

Anastomosis Patterns between the Median and Ulnar Nerves in the Upper Limbs

Padrões de anastomose entre os nervos mediano e ulnar nos membros superiores

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Abstract

There are four types of anastomoses between the median and ulnar nerves in the upper limbs. It consists of crossings of axons that produce changes in the innervation of the upper limbs, mainly in the intrinsic muscles of the hand. The forearm has two anatomical changes – Martin-Gruber: branch originating close to the median nerve joining distally to the ulnar nerve; and Marinacci: branch originating close to the ulnar nerve and distally joining the median nerve. The hand also has two types of anastomoses, which are more common, and sometimes considered a normal anatomical pattern – Berrettini: Connection between the common digital nerves of the ulnar and median nerves; and Riche-Cannieu: anastomosis between the recurrent branch of the median nerve and the deep branch of the ulnar nerve. Due to these connection patterns, musculoskeletal disorders and neuropathies can be misinterpreted, and nerve injuries during surgery may occur, without the knowledge of these anastomoses. Therefore, knowledge of them is essential for the clinical practice. The purpose of the present review is to provide important information about each type of anastomosis of the median and ulnar nerves in the forearm and hand.

Keywords

- Martin Gruber
- Marinacci
- Berrettini
- Riche-Cannieu
- median nerve
- ulnar nerve
- anastomosis

Resumo

Existem quatro tipos de anastomoses entre os nervos mediano e ulnar nos membros superiores. Elas consistem em cruzamentos de axônios que produzem mudanças na inervação dos membros superiores, principalmente na musculatura intrínseca da mão. O antebraço apresenta duas variações anatômicas – Martin-Gruber: ramo que se origina proximalmente ao nervo mediano e se une distalmente ao nervo ulnar; e Marinacci: ramo que se origina proximalmente ao nervo ulnar e se une distalmente ao nervo mediano. A mão apresenta também dois tipos de anastomoses, mais comuns, por vezes considerados padrão anatômico normal – Berrettini: conexão entre os nervos digitais comuns dos nervos ulnar e mediano; e Riche-Cannieu: anastomose entre o ramo recorrente do nervo mediano e o ramo profundo do nervo ulnar. Devido a esses

Palavras-chave

- Martin-Gruber
- Marinacci
- Berrettini
- Riche-Cannieu
- nervo mediano
- nervo ulnar
- anastomoses

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padrões de conexões, distúrbios musculoesqueléticos e neuropatias podem ser mal interpretadas, e lesões nervosas durante as cirurgias podem ocorrer, sem o conhecimento dessas anastomoses. Portanto, o conhecimento delas é fundamental para a prática clínica. O objetivo desta revisão é fornecer informações importantes acerca de cada tipo de anastomose dos nervos mediano e ulnar no antebraço e na mão.

Introduction

Anastomoses between the median and ulnar nerves can be found in the upper limbs. They consist of crossings of axons that can produce variations in the innervation of the muscles in the upper limbs, mainly the motor part of the intrinsic muscles of the hand.^{1,2} Basically, four types of anastomoses can be found between the median and ulnar nerves in the upper limbs: two connections in the forearm (Martin-Gruber and Marinacci) and two connections in the hand (Berrettini and Riche-Cannieu).

The median nerve originates from the roots of C5 to T1 of the brachial plexus. It does not innervate any muscle in the arm. In the forearm, it is responsible for the innervation of the flexor and pronator muscles, except for the flexor carpi ulnaris muscle and half of the flexor digitorum profundus III and IV, which are innervated by the ulnar nerve. In the hand, the median nerve innervates lumbrical muscles I and II, the opponens pollicis muscle, the abductor pollicis brevis muscle, and the flexor pollicis brevis muscle. In the elbow, the median nerve branches into the anterior interosseous nerve, which is a purely motor nerve that innervates the flexor digitorum I and II, the flexor pollicis longus, and the pronator quadratus muscle.³

The ulnar nerve originates from the roots of C8 and T1. It also does not innervate any muscle in the arm. As previously reported,³ in the forearm region, it innervates the flexor ulnaris carpi muscles and half of the flexor digitorum profundus III and IV. In the hand, it innervates the adductor pollicis, interosseous muscles, lumbrical muscles III and IV, the hypotenar musculature, the palmaris brevis muscle and the deep part of the flexor pollicis brevis muscle.

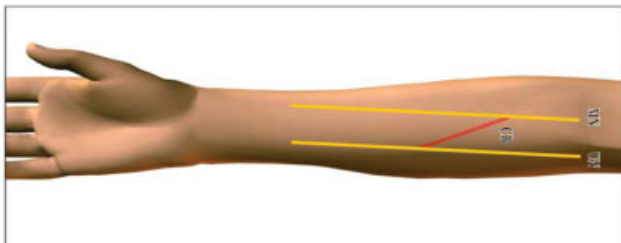


Fig. 1 Three-dimensional illustration showing the Martin-Gruber anastomosis. Abbreviations: CB, communicating branch; MN, median nerve; UN, ulnar nerve. Source: Duran JTC, Arquez HF. Anastomosis between median and ulnar nerve in forearm and hand. *Journal of c = Chemical and Pharmaceutical Research*, 2016,8(8):675–680.⁵⁸

The knowledge of the different patterns of anastomoses between the median and ulnar nerves in the forearm and hand is important to recognize the clinical manifestations in peripheral nerves and musculoskeletal disorders, as well as to plan surgical approaches and understand their prognosis.^{4–7}

Martin-Gruber Anastomosis

The anastomosis in the forearm, in which the anastomotic branch originates proximally to the median nerve and joins distally to the ulnar nerve, is known as the median-ulnar anastomosis, or Martin-Gruber anastomosis (► **Figs. 1–3**).

In 1763, Martin,⁸ a Swedish anatomist, was the first to consider the possibility of a connection between the fascicles of the median and ulnar nerves in the forearm. In the following century, in 1870, Gruber⁹ dissected 250 forearms and found 38 connections (15.2%); since then, the median-ulnar anastomosis became known as the Martin-Gruber anastomosis.

This anastomosis can occur between the branches intended for the flexor digitorum profundus, directly from the median nerve to the ulnar nerve, between the anterior interosseous nerve and the ulnar nerve, or by combinations between these types of anastomoses.¹⁰

The reported incidence of the Martin-Gruber anastomosis in the literature ranges from 10.5% to 23%.^{1,9,11–13} In a meta-analysis of 41 studies conducted by Roy et al.,¹⁴ the prevalence found was of 19.5%.



Fig. 2 Dissection of the forearm showing the Martin-Gruber anastomosis (median-ulnar). The anastomosis originates from the anterior interosseous nerve. Abbreviations: MGA, Martin-Gruber anastomosis; MN, median nerve; UN, ulnar nerve. Source: Felipe et al.²⁹

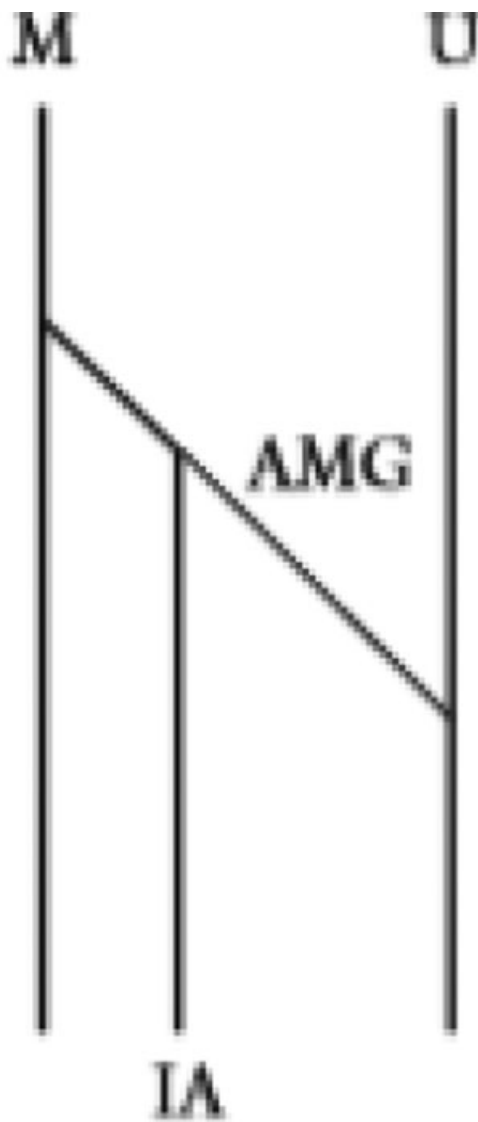


Fig. 3 Schematic representation of the Martin-Gruber anastomosis. Abbreviations: AMG, Martin-Gruber anastomosis; IA, anterior interosseous nerve; M, median nerve; U, ulnar nerve. Source: Felipe et al.²⁹

The Martin-Gruber anastomosis can be divided into six subtypes – type I: oblique anastomotic branch between the anterior interosseous nerve and the ulnar nerve; type II: double anastomosis between the anterior interosseous nerve and the ulnar nerve; type III: anastomosis between the median nerve and the ulnar nerve; type IV: anastomosis between the branches of the median and ulnar nerves that follow to the flexor digitorum profundus muscle; type V: intramuscular anastomosis; and type VI: anastomosis between the median nerve branch that leads to the flexor digitorum superficialis muscle and the ulnar nerve.¹⁵

In about 56.5% of the Martin-Gruber anastomoses discovered, the proximal anastomotic branch originates from the anterior interosseous nerve.⁹ Taams¹³ suggested that the Martin-Gruber anastomosis occurs more frequently in the right forearm than in the left forearm, and is only bilateral in 10% to 40% of the cases. Gruber⁹ further suggested that it would be more common to find only one anastomotic branch than two.

The Martin-Gruber anastomosis is observed mainly in the upper portion of the forearm, in the plane between the epitrochlear muscles and the flexor digitorum profundus muscle.^{16,17} Srinivasan and Rhodes¹⁸ congenitally examined abnormal fetuses (fetuses with trisomy 21) and found the Martin-Gruber anastomosis on both forearms of every fetus. Crutchfield and Gutmann¹⁹ and Piza-Katzer²⁰ found a communication between the median nerve and the ulnar nerve in family members of people who showed this anomalous connection, and suggested that it is a hereditary trait, probably autosomal dominant.

The recognition of the Martin-Gruber anastomosis is important for the correct diagnosis of neuropathies, and traumatic and compressive injuries of the peripheral nerves. For example, a patient may have compression of the median nerve in the wrist through the flexor retinaculum of the hand (carpal tunnel syndrome) with preservation of the clinical symptoms and atypical electromyographic findings in the tenar musculature, or, inversely, they may have symptoms of carpal tunnel syndrome without compression of the median nerve observed by the negative Tinel and Phalen tests, due to compression of the ulnar nerve in the elbow.²¹

Brandsma et al.²² described the cases of five patients with complete lesion to the ulnar nerve in the elbow and injury to the median nerve in the wrist, due to leprosy neuropathy, who maintained good function of the first dorsal interosseous muscle and flexor pollicis brevis muscle. He attributed these findings to the presence of the Martin-Gruber anastomosis, which was later confirmed by studies of nerve conduction, reinforcing its clinical importance.

Marinacci Anastomosis

Another type of anastomosis can occur between the median nerve and the ulnar nerve in the forearm. The anastomotic branch originates proximally to the ulnar nerve and joins distally to the median nerve, and it is called an ulnar-median anastomosis, reverse Martin-Gruber anastomosis, or Marinacci anastomosis. It is composed mainly of motor fibers.²³ (→ Figs. 4–6).

In 1964, Marinacci²⁴ reported the case of a patient who suffered trauma to the median nerve in the forearm, but preserved the muscles of the hand innervated by the median nerve, despite denervation of the flexors muscles of the

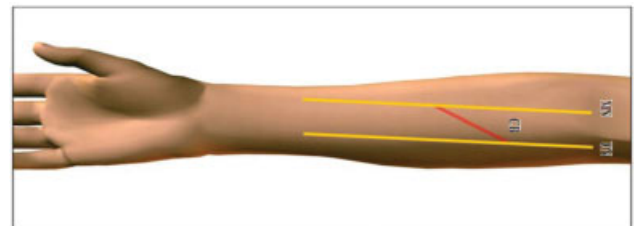


Fig. 4 Three-dimensional illustration showing the Marinacci anastomosis. Abbreviations: CB, anastomotic branch; MN, median nerve; UN, ulnar nerve. Source: Duran JTC, Arquez HF. Anastomosis between median and ulnar nerve in forearm and hand. *Journal of Chemical and Pharmaceutical Research*, 2016,8(8):675–680.⁵⁸



Fig. 5 Dissection of the forearm showing the Marinacci anastomosis (ulnar-median). The branch of the ulnar nerve gives rise to the anastomotic branch. Abbreviations: MA, Marinacci anastomosis; MN, median nerve; UN, ulnar nerve. Source: Felipe et al.²⁹

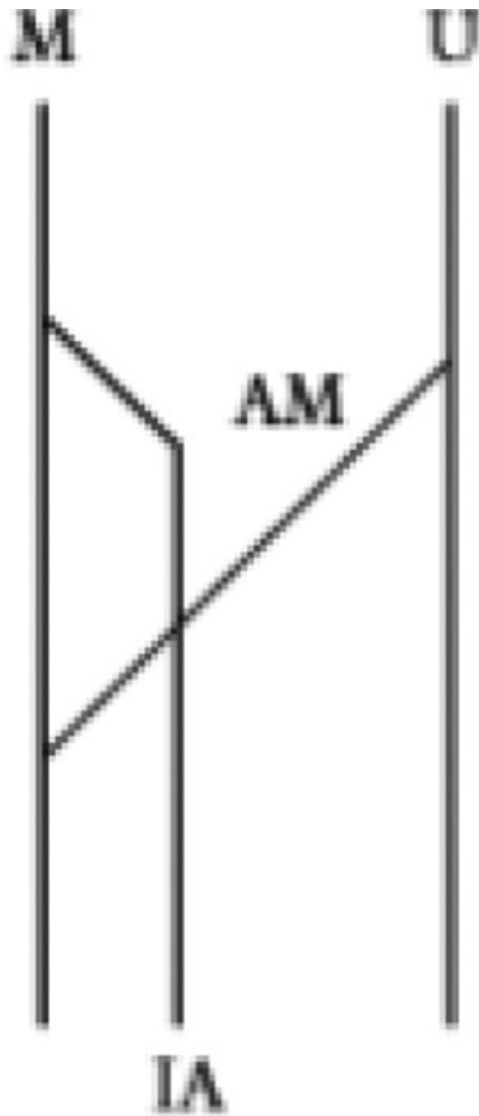


Fig. 6 Schematic representation of the Marinacci anastomosis. Abbreviations: AM, Marinacci anastomosis; IA, anterior interosseous nerve; M, median nerve; U, ulnar nerve... Source: Felipe et al.²⁹

forearm. The reported frequency of Marinacci anastomosis is very low. In many studies²⁹, this type of anastomosis was not found, and it is considered by many authors an anatomical anomaly.

The occurrence of Martin-Gruber or Marinacci anastomoses can be understood by the fact that the median and ulnar nerves develop from a similar embryonic region.²⁵ There are reports of a high incidence of peripheral-nerve connections in monkeys, which indicates a phylogenetic basis.^{1,26}

Regarding the Marinacci anastomosis, there are no studies on the incidence in cadavers, but its incidence in electro-neuromyography studies was of 5% according to Rosen²⁷ and of 16.7% according to Golovchinsky²⁸. Felipe et al.²⁹ demonstrated a dissection cadaver that presented a rare case of Marinacci anastomosis: the anastomotic branch originated proximally to the ulnar nerve, and was inserted into the anterior interosseous nerve, located on the right side; it was a single anastomotic branch measuring 7.4 cm in length.²⁷⁻²⁹

Sraj et al.³⁰ published a case report of a patient who, despite presenting typical symptoms of carpal tunnel syndrome, did not manifest any of the clinical signs of median nerve compression. The patient presented evidence of compression of the ulnar nerve in the elbow, and by testing the ulnar nerve, the authors found that the patient had the symptoms of carpal tunnel syndrome. Another case reported by Sraj et al have also reported a patient with a median nerve injury to the elbow³⁰, without clinical repercussion in the thenar muscles, such as the abductor pollicis brevis muscle, innervated by the median nerve. No changes were observed in the hand muscles, despite the denervation of the flexor muscles of the forearm.²⁹

Berrettini Anastomosis

Communications between the median nerve and the ulnar nerve can occur with great frequency in the wrist and hand, and the anastomosis between the deep branch of the ulnar nerve and the recurrent branch of the median nerve in the thenar eminence is known as the Riche-Cannieu anastomosis. Communication between common digital nerves that emerge from the median nerve and the ulnar nerve on the surface of the palm is known as Berrettini anastomosis or ramus communicans cum nervi ulnari in anatomical terminology^{4,31} (→Figs. 7 and 8).

Variations of the Berrettini anastomosis exist, and communications between the fourth common digital ulnar nerve and the third common digital median nerve may explain the variations in digital sensory innervation. The anastomotic branch originates most commonly from the fourth common digital nerve of the ulnar nerve, communicating distally to the third common digital nerve of the median nerve.³² Its incidence varies drastically, between 4% and 94%, which is why some anatomists consider the Berrettini anastomosis a normal anatomical structure, and not an anatomical variation; however, this discussion is quite controversial.^{5,32-34}

In 1991, Meals and Calkins³⁵ gave notoriety to the term Berrettini anastomosis in honor of Pietro Berrettini Cortonensi, a famous artist known for his painting of Santa Cecilia,



Fig. 7 Three-dimensional illustration showing the Berrettini anastomosis in the palm of the hand. Abbreviations: CB: anastomotic branch; MN: median nerve; UN: ulnar nerve. Source: Duran JTC, Arquez HF. Anastomosis between median and ulnar nerve in forearm and hand. *Journal of Chemical and Pharmaceutical Research*, 2016,8 (8):675–680.⁵⁸

who illustrated the occurrence of superficial communication between the ulnar and median nerves, in the engravings of the book *Tabulae Anatomicae*,³⁷ published in 1741.^{35–37}

Berrettini's anastomosis is believed to be purely sensitive, and an injury to it results in reduced sensitivity in the region between the third and fourth fingers.³⁸

Rollins and Meals³⁹ described the loss of sensory innervation caused by traumatic injury to the Berrettini anastomosis; their patient reported symptoms of paresthesia in the area between the middle and ring fingers.



Fig. 8 Anatomical piece of a dissected palm. The black arrow indicates the communicating branch between the ulnar and the median nerves. Personal record provided by Dr. Marcelo Medeiros Felipe.

Loukas et al.⁵ reported that there were no differences observed in the morphometric or topographic parameters according to the ethnicity, age or gender of the individual.

Some anatomy books do not mention the presence of this anastomotic branch, but some atlases illustrate it as a communicating branch or anastomotic branch.^{18,36,39–42} Rollins and Meals³⁹ paid attention to the fact that the presence of the Berrettini anastomosis can cause changes in the pattern of innervation of the fingers, according to the lesion and its topography, such as the persistence of sensitivity in the ulnar edge of the middle finger or in the radial edge of the ring finger in lesions to the median and ulnar nerves in the region of the wrist. The anastomosis is located in the middle palmar region, at a point of intersection between an axial line of the fourth finger and the Kaplan cardinal line.⁴³

The Berrettini anastomosis is important because injuries can occur in the volar surface on the hand. This is due to the fact that surgeons who deal with carpal tunnel syndrome are working superficially in the area of the Berrettini anastomosis, which is why knowledge of it is extremely important.⁵

Riche-Cannue Anastomosis

The Riche-Cannieu anastomosis is located between the ulnar and median nerves in the hand. It consists of a communication between the recurrent branch of the median nerve and the deep branch of the ulnar nerve in the tenar region, and it can alter the motor innervation of the hand⁴⁴ (→Figs. 9 and 10). Both motor and sensitive fibers may be involved, with the possibility of three types of clinical presentation: the hand totally innervated by the ulnar nerve; motor fibers only from the ulnar nerve; or the hand with normal innervation by the median nerve, partially supplied by the ulnar

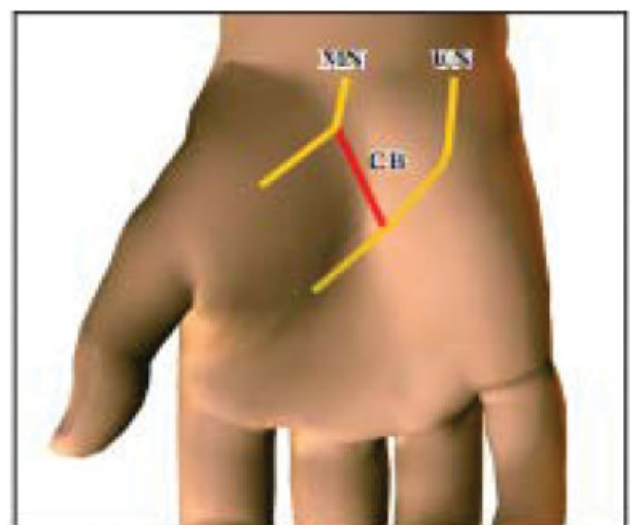


Fig. 9 Three-dimensional illustration showing the Riche- Cannieu anastomosis in the tenar region of the palm. Abbreviations: CB, anastomotic branch; MN, median nerve; UN, ulnar nerve.. Source: Duran JTC, Arquez HF. Anastomosis between median and ulnar nerve in forearm and hand. *Journal of Chemical and Pharmaceutical Research*, 2016,8(8):675–680.⁵⁸

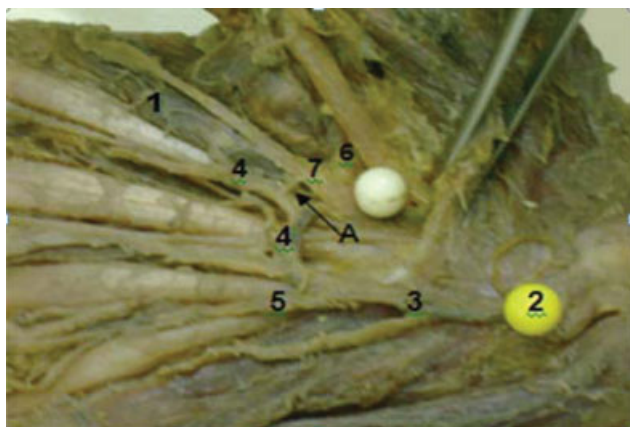


Fig. 10 Dissected palm of the hand showing the Riche-Cannieu anastomosis. Numbers: 1, first lumbrical muscle; 2, ulnar nerve; 3, trunk of the ulnar nerve; 4, deep branch of the ulnar nerve; 5, common digital palmar nerve of the ulnar nerve; 6, recurrent branch of the median nerve; 7, common palmar digital nerve of the median nerve. Personal record provided by Dr. Marcelo Medeiros Felipe.

nerve.⁴⁵ It was first described by Cannieu in 1894, who reported an anastomosis between the recurrent branch of the median nerve and the ulnar nerve in 03 out of 20 anatomical pieces that he dissected.³⁸ Later, in 1897, Riche⁴⁶ found anastomoses in 3 out of 12 anatomical specimens.

The incidence is quite controversial in the literature, with studies showing different prevalence rates. Studies on anatomical dissection describe the following incidences: Cannieu⁴⁷–7%; Bölükbaşı⁴⁸–0%; Riche⁴⁶–13%; Yang⁴⁹–50%; Souza⁵⁰–50%; Harness⁵¹–77%; and Caetano⁵²–100%. In an electrophysiological study,³⁸ the incidence found was of 83.3%. According to Boland et al.,⁵³ there is a family tendency for autosomal dominant inheritance.

The location of the Riche-Cannieu anastomosis would be at the intersection of a line perpendicular to the midpoint of the proximal flexor crease of the first finger and the axial line of the second finger.⁴³

There are three types of connections described: type I: between the deep branch of the ulnar nerve and the recurrent branch of the median nerve for the two heads of the flexor pollicis brevis muscle; type II: between the deep branch of the ulnar nerve and the branch of the median nerve, within the muscular body of the transverse head of the adductor pollicis; type III: communication between these two nerves within the lumbrical muscle body.⁴⁶

Regarding the clinical repercussion, the presence of this anastomosis can cause a risk of injury during surgical procedures, and also hinder the interpretation of electrophysiological studies in the diagnosis of neuropathies. Carpal tunnel syndrome, in particular, has been associated with exacerbated or decreased symptoms in the presence of these anastomoses.^{52,54} It can generate an “ulnar-hand” phenomenon in some cases, in which the muscles in the tenar eminence only present innervation from the ulnar nerve, with no contribution from the median nerve.⁵⁵

In an electroneuromyographic study,⁵⁶ it caused difficulty in interpreting the results, especially in the evaluation of the

lesions to the median nerve, the opponens pollicis muscle, and the abductor pollicis brevis muscle.

These anastomoses can cause confusion in the diagnosis of lesions: complete lesion to the median nerve, in a situation in which the Riche-Cannieu anastomosis exists, can be interpreted as a partial nerve injury, for example. In cases of injury to the ulnar nerve, the presence of signs of denervation of the muscles innervated by the median nerve (the opponens pollicis muscle and the abductor pollicis brevis muscle) may lead to the suspicion of brachial plexus injury (C8-T1).^{56,57}

Conclusion

Anastomoses between the median and ulnar nerves in the forearm and hand can cause confusion in the diagnosis of conditions affecting the nerve that supplies the intrinsic muscles of the hand. Crossing axons can innervate the intrinsic muscles supplied by the ulnar nerve, the median nerve, or both. This explains the cases in which nerve damage in the forearm does not cause changes in the muscles of the hand. The symptoms of carpal tunnel syndrome may be incomplete or exacerbated due to the existence of these anastomoses, which alter the innervation of the upper limb. Or a traumatic nerve injury at the level of the forearm may be mistakenly interpreted as a partial injury in the median nerve or ulnar nerve, and importance should also be given to its topography to prevent injuries to the anastomotic branches in upper-limb surgical procedures. Therefore, knowledge of these anastomoses is important, given their impact on the surgical treatment in the forearm and hand, to avoid iatrogenic injuries and prevent complications in surgeries, as well as in the clinical and electromyographic diagnosis of partial and total injuries to the median and ulnar nerves.

Conflict of Interests

The authors have no conflict of interests to declare.

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