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Main perforators of the upper limb: still birth study

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Abstract

Background: Perforator flaps are an excellent reconstructive option for functional upper limb reconstruction. **Aim of the work:** This study aimed to identify the main anatomical sites, number and length of the main perforators of the upper limb for better surgical reconstruction interventions. **Material and methods:** The material of this work included twelve fresh stillbirths. Red-colored latex was injected into the abdominal aorta. Dissection was done at the sub-fascial level of the upper limb. **Results:** Results showed that the most common sites of brachial artery perforators were located at a mean distance of 1.73 ±0.52 cm measured from the tip of the coracoid process. More than one third of ulnar perforators (35%) were located within 40 mm proximal to the pisiform. More than half of the distal forearm radial artery perforators (68%) were located within 22 mm proximal to the distal wrist crease. About (40%) of the posterior interosseous artery were located within 40 mm proximal to the ulnar head. Dorsal metacarpal artery perforators were found in the mid metacarpal region proximal to junctuate tendinae while the proper digital arteries give rise to multiple cutaneous perforators along their course on the sides of each digit. **Conclusion:** Detailed anatomy of the main perforators of the upper limb concerning its accurate site measured from fixed specific bonny points, number and length of their pedicles are very essential in the success of the different flap techniques. **Recommendations:** A wide scale of the stillbirth cases may give more standard values as regard the location of the main perforators of the upper limb. A combined adult cadaveric study could be advised to be compared with the main values with those of the stillbirths.

Keywords

Upper limb perforators, Propeller flaps, Stillbirth, Plastic surgery, Injection study.

Abbreviations

Brachial artery perforators (BAP), Radial artery perforators (RAP), Ulnar artery perforators, Posterior interosseous artery perforators (PAP), Dorsal metacarpal artery perforators (DAP), Digital artery perforators (DAP)

Introduction

Trauma contributes to one of the main causes of defects in the upper and lower limbs. Limb injuries most likely lead to complicated defects, so it may be demanding to reconstruct tissue loss. (Spyropoulou and Jeng 2010)

The replacement of the soft tissue in the upper limb is a common challenge that surgeons face after burns, trauma and infection. Reconstruction quality has an impor-

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tant effect on the functional outcome of the patient. (Appleton and Morris 2014, Peng, Li et al. 2019)

In the upper limb, there are several choices for the restoration of soft tissue, including skin grafting, local flaps, regional flaps and free flaps. (Levin and Erdmann 2001) Fascio-cutaneous flaps are provided by discrete perforator arteries which can be elevated in different areas of the human body and are regularly used in fundamental plastic surgery. (Tinhofer, Tzou et al. 2017)

In the past, numerous local and free flaps have been reported with more or less consistent morbidity of the donor site. The latest implementation of the perforator-based flap idea has resulted in an evolution in the reconstruction of the upper extremity, wonderful results at the receiving site, as well as minimizing and attaining this in the easiest manner possible. (Innocenti, Baldrighi et al. 2009, Chaput, Herlin et al. 2015).

For functional upper limb reconstruction, perforator flaps are an outstanding reconstructive choice. The upper limb keystone perforator flaps are focused on propeller flaps such as the brachial artery perforators, ulnar artery perforators, radial artery perforators, interosseous artery perforators, metacarpal artery perforates and digital artery perforators. (Sinna, Qassemyar et al. 2011, Hussein Mahmoud, M Khedr et al. 2019)Flap safety concerns depend on the degree of the perforator's intentional twist. (D'Arpa, Cordova et al. 2011, Thomas, Calcagno et al. 2019).

Microsurgery provided a strong tool for the plastic surgeon. In cases of complex defects that cannot be covered by the simpler options of reconstructive surgery, new advances in microsurgery can almost provide a solution. (Levin and Erdmann 2001, Spyropoulou and Jeng 2010).

Aim of the work

This study aimed to identify the main anatomical sites, number and length of the main perforators of the upper limb for better surgical reconstruction interventions.

Materials and methods

The material of this work included twelve stillbirth upper limbs obtained from the Dissecting Room of Anatomy Department, Faculty of Medicine, Alexandria University.

In this study, a midline abdominal incision was done, cutting through all layers, followed by reflecting the intestine to expose the abdominal aorta. Irrigation of the abdominal aorta with warm saline to dislodge blood clots after ligation of its distal segment.

The red-color latex was injected into the abdominal aorta until resistance was felt or the backflow of the dye occurred. The upper limbs were then dissected 48 hours after injection to allow the latex to regain firm rubbery consistency. A vertical midline skin incision was done along the course of the main arteries of the upper limb. Dissection was done at the sub-fascial level with reflection of the flaps. (Morris S 2006).

The data included the site of the main perforators in relation to fixed anatomical landmarks, in addition to their number, length of the pedicle and the main source vessel.

Measurements were done using manual Smith Vernier caliper and a ruler and were photographed and statistically analyzed.

Statistical analysis

The data was collected, processed and entered into the personal computer. Statistical analysis was done using Statistical Package for Social Sciences (SPSS/version 20) software. The arithmetic mean, standard deviation were used to the numerical measurements.

Results

I. Brachial artery perforators (BAP)

The length of the arms of the stillbirth specimens was measured from the tip of the acromion process to the mid-elbow point. It ranged from 5.0 to 6.9 cm with a mean value of 5.93± 0.56 cm. The number of BAP perforators ranged from 2 to 6 with a mean value of 4.21± 1.72 (Fig. 1, 8). The most common sites of BAP were pre-

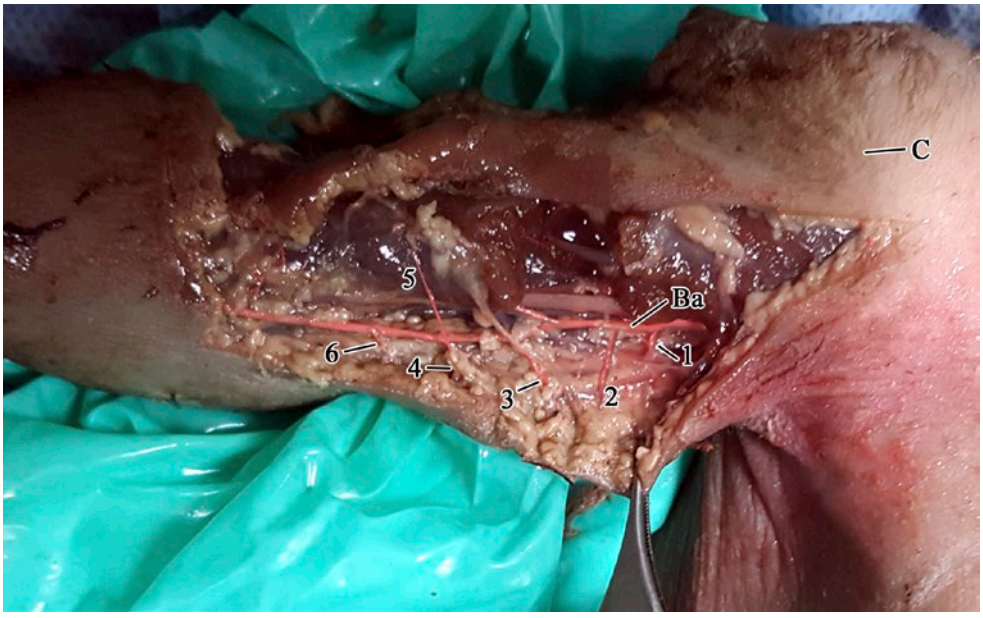

Figure 1. A photograph of a right arm of a stillbirth showing the brachial artery (Ba) and its perforators 1-6 (**C:** site of palpation of the tip of the coracoid process).

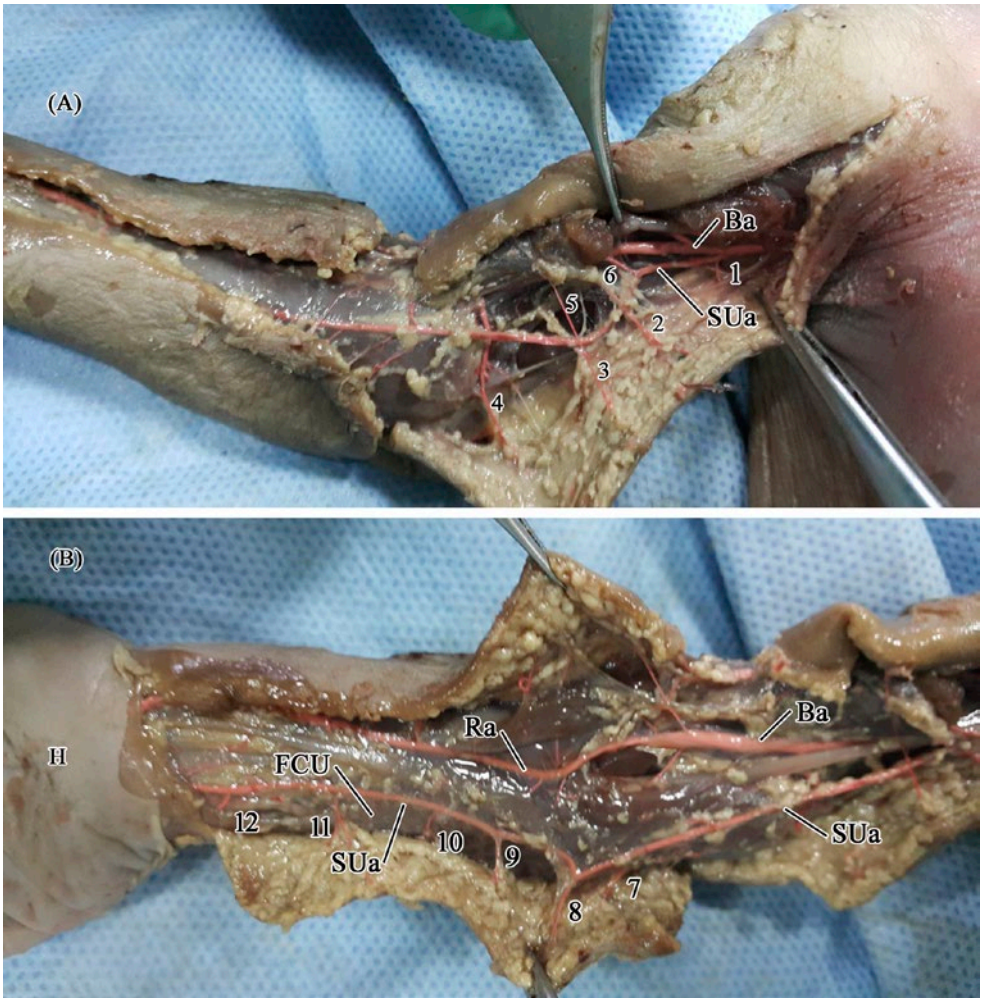

Figure 2. Picture (A): A photograph of a right upper limb of a stillbirth showing the superficial ulnar artery (SUa) arising from the brachial artery (Ba) in the upper third of the arm. **Picture (B):** Follow up of the same specimen in **picture (A)** where the superficial ulnar artery (SUa) continues to the forearm in a superficial course. (1-6: superficial ulnar artery perforators in the arm –7-12: superficial ulnar artery perforators in the forearm. (**H:** Hand - **Ra:** Radial artery – **FCU:** Flexor carpi ulnaris).

sent at a mean distance of 1.73 ±0.52 cm measured from the tip of the coracoid process (Fig. 9). The mean length of BAP was 2.13 ±0.42 cm.

In one specimen out of the twelve specimens (8.33%), the ulnar artery originated in the upper third of the arm on both the right and left sides of the brachial artery (Fig. 2). In such a case, the part of the ulnar artery in the arm gave 3 to 4 perforators at a distance 2 -3 cm from the coracoid process. The mean length of the ulnar artery perforators in the arm was 2.51 ±0.32 cm.

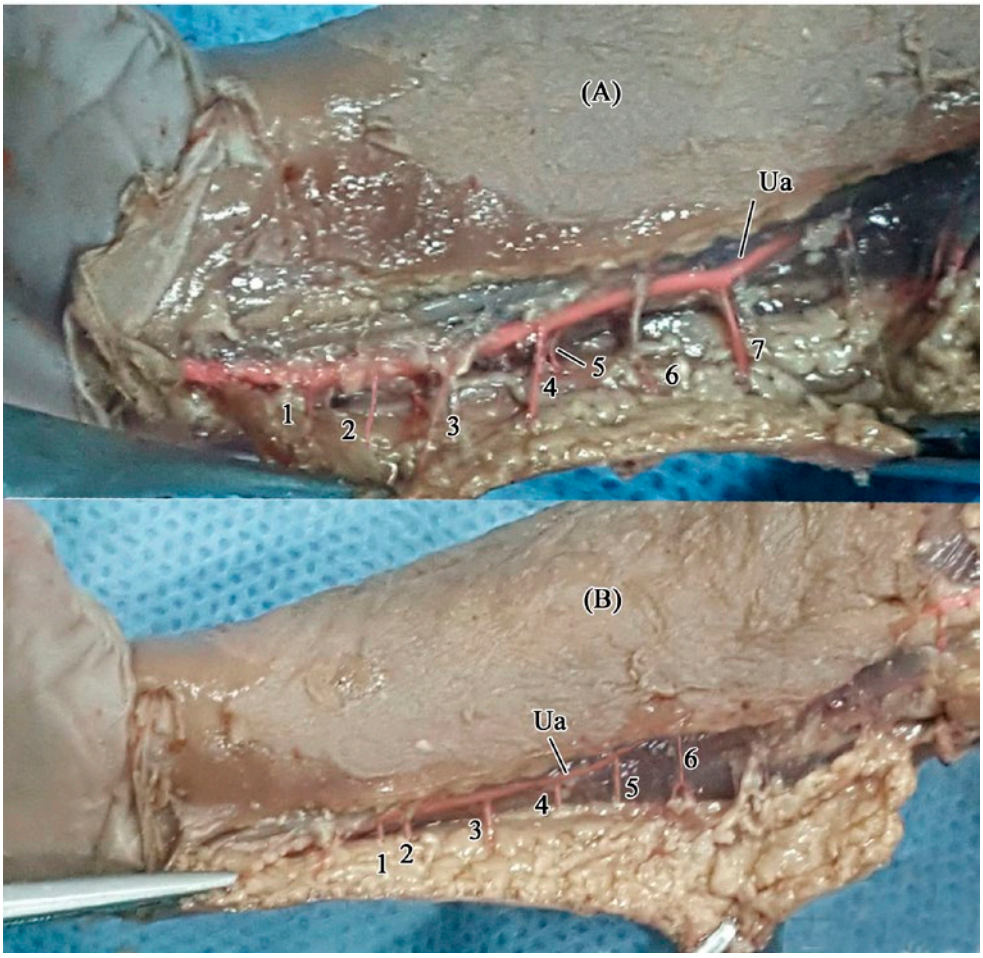

Figure 3. A photograph of a right forearm of a stillbirth showing the ulnar artery (Ua) and its perforators (1-7 in **picture A** & 1:6 in **picture B**) (note the concentration of the perforators in the lower third of the forearm).

II. Ulnar artery perforators (UAP)

The length of the forearms of the stillbirth specimens was measured from the mid-elbow point to the mid-wrist point. It ranged from 4.2 to 7.8 cm with a mean value of 6.1 ± 1.15 cm. The number of UAP ranged from 6 to 12 with a mean value of 9.63±2.14 (Fig. 3,8). The largest number of perforators were within 16.0 mm proximal to the pisiform, while the second largest number of perforators were in area 28 to 36 mm proximal to the pisiform. Taken together, more than one third of forearm perforators (35%) were located within 40 mm proximal to the pisiform (Fig. 9). About 90 % of UAP were found online drawn from the pisiform to the medial epicondyle or just medial to it. The mean length of the UAP was 1.28 ± 0.37 cm.

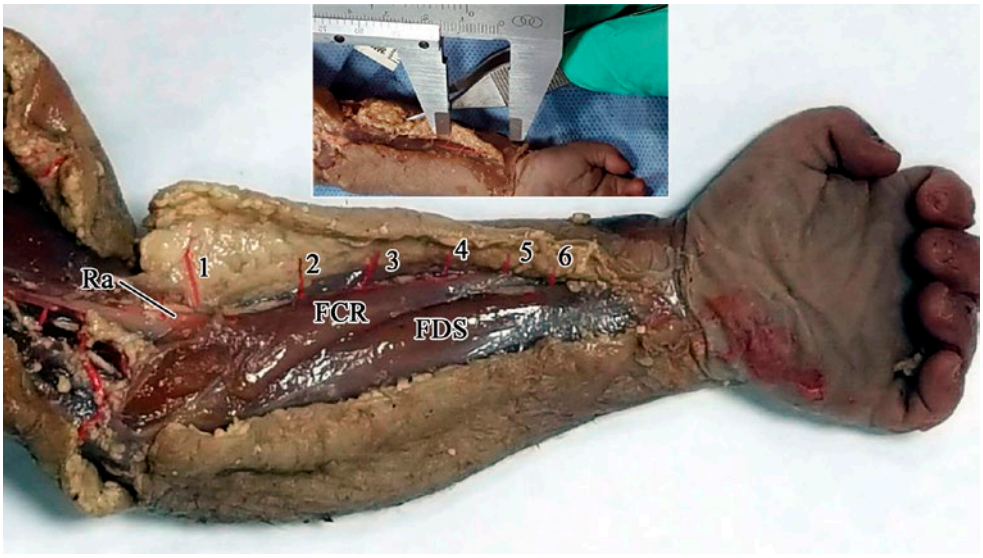

Figure 4. A photograph of a left forearm of a stillbirth showing the radial artery (Ra) and its perforators (1-6). The insert picture demonstrates the method of measuring of the distance of each perforator from the distal wrist crease. (**FCR:** Flexor carpi radialis – **FDS:** Flexor digitorum superficialis)**.**

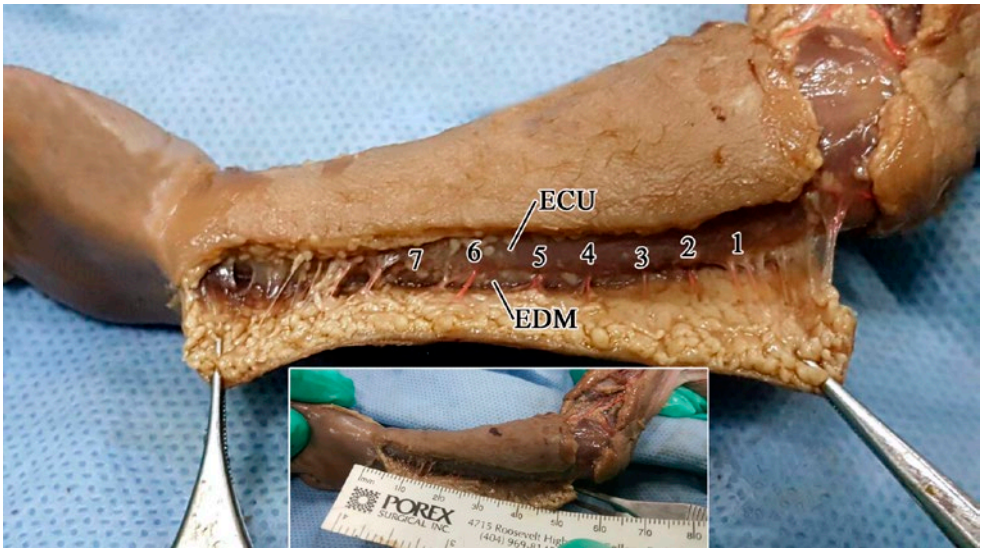

Figure 5. A photograph of the dorsum of a right forearm of a stillbirth showing the posterior interosseous artery perforators (1-7). The insert picture demonstrates the method of measuring the distance of each perforator from the ulnar head. (**ECU:** Extensor carpi ulnaris – **EDM:** Extensor digiti minimi).

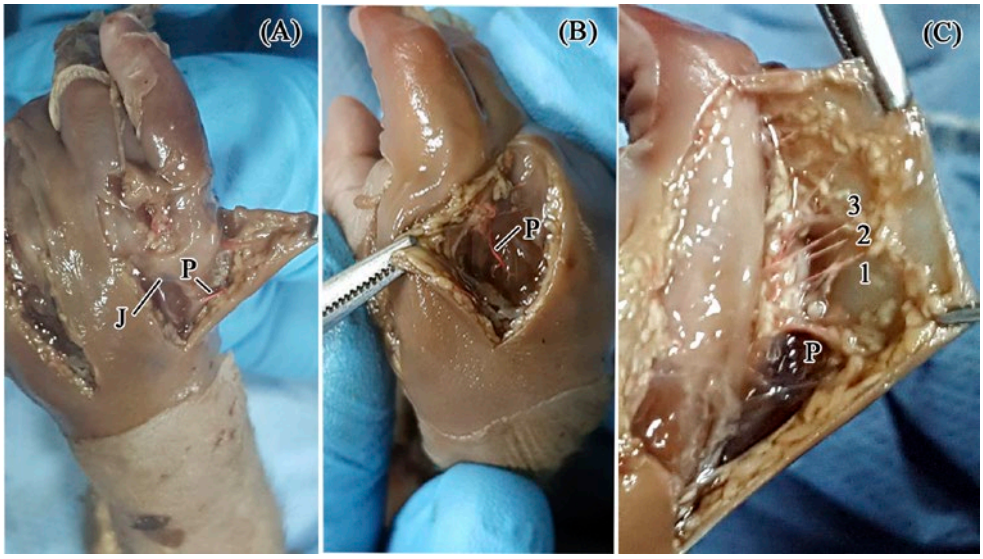

Figure 6. A photograph of the dorsum of a right hand of a stillbirth showing the junctuate tendinae (J) **(picture A)**, main dorsal metacarpal artery perforator (P) **(pictures A, B and C)** and other dorsal metacarpal artery perforators 1- 3 **(Picture C)**.

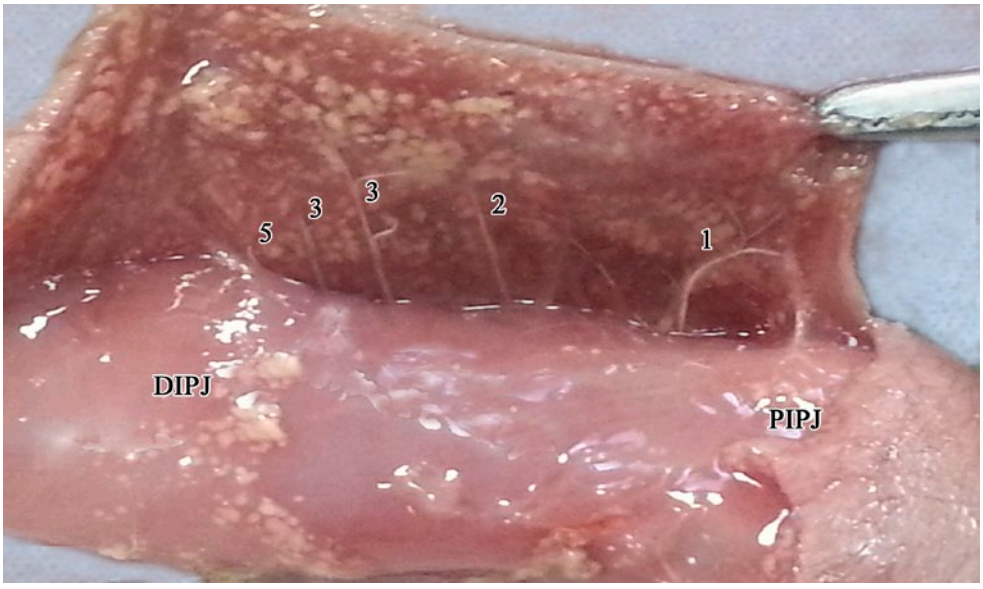

Figure 7. A photograph of a stillbirth intermediate digit of the index finger (lateral view) showing digital perforators (1-5) on the lateral side of the digit (**PIPJ:** Proximal interphalangeal joint – **DIPJ:** Distal interphalangeal joint).

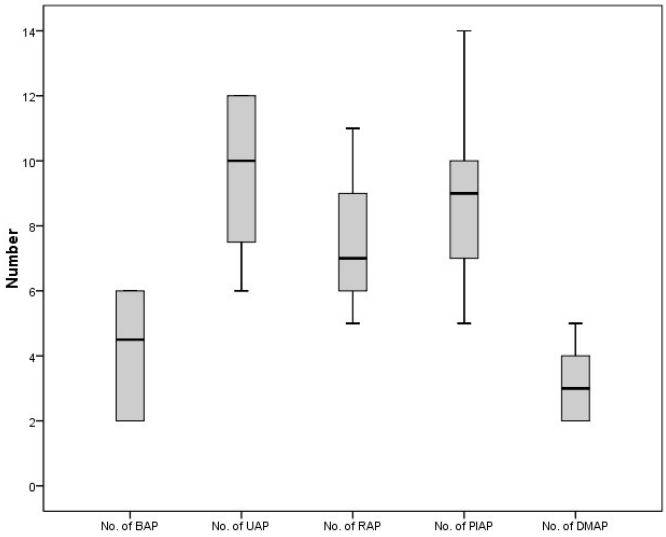

Figure 8. Box Plot showing the number of the main perforators of the upper limb.

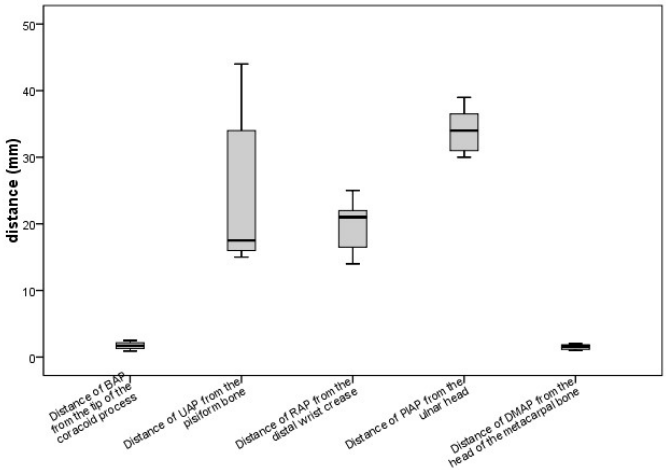

Figure 9. Box Plot showing the different distances of the main perforators of the upper limb from fixed anatomical landmarks.

III. Radial artery perforators (RAP)

The number of RAP ranged from 5 to 11 with a mean value of 7.63±1.74 (Fig. 4,8).

The largest number of perforators were found within 15 mm proximal to the distal wrist crease, while the second largest was in area 15 to 22 mm proximal to the dis-

tal wrist crease. Taken together, more than half of the distal forearm perforators (68%) were located within 22 mm proximal to the distal wrist crease (Fig. 9). The mean length of the RAP was 1.21 ± 0.28 cm.

All distal RAP were septal or direct cutaneous arose between flexor carpi radialis and brachioradialis, while proximal perforators arose between pronator teres and brachioradialis.

IV. Posterior interosseous artery perforators (PIAP)

The number of PIAP ranged from 4 to 15 with a mean value of 8.83±2.33 (Fig. 5,8)

The PIAP arose between extensor carpi ulnaris and extensor digiti mini. The largest number of perforators was 30 mm proximal to the ulnar head, and the second largest number was in area 30 to 40 mm proximal to the ulnar head. Taken together, more than one third of forearm perforators (40%) were located within 40 mm proximal to the ulnar head (Fig 9). About 95 % of PIAP were found in a line drawn from inferior radioulnar joint to the lateral epicondyle in supination or just radial to it. The mean length of PIAP perforator was 1.53 ± 0.34 cm

V. Dorsal metacarpal artery perforators (DMAP)

The length of the hand of all specimens was measured from the head of the third metacarpal bone to the proximal line of the carpal bones. It ranged from 1.5 to 3.1 cm with a mean value of 2.12 ± 0.54 cm (Fig. 6,8). The number of DMAP ranged from 2 to 6 with a mean value of 3.17±1.05. These perforators were roughly found in the mid metacarpal region proximal to junctuate tendinae (connective tissues that link the tendons of the extensor digitorum) (Fig. 9). The mean length of the DMAP was 0.52 ± 0.07 cm.

VI. Digital artery perforators (DAP)

Axial vessels in the hand and digits gave rise to both volar and dorsal DAP.

The proper digital arteries gave rise to multiple cutaneous perforators along their course ranged from 4-6 with a mean value 4.67±0.87 (Fig. 7). Many of the cutaneous digital artery perforators originated from the lateral aspect of the finger distally, forming the basis for the digital artery perforator flap design.

Discussion

In the last years, a wide range of propeller flaps were used to cover a broad range of defects. Indeed, these flaps allow for considerable freedom in the design and coverage of many complex defects. However, dissecting a perforator is not an easy task, it determines the success rate of the performed procedure. (Hussein Mahmoud, M Khedr et al. 2019)

Liu, Y. et al (2017) (Liu, Zang et al. 2017)considered the fact that perforators of the arm are more on the medial side and have long pedicles. They added the techniques of tissue expansion and perforator flap surgery. Pre-expansion in the presence

of lengthy pedicles improves the size of the flap, remodels the vasculature of the flap and decreases the morbidity of the donor site. This fact is also supported by Peng, J. Q. et al (2019). (Peng, Li et al. 2019)Another tool for demonstration of the main perforators of the upper limb was done by Dalla Pozza, E. et al (2018) (Dalla Pozza, Bassiri Gharb et al. 2018)on nine hand allografts. They injected blue ink through the brachial artery to assess the perfusion of the skin flaps. Results demonstrated sizable perforators from the brachial, superior ulnar collateral, radial, ulnar and posterior interosseous arteries. Concerning the brachial artery, the average stained area of the medial arm flap was between 85.7 and 93.9 percent indicating predominant medial side perforators. Sun, R. et al (Sun, Ding et al. 2016)added that color Doppler sonography facilitates the preoperative assessment of the origin, course, variations and locations of the main arterial pattern of the upper limb.

In the present study, the most common sites of BAP were present at a mean distance of 2 cm ± 0.5 cm from the tip of the coracoid process. The mean length of the BAP was relatively long 2.13 ±0.42 cm. This fact is beneficial in functional and aesthetic outcomes in patients with soft tissue defects on the head and neck, axilla, chest wall and upper extremity.(Liu, Zang et al. 2017)

Vascular anomalies of the upper limb are not uncommon. Panagouli, E. (2009) (Panagouli, Tsaraklis et al. 2009)reported a superficial origin of the ulnar artery in the upper part of the arm during anatomical dissection of a female Caucasian cadaver. A case of bifurcation of the brachial artery into a common radial-interosseous trunk and the superficial ulnar artery was reported by Narayanan, S. et al (2017) (Narayanan and Murugan 2017).

Baral, P. et al (2009) (Baral, Vijayabhaskar et al. 2009)concluded that single neurovascular variation is common but multiple vascular anomalies on the same upper limb is a very rare case. These variations include the branching pattern of the main arteries of the upper limb, the radial origin of the common interosseous artery and the dominant arteries that share in the formation of the palmar arches.

In the present study, a superficial origin of the ulnar artery was found in only one case of the twelve stillbirth cadavers (8.33%). The presence of a superficial position of the ulnar artery could enable the surgeons to raise a long free ulnar forearm flap for reconstructive surgeries of the head and neck. (Narayanan and Murugan 2017)

Hekner, D. D. et al (2016) (Hekner, Roeling et al. 2016)investigated the distal forearm vascular anatomy to optimize the choice between the free flap of the radial forearm and the free flap of the ulnar forearm and to choose the best site for harvesting the flap. Seven fresh cadavers were injected through the radial and ulnar arteries with epoxy resin (Araldite) and dissected the perforating arteries. The number of clinically relevant radial and ulnar artery perforators in the distal forearm was not significantly different. Most perforators were in the proximal half of the distal one-third, making this portion likely the safest flap harvest place. More perforators were detected on the ulnar side than on the radial side near the wrist, i.e. most distally. Ulnar artery stained 77 percent of the forearm's skin surface, indicating that the ulnar forearm free flap is more suitable for the restoration of large defects than the radial forearm free flap.

On the other hand, Kimura, T. et al (2017) (Kimura, Ebisudani et al. 2017) performed a study on twenty-nine human cadaveric forearms. All radial and ulnar arteries cutaneous perforators were analyzed for total number and distribution. The radial artery's cutaneous perforators were more than that of the ulnar artery, and both were

concentrated in the distal one-third of the forearm. When harvesting forearm flaps, this data could be useful. These findings are also confirmed by Tiengo, C. et al 2007 (Tiengo, Macchi et al. 2007)

The present study, in agreement with the previous studies as regard the concentration of the RAP and UAP in the lower third of the forearm. However, it disagrees with Kimura, T. et al (2017) (Kimura, Ebisudani et al. 2017) where the number of UAP is more than RAP. This means that there are great personal variations as regards the number of perforators of both radial and ulnar arteries, a fact to be considered in surgical interventions.

Liu, P. et al (2015) studied fifteen fresh human cadaveric hands using latex perfusion for micro-anatomical analysis. In the distal second dorsal metacarpal artery, they found two main clusters of arterioles that can be helpful in repairing finger defects from the second webspace border to the midpoint of the second metacarpal bone at a comparative range of 40.8 and 68.6 percent. There were no significant differences in the distribution of the skin perforators from the second dorsal metacarpal artery, either radial or ulnar. ($p = 0.779$).(Liu, Qin et al. 2015)

In the present study, both the anatomical position (proximal to junctuate tendinae) and the number of the DMAP allow it to have a longer arc of rotation of the standard DMAP flap because of its more distal pivot point.

In a study performed by Usami, S. et al (2018) (Usami, Inami et al. 2018)on thirty-two finger dorsum defects in 32 patients, they concluded that there are multiple perforators in the finger and thumb dorsum region from the proper digital artery. These perforators are suitable for pedicle free-style perforator flaps.

Compared with the present work, many of the cutaneous DAP originated from both sides of the finger distally, forming the basis for the digital artery perforator flap design. In clinical applications, this fact improves flap flexibility and reliability.

Conclusion

Detailed anatomy of the main perforators of the upper limb concerning its accurate site measured from fixed specific bonny points, number and length of their pedicles are very essential in the success of the different flap techniques. Vascular variations are not an uncommon finding of the upper limb.

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The author declare that there is no financial or conflict of interest to disclose.

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