Comprehensive Summary of Anastomoses between the Median and Ulnar Nerves in the Forearm and Hand

Jennifer L. Smith¹ Saaïd A. Siddiqui¹ Nabil A. Ebraheim¹

¹Department of Orthopaedic Surgery, The University of Toledo College of Medicine and Life Sciences, Toledo, Ohio, United States

Address for correspondence Jennifer L. Smith, MSE, Department of Orthopaedic Surgery, The University of Toledo College of Medicine and Life Sciences, 3000 Arlington Avenue, Toledo, OH 43614, United States (e-mail: Jennifer.Smith9@rockets.utoledo.edu).

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Abstract

Four main presentations of median-ulnar anastomosis exist. Those manifesting in the forearm include Martin–Gruber and Marinacci, while those found in the hand are referred to as Riche–Cannieu and Berrettini. Martin–Gruber anastomosis involves branching of the median nerve proximally to ulnar nerve distally. Marinacci anastomosis, the rarest of all the presentations, is often termed reverse Martin–Gruber, with the ulnar nerve stemming proximally to meet the median nerve distally in the forearm. Riche–Cannieu anastomosis occurs as an interconnection between the recurrent branch of the median nerve and the deep branch of the ulnar nerve in the hand. Berrettini anastomosis is the most frequently encountered of the anomalies and is described as a neural connection between common digital nerves of the ulnar and median nerves. Due to altered innervation patterns, musculoskeletal disorders of the forearm and hand may present with misleading symptoms. Additionally, existence of an anastomosis may require an alteration of surgical methods or be a source of iatrogenic injury. Consequently, knowledge of these anastomoses is crucial to clinical practice. Therefore, the objective of this review is to concisely present the most relevant information regarding median and ulnar anastomoses in the forearm and hand.

Keywords

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

Introduction

A variety of anomalous interconnections exist between the median and ulnar nerves in the forearm and hand. The four major classifications of anastomoses include Martin–Gruber anastomosis (MGA), Marinacci anastomosis (MA), Riche–Cannieu anastomosis (RCA), and Berrettini anastomosis (BA), with the former two occurring in the forearm and the latter two arising in the hand. While generally considered atypical, the presence of these anatomical variations may impact the presentation of musculoskeletal disorders and surgical outcomes, as well as mandate alteration of surgical approaches.^{1–7} Therefore, knowledge and recognition of these median-ulnar anastomoses by surgeons is clinically significant. The aim of this review is to concisely summarize current literature, to provide clinicians with an easily referenced and comprehensive resource.

Martin–Gruber Anastomosis

Located in the forearm, MGA has a prevalence of 19.5% as estimated by the meta-analysis of 41 studies ($n = 6,409$ upper limbs) conducted by Roy et al.⁷ Caetano et al.⁸ observed a prevalence as high as 27% using an anatomical dissection method, demonstrating the degree of variation that may be possible. In the same study, Roy et al further showed that MGA is more commonly unilateral and on the right side, in agreement with other studies.^{9–11} MGA is considered to follow an autosomal dominant pattern of inheritance^{12,13} and has been linked to Trisomy 21 with bilateral presentation.¹⁴ Structurally, MGA is characterized as the proximal extension of the median nerve or its branches to the ulnar nerve distally, as seen in ►Fig. 1. While there are several subtypes detailed throughout the literature, in the

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Fig. 1 Martin-Gruber anastomosis (MGA). MGA involves the median nerve stemming proximally to join the ulnar nerve distally. It is most commonly unilateral and on the right side. (Found in first paragraph under section titled “Martin-Gruber Anastomosis”).

majority of cases, the connecting branch is between the anterior interosseous nerve of the median nerve and the ulnar nerve, running an oblique course superficial to the flexor digitorum superficialis or flexor digitorum profundus and connecting posterior to the ulnar artery.^{7,9,15–18} Thirty-three percent of specimens with MGA present demonstrated this organization (type I) in Cavalheiro et al. Other possible arrangements described in the same study included double anastomosis between the anterior interosseous nerve and ulnar nerve (type II, 7.4%); anastomosis between the median and ulnar nerves (type III, 14.8%); anastomosis between branches of the median nerve and ulnar nerve heading toward the flexor digitorum profundus muscle of the fingers (type IV, 18.5%); intramuscular anastomosis (type V, 18.5%); and anastomosis between a branch of the median nerve to the flexor digitorum superficialis muscle and the ulnar nerve (type VI, 7.4%).¹⁹ While MGA is most frequently associated with the ulnar artery, it is important to note that it has also been related to the anterior ulnar recurrent artery. Awareness of this variation during open reduction and internal fixation of a radius/ulnar shaft fracture may be significant in minimizing iatrogenic damage.^{7,15}

While there is some evidence of afferents, MGA nerve fibers are most often of an efferent nature,^{15,20,21} providing innervation primarily to the first dorsal interosseous muscle.^{7,22} Hypothenar muscles are also commonly supplied, followed by thenar muscles.⁷

The clinical implications of MGA are far-reaching. Riechers et al² cite this anastomosis as the main factor causing or inducing complications during surgical procedures. In addition to cases involving the anterior ulnar recurrent artery, iatrogenic damage is possible in the management of ulnar artery reconstruction, wrist drop, and ulnar nerve transposition.^{7,23,24} Complication of diagnosis of carpal tunnel syndrome, cubital tunnel syndrome, peripheral lesions, and neuropathies may also result in the presence of MGA. For example, in the case of carpal tunnel syndrome, there may be partial or total sparing of thenar muscles, as well as unusual findings in evoked muscle potentials.^{5,23,25,26} Conversely, a patient may present with symptoms of carpal tunnel syndrome, but show negative findings with regard to Tinel and Phalen tests, due to ulnar nerve compression at the elbow.⁸ The intramuscular MGA subtype mentioned previously, found in 5% of total limbs ($n = 100$) in the study

by Caetano et al,^{8,19} is clinically relevant in and of itself. This branch penetrates the flexor digitorum profundus muscle, potentially serving as a location of nerve compression.^{15,27,28}

Marinacci Anastomosis

Also found exclusively in the forearm, MA is the rarest of the median-ulnar anastomoses, estimated at 0.7% ($n = 1,884$) via the meta-analysis by Roy et al. However, Meenakshi-Sundaram et al¹ reported its incidence to be as high as 4% ($n = 200$) in an electrophysiological study, suggesting that this type of anastomosis might be underreported. Consequently, there is little data on this variation.

MA is also known as reverse MGA, with the ulnar nerve branching proximally to join the median nerve distally, ▶ **Fig. 2**. Like MGA, MA is mainly comprised of motor fibers, with few accounts of afferents only.²⁹ Presence of MA should be suspected if ulnar nerve stimulation at the elbow yields compound muscle action potentials (CMAPs) with larger amplitudes than with stimulation at the wrist.¹ Knowledge of this possible finding can prevent interpretation of changes over the median nerve as neuropraxia.¹

Median nerve injuries at the elbow may not result in clinically significant effects on the thenar muscles, such as the abductor pollicis brevis.¹ For instance, in a patient case reported in Felipe et al,^{30,31} no disruption of innervation to the hand muscles was experienced despite trauma to the median nerve in the forearm and accompanying denervation of flexor muscles in the forearm. Alternatively, ulnar nerve

Fig. 2 Marinacci anastomosis (MA). MA is often referred to as reverse Martin-Gruber anastomosis, as the ulnar nerve is branching in the distal direction to unite with the median nerve. It is the rarest of the four types of anastomoses. (Found in second paragraph of section titled “Marinacci Anastomosis”).

injuries at the elbow may be accompanied by denervation changes over median-innervated thenar muscles.¹

Riche–Cannieu Anastomosis

RCA occurs in the hand, with a pooled prevalence of 55.5% ($n = 501$).⁷ Similar to MA, incidence of RCA may also be underestimated. Some studies have reported rates as great as 70 to 80%, which the authors emphasized could potentially be higher with finer techniques.^{32,33} This belief is supported by the findings in another study by Caetano et al,³⁴ in which the presence of RCA was recorded in 100% of dissected fresh cadaver hands ($n = 80$), with the use of careful, high magnification (10–16 $\times$) technique. It may therefore be feasible to consider RCA as a normal anatomical neural connection.^{7,34} Further, race might factor into observed prevalence.^{33,35} For example, in a study by Kimura et al³³, African-Americans presented with RCA significantly less frequently than other racial groups, and no significant difference was found between Hispanics and Caucasians.⁷ This pattern supports the notion that, like MGA, RCA is inherited in an autosomal dominant manner.³⁶

RCA exists as an interconnection between the recurrent branch of the median nerve and the deep branch of the ulnar nerve, illustrated in ►Fig. 3. Both motor and sensory fibers may be involved, with three possible presentations: a hand that is entirely supplied by the ulnar nerve³⁷; a hand with motor fibers solely from the ulnar nerve^{38,39}; or, a hand with normally median-innervated muscles partially supplied by the ulnar nerve.⁴⁰ With regard to the third scenario, Ahadi et al found that the abductor pollicis brevis is most often supplied,

Fig. 3 Riche–Cannieu anastomosis (RCA). RCA arises as an interconnection between the recurrent branch of the median nerve and the deep branch of the ulnar nerve. Three possible presentations exist: a hand may be completely supplied by the ulnar nerve; a hand with all motor innervation via the ulnar nerve; or, a hand with normally median-innervated muscles partially supplied by the ulnar nerve. (Found in second paragraph of section titled “Riche–Cannieu Anastomosis”).

followed by the opponens pollicis. Therefore, weakness of abduction and opposition of the thumb may not accurately predict compromise of the median nerve in patients with RCA.³⁵

Due to the nature of this anastomosis, neglect of RCA in patients with complete median nerve injury can lead to error in interpretation of 60.8 to 82.6% of complete median injury cases.^{35,41} Likewise, lack of recognition of RCA may lead to misdiagnosis of severe carpal tunnel syndrome and, consequently, inappropriate surgical intervention.⁴² Electrodiagnosis of polyneuropathies or focal mononeuropathies other than median mononeuropathies, as seen in diabetes mellitus or certain autoimmune disease, may also be clouded by the presence of RCA.⁴²

Berrettini Anastomosis

The fourth and final type of anastomosis, BA, also occurs in the hand. Roy et al⁷ estimated a pooled prevalence of 60.9% ($n = 1,768$), making it the most common of the anomalies. Because its incidence has been found to be greater than 80% in several other studies, there is general acceptance of BA as a normal anatomical structure.⁴

BA is described as a neural connection between common digital nerves of the ulnar and median nerves, ►Fig. 4. Reports have demonstrated that the connecting branch most commonly originates from the fourth common digital nerve, joining distally with the third common digital nerve.⁷

Fig. 4 Berrettini anastomosis (BA). BA is described as a neural connection between common digital nerves of the ulnar and median nerves. It is purely sensory and is most often bilateral, arising proximal to the distal edge of the transverse carpal ligament and following an oblique course. (Found in second paragraph of section titled “Berrettini Anastomosis”).

Additionally, it is most often bilateral, arising proximal to the distal edge of the transverse carpal ligament and following an oblique course.⁷

BA is believed to be purely sensory,⁴³ with laceration resulting in reduced sensation in the region between the third and fourth digits.⁴⁴ With its location most often adjacent to the transverse carpal ligament, several authors are in agreement that the BA is at risk of iatrogenic injury during carpal tunnel release surgeries.^{3,6,42,43,45} However, Unver Dogan et al suggest that iatrogenic injury is unlikely to occur, explaining that the working area for treatment of carpal tunnel syndrome is superficial to the anastomosis. Risk of damage of BA is also associated with ring finger flexor tendon surgery, Dupuytren fasciectomy, and mobilization of neurovascular island flaps.³ Unrecognized or unintended laceration of connecting branches should be considered in patients with palmar pain and distal sensory loss, which can be mistaken for nerve traction or scarring.⁴⁶

Conclusion

Knowledge of anastomoses between the median and ulnar nerves in the forearm and hand is extremely important given their impact on diagnoses and surgical treatments, particularly those related to carpal tunnel syndrome. While the literature may delve into deeper complexities of these neural connections, this review is intended to provide the most pertinent and applicable information to clinicians.

Conflict of Interest

None.

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