to the surgeon as such variations may lead to issues with surgical identification and thus iatrogenic injury. Trauma or entrapment of these nerves may cause functional losses different from those expected and thus result in misdiagnosis. The authors review the literature regarding such nervous system derangements. (DOI: 10.3171/2010.3.JNS10144)

Key Words • ansa pectoralis • Martin-Gruber anastomosis • Riche-Cannieu anastomosis • Berrettini branches • Marinacci connection • branch of Lejars

Variations of the branching pattern of the brachial plexus and its terminal branches are common. In 1955, Buch-Hansen identified variations in 65.3% of his studied cases (in the brachial plexus or its terminal branches). Neural connections between adjacent upper limb nerves are one such variation. These communications are thought to be embryologically derived, resulting in a fusion of nerves when segregation of the brachial plexus fails. Recognition of these communications by surgeons has resulted in, for example, the preservation of hand muscle innervation during carpal tunnel release. Such an appreciation of such neural interconnections is also important in regard to surgical repair of the brachial plexus.

In the present review, we discuss neural communications including the following: between the musculocutaneous and median nerves in the axilla (Fig. 1); between the lateral and medial pectoral nerves, termed the ansa pectoralis (Fig. 2); between the median and ulnar nerves in the forearm, known as Martin-Gruber anastomoses (Fig. 3); between the ulnar and median nerves in the distal forearm, known as Marinacci connections (Fig. 4); between the median and ulnar nerves in the palm, both deep and superficial, known as the Riche-Cannieu anastomoses, rami communicantes, and Berrettini branches (Fig. 5); between the superficial branch of the radial nerve and palmar cutaneous branch of the median nerve, known as the branch of Lejars (Fig. 5); and last, between the radial and ulnar nerves on the dorsal aspect of the hand (Fig. 6).

Musculocutaneous and Median Nerve Communications

General Anatomy

The musculocutaneous nerve originates from the C-7 nerve segment and branches from the lateral cord opposite the lateral border of the pectoralis minor muscle. It often pierces the coracobrachialis muscle and descends laterally between the biceps brachii and brachialis muscles and into the lateral aspect of the arm. The anterior

Abbreviations used in this paper: CMAP = compound muscle action potential; LPN = lateral pectoral nerve; MGA = Martin-Gruber anastomosis; MPN = medial pectoral nerve.
compartment of the arm is innervated by the musculocutaneous nerve, including the biceps brachii, the brachialis, and the coracobrachialis muscles. The musculocutaneous nerve then continues distally to become the lateral cutaneous nerve of the forearm.

The median nerve originates from the medial and lateral cords. It rarely provides muscular branches in the arm, except for a variable branch to the pronator teres muscle, arising proximal to the elbow joint. Rarely, in the absence of the musculocutaneous nerve, the median nerve may innervate the anterior compartment of the upper arm.

Musculocutaneous–Median Nerve Communications

Most musculocutaneous–median nerve communications (Fig. 1) take place in the lower third of the arm, with the musculocutaneous nerve joining the median nerve distally. These neural communications exist variably and are classified into 4 patterns, based on their branching patterns (Table 1).

Clinical Significance

Knowledge of musculocutaneous–median nerve communications is important for understanding how the limb muscles and branches of the brachial plexus are formed. Furthermore, recognition of these anatomical variations is important in surgical procedures and in the diagnoses and management of clinical neuropathy of the upper limb. Unawareness of these neural connections may result in a loss of function.

Ansa Pectoralis

General Anatomy

The lateral and medial cords of the brachial plexus typically give rise to 4 and 5 branches, respectively. Two such branches are the LPN and the MPN. The LPN is often described as having its derivation from the lateral cord, whereas the MPN is described as originating from the medial cord. This classification is too simple, however, as the LPN and MPN often have variations at their origins. A study done by our group found that 40% of the LPNs arose from the anterior division of the superior trunk or the lateral cord, whereas the other 60% of individuals were found to have an LPN that arose from the fusion of 2 rootlets. These 2 rootlets were derived from the anterior divisions of the superior trunk and middle trunk, the anterior division of the superior trunk and the lateral cord, the lateral cord and the anterior di-
vision of the middle trunk, or by 2 rootlets both arising from the lateral cord.

The same study found that the MPN arose from the medial cord in 25% of individuals, while in the remaining 75% it arose from the anterior division of the inferior trunk of the brachial plexus. Various spinal origins for these branches of the brachial plexus have been described, but there is agreement that the LPN has spinal origins from C-5 to C-7 with C-7 having the most contribution and C-5 having the least contribution. The MPN is described as having spinal origins from C-8 and T-1.

Moore and Dalley described the innervation of the pectoralis major muscle as having contributions from the C-5 to T-1 spinal nerve roots, and the pectoralis minor having contributions from C-6 to C-8. Colbert and Mackinnon stated that due to the pectoral nerve anatomy, some pectoral musculature function can be preserved in virtually any partial brachial plexus injury. With this in mind, overlap in innervation of the pectoral musculature can be recognized as a connecting neural branch between the LPN and MPN, termed the ansa pectoralis (Fig. 2). The LPN passes superficial to the first part of the

### TABLE 1: Four types and characteristics of the musculocutaneous–median neural connections in the arm

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Communication Location/Description</th>
<th>Length (cm)</th>
<th>Diameter (mm)</th>
<th>Additional Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>prox to entry of musculocutaneous nerve into coracobrachialis muscle†</td>
<td>2–13.8†</td>
<td>3–6†</td>
<td>after communicating, musculocutaneous nerve separates from median nerve &amp; gives off branches to biceps brachii muscle</td>
</tr>
<tr>
<td>II</td>
<td>oblique connection from musculocutaneous nerve to median nerve in superior, middle, &amp; inferior thirds of arm, distal to entry of musculocutaneous nerve into coracobrachialis muscle‡</td>
<td>1.5–12.5‡</td>
<td>0.1–4‡</td>
<td>subdivided into patterns: IIA, described as a single connecting branch arising from musculocutaneous nerve prox to point it enters coracobrachialis muscle; IIB, described as 2 or 3 connecting branches of musculocutaneous nerve, joining to form 1 anastomotic branch to median nerve</td>
</tr>
<tr>
<td>III</td>
<td>2 connecting branches‡</td>
<td></td>
<td></td>
<td>musculocutaneous nerve does not pierce coracobrachialis muscle</td>
</tr>
<tr>
<td>IV</td>
<td>communication begins prox to entry of musculocutaneous nerve into coracobrachialis muscle</td>
<td></td>
<td></td>
<td>additional communications may take place distally</td>
</tr>
</tbody>
</table>

* prox = proximal.
† As reported by Loukas and Aqueelah, 2005.
‡ As reported by Choi et al., 2002.
axillary artery and sends a communicating branch to the MPN, namely the ansa pectoralis. The length of the ansa pectoralis was found to be variable and ranged from 9 to 35 mm. Furthermore, the distance of the ansa pectoralis from the origin of the MPN was found to have a range of 11–68 mm, with a mean length of 28 mm, and a distance from the origin of the LPN ranging from 15 to 72 mm, with a mean of 39 mm.25

A study by Hoffmann and Elliott17 also demonstrated the importance of this neural connection after noting only slight atrophy of the pectoralis minor with complete transection of the MPN. These investigators noted that in modified radical mastectomies, the LPN may be severed, which may result in complete atrophy of both the pectoralis major and minor muscles. Tables 2 and 3 describe the ansa pectoralis with respect to its origin and incidence, as well as its relation to topographical landmarks.

Clinical Significance

In a previously published study, 62% of patients were shown to have an MPN coursing through the pectoralis minor muscle to innervate the lower half or two-thirds of the pectoralis major muscle.17 In the other 38% of patients, the MPN exited around the lateral aspect of the pectoralis minor muscle, coursing along the undersurface of the pectoralis major muscle, and innervating the proximal one-third or more of this muscle. Axillary procedures may often injure the MPN and thus cause atrophy of the pectoral musculature. Surgeons performing neurotization procedures that involve the MPN should have knowledge of the pectoral nerves and have an awareness of the ansa pectoralis for the preservation and innervation of the pectoral muscles. In addition, brachial plexus reconstruction procedures often use the MPN as a donor nerve in repairing lesions of the axillary and musculocutaneous nerves. In a cadaveric study, we found that a greater length of the MPN can be achieved for neurotization procedures to the musculocutaneous nerve by sectioning the ansa pectoralis. Consequently, becoming acquainted with the ansa pectoralis and its variations, as well as its topographical relationships, may avoid transections of the ansa pectoralis and thus, functional losses of pectoralis musculature. It may also be important in the understanding of why there may be denervation or partial atrophy of the pectoralis major muscle.17, 23

Martin-Gruber Anastomosis

The MGA is described as an upper forearm communication between the median nerve or its anterior interosseous branch and the ulnar nerve (Fig. 3). The MGA was discovered by the Swedish anatomist, Martin, who first noted such a connection in 1763. It was later de-

![Fig. 4. Schematic drawing illustrating the Marinacci anastomosis or reversed MGA.](image)

TABLE 2: Classifications and incidence of the ansa pectoralis*

<table>
<thead>
<tr>
<th>Type</th>
<th>Origin of Ansa Pectoralis</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>deep branch of LPN</td>
<td>42</td>
</tr>
<tr>
<td>II</td>
<td>LPN main trunk</td>
<td>28</td>
</tr>
<tr>
<td>III</td>
<td>lower rootlets of LPN</td>
<td>25</td>
</tr>
<tr>
<td>IV</td>
<td>upper rootlets of LPN</td>
<td>5</td>
</tr>
</tbody>
</table>

The MGA mainly transmits motor fibers, although sensory fibers have also been identified. The MGA is often unilateral and is found more commonly on the right than the left side. These fibers continue distally into the intrinsic hand muscles, with the first dorsal interosseous muscle most likely to receive this innervation. These communications may range from 1 to 1.5 mm and have a length of about 2.5 cm. The MGA has been described in as much as 31% of the population, with most studies agreeing on around 17%. It has been suggested that the MGA is a genetic trait, inherited most likely in an autosomal dominant fashion.

An MGA can be diagnosed using nerve conduction studies and CMAP amplitude changes. The CMAPs have a gain/loss pattern with the ulnar nerve gaining fibers and showing higher CMAP amplitudes. The median nerve conduction studies show a median nerve CMAP amplitude increase with the ulnar nerve CMAP amplitude decrease.

**TABLE 3: Incidence of the ansa pectoralis found near the thoracocromial artery and the lateral thoracic artery**

<table>
<thead>
<tr>
<th>Incidence of Ansa Pectoralis (%)</th>
<th>Relation to Thoracocromial Artery</th>
<th>Relation to Lat Thoracic Artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>immediately distal to</td>
<td>near where lat thoracic artery arises from axillary artery</td>
</tr>
<tr>
<td>13</td>
<td>distal to</td>
<td>prox to</td>
</tr>
<tr>
<td>8</td>
<td>distal to</td>
<td>distal to</td>
</tr>
<tr>
<td>7</td>
<td>prox to</td>
<td>loops btw thoracocromial artery &amp; lat thoracic artery</td>
</tr>
<tr>
<td>5</td>
<td>irrespective</td>
<td>loops distal to</td>
</tr>
</tbody>
</table>

* Based on information in the article by Loukas et al: The surgical anatomy of the ansa pectoralis. Clin Anat 19:685–693, 2006. The other 7% of specimens described in the study were too variable to classify.
nerve loses fibers in the forearm, and thus, it has a smaller CMAP amplitude. Sensory forearm anastomoses can be verified with blockage with, for example, lidocaine injections of the ulnar nerve distal to the elbow. Also important is the number of fibers crossing between nerves, as this may affect the magnitude of the CMAP difference. Four types of MGA have been described based on whether their origin is from the anterior interosseous nerve, the median nerve or its branch to the flexor digitorum profundus, or superficial forearm flexors (Table 4). Type IV MGA has also been noted (not shown in Table 4) and is defined as 2 interneural anastomotic connections.

Clinical Significance

While the exact etiology for the communication between the ulnar and median nerves is unknown, it is believed that such a nerve connection allows for communication when there is an absence of ulnar and median nerve connections in the hand. In 1 study in which a lesion of the median nerve was present, some of the normally median nerve innervated intrinsic muscles of the hands were still functional. We have reported a case of complete traumatic transection of the ulnar nerve in the proximal forearm in a child who maintained near-normal function of the intrinsic muscles of the hand. For this case, an MGA was suspected. Clinically, these neural interconnections may also become important when describing symptoms dealing with carpal tunnel syndrome, as there may be partial or total sparing of the thenar muscles.

Trauma or entrapment of the median nerve may cause functional losses that are different from those expected with a median–ulnar nerve communication present. Disregard of these communications may result in erroneous conclusions regarding median or ulnar nerve lesions. Distal elbow stimulation sites near the medial epicondyle (about 3 cm distal to the epicondyle) help decrease stimulation of an MGA. Other misinterpretations of an MGA may include cubital tunnel syndrome, leprosy neuropathy, and demyelinating disorders.

Marinacci Communication

Another communication between the median and ulnar nerves in the distal forearm is referred to as the Marinacci communication (Fig. 4), or a reverse Martin-Gruber communication. This interneural interconnection was first described by Marinacci in 1964 and is rarer than the MGA. Just as with an MGA, electrophysiological studies confirm a Marinacci communication. If the median nerve CMAP over the abductor pollicis brevis is greater at the wrist than with ulnar nerve stimulation at the elbow, if the median nerve CMAP over the abductor pollicis brevis is less at the wrist than with ulnar stimulation at the elbow, if there is a lower CMAP over the abductor digiti quinti muscle at the wrist compared with stimulation of the ulnar nerve at the elbow, or lastly, if there are repeat recordings of the CMAP from the abductor digiti minimi at the wrist, one can assume the presence of an ulnar to median nerve connection.

Clinical Significance

Recognition of a Marinacci communication is important when traumatic or nerve entrapment injuries are present, as well as in deciding the most effective surgical technique for carpal tunnel release. Misdiagnosis of thenar branch injury of the median nerve may occur in the presence of a Marinacci communication.

Palmar Communications Between the Median and Ulnar Nerves

Other communications between the median and ulnar nerves may occur between branches in the palm. The first is a deep motor branch connection called the Riche-Cannieu anastomosis, the second is a deep sensory connection called the ramus communicans, and the third is a superficial sensory communication called the Berrettini branch, connecting the ulnar nerve to the third common digital palmar nerve of the median nerve (Fig. 5).
Upper limb nerve communications

Table 4: Description of MGA Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Origin</th>
<th>Pathological Description</th>
<th>Additional</th>
<th>Incidence (authors &amp; yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>median nerve or its branches</td>
<td>subdivided 3 times</td>
<td></td>
<td>95% (Grüber, 1870); 100% (Thomson, 1893); 50% (Hirasawa, 1931); 100% (Srinivasan &amp; Rhodes, 1981); 95.6% (Nakashima, 1993); 100% (Taams, 1997); 64.7% (Shu et al., 1999); 89.5% (Rodriguez-Niedenführ et al., 2002); 100% (Kazakos et al., 2005)</td>
</tr>
<tr>
<td>Ia</td>
<td>median nerve</td>
<td>branch runs deep to superficial forearm flexor muscles, close to recurrent ulnar artery &amp; connecting to ulnar nerve, ~2 cm below medial epicondyle</td>
<td>supplies hypothenar muscles†</td>
<td>13% (Grüber, 1870); 3% (Thomson, 1893); 15.4% (Hirasawa, 1931); 6% (Srinivasan &amp; Rhodes, 1981); 0% (Nakashima, 1993); 7% (Taams, 1997); 0% (Shu et al., 1999); 47.3% (Rodriguez-Niedenführ et al., 2002); 7% (Kazakos et al., 2005)</td>
</tr>
<tr>
<td>Ib</td>
<td>median nerve</td>
<td>branch originates between origin of superficial forearm flexor &amp; origin of anterior interosseous nerve</td>
<td></td>
<td>8% (Grüber, 1870); 19% (Thomson, 1893); 0% (Hirasawa, 1931); 3% (Srinivasan &amp; Rhodes, 1981); 4.35% (Nakashima, 1993); 0% (Taams, 1997); 17.6% (Shu et al., 1999); 10.6% (Rodriguez-Niedenführ et al., 2002); 7% (Kazakos et al., 2005)</td>
</tr>
<tr>
<td>Ic</td>
<td>anterior interosseous nerve</td>
<td>joins with upper or middle third of ulnar nerve</td>
<td></td>
<td>74% (Grüber, 1870); 78% (Thomson, 1893); 34.6% (Hirasawa, 1931); 91% (Srinivasan &amp; Rhodes, 1981); 93% (Nakashima, 1993); 47.1% (Taams, 1997); 31.6% (Shu et al., 1999); 31.6% (Rodriguez-Niedenführ et al., 2002); 87% (Kazakos et al., 2005)</td>
</tr>
<tr>
<td>II</td>
<td>median nerve or its branches</td>
<td>communication between median &amp; ulnar nerves</td>
<td>supplies flexor digitorum profundus, although not as clinically significant as this muscle is innervated by both nerves‡</td>
<td>5% (Grüber, 1870); 0% (Thomson, 1893); 50% (Hirasawa, 1931); 0% (Srinivasan &amp; Rhodes, 1981); 4.35% (Nakashima, 1993); 0% (Taams, 1997); 17.6% (Shu et al., 1999); 10.5% (Rodriguez-Niedenführ et al., 2002); &lt;1% (Kazakos et al., 2005)</td>
</tr>
<tr>
<td>III</td>
<td>median nerve or its branches</td>
<td>branch comes from between muscular branches of flexor digitorum profundus muscle</td>
<td>supplies thenar muscles§</td>
<td>17.6% (Shu et al., 1999); 87% (Kazakos, 2000)</td>
</tr>
</tbody>
</table>

* As defined by Thompson in 1893.
† As reported by Rodriguez-Niedenführ et al., 2002, and Sarikcioglu et al., 2003.
‡ As reported by Nakashima, 1993.
§ As reported by Simonetti and Krarup, 2000.

The median nerve and the deep branch of the ulnar nerve at the level of the thenar eminence is referred to as the Riche-Cannieu anastomosis and was first described by Cannieu and Riche in 1897. This neural communication may also be an inherited trait as reported by Boland and associates. This communicating branch appears in the palm between the 2 heads of the flexor pollicis brevis, and it encircles the tendon of the flexor pollicis longus. Variations include a separate branch of the median nerve to the superficial head of the flexor pollicis brevis or one of the 2 digital branches of the thumb arising from the median nerve. A third variation is a communication between one of the branches of the digital nerve of the thumb and the branch to the adductor pollicis arising from the deep branch of the ulnar nerve. Finally, a communication that passes through the first lumbrical and receives its innervation from the deep branch of the ulnar nerve has also been described. Due to this communication, the thenar muscles and flexor pollicis brevis may have a double innervation.

Ramus Communicans

The second palmar communication is the ramus communicans, a sensory communication between the median and ulnar nerves. Previous studies have found the incidence of this communication to be close to 90%, and thus some have reported that it should not be considered an anatomical variation. Its distribution is restricted distally by the proximal transverse crease of the palm and limited on the radial side by the longitudinal crease between the thenar and hypothenar eminences.

There are many differences that exist between the communicating branch of the ulnar fourth common digital palmar nerve and the median third common digital
palmar nerve. These communications can be classified into 3 types by their incidence, branching patterns, and with the use of surface landmarks. Type I communications are those in which the ramus communicans originates proximally from the ulnar common digital palmar nerve and joins the median third common digital palmar nerve distally. Type II occurs where the ramus communicans passes perpendicularly between the third and fourth common digital palmar nerves. This type of communication is most at risk for injury during surgery. Lastly, Type III communications are described as the ramus communicans originating proximally from the median third common digital palmar nerve and joining the ulnar fourth common digital palmar nerve distally. This branching has been found in between 22 and 81% of the bistyloid-metacarpophalangeal longitudinal area, with an area ranging from 8 to 56 mm, and having a diameter of 1–2 mm. The angle of the ramus communicans may also be important and is found to be 30–59° from the common digital palmar nerve origin.7

Superficial Palmar Communications

The superficial palmar communication, also known as the Berrettini branch (Fig. 5A) (named after a famous painter of Saint Cecilia in 1741 who illustrated a superficial palmar connection between the ulnar and median nerves), is a sensory communication between the ulnar and median nerves in the palmar aspect of the hand, with distribution to the ulnar part of the middle finger and the radial part of the ring finger.17 It has been identified in up to 81% of cases. Four classifications of the Berrettini branch are used (Table 5).10

Interestingly, a communicating branch between the median and ulnar nerves, irrespective of location, was found in 85% of the specimens examined (170 of 200).26. The communicating branches between the median and ulnar nerves were studied and, based on topography, were divided into 4 major types and 15 subtypes. Our study combined endoscopic techniques and gross dissection and allowed us to identify several types of communicating branches not reported previously. One such identification was the existence of multiple communications within the same hand.25. Table 6 describes these types and subtypes, with descriptions of the communicating nerve as the nerve from which the most proximal point of the communicating branch arose.

Type I was seen in 84.1% of the specimens, Type II in 7.1%, Type III in 3.5%, and Type IV in 5.3%.26. A study done by Bas and Kleinert1 also reported median and ulnar components that could cross over or join distally to form a common nerve, corresponding to subtypes IV-B and IV-A, respectively. Kimura et al.23 described the presence of an ulnar–median nerve communication in 83.1% of their cases and reported that 7.9% of the abductor pollicis brevis muscles of their specimens received their primary motor innervation from the ulnar as opposed to the median nerve.

Clinical Significance

Double innervation of the thenar muscles of the hand is important in maintaining hand function, preventing complete paralysis of these muscles, and maintaining some function of opposition if there is injury to either the median or ulnar nerve.18 Therefore, recognition of these neural communications is important in avoiding iatrogenic injury with, for example, carpal tunnel release.7. Avoiding the area of the palm described above can help in avoiding damage to the ramus communicans connection.10 Although the ramus communicans most often crosses over in the middle third of the palm, surgeons should be aware that this branching can take place anywhere over the middle three-fifths of the palm.7 The use of electrophysiological testing can be done prior to surgery to detect the Berrettini branch and prevent hyperesthesia of the radial half of the ring finger and the ulnar portion of the third digit.50

Rollins and Meals38 described sensory loss in a patient who had a laceration of the communicating branch. The patient was said to have lost sensation in the area between the middle and ring fingers. In another case report, May and Rosen31 described a woman who underwent surgical release of the right carpal tunnel and showed consequences

<table>
<thead>
<tr>
<th>Group</th>
<th>Communication Description</th>
<th>Distance Btw Origin &amp; Distal Margin of Transverse Carpal Ligament (mm)</th>
<th>Average Angle Formed w/ Ulnar Nerve (°)</th>
<th>Incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>branch passes through transverse carpal ligament to join median nerve</td>
<td>4–5.5†</td>
<td>38–54†</td>
<td>44†, 14.8†</td>
</tr>
<tr>
<td>2</td>
<td>communication runs parallel to distal margin of transverse carpal ligament to join median nerve</td>
<td>1.5–3.5†</td>
<td>80–90†</td>
<td>22†, 19.8†</td>
</tr>
<tr>
<td>3</td>
<td>communication travels obliquely from ulnar nerve to 3rd common digital nerve</td>
<td>4†</td>
<td></td>
<td>30†, 65.4†</td>
</tr>
<tr>
<td>4</td>
<td>atypical: includes 1 case w/ double anastomotic branch &amp; 1 case where origin was at division of superficial &amp; deep branches of ulnar nerve</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Only 83% of the specimens had a Berrettini anastomosis.
† As reported by Stancić et al., 1999.
‡ As reported by Ferrari and Gilbert, 1991.
Upper limb nerve communications

<table>
<thead>
<tr>
<th>Type</th>
<th>Prevalence (%)†</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>143 (84.1)</td>
<td>CB that originated proximally from ulnar nerve &amp; proceeded distally to join median nerve</td>
</tr>
<tr>
<td>subtype I-A</td>
<td>100 (70)</td>
<td>CB arising from ulnar nerve &amp; crossing medially to intersect 3rd CDN (median nerve)</td>
</tr>
<tr>
<td>subtype I-B</td>
<td>22 (15)</td>
<td>CB originated from 4th CDN (ulnar nerve) &amp; subsequently bifurcated to yield branches connecting w/ both 2nd &amp; 3rd CDNs</td>
</tr>
<tr>
<td>subtype I-C</td>
<td>15 (10)</td>
<td>CB arose from 4th CDN &amp; bifurcated, except this subtype connected to 3rd &amp; 4th proper digital nerves</td>
</tr>
<tr>
<td>subtype I-D</td>
<td>6 (4)</td>
<td>2 separate CBs arose from ulnar nerve &amp; communicated w/ 1st &amp; 2nd CDNs as well as w/ median nerve itself</td>
</tr>
<tr>
<td>II</td>
<td>12 (7.1)</td>
<td>CB that originated proximally from median nerve &amp; proceeded distally to join ulnar nerve</td>
</tr>
<tr>
<td>subtype II-A</td>
<td>4 (33)</td>
<td>CB arising from 3rd CDN &amp; connecting to 4th proper digital nerve</td>
</tr>
<tr>
<td>subtype II-B</td>
<td>3 (25)</td>
<td>2 separate CBs arose: 1 from median &amp; 1 from 3rd CDN, which connected w/ ulnar nerve &amp; 4th CDN, respectively</td>
</tr>
<tr>
<td>subtype II-C</td>
<td>2 (17)</td>
<td>CB arose directly from median nerve &amp; connected w/ proper digital nerve supplying medial half of 5th digit</td>
</tr>
<tr>
<td>subtype II-D</td>
<td>2 (17)</td>
<td>CB arising from 3rd &amp; communicating w/ 4th CDNs</td>
</tr>
<tr>
<td>subtype II-E</td>
<td>1 (8)</td>
<td>presented as direct communication b/tw median &amp; ulnar nerves, distal to styloid line</td>
</tr>
<tr>
<td>III</td>
<td>6 (3.5)</td>
<td>CB that traversed perpendicularly b/tw median &amp; ulnar nerves, so that it was not possible to determine which nerve served as point of origin</td>
</tr>
<tr>
<td>subtype III-A</td>
<td>2 (33)</td>
<td>direct perpendicular communication b/tw 3rd &amp; 4th CDNs</td>
</tr>
<tr>
<td>subtype III-B</td>
<td>2 (33)</td>
<td>presented as a perpendicular CB b/tw median &amp; ulnar nerves</td>
</tr>
<tr>
<td>subtype III-C</td>
<td>2 (33)</td>
<td>2 CBs arose, such that 1 was found to connect median &amp; ulnar nerves, &amp; 1 formed a communication b/tw 3rd &amp; 4th CDNs</td>
</tr>
<tr>
<td>IV</td>
<td>9 (5.3)</td>
<td>mixed type in which multiple CBs existed, arising from both ulnar &amp; median nerves</td>
</tr>
<tr>
<td>subtype IV-A</td>
<td>4 (44)</td>
<td>CB arose from both 3rd &amp; 4th CDNs, then joining to form a nerve that traveled distally to supply 4th digit</td>
</tr>
<tr>
<td>subtype IV-B</td>
<td>4 (44)</td>
<td>separate CBs from median &amp; ulnar nerves, which branches proceeded to cross &amp; connect w/ 4th &amp; 3rd CDNs, respectively</td>
</tr>
<tr>
<td>subtype IV-C</td>
<td>1 (12)</td>
<td>1 CB arose from 4th CDN to communicate w/ 1st CDN, &amp; a separate one arose directly from median nerve &amp; connected w/ proper digital nerve supplying medial half of 5th digit</td>
</tr>
</tbody>
</table>

| * Modified with permission from Loukas et al., J Neurosurg 106:887–893, 2007. Abbreviations: CB = communicating branch; CDN = common digital nerve. † The numbers in this column represent the number of hands in the original work with the prevalence in parentheses. 

of dividing the communicating branch. The patient reported decreased sensation in her ring finger postoperatively and after surgical exploration, a large neuroma of the communicating branch was found, connecting the third and fourth common digital palmar nerves. For these reasons, knowledge of the specific anatomy of these types of communicating branches and individual anatomy can be of use to surgeons.

Dorsum of the Hand

The dorsum of the hand also has neural communications and moreover, these are more variable than those found on the palm. The median and ulnar nerves, dorsal branch of the ulnar nerve, and superficial branch of the radial nerve, also known as the branch of Lejars (Fig. 5A), are all important in conduction studies of the dorsal aspect of the hand.

The dorsal cutaneous branch of the ulnar nerve was described by Kaplan as a branch arising from the bifurcation of the main ulnar nerve (Fig. 6). The ramus crosses the head of the ulna dorsally and travels to the ulnar aspect of the pisiform to join the main proximal sensory branch of the ulnar nerve. A transverse branch can sometimes be identified coursing directly toward the distal radioulnar joint and provides sensory fibers to the joint and overlying skin. The transverse branch was observed to measure an average of 1.5 mm in diameter and may have 2 different patterns. The first pattern may be demonstrated as a transversely oriented branch that arises about 1.3 cm proximal to the tip of the styloid process of the ulna and may course at a 90° angle from the parent nerve. The second pattern is a recurrent nerve, beginning about 0.5 cm distal to the styloid process of the ulna, and arising from the most radial of the main sensory branches of the dorsal nerve to the hand and digits. An exact point at which the branch pierces the fascia is variable but is usually found 3–5 cm proximal to the head of the ulna. It then may penetrate the fascia as distally as the ulnar head.

In another study, we described the dorsal cutaneous surface of the hand as being supplied by the radial and ulnar nerves, limited classically by the midline of the fourth digit. The ulnar nerve has a dorsal branch that arises proximal to the wrist, passes distally and dorsally, deep to the flexor carpi ulnaris, and perforates the deep fascia to descend along the medial side of the wrist and hand to...
divide into 2 or 3 dorsal digital nerves.23 The communication comes by way of the fifth dorsal digital branch of the radial nerve, supplying the adjoining sides of the third and fourth digits and is often replaced by a dorsal branch of the ulnar nerve.8

Clinical Significance

When describing sensory distribution charts, clinicians should be aware that these are not absolute. Asymmetry between hands in the same patient may also occur, most often on the dorsum of the digits between the dorsal branch of the ulnar nerve and the superficial branch of the radial nerve.51 Surgical approaches in the vicinity of the pisiform bone (for example, decompression of the ulnar nerve in the tunnel of Guyon) have resulted in injury to the dorsal sensory branch of the ulnar nerve.13 Care to recognize and avoid such branches is important in preventing postoperative neuroma pain.29

Recognition of the radial-ulnar communicating branches has clinical potential in the ability to alter the sensory innervation of the dorsal of the hand.28 Kim21 found that recognition of such neural loops was important surgically. Lastly, radial-ulnar communicating branches can be at particular risk during dorsal approaches to the distal forearm and hand.55

Conclusions

Neural communications in the upper limb are not rare and knowledge of them is important in surgical procedures so that iatrogenic injury does not occur. In addition, recognition of these communicating branches during clinical examination and management will assist the clinician in preventing misdiagnoses.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Loukas, Tubbs. Acquisition of data: Tubbs. Analysis and interpretation of data: Cohen-Gadol, Loukas, Abel, Tubbs, Matusz. Drafting the article: Cohen-Gadol, Loukas, Abel, Tubbs. Critically revising the article: Tubbs, Matusz, Zurada. Reviewed final version of the manuscript and approved it for submission: all authors.

References


M. Loukas et al.
Upper limb nerve communications


Manuscript submitted January 26, 2010.
Accepted March 17, 2010.

Please include this information when citing this paper: published online May 21, 2010; DOI: 10.3171/2010.3.JNS10144.

Address correspondence to: R. Shane Tubbs, M.S., P.A.-C., Ph.D., Pediatric Neurosurgery, Children’s Hospital, 1600 7th Avenue South, ACC 400, Birmingham, Alabama 35233. email: rstubbs@uab.edu.