VIA MEDICA

REVIEW ARTICLE

Vol. 68, No. 4, pp. 193–200

ISSN 0015–5659
www.fm.viamedica.pl

Persistent median artery in the carpal tunnel: anatomy, embryology, clinical significance, and review of the literature

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[Received 5 June 2009; Accepted 16 September 2009]

The median artery usually regresses after the eighth week of intrauterine life, but in some cases it persists into adulthood. The persistent median artery (PMA) passes through the carpal tunnel of the wrist, accompanying the median nerve. During anatomical dissection in our department, we found two unilateral cases of PMA originating from the ulnar artery. In both cases the PMA passed through the carpal tunnel, reached the palm, and anastomosed with the ulnar artery, forming a medio-ulnar type of superficial palmar arch. In addition, in both cases we observed a high division of the median nerve before entering the carpal tunnel. Such an artery may result in several complications such as carpal tunnel syndrome, pronator syndrome, or compression of the anterior interosseous nerve. Therefore, the presence of a PMA should be taken into consideration in clinical practice. This study presents two cases of PMA along with an embryological explanation, analysis of its clinical significance, and a review of the literature. The review of the literature includes cases observed during surgical procedures or anatomical dissections. Cases observed by means of imaging techniques were not included in the study. (Folia Morphol 2009; 68, 4: 193–200)

Key words: superficial palmar arch, carpal tunnel syndrome, ulnar artery

INTRODUCTION

Variations of the usual plan of arrangement of the blood vessels are among the most common developmental irregularities. They may be due to the choice of unusual paths in the primary vascular plexuses, the persistence of vessels which normally regress, the absorption of vessels normally retained, or the incomplete development or fusions and regressions of usually distinct parts [3].

The median artery of the forearm is a case of persistence of a blood vessel. It belongs to the arteries of the forearm and develops from the axial artery. After the appearance of the axial artery, which represents the axillary, brachial, and anterior interosseous arteries, the median and the anterior interosseous arteries provide the main blood supply to the hand during the first trimester of gestation [51, 56]. After the eighth week of intrauterine life, the ulnar and radial arteries develop and the median artery usually undergoes retrogression to become a small vessel accompanying the median nerve in the carpal tunnel, the accompanying artery of the median nerve (arteria comes nervi mediani) [54]. According to Singer [54], the median artery regresses

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when the embryo is approximately 23 mm long, at stage V of development. Another hypothesis proposes that a plexus of capillaries develop and form the arterial supply of the upper limb as they progressively differentiate from proximal to distal. The definite arterial pattern is considered the result of persistence, enlargement, and differentiation of these capillaries during 28th–52nd days of intrauterine life [51]. Kopuz et al. [35] studied the presence of persistent median artery (PMA) in neonatal cadavers and raised the hypothesis that the median artery regresses at a much later stage, most likely during the perinatal period and early infancy. In their study the incidence of PMA was 20% [35].

MATERIAL, METHODS, AND RESULTS

During 36 routine anatomical dissections of 72 upper limbs of adult cadavers performed in our department, we found two cases (2.78%) of a PMA accompanying the median nerve on its route through the carpal tunnel. The first case was a 58-year-old female cadaver and the second case was a 64-year-old male cadaver. The anomaly was unilateral in both cases since it was encountered only on the right upper limb. The artery's origin was from the trunk of the ulnar artery in both cases and it passed through the carpal tunnel (Fig. 1). On the palm both persistent median arteries gave off the first and the second common digital arteries supplying the thumb, the second finger, and the lateral part of the third finger (Figs. 2, 3). There was an anastomosis between the median and the ulnar artery on the palm in both cases forming a medio-ulnar type of superficial palmar arch, according to Lanz [53] and corresponding to Type C of Group I of Coleman and Anson's classification [15]. There was no anastomosis with the superficial palmar branch of the radial artery in both cases. We also found that there was no common interosseous artery and the posterior and anterior interosseous arteries arose directly from the ulnar artery (Fig. 1). In both cases the median nerve divided into two branches before entering the carpal tunnel (Fig. 2). The first branch continued as the first common digital nerve and the second branch gave off the second and the third common digital nerves.

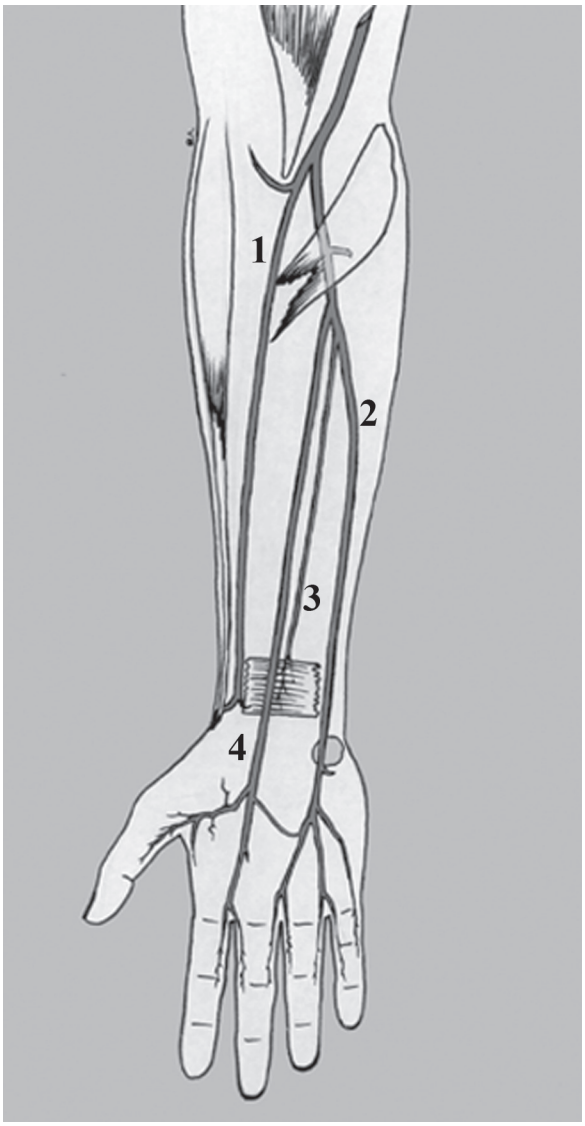

Figure 1. Schematic representation of the reported case: 1 — radial artery; 2 — ulnar artery; 3 — anterior interosseous artery; 4 — persistent median artery.

DISCUSSION

The structures running through the carpal tunnel are the flexor muscle tendons, their sheath, and the median nerve. Due to the inflexibility of the carpal tunnel walls, any thickening of the components that reduce its area may compress the median nerve and its branches.

The median artery persists into adulthood in two forms. The first, an antebrachial type, is considered normal, arises mostly from the anterior interosseous artery, and does not reach the palm. The second, a palmar type, may arise from any of the forearm arteries and accompanies the median nerve in the carpal tunnel. It usually terminates as the superficial arch or as the main blood supplier to the index and long fingers [50]. The term PMA refers to the palmar type of the median artery. When present, the median artery is the main blood supplier of the median nerve, corresponding to Types 2 and 3 of vascularization of the median nerve as described by

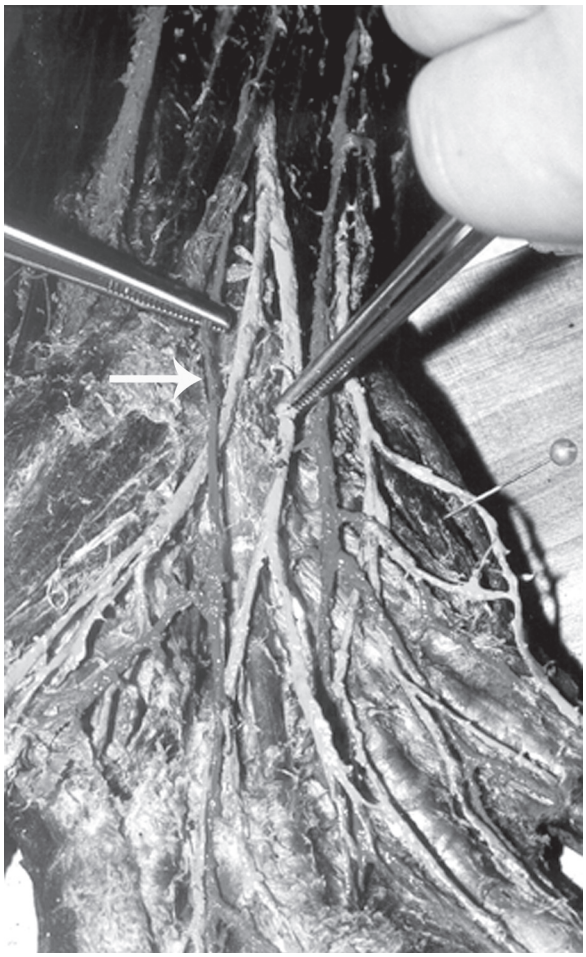

Figure 2. First case. Persistent median artery running through the carpal tunnel (arrow).

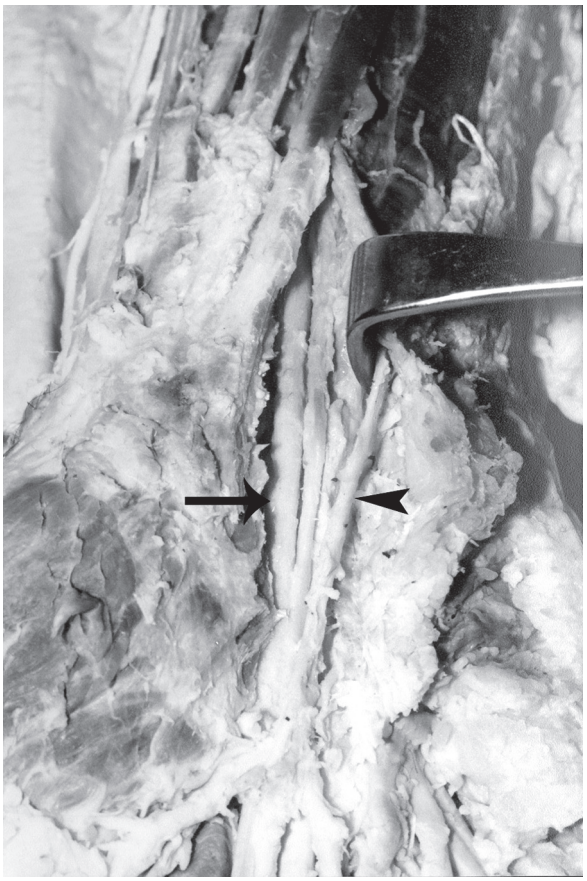

Figure 3. Second case. Median nerve (arrow) and median artery (arrow head).

Pecket et al. [46]. When a complete superficial palmar arch is formed, the median nerve receives its blood supply from the median artery in the proximal part of the forearm and from the superficial palmar arch in the distal part of the forearm. If the median artery does not exist, the blood supply to the median nerve comes from the radial and ulnar arteries and the superficial palmar arch when it is formed [46].

In normal subjects, the radial and the ulnar arteries anastomose within the hand to make a superficial and a deep palmar arch so that occlusion in one forearm vessel will not compromise vascular supply to the hand [28]. Coleman and Anson [15] suggested two groups of superficial palmar arch: a complete and an incomplete. Group I can be subdivided into five types of complete superficial palmar arch. The median artery contributes to the third and fourth type as it anastomoses with the ulnar artery or with both ulnar and radial arteries. Group II can be subdivided into four types of incomplete superficial palmar arch. The median artery contributes to the arterial supply of the hand in the third and fourth type.

In Table 1 we present the incidence of the PMA found only during anatomical dissection or a surgical procedure, the frequency of the unilateral and bilateral cases, and the origin of the artery. All other cases, studied using imaging techniques, were excluded from our study. The incidence of the PMA has been reported to range from 0.6% [2] to 44.2% [24]. The amplitude of the percentage seems to be very wide. This could be the result of absorption of the artery at a later stage, during early infancy or childhood. Mortality of the neonates that have the artery or disparity between generations could also be the cause of these differences [24]. Kopuz et al. [36] found the PMA in 4.5% of forearms, but the incidence of PMA in the neonatal cadavers of the same study was 12.5%; much higher than the overall incidence. The incidence of the PMA can be influenced by racial differences. This may be the result

Table 1. Overall incidence of persistent median artery.

Author (year), references	Sample	Incidence	Percentage	Side origin							Specimen	Method
				Unilateral	Bilateral	Ulnar a.	Radial a.	CIA	AIA	Tripoid		
McCormack et al. (1953) [43]	750	31	4.43%	–	–	–	–	–	–	–	Cadavers	Dissection
Coleman and Anson (1961) [15]	650	64	9.9%	–	–	–	–	–	–	–	Cadavers	Dissection
Keen (1961) [32]	284	27	9.5%	–	–	–	–	–	–	–	Cadavers	Dissection
Jackson and Campbell (1970) [29]	1	1		1	–	–	–	–	–	–	Patient	Operation
Pecket et al. (1973) [46]	60	6	10%	–	–	–	–	–	–	–	Cadavers	Dissection
Chalmers (1978) [13]	228	10	4.4%	10	–	–	–	–	–	–	Patients	Operation
Levy and Pauker (1978) [39]	1	1		1	–	–	–	–	–	–	Patient	Operation
Boles et al. (1982) [12]	1	1		1	–	–	–	–	–	–	Patient	Operation & angiography
Libersa et al. (1982) [40]	100	16	16%	–	–	–	–	–	–	–	Cadavers	Dissection and X-ray
Luyendijk (1986) [42]	1117	20	1.8%	–	–	–	–	–	–	–	Patients	Operation
Faithfull and Wallace (1987) [18]	1	1		1	–	–	–	–	–	–	Patient	Operation
Gainor and Jeffries (1987) [21]	1	1		1	–	–	–	1	–	–	Patient	Operation
Jelicic et al. (1988) [30]	50	1	2%	1	–	–	–	–	–	–	Cadavers	Dissection
Jones and Ming (1988) [31]	1	1		1	–	–	–	–	1	–	Patient	Operation
Toranto (1989) [58]	2	1		1	–	–	–	–	–	–	Patient	Operation
Srivastava and Pande (1990) [55]	134	2	1.5%	2	–	2	–	–	–	–	Cadavers	Dissection
Dickinson and Kleinert (1991) [17]	1	1		1	–	–	–	–	–	–	Patient	Operation
Henneberg and George (1992) [26]	96	26	27.1%	8	9	–	–	–	–	–	Cadavers	Dissection
Proudman and Menz (1992) [48]	1	1		1	–	–	–	1	–	–	Patient	Operation
Sañudo et al. (1994) [52]	1	1		1	–	1	–	–	–	–	Cadaver	Dissection
Feldkamp et al. (1995) [20]	1	1		1	–	–	–	–	–	–	Patient	Operation
Kopuz et al. (1995) [36]	110	5	4.5%	5	–	4	–	1	–	–	Neonatal & adult cadavers	Dissection
Rodriguez-Baeza et al. (1995) [49]	320	10	3.1%	8	1	–	–	7	–	3	Cadavers and foetuses	Dissection
George and Henneberg (1996) [24]	120	53	44.2%	7	23	–	–	–	–	–	Neonatal & infant cadavers	Dissection
Balakrishnan et al. (1997) [4]	1	1		1	–	–	–	–	–	–	Patient	Operation
Beran et al. (1997) [9]	1	1		1	–	–	–	–	–	–	Patient	Operation & arteriogram
Kopuz et al. (1997) [35]	60	12	20%	4	4	8	–	4	–	–	Neonatal cadavers	Dissection

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Table 1. Overall incidence of persistent median artery.

Author (year), references	Sample	Incidence	Percentage	Side origin							Specimen	Method
				Unilateral	Bilateral	Ulnar a.	Radial a.	CIA	AIA	Tripoid		
Olave et al. (1997) [45]	102	23	23%	9	7	–	–	–	–	–	Cadavers	Dissection
Balakrishnan et al. (1999) [5]	1	1		1	–	–	–	–	–	–	Patient	Operation
Rodriguez-Niedenführ et al. (1999) [50]	240	29	12%	19	5	5	1	2	4	17	Cadavers	Dissection
Ahn et al. (2000) [2]	192	2	0.6%	2	–	–	–	–	–	–	Patients	Operation
Gutowski et al. (2000) [25]	1	1		1	–	1	–	–	–	–	Patient	Operation
Patnaik et al. (2000) [47]	1	1		1	–	–	–	1	–	–	Cadaver	Dissection
Gellman et al. (2001) [23]	45	7	15.5%	–	–	–	–	–	–	–	Cadavers	Dissection
Khashaba (2002) [33]	1	1		1	–	–	–	–	–	–	Patient	Operation
Lindley and Kleinert (2003) [41]	526	18	3.4%	10	4	–	–	–	–	–	Patients	Operation
Bilgin et al. (2004) [11]	313	4	1.3%	4	–	–	–	–	–	–	Patients	Operation
Fazan et al. (2004) [19]	46	5	10%	3	1	–	–	–	–	–	Cadavers	Dissection
Kumar (2004) [38]	2	2		–	1	2	–	–	–	–	Cadaver	Dissection
Barbe et al. (2005) [6]	89	2	2.5%	2	–	–	–	–	–	–	Cadavers	Dissection
Król et al. (2005) [37]	2	1		1	–	1	–	–	–	–	Cadavers	Dissection
Bataineh and Moqattash (2006) [8]	2	1		1	–	1	–	–	–	–	Cadaver	Dissection
Bilge et al. (2006) [10]	50	4	8%	4	–	–	–	–	–	–	Cadavers	Dissection
D'Costa et al. (2006) [16]	19	6	15.8%	6	–	2	–	2	2	–	Cadavers	Dissection
Tsuruo et al. (2006) [59]	2	2		–	1	2	–	–	–	–	Cadaver	Dissection
Acaturk et al. (2008) [1]	1	1		1	–	–	1	–	–	–	Patient	Operation
Claasen et al. (2008) [14]	54	4	7.4%	4	–	2	–	2	–	–	Cadavers	Dissection
Tollan and Sivarajan (2008) [57]	1	1		1	–	–	–	–	–	–	Patient	Operation
Varley et al. (2008) [60]	1	1		1	–	–	–	–	–	–	Patient	Operation
Vollala et al. (2008) [61]	2	1		1	–	–	–	–	1	–	Cadaver	Dissection
Nayak et al. (2009) [44]	84	13	15.4%	–	–	4	–	5	4	–	Cadavers	Dissection
Vollala et al. (2009) [62]	2	1		1	–	–	–	1	–	–	Cadaver	Dissection
Natsis et al. (current study)	72	2	2.78%	2	–	2	–	–	–	–	Cadavers	Dissection

CIA — common interosseous artery; AIA — anterior interosseous artery; Tripoid — common branch of the brachial artery together with the ulnar and the common interosseous arteries

of the allelic variation of genes regulating this anatomical variation [16]. The study performed by Ahn et al. [2] in 2000 among Asians has the lowest incidence of PMA at 0.6%. In 1992 Henneberg and George [26] reported a high incidence (27.1%) of the median artery among South African cadavers. In a sample of 60 neonates and infants from black communities, a PMA was found in 44.2% of the forearms [24]. Furthermore, the size of the artery, which varies from a very small vessel of the antebrachial type to one as large as the radial artery of the palmar type, affects the terminology of the artery and thereby the frequency of the palmar type of the median artery reported by different authors.

The PMA has been found both unilaterally and bilaterally. George and Henneberg [24, 26] found the artery to be significantly more often bilateral than unilateral in two of their studies, and they concluded that the artery tends to occur bilaterally. However, the bilateral cases were evidently more frequent than the unilateral cases in the study performed in a sample of neonates and infants [26]. They also reached the conclusion that the difference of the frequency of the artery between genders and sides is not significant [24]. D'Costa et al. [16] found that the incidence of PMA on the left side was double that on the right side. Rodriguez-Niedenführ et al. [50] found no significant difference between right and left side or between male and female cadavers, but they concluded that PMA was found significantly more often unilaterally than bilaterally. Both of the cases presented in our study are unilateral and were observed on the right side. However, the small number of cases does not allow us to come to any statistical conclusion concerning the difference between unilateral and bilateral cases or between the two sides.

Variations of the origin of the PMA have been reported earlier. It can branch off from the ulnar artery distal or proximal to the origin of the common interosseous artery. Table 1 also presents the incidence of PMA originating from the ulnar, the radial, the common interosseous, and the anterior interosseous arteries or from a common branch of the brachial artery together with the ulnar and the common interosseous arteries. The incidence of PMA originating from the ulnar artery may range from 1.5% [55] to 13.3% [35]. Hollinshead [27] reported that PMA occasionally originated from the brachial artery.

High division of the median nerve at the upper third of the forearm or before entering the carpal tunnel can be associated with a PMA. This malformation belongs to Group III, according to median nerve course classification by Schmidt and Lanz [53]. A conjuncture of a split median nerve with the persistence of a median artery has been reported in the literature [6, 13, 25, 37, 38, 41, 44, 49, 52, 58]. The PMA can also perforate the median nerve just proximal to the origin of the anterior interosseous nerve, below the pronator teres muscle, dividing it into two branches that join again to form a single nerve [14, 16, 21, 31–33, 43, 50, 55]. Rodríguez-Niedenführ et al. [50] found that the PMA pierced the median nerve in 41% of the cases studied.

The presence of a PMA may result in several complications. The PMA has been associated with anterior interosseous nerve syndrome, which is characterized by paralysis of the flexor pollicis longus muscle, the flexor digitorum profundus muscle of the index and middle fingers, and the pronator quadratus muscle [48].

The PMA has been described penetrating the median nerve from below, immediately proximal to the origin of the anterior interosseous nerve in association with pronator syndrome [21, 31] and carpal tunnel syndrome [31].

Symbrachydactyly in association with carpal tunnel syndrome and a PMA has been reported by Tollan and Sivarajan [57].

Any constriction in the carpal tunnel may affect the conductivity of the median nerve. This can be the result of mechanical pressure to the nerve or obstruction of its blood supply [53]. Although the reported frequency of PMA varies in the literature, all authors agree that the presence of an artery in the carpal tunnel is of great clinical significance. A large PMA [11, 12], an aneurysm [58], thrombosis [5, 9, 29, 33, 39, 41], or traumatic rupture [18] of such an artery may cause carpal tunnel syndrome as a result of the pressure exerted on the median nerve. Calcification of the PMA can also be the cause of carpal tunnel syndrome in patients with renal failure, as reported by Dickinson and Kleinert [17]. A case of double thrombosed PMA accompanying the median nerve and causing carpal tunnel syndrome was reported by Levy and Pauker in 1978 [39]. In 1995 Feldkamp et al. [20] reported the first case of a PMA in a haemodialysis patient who had symptoms contralateral to the side of the arteriovenous fistula used for haemodialysis. The PMA may cause damage to the median nerve in two ways: 1) compression and 2) ischaemia. Pathogenesis of the latter is especially advocated when anastomotic connections between the median artery and the radial and ulnar arteries, as well as the superficial palmar

arch, are poor [22]. Luyedijk [42] considers that the persistent median artery is a rare cause of carpal tunnel syndrome. According to Barfred et al. [7], among the group of carpal tunnel syndromes it is possible to distinguish two distinct entities which are related to PMA. The first is associated with thrombosis, which causes a sudden onset of pain and paresthesia, often severe, while the second is associated with a normal median artery. In the latter case, symptoms predominate during work, and the physical signs are inconsistent. Resection of the artery is recommended after ensuring an adequate arterial supply to the fingers.

The decompression of the carpal tunnel and dissection of the PMA are recommended as treatment of carpal tunnel syndrome. However, the excision of the vessel is considered possible only when a sufficient anastomotic blood supply is ensured. Orthopaedic surgeons have to be careful during endoscopic decompression aiming at decompressing the carpal tunnel, in order not to injure a possible division nerve or an existing PMA [34].

CONCLUSIONS

In conclusion, PMA is not such a rare anatomical variant, and its presence should be taken into consideration in clinical practice, especially in neonatal surgery, for several reasons. It may cause carpal tunnel syndrome symptoms, it may supply the hand in radial or ulnar injuries, and it may be used as a graft artery elsewhere in the body.

ACKNOWLEDGEMENTS

The authors would like to thank Athanasios Lourbopoulos, MD, for his wonderful drawing of Figure 1.

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