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Comprehensive study of superficial palmar arch – A revisit

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Abstract

Hand vasculature can be affected by various traumatic and non-traumatic pathologies. A precise understanding of arterial anatomy is pertinent to preoperative diagnosis, operative procedure and post operative outcome as the vascular pattern of hand has a wide range of variations. Considering recent interest, the present study was undertaken i) to observe the morphology of superficial palmar arch and ii) to establish clinico-anatomical correlation of such variations. Sixty-four cadaveric hands were dissected. Superficial palmar arches were classified based on morphology of arches into three types and different subtypes. The variations of superficial palmar arch and their digital branches were noted. Complete arches were more prevalent in present study, observed among 76.56% hands and incomplete arches found in 21.88% hands. Another type was found as combined type, in 1.56% hands. Classical picture of superficial palmar arch was found in 29.69% in right side and 28.12% in left side. The rest of cases were variable. Digital supply varied according to different types and subtypes of superficial palmar arch. Hand ischemia after radial artery cannulation is a rare but potentially devastating complication. Awareness of variations regarding circulatory dynamics of hand is worth knowing in successful planning of surgery involving palm to achieve least complications.

Key words

Superficial palmar arch, morphology, digital vascular supply, clinico-anatomical correlation.

Introduction

Vascular trauma of the hand has become increasingly common and causes a high degree of morbidity with severe consequences on function. To reduce this risk, even the smallest hand injuries require proper medical care. But the vascular anatomy of hand is complex and challenging due to a high prevalence of previously identified variations. These variations are usually found in the palmar arches of which the superficial palmar arch (SPA), through which the hand receives its major blood supply, has been shown to be more variable (Ikeda et al., 1988).For any physician or therapist, treating the hand injury (traumatic or non-traumatic), the mastery of such anatomy is fundamental in order to provide the best quality of care.

Conventionally, SPA is an anastomosis that provides blood supply to all fingers together with deep palmar arch. It is formed predominantly by a branch of the ulnar artery and is completed laterally with a branch of radial artery (Standring, Johnson, 2008). A persistent median vessel or interosseous vessel, sometimes communicating

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with SPA, is present in 4%,9.9%and 14%of hands according to different authors (Coleman and Anson, 1961; Chimmalgi et al., 2004; Joshi et al., 2013).However, this collateral circulation depends on the pattern of arch which may or may not be completed (Standring, Johnson, 2008). In the pathogenesis of peripheral vascular disease, efficiency of collateral circulation is crucial. Incompetent collaterals might result in hand ischemia also during radial artery harvesting. It is quite sensible to believe that variations in morphology of SPA might influence hand surgery. So review of the vascular pattern by modified Allen's test as well as different radiological screening methods prior to any surgical intervention is mandatory(Greenwood et al., 2005). Unfortunately angiographic interpretation of small vessels sometimes is unreliable due to uncontrolled vasospasm and reactive vasodilatation following dye injection; in these cases, evaluation of arteries can be challenging for the radiologists whereas anatomical studies might provide useful details of vascular territories (Uglietta and Kadir, 1989). Considering the recent progress of microsurgery in revascularization, re-implantation and composite tissue transfer, detailed knowledge about circulatory dynamics of hand including possible variations would be fundamental in clinical practice (Ikeda et al., 1988; Joshi et al., 2013).In the perspective of updating the unusual configurations, the present study was attempted to revisit the morphological details of SPA and provide clinico-anatomical correlations.

Materials and methods

Sixty-four hands of 32 embalmed cadavers of either sex, aged 50-80 years were examined. Cadavers exhibiting deformities, trauma or fractures or any kind of surgical interventions in upper limbs were excluded from the study. Hands were dissected out according to standard dissection technique with special attention given to SPA and its contributing vessels. For better exposure, flexor retinaculum between thenar and hypothenar muscles was divided. Radial, ulnar and median (if present) arteries were identified and preserved proximal to wrist. Their morphology and branching pattern were observed and noted. Digital branches were searched and traced up to the digits to acquire knowledge about feeder arteries of fingers. Variations were documented carefully with photographs.

To define the arch, criteria was chosen in order to be coherent with previous study (Coleman and Anson, 1961). In the present study analyses were done taking into account the side and rare subtypes. An arch was complete if anastomosis was present between the palmar arteries or an arch was formed by a single artery to provide all digital branches. An arch was double when two anastomosis (proximal and distal) were present between arteries. In an incomplete arch, on other hand, anastomosis between palmar arteries was missing and all individual arteries according to subtype provided independent digital branches. Cases where two arteries joined to make an arch and a third artery remained separate in course were considered as combined type presenting individual mode of digital supply digital branches arising from both complete and incomplete components. Each type again was sub-typed and named according to vessels contributing to the arches: radial-ulnar, ulnar, median-ulnar, radial-median-ulnar.

Results

In the present study, complete arches were found in 76.56% cases (right side 34.37%; left side 42.19%), incomplete arches in 21.88% cases (right side 14.06%, left side 7.81%) and combined arches in 1.56% cases (only on right side). Thus, complete arches were predominant on left hands while incomplete arches were more on right side. Complete arches, on right side, were radial-ulnar and ulnar only while on left side radial-ulnar, median-ulnar, radial-median-ulnar and radial-ulnar double arches were found. In incomplete type, on right side radial-ulnar, median-ulnar, ulnar and radial-median-ulnar subtypes were present while on left side only radial-ulnar subtype was observed. The third type was radial-median-ulnar combined type where radial and median arteries formed a small anastomotic arch (radial-median arch) close to the proximal part of thenar muscles and ulnar artery, with its digital branches, followed an independent course on medial side of palm. Table 1 summarizes morphological data with the incidence of types and subtypes. Figures 1-5 represents the different subtypes of arches.

Presence of persistent median artery was observed in in 18.75% hands. In (12.5%) cases of median-ulnar subtype, no branch from radial artery was seen as part of either a complete or an incomplete arche. In radial-median-ulnar subtype (6.25%), the course of the branch from radial artery was varied. In complete type it passed through first dorsal web space to communicate with the median-ulnar arch whereas in incomplete type it entered deep to thenar muscles to appear into palm and in combined type it crossed thenar muscles superficially to join with median artery to form radio-median arch.

The digital supply varied according to different types of SPA. Figure 6 represents a schematic diagram of SPA with digital branches in detail.

In case of radial-ulnar (Figure 1a), ulnar (Figure 2a) and median-ulnar subtype (Figure 1b) of complete arches, digital supply was derived from SPA in the form of

Table 1. Morphological data with incidences of different types and subtypes of arch.

Type of Arch		Side	Subtype	n (%)
Complete (76.56%)	Single	Right (34.37%)	Radial-Ulnar	19 (29.69)
			Ulnar	3 (4.69)
		Left (39.06%)	Radial-Ulnar	18 (28.12)
			Radial-Median-Ulnar	2 (3.13)
			Median-Ulnar	5 (7.81)
	Double	Left (3.13%)	Radial-Ulnar	2 (3.13)
Incomplete (21.88%)		Right (14.06%)	Radial-Ulnar	3 (4.69)
			Ulnar	2 (3.13)
			Median-Ulnar	3 (4.69)
			Radial-Median-Ulnar	1 (1.56)
		Left (7.81%)	Radial-Ulnar	5 (7.81)
Combined (01.56%)		Right (1.56%)	Radial-Median-Ulnar	1 (1.56)

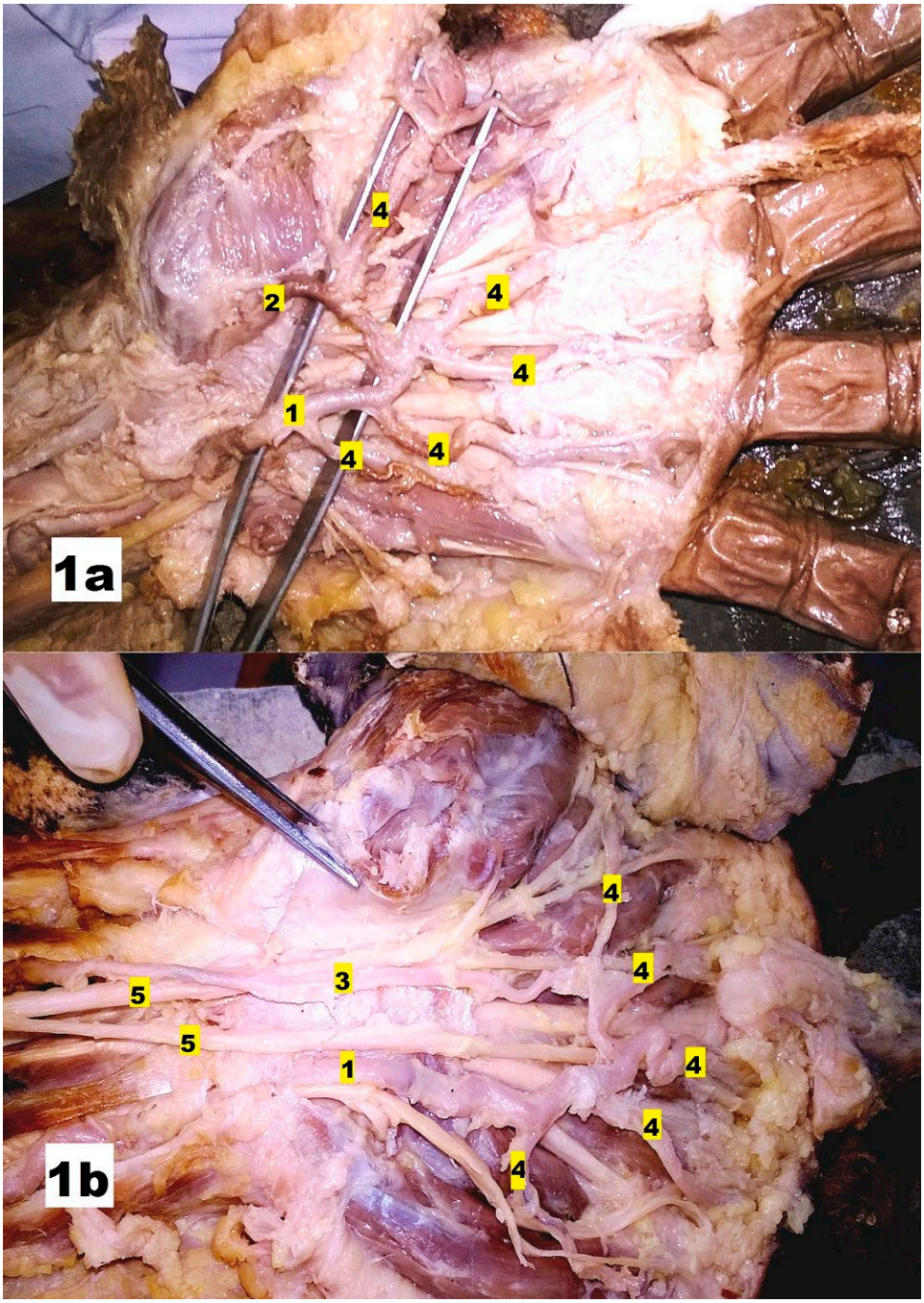

Figure 1. Complete superficial palmar arch. a) Radial-ulnar arch (left hand);b) Median-ulnar arch (left hand). 1: ulnar artery; 2: superficial branch of radial artery; 3: median artery; 4: digital branches; 5: median nerve.

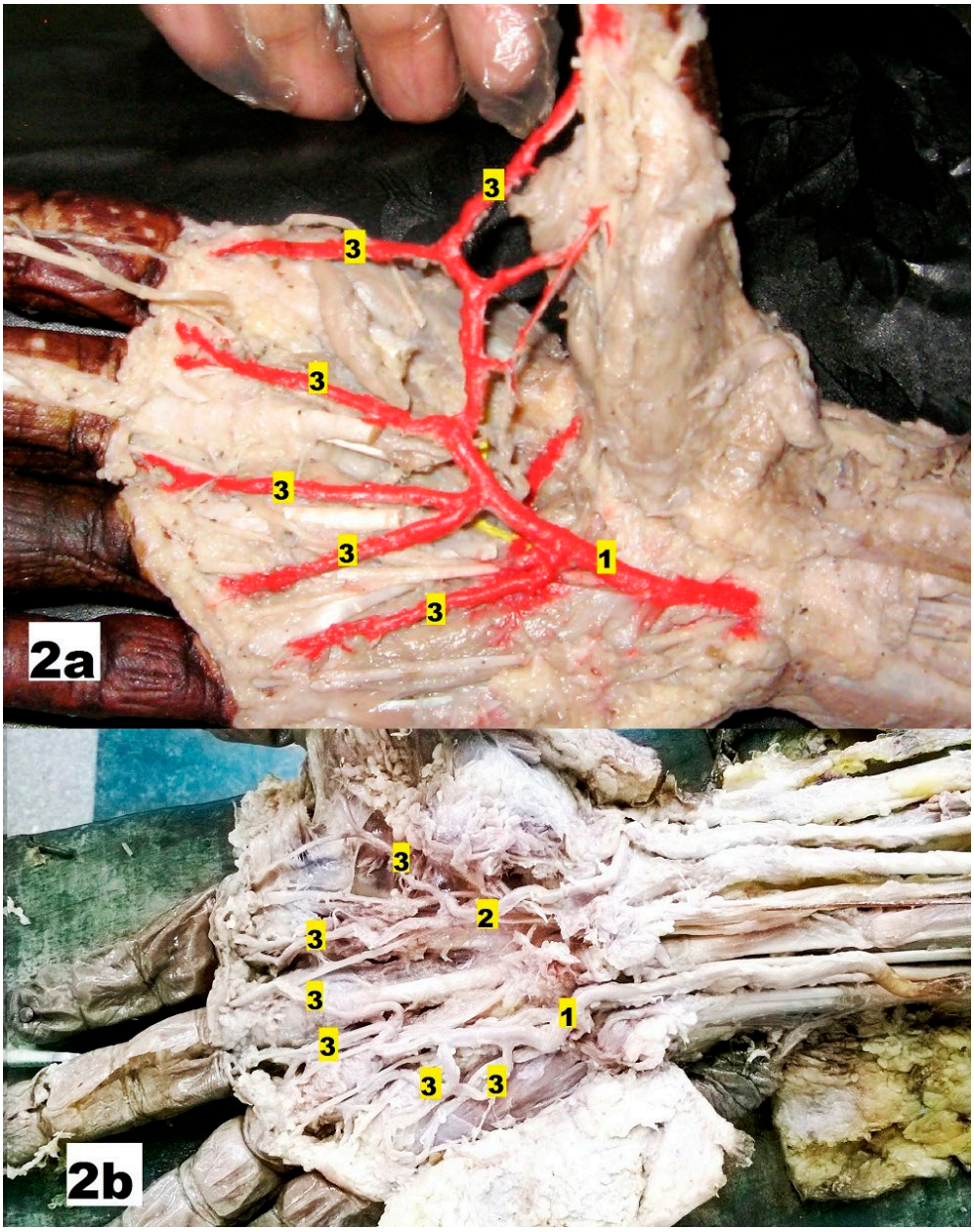

Figure 2. Ulnar superficial palmar arch. a)Complete arch (right hand); b)Incomplete arch (right hand). 1: ulnar artery; 2: radial artery; 3: digital branches.

four common digital arteries for 1st, 2nd, 3rd and 4th interdigital spaces and proper digital arteries for radial side of thumb and ulnar side of little finger; while in radial-median-ulnar subtype (Figure 3b) common digital arteries arose for 2nd, 3rd and 4th

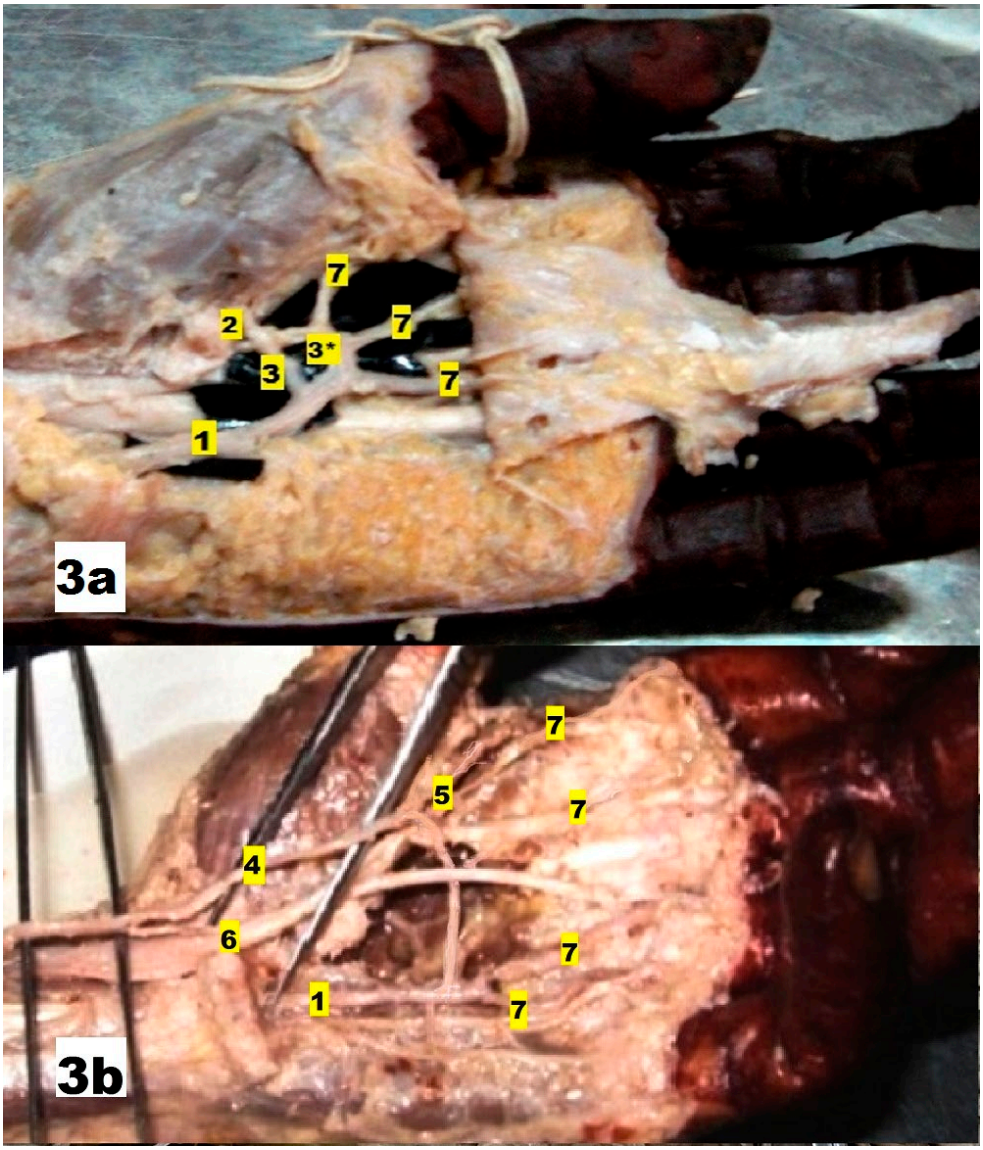

Figure 3. Subtypes of superficial palmar arch. a) Radial-ulnar (double) complete arch (left hand); b) Radial-median-ulnar complete arch (left hand).1: ulnar artery; 2: superficial branch of radial artery; 3: proximal communication; 3*: distal communication; 4:median artery; 5:communicating branch from radial artery; 6:median nerve; 7: digital branches.

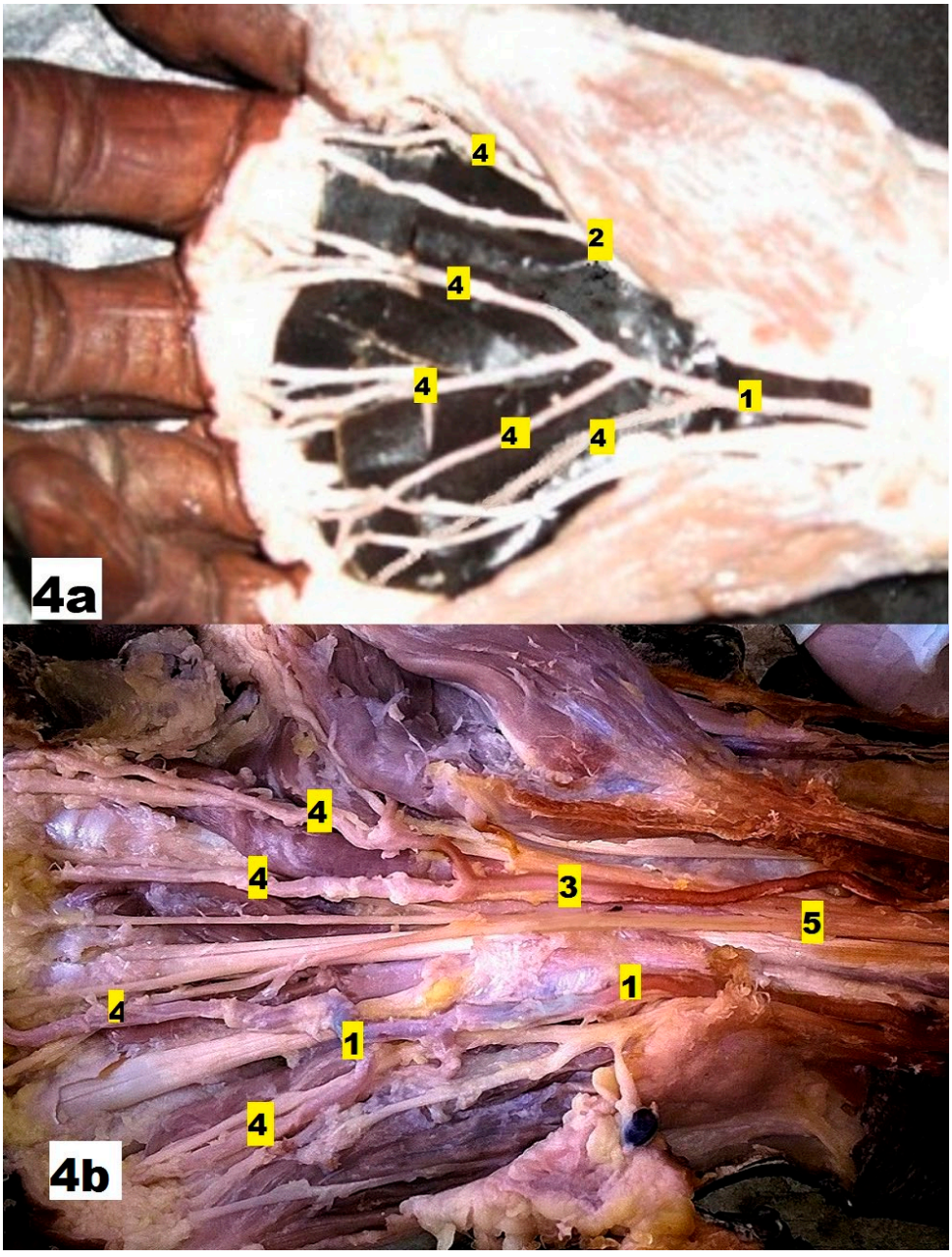

Figure 4. Incomplete superficial palmar arch. a) Radial-ulnar arch (right hand); b) Median-ulnar arch (right hand). 1: ulnar artery; 2: superficial branch of radial artery; 3: median artery; 4: digital branches; 5: median nerve.

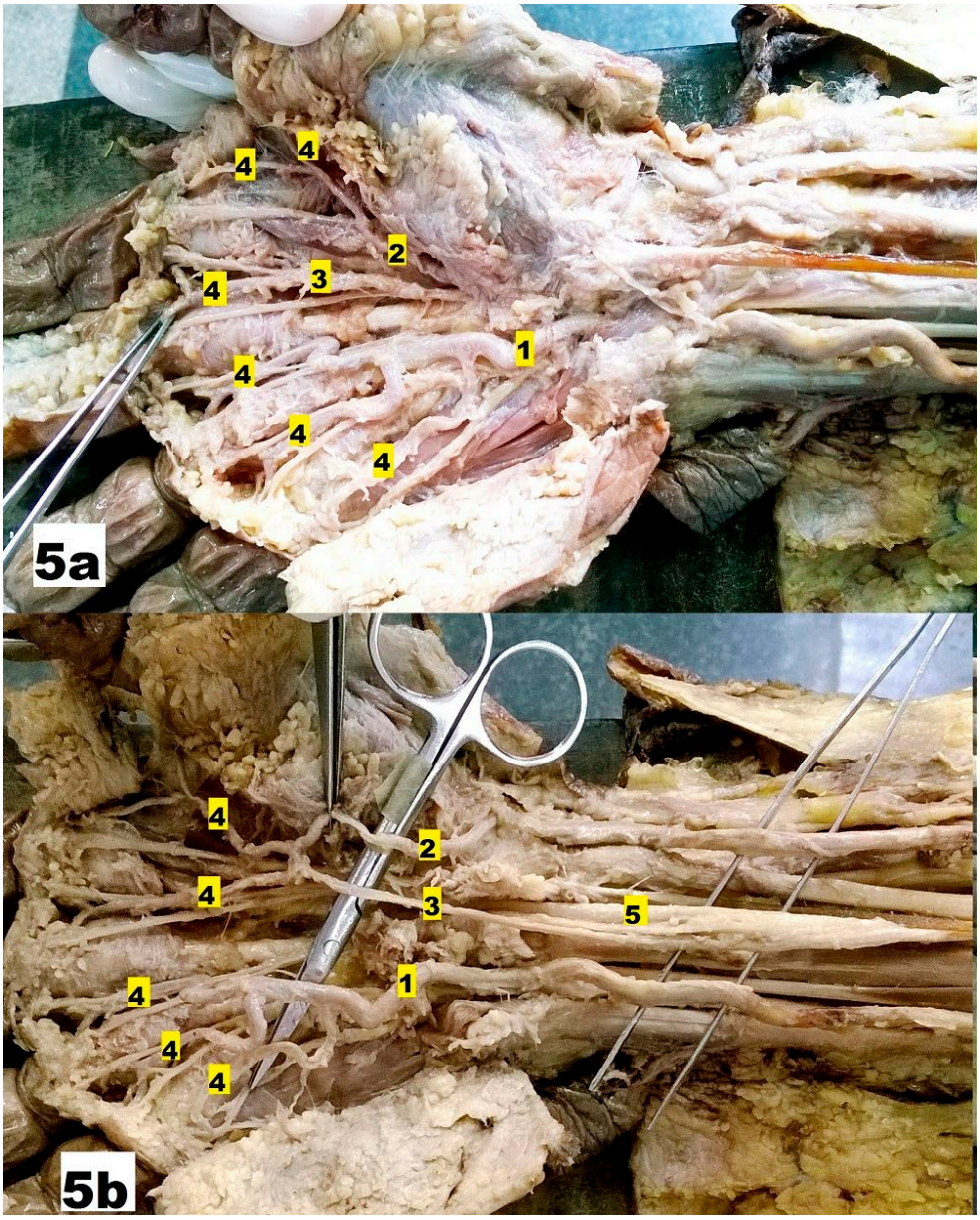

Figure 5. Subtypes of incomplete superficial palmar arch. a) Radial-median-ulnar arch (right hand); b) Combined arch, radial-median and ulnar (right hand.1: ulnar artery; 2: superficial branch of radial artery; 3:median artery; 4 digital branches; 5: median nerve.

interdigital spaces while the radial side of index, the ulnar side of little finger and both sides of thumb were supplied by proper digital arteries. In cases of double arch, all common and proper digital branches arose from SPA, as seen in radial-ulnar complete type but from a distal component which was larger than a proximal one (Figure 3a). In incomplete arches digital branches for the lateral half of hand varied widely. In radial-ulnar incomplete type radial and ulnar artery shared unequal proportions of vascular field and supplied lateral one and a half and medial three and a half digits respectively (Figure 4a). In ulnar incomplete type (Figure 2b), medial 3 fingers were supplied by ulnar artery whereas thumb and index finger were supplied by radial artery, which made a difference from radial-ulnar incomplete subtype. When median and ulnar arteries were present without anastomosis (Figure 4b), both were taking equal shares (lateral two and a half and medial two and a half digits respectively) of digit supply. When radial, median and ulnar appeared in palm without any anastomosis (Figure 5a), the thumb and lateral side of index finger were supplied by radial artery, adjacent sides of index and middle finger by median artery and medial two and a half fingers by ulnar artery. In combined arch (Figure 5b), medial two and a half digits were supplied by ulnar artery whereas lateral two and a half were supplied by branches from radial-median arch.

Discussion

The importance of variations in SPA is highlighted since the time of harvesting radial artery as arterial graft for coronary artery bypass grafting. A key guide to understand the anatomy of the arterial distribution of palm is the classification of SPA into complete and incomplete arches (Mbaka et al., 2014). The anomalies of blood vessels may be due to unusual paths in the primitive vascular plexuses in the form of either persistence of vessels normally disappearing or incomplete development or fusion and absorption of parts usually persisting (Arey, 1957). Complete SPA was observed by Coleman and Anson (1961) in 78.5 % cases, Al-Turk and Metcalf (1984) in 84% cases, Ikeda et al. (1988) in 96.4 % cases, Loukas et al. (2005) in 90 % cases and Gokhroo et al. (2016) in75% cases. In the present study, out of 64 dissected hands, complete arches were found in 76.56% cases of which most were on the left side. In spite of such high incidence of complete arches, blood supply still may be compromised when any contributing vessel is ligated due to variations encountered in these arches. So an in-depth knowledge about the vascular pattern of palm, its dominance and distributions to digits is crucial for hand surgeons.

Ikeda et al., 1988 conducted stereoscopic arteriographic study among 220 specimens and found 55.9% classical type of complete radial-ulnar arch, what we found in 57.81% cases. Doppler ultrasonic flow metric study recorded this type in as many as 78%cases (Al-Turk and Metcalf, 1984), although a lesser incidence (4-10%) was noticed in other studies (Ruengsakulrach et al., 2001a, Joshi et al., 2014).The frequency of ulnar subtype of complete arch reported by previous authors is moderate to high (Karlsson and Niechajev, 1982), however Patnaik et al. (2002) observed a very low incidence (only 2%) and a Doppler ultrasound study (Al-Turk and Metcalf, 1984) did not record this type at all. On the contrary, as 50% SPAs were completely formed by ulnar artery only, authors have denied reporting this pattern as a variant type (Suman and Jayan-

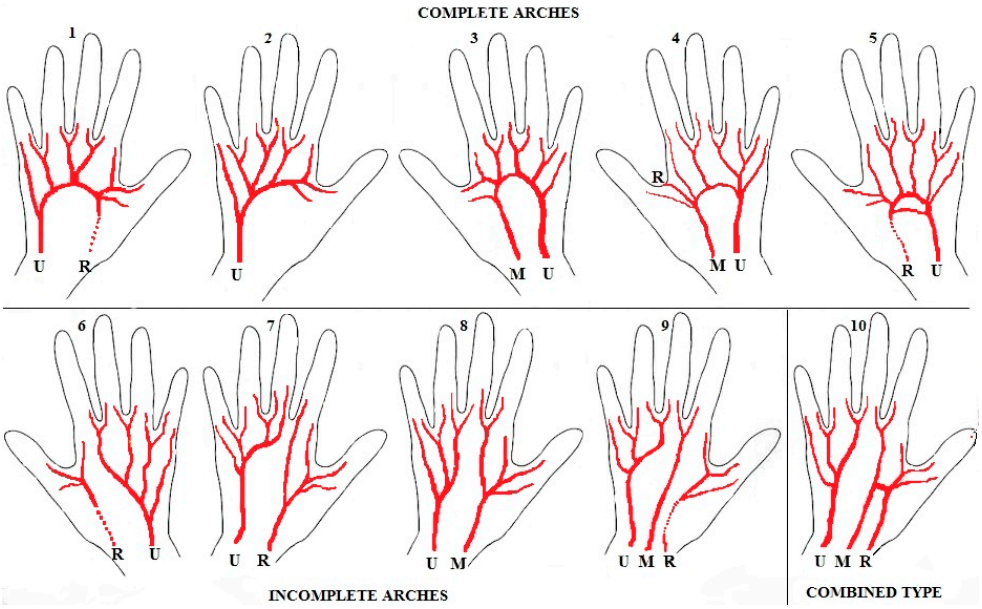

Figure 6. Schematic diagram representing different types of superficial palmar arch with digital branches. U:ulnar artery; R:radial artery; M:median artery.

thi, 2011). We have found such subtype only in 4.69% specimens. Presence of an ulnar complete arch favors free access of radial artery for any surgical intervention without hazard of digital ischemia. But ulnar artery often becomes vulnerable in hypothenar hammer syndrome which is an occupational hazard and would easily lead to post-traumatic vascular insufficiency of hand (Carpentier et al., 2009).

A double arch was reported previously as radial-ulnar and median-ulnar in 16.6% cases (Singh et al., 2012). Patnaik et al. (2002) reported 6% cases where proximal arch was complete but distal one was incomplete. In the present study only radial-ulnar double complete arches were found in 3.13% cases, which is less than previously reported incidence. Based on knowledge of the vascular anatomy of digits, several local flaps can be elevated to reconstruct the defects (Rehim and Chung, 2014). As a double arch contributes an additional collateral it could prove favorable in this field. On the other hand, the presence of a double arch may be fatal as it might lead to serious secondary hemorrhage due to incomplete ligation of vessels in injury (Singh et al., 2012).

Basically collateral circulation is formed to preserve the perfusion well enough to avoid symptoms of ischemia in case of blockage of any arterial system. Hence, aplasia or narrowing of communicating vessels does not lead to any symptoms if individual components are normally functioning and this explains the presence of incomplete arches in otherwise normal persons. But prior to any surgery including incision for draining deep seated abscesses involving palmar spaces special attention should be paid to avoid unexpected complications (Patnaik et al., 2002). We observed such arches in 21.88% cases which is in the line with previous studies (Coleman and Anson, 1961). The highest frequency of distribution was observed for radial-ulnar

subtype (12.5%) where each contributing artery was an independent component of SPA and shared digital supply to lateral one a half and medial three and a half digits respectively. In such circumstances, the radial artery is of immense importance as the main vascular structure on the lateral part of palm and its distribution should be evaluated before any vascular intervention. According to present study incomplete arches were present more on the right side, so it would likely be safe and suggestive for consideration of the left hand as a first choice for arterial graft.

Although a majority of the blood supply to hand is provided by radial and ulnar arteries, additional circulation may come from the median artery or the interosseous arterial system (Ruengsakulrach et al., 2001b). D'Costa et al. (2006) concluded that palmar type of median artery has a higher incidence and may be involved in the pronator teres syndrome, carpal tunnel syndrome and anterior interosseous syndrome. Our study indicates persistent median artery in 18.75% cases which is more than previous reports (Joshi et al., 2013; Coleman and Anson, 1961; Chimmalgi et al., 2004). However, we found a rare pattern of SPA where a radial-median arch was formed providing digital branches for lateral two and half digits and ulnar artery followed a discrete course to supply medial two and half digits. Such type SPA was mentioned in literature but its incidence is not yet reported (Keen, 1961; Nayak et al., 2008). From the present study it becomes clear that if arch is complete then digital arteries are branches of SPA. In incomplete arches, digital supply of lateral half varies in different subtypes but medial half of palm is constantly supplied by branches of ulnar artery (Figure 6). So in claudicatio rest pain or gangrene of medial two and half fingers are sign of digital ischemia; occlusion of ulnar artery without or with insufficient collateral flow from other components of SPA should be in differential diagnosis. Lateral two and half digits receive blood supply either from radial or median or from ulnar artery. Though conventionally radialis indicis and princeps pollicis arise from radial artery, Ruengsakulrach et al. (2001) reported digital supply of thumb coming from SPA in 66% cases. In this study, we found digital supply of thumb and index finger arising from the arch in 78.12%cases, which means that maintenance of collateral circulation of hand would be safe in terms of least number of complications in radial artery interventions. On the other hand, median artery is replacing the radial artery in 12.5% cases in terms of digital supply of lateral two and half fingers, and in 4.7% cases there is a communication persisting between radial and median arteries when both are present. The most striking feature is that supply of ulnar artery in presence of median artery is restricted only to medial two and half fingers instead of its conventional distribution in cases other than complete type.

Thus we can conclude that the presence of persistent median artery leaves free access to radial artery for coronary artery bypass grafting or during hemodialysis without fear of digital ischemia except in radial-median-ulnar incomplete type (1.56%), where thumb and radial side of index finger are supplied by radial artery. It is well-known that in transversely crushed hand, to bridge the gap and repair transected common digital artery, grafting of vein or utilization of palmar arch is the choice of surgery (Korambayil, 2011).In such cases, from an anatomical perspective, we could expect grafting of median artery in future as a better and preferable option if a radial-median-ulnar SPA is present.

It is a matter of fact that the presence of extensive arterial anastomosis in the hand leads to profuse bleeding from its wounds; but for the same reasons, healing

is also very rapid. That's why particular attention has been paid since long time to the superficially placed arch while making incisions. Nowadays, though advanced imaging techniques are used for morphological evaluation, accuracy and reliability of radiological interpretation still often depends on anatomical references. All these data must support decisions in reconstructive surgery. Also, the incidence of rare type of variant, combined SPA found in this study adds to the knowledge of palmar arch. We have not classified the deep palmar arch as it plays only a minor role in digital circulation. Also, SPA was not evaluated for gender difference and hand dominance. These issues may be addressed by further studies on a larger scale.

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There is no conflict of interest to declare.

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