



Newer insights in the anatomy of superficial palmar arch

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Abstract

Purpose The purpose of the study is to study and classify the superficial palmar arch and its variation based upon the gross dissection and to check the bilateral symmetry of the arches. Specifically, we checked for the presence of the superficial palmar arch as described in the standard textbooks.

Methods We dissected 55 hands from 28 cadavers of both sexes that include 18 males and 10 females. The superficial palmar arch was carefully dissected and the arteries contributing its formation were traced. It was classified into complete, incomplete arches. Bilateral symmetry of the arches was also studied.

Results The most common pattern of superficial palmar arch observed is complete. And it is further classified into radio-ulnar and predominantly ulnar types. A consistent proportion of radio-ulnar type arch is completed around first web space. None of the dissected hand meets the definition of the classical superficial palmar arch as described in the standard anatomical textbooks. We also encountered few rare variants of the incomplete superficial palmar arch.

Conclusions Type 1–4 superficial palmar arch is complete and can be utilized for radial artery or ulnar artery cannulation and radial artery harvesting procedure. In type 5 arch, ulnar artery occlusion could lead to severe hand ischemia and at the same time the radial artery in this type can be harvested without ischemic complication. We suggest that the definition of the complete superficial palmar arch should be rechecked and modified as complete superficial palmar or complete superficial first web space arch.

Keywords Arterial cannulation · Coronary graft · Palmar arches · Radial artery · Ulnar artery

Introduction

Human hand receives blood supply through the ulnar artery (UA) and radial artery (RA) after forming superficial and deep palmar arches. The superficial palmar arch (SPA) is the most important as it supplies all the digits of the hand. The SPA is formed by entirely UA alone in one-third case; another third is completed by the superficial palmar branch of radial artery (SPBRA), the further third by radialis indicis artery (RIA) or arteria princeps pollicis (APP) branches of RA or the median artery (MA). APP and RIA arises from the RA either as a common trunk or individually before it turns into the palm as the deep arch. The three common palmar digital arteries to the second, third and fourth web

spaces arise from the SPA where it divides to form proper digital arteries to supply the adjacent digits. The ulnar side of the little finger is supplied by digiti minimi artery [4, 5, 12, 20, 21, 23].

Variation in the formation of the SPA is not uncommon. Keen [12] has described an earlier classification of SPA by Adachi consisting of 3 types namely, the ulnar type—here the RA contribution is absent or minimal, the radio-ulnar type—formed by UA and SPBRA and the mediano-ulnar type—MA reaches the palm to take part in the formation of the arch. According to Keen [12] the classification of the ulnar and radio-ulnar types may vary as it depends upon the observer's interpretation as to what makes a minimal contribution by the RA. Ikeda et al. [8] by arteriographic analysis of 220 hands classified the complete SPA into four groups, but no detailed classification was given about the incomplete type. Ottone et al. [20] grouped the SPA into arch and non-arch type based on presence or absence of anastomosis between the arteries entering the palm and supplying the digits. Gokhroo et al. [7] classified the SPA into complete

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and incomplete arch by arteriogram done through UA cannulation. However, they did not include MA in the SPA classification although it takes part in the arch formation.

RA harvest has been reintroduced recently for coronary artery bypass grafting. RA cannulation is done for continuous monitoring of blood pressure and arterial blood gas analysis in major surgeries. It is also used for creating the arterio-venous fistula for a hemodialysis [3, 7, 10, 11]. There is increased risk of ischemia of hand if the SPA is incomplete, when RA provides dominant supply to the hand or if UA is stenosed and malformed [17].

Understanding the importance of complexity and variation in the formation of the SPA is important for vascular hand surgeons to increase the success of reconstructive hand surgeries involving microvascular repair and reimplantation using composite flaps [25]. Because of its paramount clinical importance in microvascular surgeries and the existing controversies in the literature regarding its formation and classification, the present study was conducted to study and classify the SPA and its variation based upon the gross dissection and to check the bilateral symmetry of the arches. Specifically, we checked for the presence of the SPA as described in the standard textbooks the radio-ulnar type.

Methodology

The study comprised of 55 hands from 28 embalmed cadavers of adult individuals of both sexes (18 males and 10 females). It was performed in the department of anatomy, Jawaharlal Institute of Postgraduate medical education and Research (JIPMER), Pondicherry from the cadavers

procured through the institutional body donation programme following ethical guidelines. In one female cadaver the right hand was damaged, thus, it was excluded from the study. All the hands were dissected according to the Cunningham's manual of Practical anatomy by incising the skin, superficial fascia, and reflecting the palmar aponeurosis [23]. The SPA was traced and variation in the formation of the arch, common digital artery and proper digital arteries arising from it was noted. The arteries were painted with acrylic red colour and photographs were taken. The SPA was classified into two, complete and incomplete types according to Coleman and Anson [5]. The SPA is defined as complete when there is an anastomosis of terminal branch of UA with any of the branches of RA before it continues as deep palmar arch, anastomosis with MA or with both MA and RA in hand, and also as complete SPA when UA alone provides blood supply to all the digits as far as the radial index and ulnar side of the thumb or both sides of the thumb. In the incomplete SPA, the UA supplies little, ring up to middle finger irrespective of anastomosis of RA and MA [3]. Bilateral symmetry of the arch was also noted. The results were expressed in proportions.

Results

The complete SPA was observed in 80% of the dissected hands and incomplete arch in 20%. The complete SPA was classified into radio-ulnar and predominantly ulnar type. Further radio-ulnar type was classified into four types and described in Table 1 in detail with figures (Figs. 1, 2, 3, 4). The incomplete SPA was classified into six types and

Table 1 Classification of the complete superficial palmar arch

Types	Name of the arch	Complete arch	% (n)
1a	Palmar arch Radio-ulnar	Terminal part of superficial branch of ulnar artery anastomosis with superficial palmar branch of radial artery. 1st common digital artery giving radialis indicis artery and artery to the ulnar side of the thumb, 2nd, 3rd, 4th common digital arteries and digiti minimi artery arise from the superficial palmar arch (Fig. 1a)	36.36 (20)
1b	Palmar arch Radio-ulnar	Same as type 1a but 2nd common digital artery arises from deep palmar arch (Fig. 1b)	3.64 (2)
2	1st web arch Radio-ulnar	Terminal part of superficial branch of ulnar artery anastomosis with palmar continuity of first dorsal metacarpal artery in the first web space. Branches arising from the arch supply as far as the ulnar side of the thumb (Fig. 2a, b)	20 (11)
3	1st web arch Radio-ulnar	Superficial branch of ulnar artery anastomosis with superficial palmar branch of radial artery and palmar continuity of first dorsal metacarpal artery in the first web space. Branches arising from the arch supply till both the radial and ulnar side of the thumb	1.82 (1)
4	Palmar arch Radio-ulnar	Terminal part of superficial branch of ulnar artery anastomosis with first palmar metacarpal artery in the first web space (Fig. 3)	1.82 (1)
5a	Palmar arch Predominantly ulnar	The arch is entirely made of the ulnar artery that continues as far as the index finger and thumb without any connection with other arteries (Fig. 4a)	12.73 (7)
5b	Palmar arch Predominantly ulnar	Same as type 5a but the ulnar artery supplies both the side of the thumb (Fig 4b)	1.82 (1)

Fig. 1 **a** Type 1a, **b** type 1b. 1, 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA 1, 2 proper digital artery to the ulnar and radial side of the thumb, SPBRA superficial palmar branch of radial artery, FPMA first palmar metacarpal artery

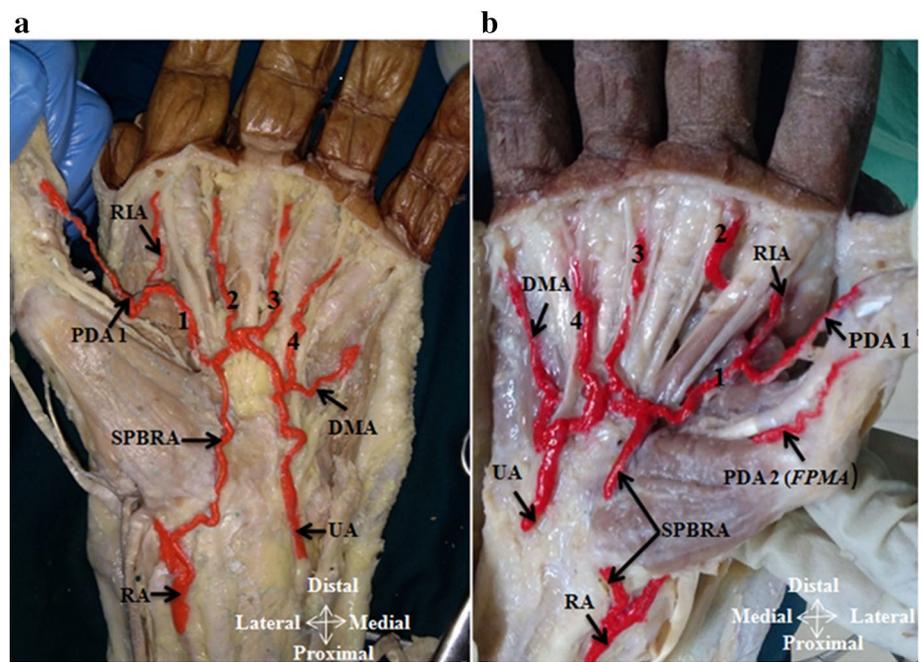
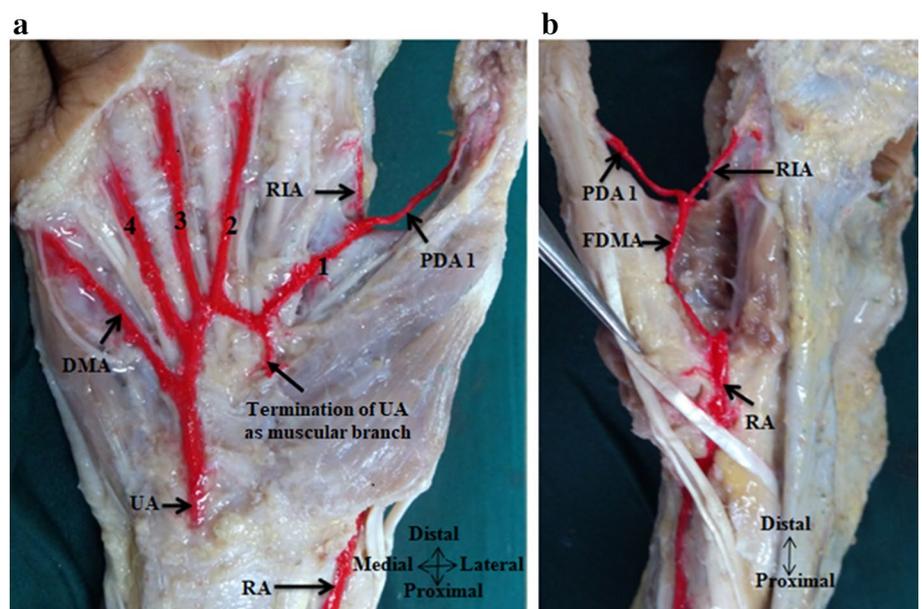


Fig. 2 **a, b** Type 2. 1, 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA 1 proper digital artery to the ulnar side of the thumb, FDMA first dorsal metacarpal artery



described in detail in Table 2 with figures (Figs. 5, 6, 7, 8). Standard textbooks [4, 6, 16] description of the classical complete SPA formed by anastomosis of SPBRA with the terminal branch of UA supplying medial three and a half digits and lateral one and a half digits by RIA and APP from RA is not seen in any of the dissected hands in this study.

Bilateralism was examined in 54 hands of 27 cadavers. Thirteen cadavers exhibited symmetrical SPA. Symmetrical complete SPA type was observed in 40%. Out of which 26% (14 hands) showed type 1a. Type 2 and type 5

SPA was seen in 7.5% each (4 hands each). Symmetrical incomplete SPA was seen in 3.7% cases in type 3 and type 6 (2 hands each). In one of the dissected hands revealing type 1a SPA, the DMA and fourth common palmar digital artery arose from common trunk from the arch (Fig. 1b). The SPA is complete either in the palmar aspect or around the first web space. All the types of complete SPA are segregated under palmar and first web space arch and source artery to each digit is provided (Fig. 9).

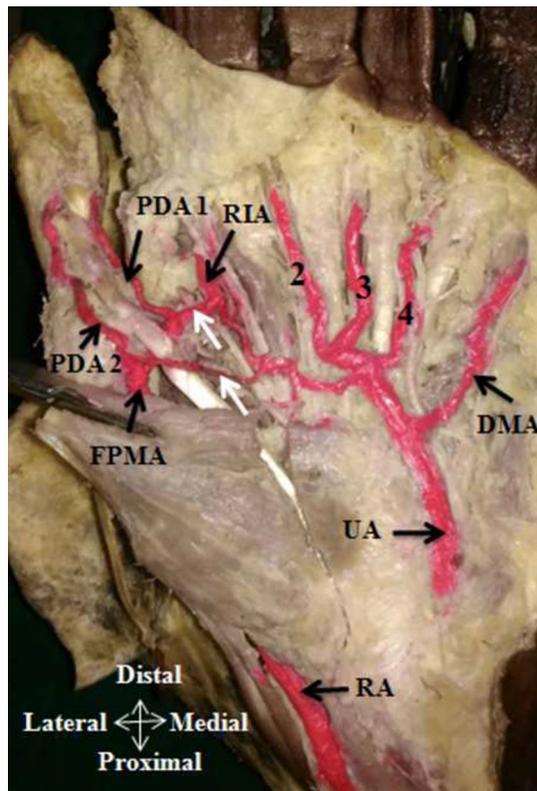


Fig. 3 Type 4. 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA 1, 2 proper digital artery to the ulnar and radial side of the thumb, FPMA first palmar metacarpal artery. White arrows— anastomosis of UA with FPMA

Discussion

The axis artery of the upper limb seventh cervical intersegmental artery continues at first as the anterior interosseous

artery. It runs along the ventral axial line and terminates in the palm as a deep network of capillary plexus. When the latter recedes, it is replaced by MA that grows distally and communicates with the superficial palmar capillary plexus. Digital arteries of the hand develop from the superficial palmar capillary plexus. The MA later recedes and is replaced with the RA and UA. The RA appears earlier and communicates with deep palmar arch and the UA later links with the SPA [4, 8]. Developmentally the variations in blood vessels could be explained due to the persistence of the vessels that are obliterated normally, the disappearance of the vessels that is retained normally, incomplete development of the vessel, faulty fusion and absorption of the parts usually distinct, choice of the variant pathway in the development of primitive vascular plexus [2]. So, the variation in SPA could be due to any one of the above reasons.

Jaschtschinski [9] who is pioneer in classification of SPA has classified SPA in four types namely radio-ulnar, ulnar alone, mediano-ulnar and radio-mediano-ulnar types, respectively, with radio-ulnar being the most common (32–35%). In our study, we further classified the radio-ulnar type into complete and incomplete and further sub classification was based on the branches of SPA supplying the thumb and the fingers. Type Ia complete radio-ulnar arch was the most commonly observed pattern of SPA in our study (36.36%). Lippert and Pabst [14] classified SPA into closed and incomplete arch based on presence or absence of anastomosis between the UA with MA or branches of RA similar to Ottone et al. [14, 20].

Comparison of incidence of different types of SPA with other studies is described in Tables 3 and 4. The incidence of MA reported by other studies varies from 9% to as high as 30% [19]. In our study, in 9% cases, the MA reached the palm and formed incomplete SPA type 9, 10, 11. Olave et al. [19] observed that MA reaching the palm and did not

Table 2 Classification of the incomplete superficial palmar arch

Types	Name of the arch	Incomplete arch	% (n)
6	Palmar arch Radio-ulnar	Superficial branch of ulnar artery-medial three digits. Superficial palmar branch of radial artery-lateral two digits	3.64 (2)
7	Palmar arch Radio-ulnar	Superficial branch of ulnar artery-medial three and half digits Superficial palmar branch of radial artery-lateral one and half digits (Fig. 5)	5.45 (3)
8	Palmar arch Radio-ulnar	Superficial branch of ulnar artery-medial three and half digits. First palmar metacarpal artery branch of radial artery-radialis indicis artery and artery to the ulnar side of the thumb (Fig. 6)	1.82 (1)
9	Palmar arch Median-ulnar	Superficial branch of ulnar artery-medial two and half digits. Median artery-lateral two and half digits except lateral side of thumb (Fig. 7)	5.45 (3)
10	Palmar arch Median-ulnar-radial	Superficial branch of ulnar artery-medial three and half digits. Median artery-lateral one and half digits except lateral side of thumb. Median artery anastomosis around 1st web space with first dorsal metacarpal artery (Fig. 8)	1.82 (1)
11	Palmar arch Median-ulnar-radial	Superficial branch of ulnar artery-medial three and half digits. Median artery-lateral one and half digits including lateral side of thumb. Median artery anastomosis around 1st web space with first dorsal metacarpal artery	1.82 (1)

Fig. 4 a Type 5a, type 5b. 1, 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA1, 2 proper digital artery to the ulnar and radial side of the thumb

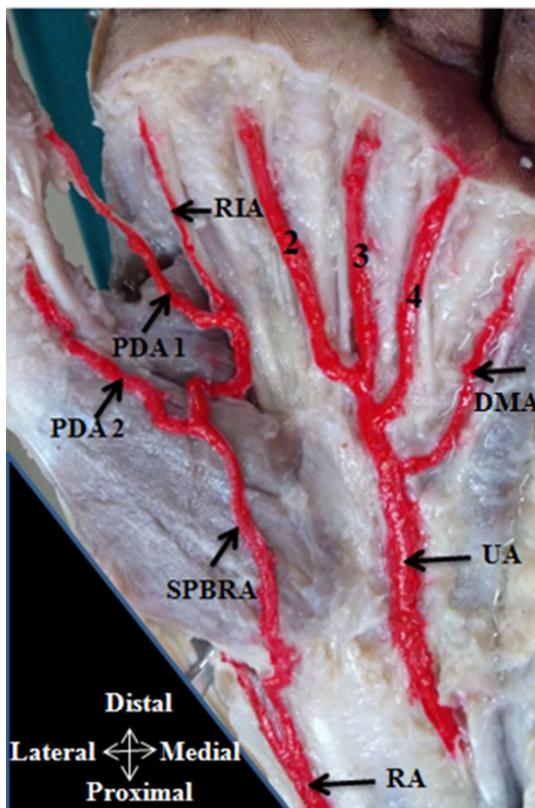
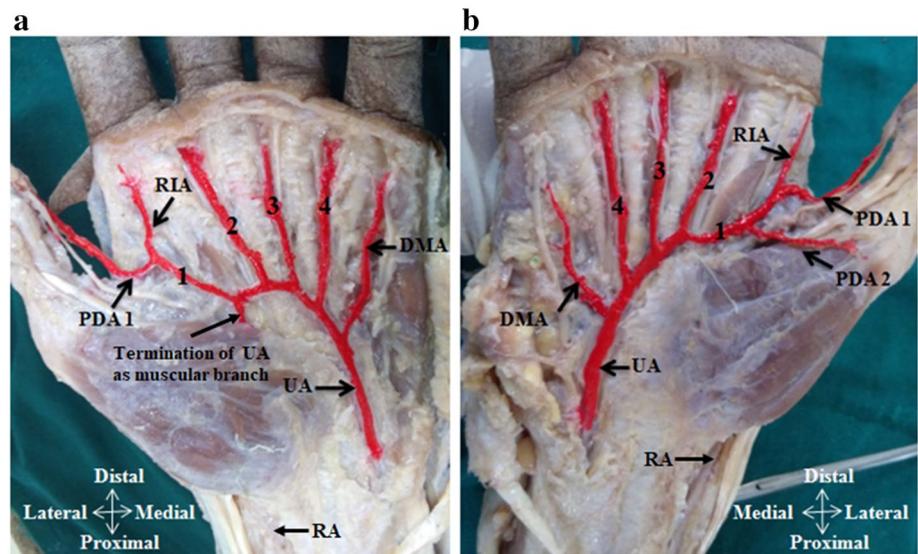


Fig. 5 Type 7. 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA1, 2 proper digital artery to the ulnar and radial side of the thumb, SPBRA superficial palmar branch of radial artery

anastomose with either UA or branches of RA in 6.8% cases. Out of which 4.9% corresponds to the type 9 SPA observed in our study (5.45%). Remaining in 1.9% subjects, the MA

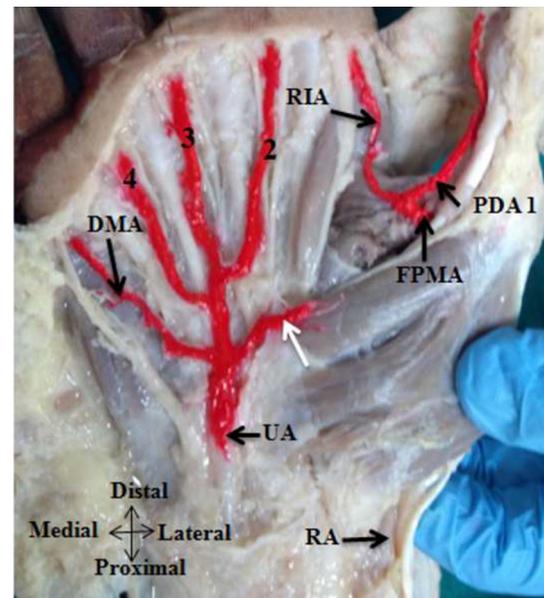


Fig. 6 Type 8. 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA1 proper digital artery to the ulnar side of the thumb, FPMA first palmar metacarpal artery, white arrow—thenar branch

just supplied the lateral one and half digits. Nayak et al. [18] reported the type 9 SPA in 3.5% cases. The mediano-ulnar and radio-mediano-ulnar types of SPA reported by Coleman and Anson [5] in 3.8% and 1.2% hands and by Al-Turk and Metcalf [1] in 4% and 2% hands are not seen in present study.

The recent meta-analysis by Zarzecki et al. [27] reported that SPA was complete in 81.3% with radio-ulnar anastomosis being the most common variant (72%) and incomplete SPA in 18.7% of cases. Ikeda et al. [8] also could not find the

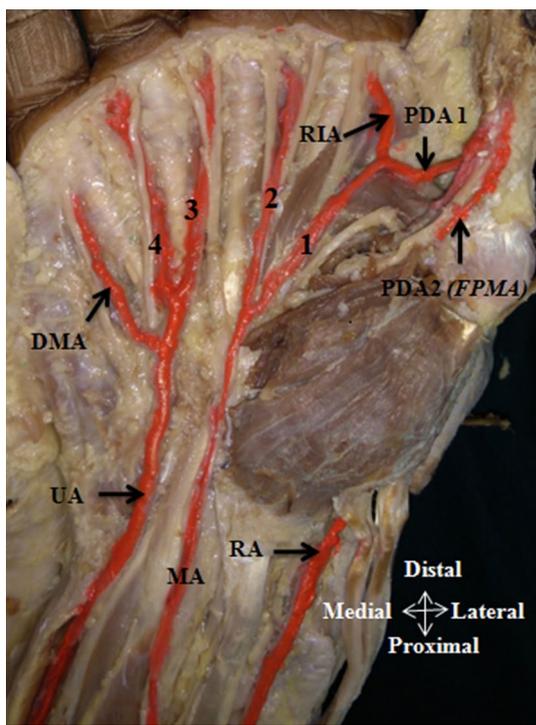


Fig. 7 Type 9. 1, 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, MA median artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA1, 2 proper digital artery to the ulnar and radial side of the thumb, FPMA first palmar metacarpal artery

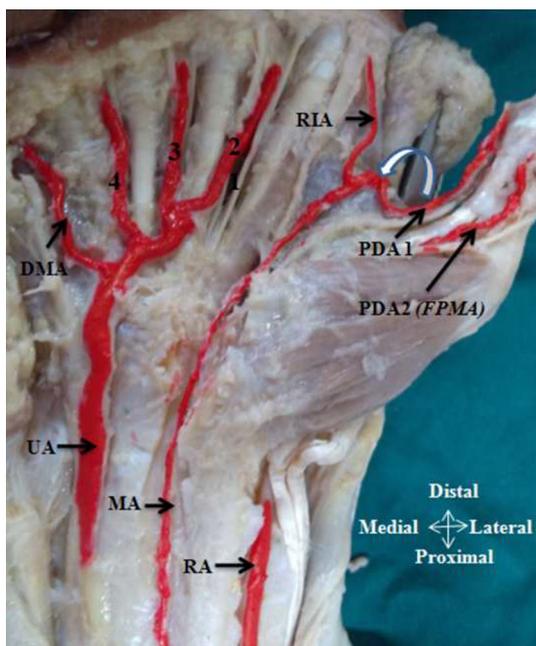


Fig. 8 Type 10. 2, 3, 4 common palmar digital artery, UA ulnar artery, RA radial artery, MA median artery, RIA radialis indicis artery, DMA digiti minimi artery, PDA1, 2 proper digital artery to the ulnar and radial side of the thumb, FPMA first palmar metacarpal artery. White arrow— anastomosis of MA with first dorsal metacarpal artery

mediano-ulnar type in their study but radio-mediano-ulnar in 0.9% of subjects. The incidence of both types reported by Loukas et al. [15] in 200 hands was relatively high (15% and 6%). Keen [12] had mentioned that Adachi observed in 3.64% a rare variant of SPA called as radio-medial type in which the MA anastomosis with the RA and the UA have very minimal or absent contribution to the arch. This corresponds to type 10 and 11 as seen in our study. The same was observed by Nayak et al. [18] in 1.1% subjects. Sawant [24] observed variation in SPA in 36 out of 200 hands. In 15 hands, the SPA was formed by UA alone that gave RIA and APP branches. In another 15 hands, the SPA was of mediano-ulnar type.

Patnaik et al. [21] found double SPA in 6% (3 of 50) limbs and encountered radio-ulnar in two and mediano-ulnar in one limb. In the absence of the SPA, which connects the RA and UA, if the RA thrombosis occurs following cannulation, the patient would be at increased risk of developing ischemia of hand supplied by branches of RA [11, 17, 26]. So, all complete SPA escapes ischemia and all incomplete SPA are at increased risk according to our study. The MA in the carpal tunnel if it develops an aneurysm, thrombosis or an increase in caliber could compress the median nerve and consequently develops carpal tunnel syndrome [19].

An RA graft is preferred in coronary artery bypass surgery for several following reasons: the RA diameter is close to that of the coronary artery, the wall of the artery has an appropriate thickness and resistance for a graft and the RA length is sufficient for myocardial revascularization. An RA graft is relatively easy to harvest, and it can be kept for long periods similar to internal mammary arteries [7]. Harvesting RA may cause the development of ischemic signs in the hand in case of presence of anatomical variations such as incomplete SPA, UA malformation and dominance of the RA in vascularization of the hand or atherosclerotic stenotic lesions in UA [7, 22]. Hence, the RA can be harvested safely in all complete SPA types except type 2b. First dorsal metacarpal artery (FDMA) flaps in different forms such as island flap, pedicled flap, and reverse flow flap has been used widely in thumb reconstructive surgeries [25]. The FDMA in type 2, 3, 4 complete SPA and type 9, 10, 11 of incomplete SPA can be used in taking FDMA flaps. In both the groups, the thumb and the index finger escape ischemia as they are supplied by collaterals by either UA or MA. Anatomical knowledge of variation in SPA is also helpful in vascular reconstructive surgeries of the injured hand [13]. In our study, complete SPA is seen in 80% cases which imply that collateral circulation is well maintained in most of the hands between UA and RA.

The risk of hand ischemia following RA harvest or occlusion of RA following cannulation could be prevented by proper evaluation for the complete SPA. Various methods are available such as modified Allen test, Doppler

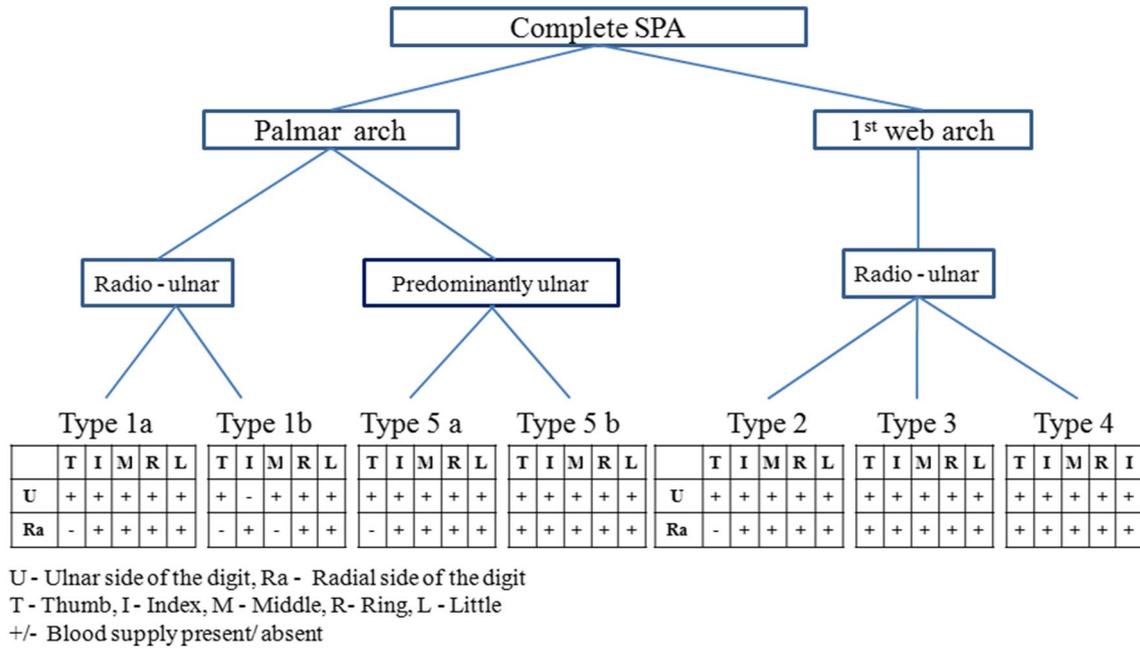


Fig. 9 Flowchart depicting the new classification of complete superficial palmar arch

Table 3 Comparison of incidence of different types of complete SPA with other studies

S. no.	Various studies	Complete arch (%)	Classical type (%)	Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	Type 5	Others (%)
1	Present study	80	–	40	20	3.6	1.82	14.54	–
2	Coleman and Anson [5]	78.5	34.5	–	–	–	–	37.0	7
3	Ikeda et al. [8]	96.4	55.9	–	–	–	–	25.5	15
4	Patnaik et al. [21]	78	76	–	–	–	–	2	–
5	Loukas et al. [15]	90	40	–	–	–	–	35	15
6	Bilge et al. [3]	86	–	34	28	–	–	14	10
7	Ottone et al. [20]	87	–	20.9	8	–	–	20.9	–
8	Joshi et al. [10]	82	4	–	–	–	–	56	22

Table 4 Comparison of incidence of different types of incomplete SPA with other studies

S. no.	Various studies	Incomplete arch (%)	Type 6 (%)	Type 7 (%)	Type 8 (%)	Type 9 (%)	Type 10 (%)	Type 11 (%)	Others (%)
1	Present study	20	3.64	5.45	1.82	5.45	1.82	1.82	–
2	Coleman and Anson [5]	21.5	3.2	–	–	–	–	–	17.2
3	Ikeda et al. [8]	3.6	–	–	–	–	–	–	–
4	Patnaik et [21]	16	12	–	–	–	–	–	4
5	Loukas et al. [15]	10	–	–	–	–	–	–	–
6	Bilge et al. [3]	14	6	–	–	–	–	–	8
7	Ottone et al. [20]	13	–	8.3	–	4.7	–	–	–
8	Joshi et al. [10]	18	4	–	–	–	–	–	14

ultrasonography, plethysmography, CT angiography, digital subtraction angiography and Doppler ultrasonography being the gold standard procedure among all [3]. Since the formation of complete SPA does not follow the standard description given in textbooks, it can be proposed that “Complete SPA can be defined as complete superficial palmar or first web arch based on whether the arch is completed by anastomosis of terminal branch of UA with the branches of RA in palmar aspect or around the first web space and if UA alone provide blood supply to all the digits from the palmar aspect of the hand”.

The study is performed in fresh embalmed cadavers. As there is shortage of fresh embalmed cadavers our study includes only 55 hands. However, it can be considered as limitation of the study. Caliber of the vessels has not been measured as our area of interest was to classify the SPA. Anatomical study by in vivo dynamic imaging is the future scope of our study.

Conclusion

Type 1 to 4 SPA is complete and can be utilized for RA or UA cannulation and RA harvesting procedure. In type 5 arch, UA occlusion could lead to severe hand ischemia and at the same time the RA in this type can be harvested without ischemic complication. We suggest that the definition of the complete SPA should be rechecked and modified as complete superficial palmar or complete superficial first web arch. Thus, understanding the variability and the types of complete or incomplete SPA may help in increasing the success rate of various interventional procedures of hand.

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Author contributions RV: Project development, manuscript editing. DG: Project development, data collection, data analysis, manuscript writing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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