

## Original Research Article

# Anatomical variations of radial artery and its morphology with clinical implications

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## ABSTRACT

**Background:** The radial artery (RA) is a continuation of the brachial artery and is one of the major blood supplying vessels to the structures of the forearm. It is originated in the cubital fossa at the level of the neck of the radius. It runs on the lateral aspect of the forearm before it reaches the wrist and branches out to supply the hand. The RA is also important clinically due to its location at the wrist, as it can be felt as a pulse and can be used to determine the heart rate. It is the artery of choice for coronary artery angiography, percutaneous coronary artery intervention, cannulation, and others. The main objective of this study is to study the variation in origin and course of the RA in cadavers.

**Methods:** The present study was conducted with 100 upper limbs of 50 cadavers in the department of anatomy, Gouri devi institute medical sciences and hospital, Durgapur, West Bengal over a period of 2 years. By conventional dissection method, the axillary region, arm, forearm, and hand of each limb were dissected to clarify the course and branches of the RA. This anatomical descriptive study was conducted after approval of the ethical committee. The study period was March 2018 to August 2020.

**Results:** RA took high origin from the brachial artery in arm is 6.66%. The maximum length was measured was 23.7 cm, minimum length was 18 cm and the mean value is 21.25. The RA after giving its branches continued in the forearm. In 96.88%, RA arose normally in cubital fossa.

**Conclusions:** The anatomy and morphology of RA have many documented variations. Radiologist and surgeons should have a good understanding of normal morphological variations of RA.

**Keywords:** RA, Brachial artery, Ulnar artery, Recurrent RA, Anterior interosseous artery, Arteria princeps pollicis, Superficial palmar arch

## INTRODUCTION

A comprehensive understanding of the possible arrangements of the arterial pattern of the upper limb is of great clinical importance.<sup>1-6</sup> In particular, the RA demonstrates high anatomical variability regarding its origin, various arrangements of radial recurrent arteries, and the vascular territory within the hand.<sup>6,7,10,15-19</sup> The origin of the RA is commonly located in the cubital fossa at the level of the neck of the radius.<sup>20</sup> The brachial

artery provides the main arterial supply to the arm. It begins as a continuation of axillary artery at the lower border of teres major muscle and terminates by dividing into RA and UA at the level of the neck of radius in cubital fossa.<sup>21</sup> Variations in the origin, branching pattern and course of the arteries of upper limb have received the attention of anatomists, cardiologists and vascular surgeons. Incidence of variation in the arterial pattern of the upper limb varies from 18.53% to 20%.<sup>10,12</sup> Knowledge about the vascular structure of the upper

extremity is important for diagnostic interventions and surgical approaches.<sup>22</sup> In the inferior part of the cubital fossa medial to the biceps tendon, the brachial artery bifurcates into radial and ulnar arteries.<sup>23</sup> It arises at the level of the neck of radius and runs on the lateral aspect of the forearm, beneath the brachioradialis muscle, lateral to the flexor carpi radialis. It extends from the cubital fossa to the palm and ends by anastomosing with the UA to form deep palmar arch.<sup>20</sup> The trunk of RA is divided into three parts. The first part is from the origin to the apex of styloid process, second part curves round the lateral side of the wrist to the proximal part of first interosseous space and the third part passes through the interosseous space into the palm.

## METHODS

This was a descriptive type of anatomical study conducted by the conventional dissection method the axillary region, arm, forearm, and hand of each limb were dissected to clarify the course and branches of the RA in 100 (42 male and 8 female) adult age group of upper limb specimens, which were obtained from 50 embalmed cadavers which were allotted for routine academic dissection to the first year MBBS Gouri Devi institute medical sciences and hospital, Durgapur, West Bengal over the period of 2 years i.e. from between March 2018 to August 2020. After getting the approval from the ethical committee clearance this work was started.

### *Conventional dissection method*

A horizontal incision was made in arm at the junction of the upper 1/3 and middle 1/3. A vertical incision was made from the middle of cubital fossa to the wrist extending over the palm up to the tip of middle finger. This incision was extended upwards meeting the first horizontal incision. Another horizontal incision was made at the level of wrist and the skin flap was raised medially and laterally. Another horizontal incision was made in the palm at the level of base of metacarpals and the skin flaps were raised. The deep fascia of the forearm was reflected. The RA lies in the groove between the two groups of extensor and flexor muscles along with the superficial radial nerve.

RA was traced proximally up to its origin from the brachial artery in the cubital fossa or higher up in the arm. The length of RA was measured from its origin to the styloid process using thread and it was transferred to the scale. At wrist joint, dissection was done to identify the palmar and dorsal carpal arteries and the superficial palmar branch. The superficial palmar branch was traced distally into the palm after splitting the palmar aponeurosis. The RA passing between the heads of first dorsal interosseous muscle and its branches, arteria princeps pollicis and arteria radialis indicis in the palm were identified in the palm, and formation of deep palmar arch was noted and photographed.

## RESULTS

### *Site of origin of RA*

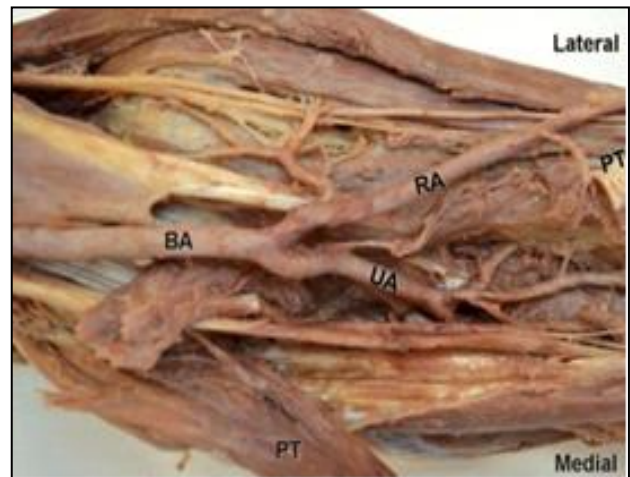
Of the 100 upper limb specimens dissected, in 94 specimens (94%) the origin of RA was found from the brachial artery (BA) in cubital fossa (CF) (Figure 1). In 6 specimens (6%) was the RA arose from the brachial artery (BA) in the arm (Figure 2).

### *Course of RA*

In all the dissected specimens, course of the RA was found to be normal (Figure 3).

### *Length of RA*

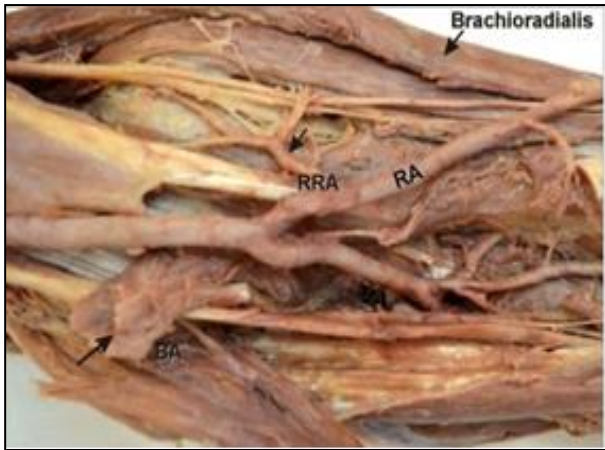
Length was measured from origin of RA in CF to styloid process, excluding the high origin. The minimum length of RA was 18 cm, maximum length was 23.7 cm and the mean length was 21.25 cm.



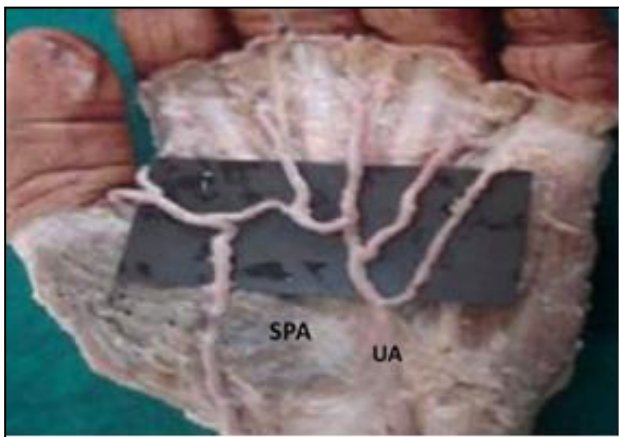
**Figure 1: Origin of RA from brachial artery (BA) in cubital fossa.**



**Figure 2: High origin of RA from BA.**



**Figure 3: Origin of recurrent radial artery (RRA) from RA completes the SPA.**



**Figure 4: Superficial palmar branch.**

*Branches of RA*

*Recurrent radial artery (RRA)*

Out of 100 upper limbs dissected, in 96 specimens (96%) RRA arose from the RA near its origin (Figure 3). In 2 specimens (4%) of upper limb RRA arose from the UA. In 2 specimens (4%) accessory RRA was present and they arose from the RA near its origin.

*Superficial palmar branch (SPB)*

Out of 100 lower limbs dissected, SPB of RA ends by completing the superficial palmar arch (SPA) in 70 (70%) specimens (Figure 4), it ends by dividing into arteria princeps pollicis (APP) and arteria radialis indicis (ARI) in 16 (16%) specimens and it ends by supplying the thenar muscles in 10 specimens (10%). It divides into 4 common digital arteries (for the first and second web space) in 4 specimens (4%). In 50 specimens (50%) SPB of RA passes through the substance of thenar muscles, in 38 specimens (38%) RA passes superficial to the thenar muscles and in 12 specimens (12%) it ends by supplying the thenar muscles (Table 1).

*Arteria princeps pollicis (APP) and arteria radialis indicis (ARI)*

Out of 100 specimens dissected, APP and ARI arose as common trunk from SPA (formed by the SPB of UA and RA) in 72 specimens (72%), from the SPA formed by the UA alone in 8 specimens (8%), from the common digital artery (branch from the SPB) to the first web space in 4 specimens (4%), and as the terminal branches of SPB in 16 specimens (16%) (Table 1).

**Table 1: Superficial palmar branch (SPB) of RA.**

SPB of RA and Origin of APP, ARI and CIA	N	%
<b>Completing the SPA</b>	70	70
<b>Divides into APP and ARI</b>	16	16
<b>Ends by supplying the thenar muscles</b>	10	10
<b>Divides into common digital arteries to the 1<sup>st</sup> and 2<sup>nd</sup> web space</b>	4	4
<b>Passes through thenar muscles</b>	50	50
<b>Passes superficial to thenar muscles</b>	38	38
<b>Ends by supplying thenar muscles</b>	12	12
<b>From SPA (formed by the of UA and RA)</b>	72	72
<b>From SPA formed by UA alone</b>	8	8
<b>From common digital artery to the first web space (from SPB)</b>	4	4
<b>As terminal branches of SPB</b>	16	16
<b>From UA</b>	98	98
<b>From RA</b>	2	2

*Palmar carpal branch (PCB)*

In all the dissected specimens, PCB of RA arose from the RA at the level of wrist joint.

*Dorsal carpal branch (PCB):* DCB of RA arose from RA at the level of wrist joint in all 100 dissected specimens.

*First dorsal meta carpal artery (FDMA):* In all the dissected specimens, FDMA arose from the RA in the dorsal aspect of hand before it passes between the two heads of first dorsal interosseous muscle.

*Any other branches of RA:* Out of 100 upper limb specimens dissected, common interosseous artery (CIA) arose from the RA in CF in 2 specimens (2%). In 98 specimens (98%) CIA arose from the UA (Table 1).

**Completion of superficial palmar arch (SPA) by RA**

Out of 100 specimens, complete arch observed in 80 specimens (80%), incomplete arch-20 specimens (20%).

The complete SPA was classified in to five types based on the classification of Coleman and Anson as follows: type I: SPB of RA UA with the SPB of RA, observed in 70 specimens (70%), type II: Entirely formed by the UA,

observed in 8 specimens (8%), type III: Mediano-ulnar arch, not observed in the present study, type IV: Radio-mediano-ulnar arch, not observed in the present study and type V: UA with the branch from deep palmar artery was observed in 2 specimens (2%).

The incomplete SPA was classified into four types based on the classification of Coleman and Anson as follows: Type I: SPA formed by the UA, which does not contribute to the blood supply of thumb and index finger (APP and ARI), which arose from the SPB of RA, observed in 4 specimens (4%). Type II: common digital artery to the 1<sup>st</sup> and 2<sup>nd</sup> web spaces was from the SPB of RA and to the 3<sup>rd</sup> and the 4<sup>th</sup> web spaces was from the UA, observed in 16 specimens (16%). Type III: SPA formed by the independent radial, median and ulnar arteries with APP and ARI as branches from the median artery, not observed in the present study. Type IV: SPA formed by the independent radial, median, ulnar arteries. Common digital artery to the 1<sup>st</sup> web space from RA, artery to 2<sup>nd</sup> web space from median artery and arteries to the 3<sup>rd</sup> and 4<sup>th</sup> web space from UA, not observed in the present study Median artery not observed in this study.

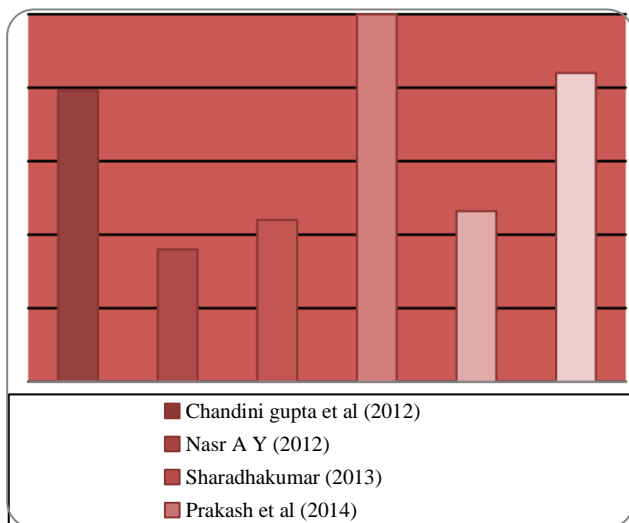
**Formation of deep palmar arch (DPA)**

In all the dissected specimens, DPA was formed by the RA, completed by the deep palmar branch of UA.

**DISCUSSION**

**Origin of RA**

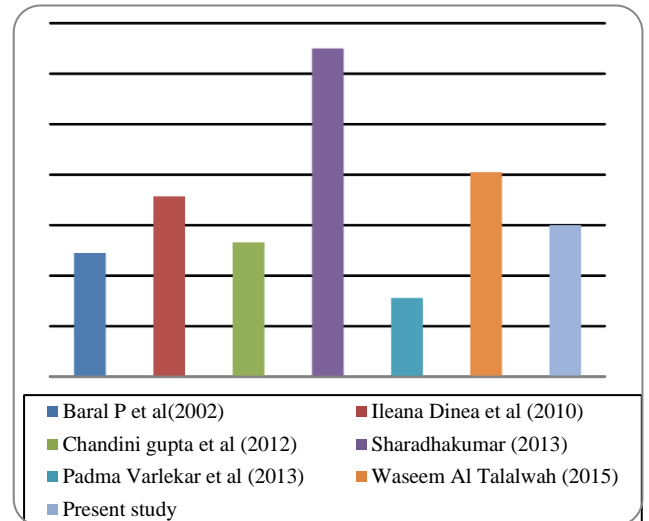
In the present study, in 96% specimens of RA arose from the brachial artery in cuboidal fossa was similar to studies mentioned above (Figure 5).<sup>11,25-27</sup> The absence of RA as mentioned in Suganthi et al and Dogan et al was not found in the present study.<sup>22,23</sup> The persistence of median artery also not found in study as noted by Dogan et al.



**Figure 5: Origin of RA from BA in CF origin of RA from BA in CF.**

**High origin of radial artery (HORA)**

In the present study HORA from BA in arm was observed in 3 specimens (6%) (Figure 6).<sup>25,26,29-32</sup> Radial artery was the third most common artery used as a graft for CABG, as the diameter of RA is similar to that of coronary artery. RA arising at a higher level may have a smaller diameter which cannot be used for grafting and also leads to failure of catheterization.<sup>24</sup>



**Figure 6: High origin of RA (HORA).**

Autologous grafting of RA has a decreased incidence of hypo perfusion syndrome compared to the internal mammary artery grafting.<sup>28</sup> High origin of RA in the arm is more prone to accidental injury and heavy bleeding.<sup>33</sup> It can be mistaken for vein and ligated during surgery on humerus leading to gangrene of hand. Usually, the blood pressure is recorded by auscultating the BA in the CF. HORA may be associated with difficulty in measuring the blood pressure.

Hence knowing the origin of RA is mandatory for the orthopedic surgeries and vascular surgeries.

**Course of RA**

In the present study, course of RA was normal in all the specimens (100%). Superficial course of RA was not found. Cutaneous and Muscular branches are given off from the RA in the lateral aspect of forearm. Radial Artery is easily accessible for interventional and diagnostic procedures as most of its course in forearm is superficial which lies deep to deep fascia is normally. In its course, radial artery is not closely related to any neurovascular structures in forearm. Also, the collateral blood supply by the UA in the hand makes it suitable for invasive procedures like catheterisation and grafting.<sup>26</sup> superficial course of radial artery in the CF may be mistaken for vein and is more dangerous during median cubital vein puncture. Accidental intra arterial injections will lead to arterial spasm and even gangrene of hand. Superficial

course of RA in forearm is more prone for injuries. Reconstruction of mandible and thumb is done using the radius. The bony flap is vascularised by the muscular branches of Radial Artery the radius is harvested from the insertion of pronator teres proximally to the insertion of brachioradialis distally. Hence the knowledge about the course of RA is important.

**Length of RA**

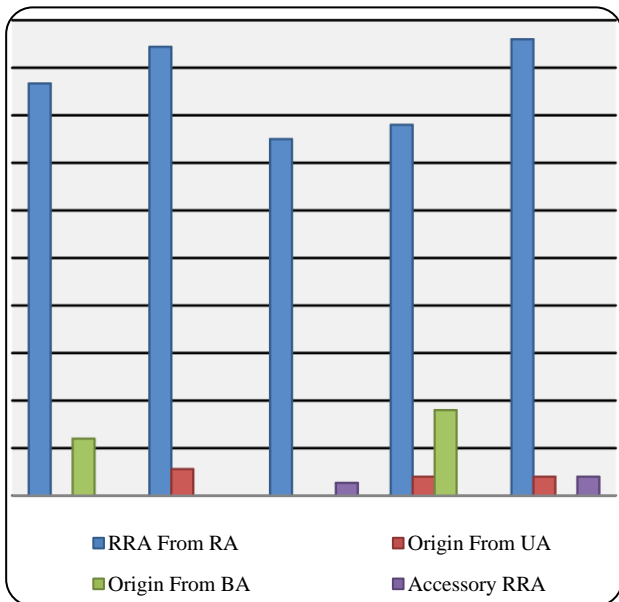
In the present study the mean length of RA was 21.25 cm. Entire length of RA from origin to styloid process will be harvested for CABG as arterial length needed for the surgery is around 20 cm.<sup>11,27</sup>

**Branches of RA**

*Recurrent radial artery (RRA)*

In present study 96% of RRA arose from RA and in 4% it arose from UA and no RRA arose from BA. Accessory RRA was present in 4% of specimens (Chart no: 3). Findings in the present study coincide with study done by Hamahata et al, Prakashet al and Vazquez et al.<sup>16,18,27</sup>

As the anastomosis around elbow is well developed, RRA based flap is used for microsurgical and reconstruction procedure around elbow. Survival of RRA flap is high. Presence of accessory RRA has an additional advantage during harvesting of the flap.



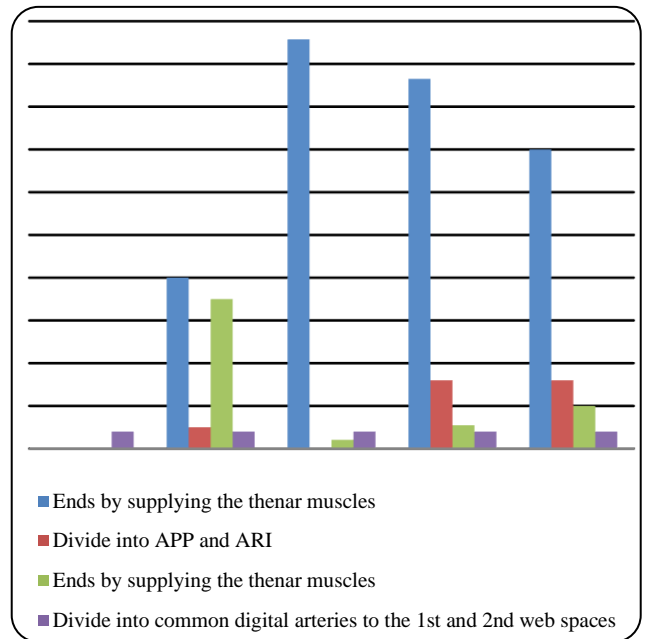
**Figure 7: Origin of RRA and presence of accessory RRA.**

*Superficial palmar branch (SPB)*

In the present study SPB of RA ends by anastomosing with the UA to form SPA in 70%, divides into APP and ARI in 16%, as a slender branch ends by supplying the

thenar muscles in 10% and divides into common digital arteries to the first two web spaces in 4%, which is similar to the studies done by Madhyastha et al and Gupta et al (Figure 8).<sup>25,34,36</sup>

RA is the third most commonly used graft next to right and left internal mammary artery for CABG. If the SPB of RA does not complete the SPA, harvesting the RA will lead to loss of blood supply to the thumb resulting in gangrene. Knowledge about the termination of SPB of RA is essential before harvesting the RA for CABG.<sup>35</sup>



**Figure 8: Mode of termination of SPB of RA.**

*Arteria princeps pollicis (APP) and arteria radialis indicis (ARI)*

In the present study, APP and ARI arose from the SPA formed by the UA completed by the RA in 72%, from SPA formed entirely by UA in 8%, from SPB of RA (as its terminal branches) in 2%, from the artery to the first web space a branch of SPB in 6% of specimens.<sup>36-39</sup>

Blood supply to the thumb and index finger is by the APP and ARI. Grafting of RA is done during CABG. Knowledge about the arterial supply of thumb and index finger is essential before harvesting the RA.

*Palmar carpal branch (PCB)*

In the present study PCB arose from the RA at the level of wrist joint, coursed medially deep to flexor tendons in all the specimens. PCB of RA participates in the formation of anterior carpal arch, any injury around the wrist joint causes severe bleeding and it is necessary to ligated all the arteries participating in the formation of arch.<sup>40</sup>

### Dorsal carpal branch (DCB)

In the present study, in all the specimens DCB arose from the RA deep to the tendons of anatomical snuff box. Arterial anastomoses around wrist joint may cause heavy bleeding in case of injury.<sup>41</sup> Ligation of all the arteries taking place in anastomoses is essential to control the bleeding.

### First dorsal meta carpal artery (DMA)

In the present study, first DMA arose from the RA in the dorsal aspect of hand in all upper limbs, which is similar to the studies mentioned above. First DMA based flaps is used for the reconstruction of thumb in crush injuries as it has a subcutaneous course. The nutrient artery to the first metacarpal bone is a branch from the first DMA, so injury of the artery may lead to a vascular necrosis of the bone. Hence the knowledge about the origin and the course of FDMA is important.

### Any other arteries from RA

In the present study 2% of CIA arose from the proximal part of RA.<sup>26,29</sup>

Knowledge about such variation was important during invasive and non-invasive investigative procedures, orthopedic, reconstructive and surgical procedures to avoid unnecessary complications.

### Completion of superficial palmar arch (SPA) by RA

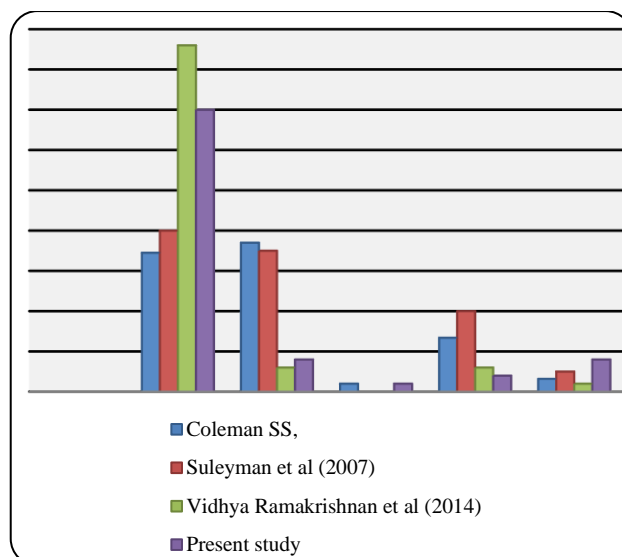
In the present study, 80% of specimens showed complete arch and 20% of specimens showed incomplete arch (Figure 9).<sup>36,39,42</sup> Among the complete arches, type I was 70%, type II was 8% and type V was 2%. Type II and IV were not observed in the present study. Of the incomplete arches, type I was 4% and type II was 8%. Type III and IV were not observed in the present study. Injury to the SPA can compromise the arterial supply of the fingers, especially if there is an insufficient anastomosis between the RA and UA.<sup>43,44</sup> Knowledge about the arterial arches of hand is important during the microsurgical procedures in hand reconstructions and harvesting of the RA for CABG.<sup>33,45</sup>

Hence it is mandatory to investigate the arterial pattern of hand before any invasive procedures.

### Formation of deep palmar arch (DPA)

In the present study, DPA was present in all specimens and the RA contributed to the formation of arch.

Any injury in hand will bleed profusely and heal quickly, as hand is richly supplied by the arterial arches. Knowledge about the blood supply of hand is essential during microsurgical hand reconstructive procedures for safe and successful outcomes.



**Figure 9: Completion of superficial palmar arch (SPB) by RA.**

### Limitations

Here in our study, we have not studied in depth about the branching pattern in the forearm i.e., from cubital fossa to the flexor retinaculum. Arterial anastomoses around the elbow joint. And there is scope to extend the study about the RA in the diagnostic procedures like angiographs, and etc.

### CONCLUSION

The RA and its branching pattern have been of great interest to anatomists and surgeons, due to wide clinical and radiological implications. Present study was done to document and provide information of both normal and variant morphology of the RA in adult human cadavers by dissection method. RA is one of the most commonly used arterial vessels for monitoring, interventions and a wide variety of procedures. There were variations with respect to the origin, course and branching pattern of the RA in the present study. Such variations have clinical importance in the field of vascular surgeries like CABG, Orthopedic surgeries, plastic and reconstructive surgeries. To avoid iatrogenic injuries radiologists and surgeons should have good understanding of normal morphological variations of RA.

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*Ethical approval: The study was approved by the Institutional Ethics Committee*

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