Based on a study of 70 human cadavers (31 male, 39 female) and on cases described previously, we propose a new classification of the Martin-Gruber anastomosis, a neural connection between the median and ulnar nerves in the forearm. The anastomosis was found in 16 (22.9%) cadavers, being bilateral in three (18.7%) and unilateral in 13 (81.3%), five right and eight left. It occurred in eight (25.8%) of the 31 male cadavers and in eight (20.5%) of the 39 females. Therefore, the anastomosis was found in 19 (13.6%) of the 140 forearms. In Pattern I (89.5%) the anastomosis was made by only one branch, whereas in Pattern II (10.5%) it was made by two. The individual branches were classified as Types a, b, and c based on the nature of their origin from the median nerve. Type a (47.3%) arose from the branch to the superficial forearm flexor muscles, Type b (10.6%) from the common trunk, and Type c (31.6%) from the anterior interosseous nerve. Pattern II was a duplication of Type c (10.5%). The anastomotic branch took an oblique or arched course before joining the ulnar nerve, undivided in 15 cases, but divided into two branches in four cases. The anastomosis passed in front of the ulnar artery in four cases, behind it in six, and in nine cases it was related to the anterior ulnar recurrent artery. Clin. Anat. 15:129–134, 2002.

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Key words: nerve anastomosis; median nerve; ulnar nerve

INTRODUCTION

The Martin-Gruber anastomosis is a neural connection between the median and ulnar nerves in the forearm. It has been considered as carrying motor (Sunderland, 1978) or sensory fibers (Ranschburg, 1917) between the median and ulnar nerves (Pye-Smith et al., 1870; Leibovic and Hastings, 1992). Its reported incidence differs between physiologic and anatomic studies. In the former it has been described as occurring in 5–40% of cases (Mannerfelt, 1964; Crutchfield and Gutmann, 1980; Sonck et al., 1991; Gutmann, 1993; Gert Van Dijk and Bouma, 1997) whereas anatomic studies report a narrower range of 10–30.6% (Gruber, 1870; Curtis, 1886; Thomson, 1893; Hirasawa, 1931; Srinivasan and Rhodes, 1981; Nakashima, 1993; Taams, 1997; Shu et al., 1999).

Since Gruber’s original report (1870) the anastomosis has been classified into several types and subtypes, but the lack of common criteria makes it very difficult to compare data (Thomson, 1893; Hirasawa, 1931; Srinivasan and Rhodes, 1981; Nakashima, 1993; Shu et al., 1999). Moreover, the authors did not take into account all the morphological aspects reported by Gruber (1870), or aspects of clinical relevance (side, sex, course, relations, form of connection with the ulnar nerve). Therefore, the present study revisits various anatomic aspects of the anastomosis, in particular patterns, course, and relations, with a view to creating an easily accessible, clinically relevant classification.

MATERIALS AND METHODS

In total, 70 embalmed cadavers (140 upper limbs) were examined by magnification-aided dissection. The sex distribution was 31 male to 39 female cadavers, with an age at death ranging from 64 to 101 years.
Statistical comparisons between percentages were made using the chi-squared test. $P < 0.05$ was regarded as statistically significant.

**RESULTS**

The Martin-Gruber anastomosis was found in 16 (22.9%) of the whole sample of 70 cadavers, being bilateral in three (18.7%) and unilateral in 13 (81.3%), five right and eight left. It occurred in eight (25.8%) of the 31 male and also in eight (20.5%) of the 39 female cadavers. Therefore, the anastomosis was found in 19 (13.6%) of the 140 upper limbs (Table 1). There was no statistically significant difference between the incidences in male and female subjects, or right and left sides, but there was a statistically significant difference in favor of a unilateral as opposed to bilateral presence. The anastomosis was made by one branch (Fig. 1a), Pattern I, in 17 (89.5%) cases and by two branches (Fig. 1b), Pattern II, in two (10.5%) cases (Table 2). Pattern I was classified into three types (Table 2) based on the level at which the anastomotic branch arose from the median nerve or one of its branches (Fig. 2).

In Type a, the anastomosis arose from the branch of the median nerve to the superficial forearm flexor muscles (Fig. 2a) and this occurred in nine (47.3%) cases. The slender anastomotic branch ran downwards deep to the superficial forearm flexor muscles, intimately related to the anterior ulnar recurrent artery, (Fig. 2a) and connected with the ulnar nerve about 2 cm below the medial epicondyle (range from 1.6–2.5 cm), very close to the level at which the ulnar nerve gave off its branch to flexor digitorum profundus (Fig. 1a). In one case, the communicating branch pierced this muscular branch before joining the ulnar nerve (Fig. 2a).

In Type b, the anastomosis arose between the origin of the branch to the superficial forearm flexors and the origin of the anterior interosseous nerve (Fig. 2b). This occurred in only two (10.6%) cases, and in one of these, the anastomosis divided into two branches, one of which pierced the branch of the ulnar nerve to the flexor digitorum profundus while the other connected with it (Fig. 1a).

In Type c, the anastomotic branch arose from the anterior interosseous nerve (Fig. 2c). This occurred in six (31.6%) cases and the branch passed medially to join the ulnar nerve in either its upper or middle one-third (Figs. 1b and 2c).

The two cases with a double anastomotic branch in the same forearm, classified as Pattern II, were a duplication of Type Ic (Fig. 1b).

The Pattern I adopted an oblique course in 13 cases and an arciform course in four cases. In Pattern II, the superior connection was arciform and the inferior was oblique (Fig. 1b).

The anastomoses in Pattern I, Type a, were related to the anterior ulnar recurrent artery, rather than to the ulnar artery, passing behind it in seven cases and in front in two (Fig. 2a). In the rest of cases (Type b or c), the anastomosis passed in front of the ulnar artery in four cases (Fig. 1a) and behind it in six (Figs. 1b and 2b,c).

The anastomosis joined the ulnar nerve, or its branch to the flexor digitorum profundus, as a single branch in 15 cases (Fig. 2) and split into two branches in four cases (Fig. 1a). The superior branch had a recurrent course and the inferior one ran downwards (Fig. 2c).

The width of the anastomosis ranged from 1–1.5 mm and its length measured about 2.5 cm (range from 2–3 cm), except that of Type c, which measured about 6 cm (range from 4.5–7.4 cm).

**DISCUSSION**

The incidence of the Martin-Gruber anastomosis reported in previous anatomic studies ranges from 10–30.6% (Gruber, 1870; Curtis, 1886; Thomson, 1893; Hirasawa, 1931; Srinivasan and Rhodes, 1981; Nakashima, 1993; Shu et al., 1999). We found an incidence of 13.6%, close to that reported by Taams (1997). The only study that related the incidence to race, side, and sex (Taams, 1997) found no statistically significant differences. Our results in relation to sex and side concur.

Thomson (1893) classified the Martin-Gruber anastomosis into four types, based on whether the origin was from the anterior interosseous nerve, the median nerve, the branch to the flexor digitorum profundus, or the branch to the superficial forearm flexor muscles. Subsequent studies did not use this classification and included cases in which two anastomotic branches were present (Hirasawa, 1931; Srinivasan and Rhodes, 1981; Nakashima, 1993; Shu et al., 1999). Although

<table>
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<tr>
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<th>Left</th>
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<tr>
<td>Male (n = 31)</td>
<td>6 (19.3%)</td>
<td>4 (12.9%)</td>
</tr>
<tr>
<td>Female (n = 39)</td>
<td>5 (12.8%)</td>
<td>4 (10.2%)</td>
</tr>
<tr>
<td>Total (n = 70)</td>
<td>11 (15.7%)</td>
<td>8 (11.4%)</td>
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many of these classifications show similarities, e.g., Type Ib (Nakashima, 1993) also Type 3 (Srinivasan and Rhodes, 1981), or Type II (Shu et al., 1999), the differences make it extremely difficult to compare their data.

Our results confirm that the anastomosis appears as one or two branches with various origins from the median nerve or its branches, as already described by Gruber (1870), Curtis (1886), Villar (1888), Hirasawa (1931), Srinivasan and Rhodes (1981), Nakashima (1993), Shu et al. (1999). Based on our results, and those of previous reports, we propose a new unifying classification of patterns and types. Pattern I comprises cases with one communicating branch, and Pattern II those with two. Types a, b, and c are subdivisions depending on the level of origin of the anastomosis.

![Fig. 1. Anterior view of the forearm showing two patterns of Martin-Gruber anastomosis (arrows). a: Pattern I shows only one communicating branch. b: Pattern II shows two communicating branches, superior (proximal black and white arrows) and inferior (distal black arrows). ai, anterior interosseous nerve; mn, median nerve; un, ulnar nerve; ua, ulnar artery; ra, radial artery.](image)

**TABLE 2. Patterns and Types of Martin-Gruber Anastomosis Shown by Different Authors**

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<tbody>
<tr>
<td>Pattern I</td>
<td>95%</td>
<td>13%</td>
<td>8%</td>
<td>74%</td>
<td>5%</td>
<td>100%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>Type Ia</td>
<td>15.4%</td>
<td>6%</td>
<td>3%</td>
<td>91%</td>
<td>4,35%</td>
<td>7%</td>
<td>0%</td>
<td>7%</td>
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<tr>
<td>Type Ib</td>
<td>15.4%</td>
<td>6%</td>
<td>3%</td>
<td>91%</td>
<td>4,35%</td>
<td>7%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Type Ia</td>
<td>15.4%</td>
<td>6%</td>
<td>3%</td>
<td>91%</td>
<td>4,35%</td>
<td>7%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Type Ib</td>
<td>15.4%</td>
<td>6%</td>
<td>3%</td>
<td>91%</td>
<td>4,35%</td>
<td>7%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Type Ic</td>
<td>15.4%</td>
<td>6%</td>
<td>3%</td>
<td>91%</td>
<td>4,35%</td>
<td>7%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>Pattern II</td>
<td>100%</td>
<td>3%</td>
<td>19%</td>
<td>78%</td>
<td>0%</td>
<td>100%</td>
<td>7%</td>
<td>0%</td>
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*aAdapted from Gruber’s criteria (1870).*

Pattern I: only one communicating branch; Pattern II: two communicating branches; Type Ia: the anastomosis arose from the branch of the median nerve to the superficial forearm flexor muscles; Type Ib: the anastomosis arose from the median nerve trunk between the origins of the branch to the superficial forearm flexors muscles and the anterior interosseous nerve; Type Ic: the anastomosis arose from the anterior interosseous nerve or its branches.
from the median nerve. Type a originates from the branch of the median nerve to the superficial forearm flexor muscles, Type b from the median nerve itself and Type c from the anterior interosseous nerve.

In Pattern II, the different types are duplications or combinations of Type a, b, and c. This has been previously reported by other authors, but with considerable variation in incidence and description (Table 2). A combination of both proposed categories (Patterns I and II and Types a, b, and c) encompasses all the anastomotic patterns previously described.

Our results confirm that Pattern I is much more frequent than Pattern II (Table 2). The most common previously reported Type was c, whereas we found Type a the most frequent (Table 2).

The inclusion in the Martin-Gruber anastomosis of the branches of the median and ulnar nerves to the flexor digitorum profundus has been given two different interpretations. Some authors considered this anastomosis as taking place between both muscular branches and classified it as a specific type (Thomson, 1893; Nakashima, 1993). However, the branch to the flexor digitorum profundus arose from the anterior interosseous nerve. Therefore, we considered, as did Gruber (1870) and Curtis (1886), that these cases correspond to Type c in which the muscular branches to flexor digitorum profundus (median and ulnar) arose from the anastomosis. Intramuscular Martin-Gruber anastomoses have also been described (Verchere, 1883; Nakashima, 1993), but we did not find one, despite the use of magnification during dissection.

Other morphological details reported, but not discussed by most authors, are the course of the anastomosis, its relationships to the ulnar artery and how it anastomoses with the ulnar nerve (Gruber, 1870).

The course of the anastomosis has been more frequently described as transverse or oblique than arched (Gruber, 1870; Hirasawa, 1931). We found that the transverse or oblique course depended on whether the anastomotic end at the ulnar nerve was in the superior, middle or inferior one-third of the forearm. When two anastomoses were present (Pattern II), the superior one was arched and the inferior one oblique, as previously described by Gruber (1870).

The anastomosis most frequently passes behind the ulnar artery (Gruber, 1870; Taams, 1997). However, like Gruber (1870), we found that the Type a anastomosis was always related to the anterior ulnar recurrent artery rather than to the ulnar artery.

Fig. 2. Anterior view of the elbow and forearm showing the different origins of the Martin-Gruber anastomosis (arrows). a: Origin from the muscular branch of the median nerve to the superficial forearm flexors muscles (Type a). b: Origin from the median nerve trunk between the origins of the muscular branch to the superficial forearm flexors muscles and the anterior interosseous nerve (Type b). c: Origin from the anterior interosseous nerve or its branches (Type c). ai, anterior interosseous nerve; mn, median nerve; un, ulnar nerve; ua, ulnar artery; aur, anterior ulnar recurrent artery; ra, radial artery.
At its termination, the anastomosis has been recorded either as a single branch or as two branches, one with an oblique course and the other with a recurrent course (Gruber, 1870; Hirasawa, 1931). Like Gruber (1870), we found a single connection more frequently than a double one.

In two of our cases, the anastomosis pierced the branch of the ulnar nerve to flexor digitorum profundus, a finding reported only once previously (Gruber, 1870).

Martin (1763), who first reported the anastomosis, suggested that at the forearm level it could compensate for the absence of communication between the ulnar and median nerves in the palm of the hand. This was refuted by Gruber’s (1870) finding of an anastomosis in the forearm in conjunction with a palmar anastomosis in 14 of 15 arms (93%). The coexistence of both anastomoses in the forearm and hand has been related with anomalous innervation of the intrinsic hand muscles and of the skin (Clifton, 1948; Kimura et al., 1976; Streib, 1979; Brandsma et al., 1986; Sonck et al., 1991; Valls-Sole, 1991; Amoiridis, 1992; Gutmann, 1993; Sander et al., 1997). Usually these patterns are asymptomatic, but in carpal tunnel syndrome or in section of the ulnar nerve they become easily recognizable (Debierre, 1888; Gutmann 1977; Sunderland, 1978; Uchida and Sugioka, 1992; Kingery et al., 1996). In electrophysiological studies it may be manifest as anomalous nerve conduction in carpal tunnel syndrome and as persistence of muscle innervation in spite of ulnar nerve section (Iyer and Fenichel, 1976; Sonck et al., 1991; Gutmann, 1993).

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REFERENCES


