

Electrophysiological study of Martin–Gruber anastomosis in a sample of Egyptians

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Introduction

Martin–Gruber anastomosis (MGA) is one of the most common anomalous innervations present in the body. Missing these anomalous innervations may easily be mistaken for technical pitfalls or even for actual pathology.

Aim

The aim of the current study was to determine the presence and the frequency of MGA by electrophysiological examination in a sample of Egyptian subjects.

Subjects and methods

It is a cross-sectional study of consecutive apparently healthy volunteers. The study included 200 forearms from 100 apparently healthy Egyptian volunteers in a single-center public-hospital-based electromyography laboratory. Electrophysiological studies in the form of motor conduction study for the median and ulnar nerves were performed by recording the hypothenar, first dorsal interosseous, and thenar muscles. Qualitative data were analyzed using Pearson's Chi-square test and Fisher's exact test.

Results

The present study included 69 (69%) women. MGA was found in 39 (19.5%) forearms of 26 (26%) subjects electrophysiologically. There was no statistical significant difference between the occurrence of MGA in men versus women ($P=0.127$). The most common form was MGA to the first dorsal interosseous muscle. It was present in 30 (15%) forearms of 24 (24%) subjects. MGA to thenar muscles was present in 13 (6.5%) forearms of 12 (12%) subjects. MGA to the abductor digiti minimi muscle was present in five (2.5%) forearms of five (5%) subjects.

Conclusion

Martin–Gruber anastomosis is present in Egyptians. The frequency of occurrence of MGA in a sample of Egyptian subjects was found to be 26% in electrophysiological examination.

Keywords:

anastomosis, anomalous innervations, Egyptians, Martin–Gruber anastomosis, median nerve

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Introduction

Anomalous innervations of the peripheral nerves are important issues in routine electrophysiological assessment of any patient [1,2]. Missing these anomalous innervations may easily be mistaken for technical pitfalls or even for actual pathology [3]. Martin–Gruber anastomosis (MGA) is one of the most common anomalous innervations present in the body [3]. It is present in the upper limb [3]. This anomaly is formed from cross-over of median-to-ulnar motor nerve fibers [1,4,5]. The communication usually takes place in the forearm [6–9]. Its prevalence varies from 3.3 to 40% [10,11]. It occurs bilaterally in 10–40% of the individuals with MGA [12]. It can be diagnosed electrophysiologically by detecting the presence of certain differences in the compound muscle action potentials (CMAP) recorded from the intrinsic hand muscles when the median and ulnar nerves are stimulated electrically at the wrist and elbow [3]. MGA is asymptomatic and usually diagnosed accidentally

during neurophysiological assessment of the median and ulnar nerves [2,13,14].

So far, there have been no studies that have assessed the presence and the frequency of MGA in Egyptian subjects. It is important to assess this issue among Egyptian individuals. The aim of the current study was to determine the presence and the frequency of MGA by electrophysiological examination in a sample of Egyptian subjects.

Subjects and methods

The present cross-sectional study included 200 forearms from 100 apparently healthy Egyptian

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volunteers. The volunteers included medical staff, their relatives, and relatives of patients attending the outpatient clinic of Physical Medicine, Rheumatology and Rehabilitation Department, Main University Hospital, Alexandria Faculty of Medicine. Inclusion criteria included the absence of any neurological complaints associated with normal neurological examination of both upper limbs. Exclusion criteria included diabetes mellitus, endocrine disorders, metabolic disorders, rheumatologic disorders, and neurological disorders, including peripheral neuropathy, ulnar neuropathy, and carpal tunnel syndrome (CTS). The study was explained to the participants and an informed consent was given by each. The study had been approved by the Ethics Committee of Faculty of Medicine, Alexandria University, Egypt.

Demographic data were collected and neurological examination was done for all studied participants.

Electrophysiological studies were conducted on a NIHON KOHDEN Neuropack MEB-7102 mobile unit with a two-channel evoked potential/EMG measuring system (Nihon Kohden Corporation, Tokyo, Japan). Skin temperature at the site of the recording electrodes was maintained around 33–34°C by means of hot packs. The ground electrode was placed between the recording electrodes distally and the stimulation site proximally. Conduction distances were measured by a measured tape with precision of 1 mm [15].

For motor nerve conduction studies, the following was applied: the sweep speed was 5 ms/division and the sensitivity was 5 mV/division. The filter bandwidth was 10 Hz–10 kHz. The bipolar stimulator had a production current ability of 50 mA. The pulse duration was 0.2 ms. Measurement included the amplitude of CMAP. The amplitude was measured from the first negative peak to the next positive peak expressed in millivolt [3,15]. All the electrophysiological tests were done by caution, to make sure that the change in the CMAP amplitude obtained was not due to technical factors such as submaximal stimulation and costimulation of nearby nerves. To ensure supramaximal stimulation, the current intensity of the stimulus was slowly increased until the amplitude of the recorded CMAP was no longer increased. Then, a further increase in the stimulus intensity by about 25% was done to make sure that the CMAP amplitude would not increase further, which is a confirmation that supramaximal stimulation had been achieved [3]. Avoidance

of costimulation of nearby nerves was done by avoidance of unnecessary excessive stimulation current and observation of sudden changes in the morphology of the recorded CMAP especially when the stimulus intensity increased [3].

The median and ulnar motor nerve conduction studies were done and the recording was from the hypothenar [abductor digiti minimi (ADM)], first dorsal interosseous (FDI), and thenar [abductor pollicis brevis (APB)] muscles. These were done by stimulating both nerves at the wrist (distally) and at proximal sites [1].

The electrophysiological techniques used to recognize MGA included the following:

Detection of MGA to hypothenar muscles in routine ulnar nerve motor conduction study recording the abductor digiti minimi muscle

An active recording surface disc electrode was attached over the motor point of ADM muscle and the reference surface disc electrode was attached over the fifth finger metacarpophalangeal joint. Electrical stimulation of the ulnar nerve was done at 7 cm proximal to the active recording electrode at the wrist crease just lateral to the flexor carpi ulnaris tendon (wrist stimulation), at 4 cm distal to the medial epicondyle (below-elbow stimulation) and at 10 cm proximal to the site of below-elbow stimulation (proximal to the medial epicondyle) measured while the elbow joint was at 90° flexion (above-elbow stimulation) [3]. The CMAP amplitudes were taken for analysis [1,3].

Martin–Gruber anastomosis to the hypothenar muscles was suspected if the amplitude of the ulnar CMAP recorded at the below-elbow stimulation was lower than that recorded at wrist stimulation by more than 10% [3].

To confirm the presence of MGA in this situation, electrical stimulation of the median nerve was done at the wrist between the flexor carpi radialis tendon and palmaris longus tendon (wrist stimulation), and at the antecubital fossa medial to the biceps brachii tendon (antecubital fossa stimulation) while recording the ADM muscle [3]. The CMAP amplitudes were taken for analysis [1,3].

In the presence of MGA, there was a median CMAP at antecubital fossa stimulation that was not present at wrist stimulation [1,3]. This was considered MGA type I [3].

Detection of MGA to first dorsal interosseous muscle in ulnar nerve motor conduction study recording the first dorsal interosseous muscle

An active recording surface disc electrode was attached over the motor point of the FDI muscle and the reference surface disc electrode was attached over the first finger metacarpophalangeal joint dorsally. Electrical stimulation of the ulnar nerve was done at the wrist stimulation site, at the below-elbow stimulation site, and at the above-elbow stimulation site as described in the routine ulnar nerve motor conduction study [3]. The CMAP amplitudes were taken for analysis [1,3].

Martin–Gruber anastomosis to the FDI muscle was suspected if the amplitude of the ulnar CMAP recorded at the below-elbow stimulation was lower than that recorded at wrist stimulation by more than 10% [3].

To confirm the presence of MGA in this situation, electrical stimulation of the median nerve was done at the wrist stimulation site, and at the antecubital fossa stimulation site while recording the FDI muscle [3]. The CMAP amplitudes were taken for analysis [1,3].

In the presence of MGA, the median CMAP amplitude at the antecubital fossa stimulation was larger than that present at wrist stimulation [1,3]. This was considered MGA type II [3].

Detection of MGA to thenar muscles in routine median nerve motor conduction study recording the abductor pollicis brevis muscle

An active recording surface disc electrode was attached over the motor point of the APB muscle, and the reference surface disc electrode was attached over the first finger metacarpophalangeal joint. Electrical stimulation of the median nerve was done at 7 cm proximal to the active recording electrode at the wrist stimulation site, and at the antecubital fossa stimulation site [3]. The CMAP amplitudes were taken for analysis [1,3].

Martin–Gruber anastomosis to the thenar muscles was suspected if the amplitude of the median CMAP at the antecubital fossa stimulation was larger than that obtained with wrist stimulation [1,3,16].

To confirm the presence of MGA in this situation, electrical stimulation of the ulnar nerve was done at the wrist stimulation site, at the below-elbow stimulation site, and at the above-elbow stimulation site as described in the routine ulnar nerve motor conduction study while recording the APB muscle [3]. The CMAP amplitudes were taken for analysis [1,3].

In the presence of MGA, the ulnar CMAP amplitude at the below-elbow stimulation was substantially lower than that obtained at wrist stimulation [1,3]. This was considered MGA type III [3].

Type IV MGA was the presence of a combination of two or more of the previous three types in the same forearm [3].

Statistical analysis

Statistical analysis of data was done by using the Statistical Package of Social Science (version 17) software [17]. Descriptive measures [count, frequency, minimum, maximum, mean and standard deviation (SD)], as well as analytic measures (Pearson's Chi-square test and Fisher's exact test), were used. Statistical significance was assigned to any *P* value at less than 0.05.

Results

The present study included 200 forearms that were obtained from 100 healthy individuals [69 (69%) women and 31 (31%) men]. Their mean age was 41.98 ± 12.15 years (ranged from 18 to 79 years). By electrophysiological examination, MGA was found in 39 (19.5%) forearms of 26 (26%) subjects. There was no statistically significant difference between the occurrence of MGA in men versus women ($\chi^2=2.491$, $P=0.127$). MGA occurred in 20 (10%) right forearms and in 19 (9.5%) left forearms.

The most common type of MGA was that to FDI (type II). It was present in 30 (15%) forearms of 24 (24%) subjects. MGA to ADM (type I) was the least one, as it was present in five (2.5%) forearms of five (5%) subjects. However, MGA to thenar muscles (type III) was present in 13 (6.5%) forearms of 12 (12%) subjects. The distribution of different types of MGA according to the sex is tabulated in Table 1. There was no statistically significant difference between men and women regarding the frequency of different types of MGA except for MGA to FDI (type II), which was significantly higher among women than among men (Table 1).

Among subjects with MGA, it was present bilaterally in 13 (50%) subjects, which represents 13% of the total number of individuals included in the current study. Among them, the same type of MGA was present in both forearms of seven (53.85%) subjects. The most common type of MGA that was present bilaterally was that to FDI (type II). It was present in six (85.71%) subjects of those who had the same type of MGA bilaterally.

Table 1 Prevalence of Martin–Gruber anastomosis and its different electrophysiological types among the forearms of studied participants

Forearms of studied participants	Type I (ADM) [n (%)]	Type II (FDI) [n (%)]	Type III (thenar muscles) [n (%)]	MGA presence [n (%)]
Forearm of men (n=62)	1 (1.6)	4 (6.5)	4 (6.5)	8(12.5)
Forearm of women (n=138)	4 (2.9)	26 (18.8)	9 (6.5)	31 (22.5)
Total (n=200)	5 (2.5)	30 (15)	13 (6.5)	39 (19.5)
χ^2	0.290	5.150	0.000	2.491
P	0.507 [#]	0.031 ^{#,*}	1.000 [#]	0.127 [#]

ADM, abductor digiti minimi muscle; FDI, first dorsal interosseous muscle; MGA, Martin–Gruber anastomosis; n(%), number of forearms (percentage of forearms); χ^2 , value of Pearson's chi-square test. [#]Significance by Fisher's exact test * $P < 0.05$ is significant.

Among the 13 (50%) subjects with unilateral MGA, it was present in the right side in seven (53.8%) subjects. There was no statistically significant difference between the occurrence of unilateral MGA in the right forearms versus left forearms ($\chi^2 = 0.051$, $P = 0.545$).

More than one type of MGA in the same forearm (i.e. type IV) was present in nine (23.08%) forearms of different nine (34.62%) subjects. Of them, six (66.67%) subjects had bilateral MGA, while three (33.33%) subjects had unilateral MGA. The combination of MGA to thenar muscles and FDI in the same forearm was present in six (66.67%) forearms of six (66.67%) subjects. The combination of MGA to ADM and FDI in the same forearm was present in three (33.33%) forearms of three (33.33%) subjects.

Discussion

Martin–Gruber anastomosis is the cross-over of median nerve motor fibers to the ulnar nerve in the forearm [18,19]. A Swedish anatomist Martin was the first one who described this anastomosis in 1763, followed by Gruber in 1870 [2]. It can take place from the trunk of the median nerve or from one of its branches in the forearm, mainly the anterior interosseous nerve [20]. The crossing motor nerve fibers arising from the median nerve can innervate any intrinsic hand muscles supplied by the ulnar nerve such as ADM, FDI, deep head of flexor pollicis brevis and adductor pollicis, or any combination of them [2,3,20]. The presence of MGA could alter the usual clinical picture and electrophysiological characters of median nerve injury and ulnar nerve injury [2,3].

In the current study, the prevalence of MGA was 26% electrophysiologically among a sample of Egyptian individuals. The results of the current work were

within the range of prevalence of MGA present in other studies, which varied from 3.3 to 40% [1,2,10,11,16,21,22]. However, it was noticed that there was a wide variation of prevalence of MGA among different studies. This could be because of the difference regarding the electrophysiological diagnostic criteria of MGA. There are various diagnostic criteria. On one hand, some studies required changes in the amplitude between the distal and proximal stimulation sites by more than 1 mV [23]. On the other hand, other studies applied more conservative definition and limit the changes in the CMAP amplitude by more than 10% only [2,3].

In the current study, there was no statistically significant difference between males and females regarding the frequency of MGA except for MGA to FDI (type II). This was partially in accordance with Erdem *et al.* [23]. They reported that there was no difference between males and females regarding the frequency of MGA. This could be because of the autosomal dominant inheritance of MGA. It was reported to be present in the family members of persons who had MGA [8]. In the current study, the frequency of MGA to FDI (type II) was significantly higher among women than among men. This could be explained by the high percentage of women (69%) in comparison with men (31%) included in the current study.

In the present study, MGA was present bilaterally in 13 (13%) subjects. This was in agreement with that reported for MGA. It had been reported to be present bilaterally in about 10–40% of subjects [2,12,21]. Six (46.15%) subjects with bilateral MGA had type IV MGA (i.e. the presence of more than one type of MGA in the same forearm) unilaterally. This indicated that the presence of type IV MGA in a forearm could be associated with bilateral MGA.

In the current study, there was no statistically significant difference between the occurrence of MGA in the right forearm versus the left one. This was in agreement with other studies [6,11,19,24,25]. However, this was not in agreement with a few other studies [1,12,26]. Some studies reported that unilateral MGA occurs mainly in the right forearm more than the left one [1,12]. There was another study that reported that it occurs more frequently in the left forearm [27]. This controversy between the current study and these studies could be explained by the absence of standardized diagnostic criteria for the diagnosis of MGA and variation in the methods used for

assessment of it (some were anatomical studies, while others were electrophysiological studies).

As regards the frequency of different electrophysiological types of MGA, the current study was in agreement with other studies in which MGA to the FDI (type II) is the most common type [16,23]. However, the ulnar motor conduction study to the FDI is not a routine study. It is important in the assessment of ulnar nerve lesions. Unfortunately, in the electrophysiological study of the deep palmar branch of ulnar nerve, MGA to FDI makes the interpretation of findings to be difficult [3,22,23].

In the current study, MGA to thenar muscles (type III) was the second most common type. This type is important in the electrophysiological assessment of CTS [3,13,22,28]. MGA in CTS has specific electrophysiological features. In patients with delayed median motor distal latency, MGA leads to two important features: the presence of an initial positive deflection in the median CMAP at the antecubital fossa stimulation recording from the thenar muscles and a surprisingly very fast median motor conduction velocity in the forearm segment. The explanations of these findings are as follows: (i) during stimulation of median motor fibers at the antecubital fossa, most of them travel along the forearm and then pass through the carpal tunnel. However, median fibers that form MGA bypass the carpal tunnel along the ulnar nerve to supply the thenar muscles before the impulses pass through the entrapped median nerve across the carpal tunnel. These bypassed fibers depolarize the ulnar innervated muscles and produce an initial positive deflection. (ii) Depending on the previous explanation, when subtracting the prolonged median distal latency from the within normal median antecubital latency, the time difference is so short that it makes the median forearm conduction velocity surprisingly fast [3,13,14,28].

In the present study, MGA to ADM (type I) was the least type. This type is important in the electrophysiological assessment of ulnar nerve. In this situation, ulnar CMAP of proximal site of stimulation is substantially lower than that obtained at the distal site of stimulation in the wrist. For proper diagnosis of ulnar nerve lesion, exclusion of MGA is essential [3,23].

Recognition of MGA is essential in the assessment of median and ulnar nerves lesions and injuries [3,22,29–33].

The concept of the electrophysiological study for the diagnosis of MGA could be explained as follows: the cross-over motor fibers make the ulnar nerve to gain motor fibers. Subsequently, its CMAP following wrist stimulation will have larger amplitude than that obtained at the below-elbow site of stimulation. This is because the maximum numbers of motor fibers that are ultimately fired are larger at the wrist stimulation site, provided that supramaximal stimulation was applied in both sites of stimulation. The number of motor fibers crossing over will affect the obtained median CMAP amplitude difference between distal and proximal stimulation sites. Consequently, the median CMAP following antecubital stimulation will have a larger CMAP amplitude than that at wrist stimulation [2,3].

It is important to note that if the amount of anastomosis results in less than 10% change in ulnar CMAP amplitude between distal and proximal sites of stimulation, it will not be classified as MGA by the diagnostic criteria used in the current study. This means that the diagnosis of MGA depends on a minimal amount of crossed motor fiber that leads to a minimum of 10% change in amplitude of ulnar CMAP to differentiate it from normal temporal dispersion and phase cancellation that is a normal electrophysiological phenomenon known in electrophysiology [2,3]. Therefore, minimal MGA cannot be detected in this situation.

In the current study, there were no subjects with ulnar-to-median communication. This anomaly is known as reversed MGA or Marinacci communication. It is a very rare anomalous innervation [7,12,24,34–37].

The current study had a limitation. The electrophysiological assessment for detection of sensory forms of MGA was not done. The cross-over of sensory fibers from the median-to-ulnar nerve is unusual to take place and it is considered to be rare [38,39].

Further studies are recommended, and well-identified standardized criteria for MGA are necessary to allow the comparison of the prevalence of MGA between different populations in different countries and different ethnic groups. Further studies on a larger scale of Egyptian citizens from different governorates are recommended to better calculate the prevalence of MGA among the Egyptian population.

Conclusion

Martin–Gruber anastomosis is present in Egyptians. The frequency of occurrence of MGA in a sample of

Egyptian subjects was found to be 26% in electrophysiological examination. Recognition of different forms of MGA makes the mistake in the diagnosis of median and ulnar nerves lesions to be avoidable.

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Conflicts of interest

There are no conflicts of interest.

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