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Multidetector-row Computed Tomography Analysis of the Radial Midpalmar Flap: A Retrospective Anatomical Study

Tien Linh Nguyen Doan, MD, PhD*†
Shimpei Ono, MD, PhD*
Goh Akiyama, MD, PhD*
Hoyu Cho, MD*
Hiromitsu Hayashi, MD, PhD‡
Rei Ogawa, MD, PhD*

Background: Soft tissue defects on the palm side of the thumb can be effectively covered by using the radial midpalmar (RMP) flap, which is usually harvested as a pedicled flap. However, previous anatomical studies on this flap are limited. We analyzed multidetector-row computed tomography angiograms of the radial midpalm of hands to more precisely characterize the 3-dimensional anatomical structure of the perforators in living patients.

Methods: This retrospective cross-sectional study included all eligible patients from 2014 to 2019. All Digital Imaging and Communications in Medicine (DICOM) data were analyzed by the DICOM viewer. RMP area vascularization pattern and cutaneous perforator number, location, origin, internal diameters, and bifurcation-to-dermis lengths were recorded.

Results: In total, 41 perforators were found in 30 patients: 21 patients had 1 perforator, 7 had 2, and 2 had 3 perforators. All were located inside a 23.2-mm diameter circle with an origin on the second metacarpal bone axis approximately 10 mm distally from the Kaplan cardinal line. Their origins were the superficial palmar arch system (61%), palmar arteries of the thumb (24%), and radialis indicis artery (15%). The mean perforator diameter and length were 0.61 and 8.48 mm, respectively.

Conclusions: All patients had at least 1 reliable perforator in the radial midpalm. Our results suggest that plastic surgeons can easily and safely plan the RMP flap design, potentially without preoperative perforator mapping. Guidelines for this flap are proposed. *(Plast Reconstr Surg Glob Open 2025; 13:e6484; doi: 10.1097/GOX.0000000000006484; Published online 23 January 2025.)*

INTRODUCTION

The options for reconstructing soft tissue defects on the palmar side of the thumb range from simple healing by secondary intention to skin grafting, local homodigital or heterodigital flaps, and partial-toe transfers.[1,2] Flap reconstruction is often required when the defect is large and/or when deep important structures (eg, bones or tendons) are exposed. For defects on the palmar side of the hand and digits, reconstruction using palmar skin, which is a similar tissue, is recommended for better aesthetic and functional outcomes.[3] From this point of view, the radial midpalmar (RMP) flap, an island flap harvested from the radial aspect of the midpalm, is one of the useful treatment options for defect reconstruction on the palmar side of the thumb.[4–6]

To use the RMP flap, it is necessary to understand the arterial vasculature in the radial aspect of the midpalmar area, particularly the anatomical structure and morphology of the perforators and their arterial origin. Although the term "radial mid-palmar island flap" was first proposed by Kim and Hwang,[6] Omokawa et al[4] were the first to describe the vascular anatomy that relates to this flap. Their cadaveric study confirmed that the palm is supplied primarily by the radial artery and ulnar artery via the superficial palmar arch (SPA) and the deep palmar arch (DPA), and then showed that the midpalmar area can be divided

*From the *Department of Plastic, Reconstructive and Aesthetic Surgery, Nippon Medical School Hospital, Tokyo, Japan; †Department of Plastic, Reconstructive and Aesthetic Surgery, Plastic, Reconstructive and Aesthetic Surgery Center, National Burn Hospital, Ha Noi, Vietnam; and ‡Department of Clinical Radiology, Graduate School of Medicine, Nippon Medical School, Tokyo, Japan.*

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on the basis of the contributory vascularization into proximal and distal regions.[4] Moreover, they and other studies observed that the radial aspect of the midpalmar area is nourished by cutaneous perforators originating from the terminal branch of the SPA,[4] the radialis indicis artery (RIA),[5] or the princeps pollicis artery (PPA).[6] In addition, Omokawa et al[7] observed that the keystone blood supply area of the RMP flap is located over the ulnar half of the adductor pollicis muscles.

Several studies have shown that perforator-computed tomographic angiography (P-CTA) with multidetector-row computed tomography (MDCT) is very useful for determining the key anatomical details of perforators.[8–11] However, to the best of our knowledge, the arteries in the RMP area have not been examined with this modality. Thus, the aim of this study was to characterize the three-dimensional (3D) anatomical structure and morphology of the perforators and their arterial origin in the radial aspect of the midpalmar area.

Takeaways

Question: Using multidetector-row computed tomography analyses of the palmar to precisely map all perforators and assess the general arterial patterns in the radial midpalmar (RMP) region.

Findings: On the basis of this novel study and the previous literature, we propose guidelines for the safe and easy design and harvest of the RMP.

Meaning: Guidelines for the RMP flap design are proposed.

MATERIALS AND METHODS

This retrospective anatomical study was conducted at the Nippon Medical School Hospital in Tokyo, Japan. The institutional review board of the hospital waived the need for ethics approval due to the retrospective nature of the study. The study was conducted according to the principles of the Declaration of Helsinki. All patients gave written informed consent to undergo the surgery and for their clinical details to be used for research.

The study cohort consisted of all consecutive patients who had soft tissue defects of the digits and underwent preoperative MDCT angiography followed by reconstruction with various flaps between June 2014 and December 2019. Patients with additional soft tissue defects, such as on the palm or wrist, and patients with inadequate MDCT angiography due to insufficient contrast enhancement and/or scan timing were excluded.

To preoperatively map the perforators, the upper limbs of all patients underwent MDCT angiography. All P-CTA data were acquired on the basis of the scan parameters reported in our previous study.[9] The patients were scanned in a supine position in accordance with the operative positioning. The scan range was set from the midpoint of the forearm to the fingertips. The resulting Digital Imaging and Communications in Medicine (DICOM) data were transferred to the SYNAPSE VINCENT software (Fujifilm Medical Co., Tokyo, Japan), which shows detailed 3D data of the tissues from the superficial through to the deep layers. The arteries and their perforators in the midpalmar area were traced in 3D reconstructions.

The DICOM data were collected from the radiology department for the study. We divided the palmar aspect into 6 regions based on the axis of the third metacarpal bone, the proximal transverse crease distally, the Kaplan cardinal line proximally, and the border of the first web space at the radial side (Fig. 1). All cutaneous midpalmar perforators were identified regardless of size. The following variables were recorded: (1) the arterial pattern in the RMP area and the (2) number, (3) location, (4) origin artery, (5) internal diameter, and (6) length of each perforator from origin artery to the dermis. The 3D perforator location was determined by generating a Cartesian plane whose origin was located mid-axis at the radial styloid process. The x coordinate of each perforator that penetrated this plane was measured along the line that ran from the radial styloid process along the distal wrist crease to the ulnar side. The y coordinate was measured along the line that ran perpendicular to the origin toward the tips of the fingers (Fig. 2). Perforator diameter and length data were expressed as mean, SD, and range.

RESULTS

In total, 58 patients underwent preoperative P-CTA for reconstruction of soft tissue digit defects during the study period. Of these, 28 were excluded because they also had lesions at the palm or wrist (10) or inadequate MDCT angiography (18). The resulting 30 patients were included in the study (Fig. 3). The digit lesions were due to injuries, tumors, or scar contractures. Of the patients,

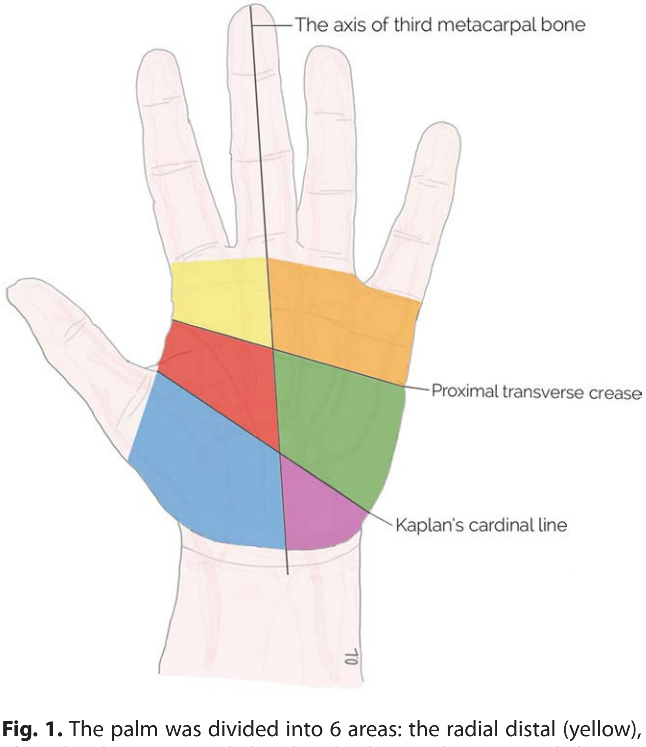

Fig. 1. The palm was divided into 6 areas: the radial distal (yellow), ulnar distal (orange), radial mid (red), ulnar mid (green), radial proximal (blue), and ulnar proximal (purple) palmar regions.

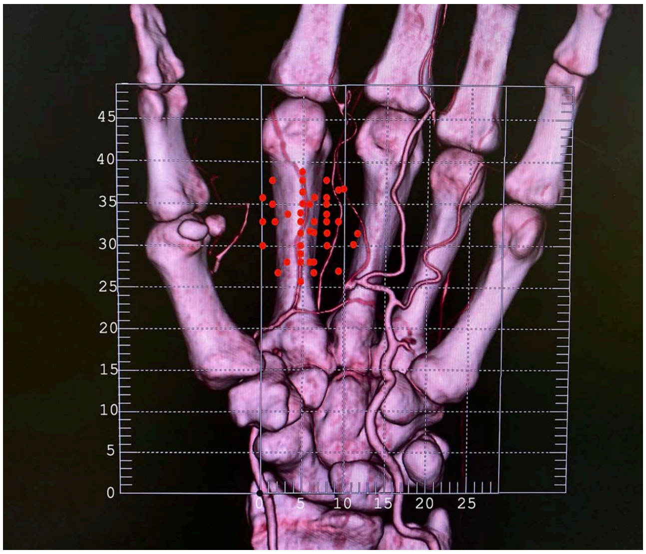

Fig. 2. A Cartesian plane was generated, with the origin at the radial styloid process (black dot). Red dots indicate all perforators detected during the study.

73% (n = 22) were men, and the average age (range) was 47 (22–81) years.

Arterial Patterns in the RMP Area

The SYNAPSE VINCENT software yielded high-resolution 3D images that revealed the anatomy and morphology of the hand and digital vessels (Fig. 2). The SPA consists of the ulnar artery either on its own or anastomosed with the superficial palmar branch of the radial artery (SPBRA). This arterial constellation is termed the SPA-SPBRA system. Consistent with the literature,[12] the SPA-SPBRA system in our patients could be classified as complete or incomplete depending on whether it had a terminal branch that directly supplied the ulnar side of the thumb (complete) or lacked the branch and, therefore, failed to reach the thumb (incomplete). The complete SPA is shown in Figure 4 (the terminal branch is at the center of the orange circle). In our cohort, the complete and incomplete SPA types accounted for 73% (22 of 30) and 27% (8 of 30) of all cases, respectively. In 60% of cases, the terminal branch of the SPA-SPBRA system anastomosed with the RIA and/or with the PPA. Moreover, in 83% of cases, the SPA-SPBRA system anastomosed with the palmar digital arteries of the thumb, namely, the ulnopalmar digital artery of the thumb (UPDAT) and radiopalmar digital artery of the thumb (RPDAT). Thus, the UPDAT and RPDAT were formed by the PPA alone in 17% of cases, the SPA-SPBRA system alone in 33%, or both the SPA-SPBRA system and PPA in 50% (Fig. 4). The RIA was formed by the DPA (12 of 30), the SPA (6 of 30), or both (12 of 30).

Cutaneous Perforators in the RMP Area

The 30 cases had 41 perforators in total (Table 1). Their locations are indicated in Figures 2 and 5. All 30 patients had at least 1 cutaneous perforator. Seven patients had 2 perforators and 2 had 3. All perforators were located inside a 23.2-mm diameter circle whose center was located on the axis of the second metacarpal bone approximately 10 mm distally from the intersection point with the Kaplan cardinal line (Figs. 4, 5). Based on their arterial origin, the perforators could be divided into 3 types (designated

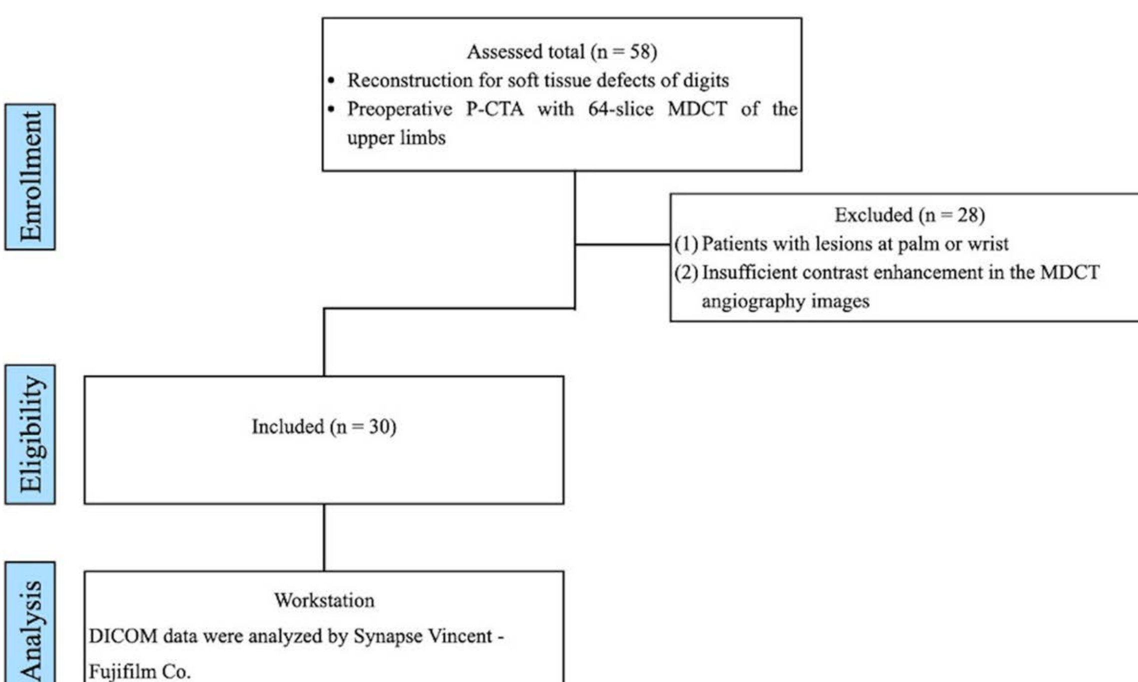

Fig. 3. Flow diagram depicting inclusion and exclusion of patients.

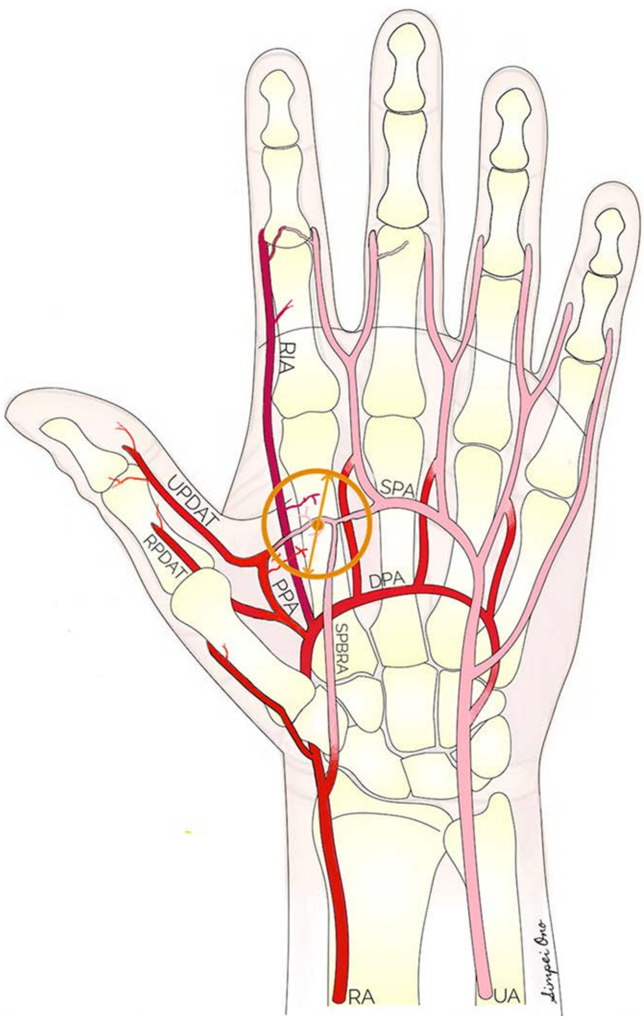

Fig. 4. The radial aspect of the mid-palmar region is nourished by perforators from the terminal branch of the SPA, the RIA, or the PPA. The perforators are located in a 23.2-mm diameter circle (orange). RA, radial artery; UA, ulnar artery.

A–C): SPA-SPBRA system perforators (25 of 41, 61%; type A), PPA/UPDAT/RPDAT perforators (10 of 41, 24%; type B), and RIA perforators (6 of 41, 15%; type C). Of the 25 SPA-SPBRA perforators, 23 originated from the terminal branch of the SPA and 2 from the SPBRA. Of the 10 PPA/UPDAT/RPDAT perforators, 2, 5, and 3 arose from the PPA, UPDAT, and RPDAT, respectively. Examples of these perforators are given in Figure 6.

The average internal diameter of all cutaneous perforators was 0.61 ± 0.1 (range 0.5–0.8) mm, and their mean bifurcation-to-dermis length was 8.36 ± 4.41 (range 2.6–19.8) mm (Table 2). The average internal diameters of the SPA-SPBRA, PPA/UPDAT/RPDAT, and RIA perforators were 0.61 ± 0.1 (range 0.5–0.8), 0.65 ± 0.09 (range 0.5–0.8), and 0.57 ± 0.05 (range 0.5–0.6) mm, respectively. Their average lengths were 9.14 ± 4.47 (range 3.3–19.8), 5.97 ± 2.87 (range 2.6–11.7), and 9.83 ± 6.94 (range 3.5–18.5) mm, respectively.

DISCUSSION

History of the RMP Flap

Reconstruction of palmar defects with the RMP flap has a relatively short history: Omokawa et al[4] first proposed it in 2001, and 4 years later, Kim et al[6] gave the name "radial mid-palmar flap" to a flap that was based on blood supply from the PPA, SPA, and RIA. Since then, multiple studies have shown that pedicled flaps from this area reliably yield good functional and cosmetic outcomes for palmar thumb, index finger, and first web space defects such as contractures.[7,13–15] A cadaver-based anatomical study[6,7] and other studies on the clinical use of RMP flaps[4,14,15] suggest that this versatility reflects the multiple perforators in the radial aspect of the midpalmar area, which in turn facilitate various design patterns. The present study advances the field further by conducting the first detailed 3D anatomical analysis of the RMP area. This information allowed us to develop a guideline for safely designing and harvesting the RMP flap, as follows.

Anatomical Arterial Pedicle Considerations

General Arterial Patterns

Previous studies show that the palm is nourished by the SPA and DPA and that the SPA can be classified as either complete (ie, it directly feeds the ulnar side of the thumb) or incomplete.[15–18] When Coleman and Anson[18] investigated 650 specimens, they found complete and incomplete SPAs in 78.5% and 21.5%, respectively. We observed similar frequencies, namely, 73% and 27%, respectively.

Omokawa et al[4] proposed that the palmar area can be divided on the basis of the contributory vascularization into distal, proximal, and radial regions, but they defined the radial aspect of the midpalmar area as "over the ulnar half of adductor pollicis muscle," which is a bit unspecific. Therefore, in the present study, we defined the RMP region according to specific landmarks, namely, the Kaplan cardinal line proximally, the proximal transverse crease with metacarpal joints distally, the axis of the third metacarpal bone at the ulnar side, and the border of the first web space at the radial side (Fig. 1).

A number of cadaveric studies have reported on the vascular anatomy of this region, as follows. First, Omokawa et al[7] found that the terminal branch of the SPA connects to UPDAT/RPDAT in 85% of cases and anastomoses

Table 1. Characteristics of 41 Cutaneous Perforators That Were Detected on the RMP Region

Origin Artery	No. Perforators	Mean Diameter (mm)	Mean Length (mm)
SPA-SPBRA system	25	0.61 ± 0.1	9.14 ± 4.47
PPA/UPDAT/RPDAT	10	0.65 ± 0.09	5.97 ± 2.87
RIA	6	0.57 ± 0.05	9.83 ± 6.94

Fig. 5. All perforators (red dots) are located inside a 23.2-mm diameter circle whose origin (yellow dot) lies on the axis of the second metacarpal bone, approximately 10 mm distally from the intersection point (blue dot) with the Kaplan cardinal line.

with RIA in all cases. Similarly, we found the connection between the SPA and UPDAT/RPDAT in 83% of our cases. However, only 60% of our cases displayed anastomosis between the SPA and RIA. Thus, in our cohort, the RIA was formed by the DPA, the SPA, or both. These vascular connections among the SPA, DPA, RIA, and UPDAT/RPDAT suggest that the RMP flap will be able to reach the thumb tip, first web space, and proximal of the index finger.

Second, cadaveric studies by Earley[19] and Ames et al[20] reported that the PPA plays a minor role in the blood supply of the thumb. Specifically, Earley[19], who referred to the PPA as the first palmar metacarpal artery, showed that 40% of both UPDATs and RPDATs originated from the PPA. Similarly, we found that the UPDAT and RPDAT were formed by the PPA alone in 42% of our cases. However, Ramírez and Gonzalez[21] observed that the PPA was the dominant vessel in terms of thumb irrigation in 73% of their dissections. A similar result was shown by Miletin et al,[22] who indicated that the PPA was the common dominant source vessel for the thumb in 65%. Notably, we found that both the PPA and the SPA-SPBRA system fed 50% of the UPDATs/RPDATs due to a union between the PPA and SPA-SPBRA in the first web space. A similar union between the PPA and SPA was observed by Omokawa et al,[4] who reported that the terminal branch of the SPA connected with the DPA at the first web space through the PPA in 42% of their specimens. These observations suggest that the PPA and SPA together or alone feed the digital arteries of the thumb. However, additional anatomical research is needed to further clarify the arterial supply of the thumb.

Perforators in the RMP Area

Our results and those of the previous anatomical studies[6,7] on the perforators in the RMP region are summarized in Table 2. Together, these and our studies show that the skin in this region is supplied by 1 or more perforators that branch off 3 source vessels, namely, the SPA-SPBRA system, the RIA, and PPA/UPDAT/RPDAT (Fig. 6). Thus, we observed that the perforators originated most commonly from the SPA-SPBRA system (61% of all cases), namely, the terminal SPA branch in 21 of 23 cases and the SPBRA in 2 cases. Similarly, Omokawa et al[7] detected 3–6 cutaneous perforators that bifurcated from the terminal branch of the SPA. The next most common source in our study was the PPA/UPDAT/RPDAT (24%), namely, the PPA in 2 of 10 cases, the UPDAT in 5, and the RPDAT in 3. Similarly, Kim and Hwang[6] reported that the PPA bears 1–2 perforators that supply the RMP region. The least common perforator source in our study was the RIA (15%). Similarly, Vasconez et al[5] found that each of their patients had 1–2 perforators that arose from the RIA.

In terms of perforator location, previous studies reported that the perforators were concentrated 2–38 mm distally from the SPA[4] or along the radial margin of the second metacarpal bone.[6] However, these locations are not very precise. In the present study, we standardized the

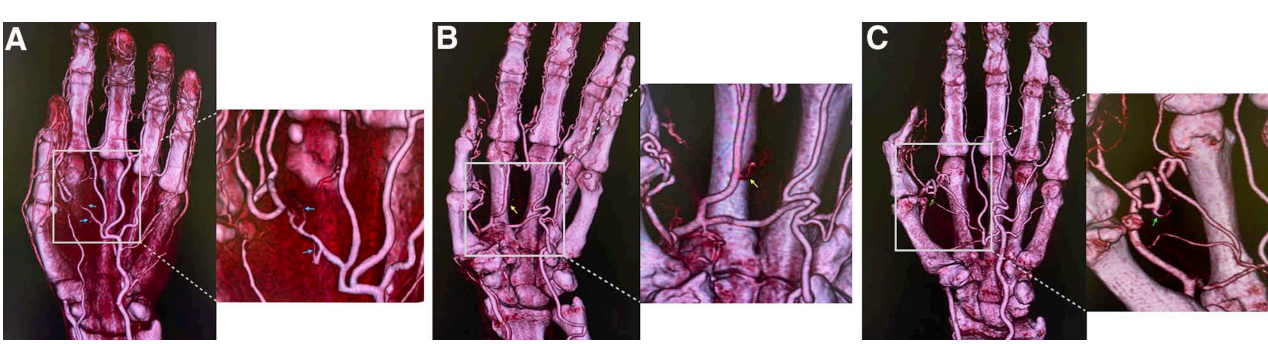

Fig. 6. Image showing the RMP skin being supplied by perforators originating from the terminal branch of the SPA (A), from the RIA (B), and from the palmar arteries of the thumb (C).

Table 2. Comparison of the Studies That Conducted Anatomical Research on the RMP Region

Authors (Publication Year)	Variables							
	Study Design	No. Cases	Anatomical Area Studied	No. Perforators	Diameter of Perforators	Location of Perforators	Origin Artery of Perforators	Average Length of Perforator
Kim and Hwang(2005)[6]	Retrospective clinical study on cadavers	15	RMP	1–2	N/A	Along the radial margin of the second metacarpal bone	PPA	N/A
Omokawa et al (2009)[7]	Retrospective clinical study on cadavers	15	Midpalmar	3–6	Range, 0.1–0.5 mm	2–38 mm distally from the SPA	SPA	N/A
Our research (2021)	Retrospective anatomical study on living body	30	RMP	1–2	Mean ± SD, 0.6 ± 0.1 mm	Inside a 23.2-mm diameter circle (origin on axis of second metacarpal bone approximately 10 mm distally from intersection point with the Kaplan cardinal line	• SPA-SPBRA system • RIA • UPDAT, RPDAT	8.36 ± 4.41 mm

N/A, not available.

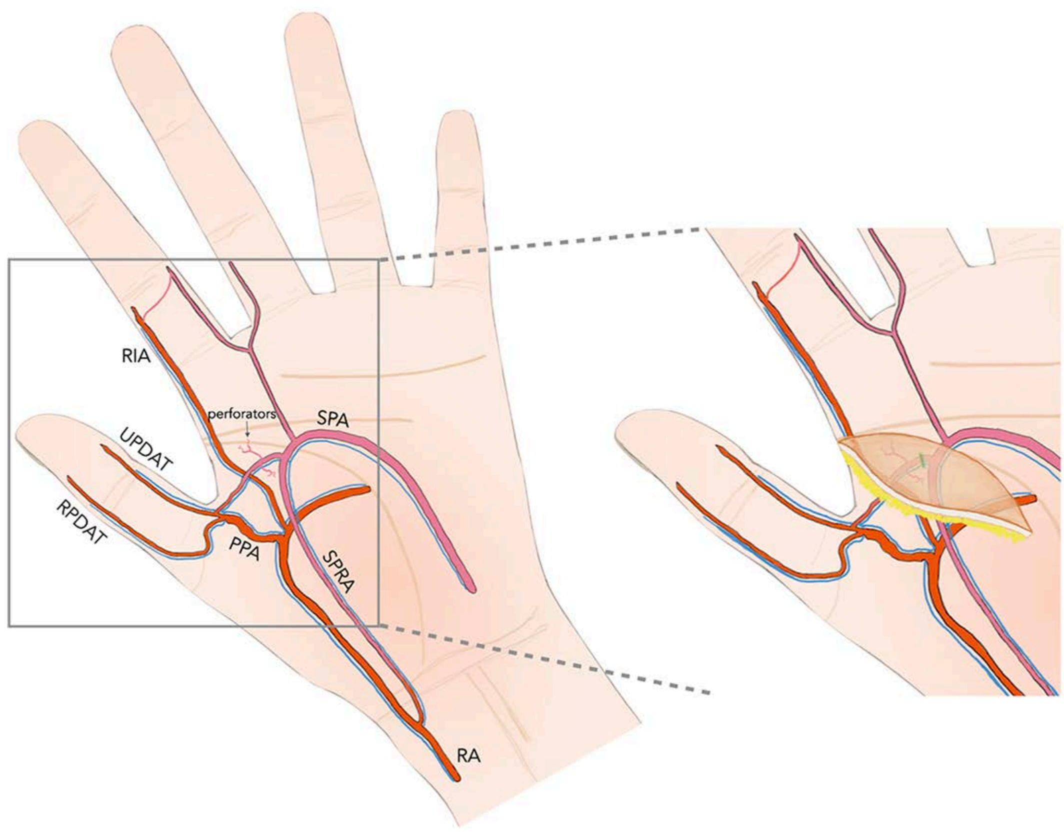

Fig. 7. (Type A) RMP flaps are designed to reach the tip of the thumb or cover a defect at the first web space or proximal of the index finger. They bifurcate from the terminal branch of the radial artery (SPA) and are nourished by UPDAT/RPDAT when the SPA is complete and anastomoses with the UPDAT/RPDAT. RA, radial artery.

location of the cutaneous perforators and compiled these data from multiple specimens into a single plot (Figs. 2, 5). This showed that the cutaneous perforators were all located inside a 23.2-mm diameter circle whose origin was on the axis of the second metacarpal bone approximately 10 mm distally from the intersection with the Kaplan cardinal line.

In terms of midpalmar perforator diameter, Omokawa et al[7] reported that they ranged from 0.1 to 0.5 mm, whereas in our study, the average perforator diameter was 0.61 (range 0.5–0.8) mm. In terms of midpalmar perforator length, we are the first to report these data: the perforators were on average 8.4 mm long.

Clinical Application Guidelines

On the basis of these findings, we suggest that the RMP flap can be safely designed and harvested by adhering to

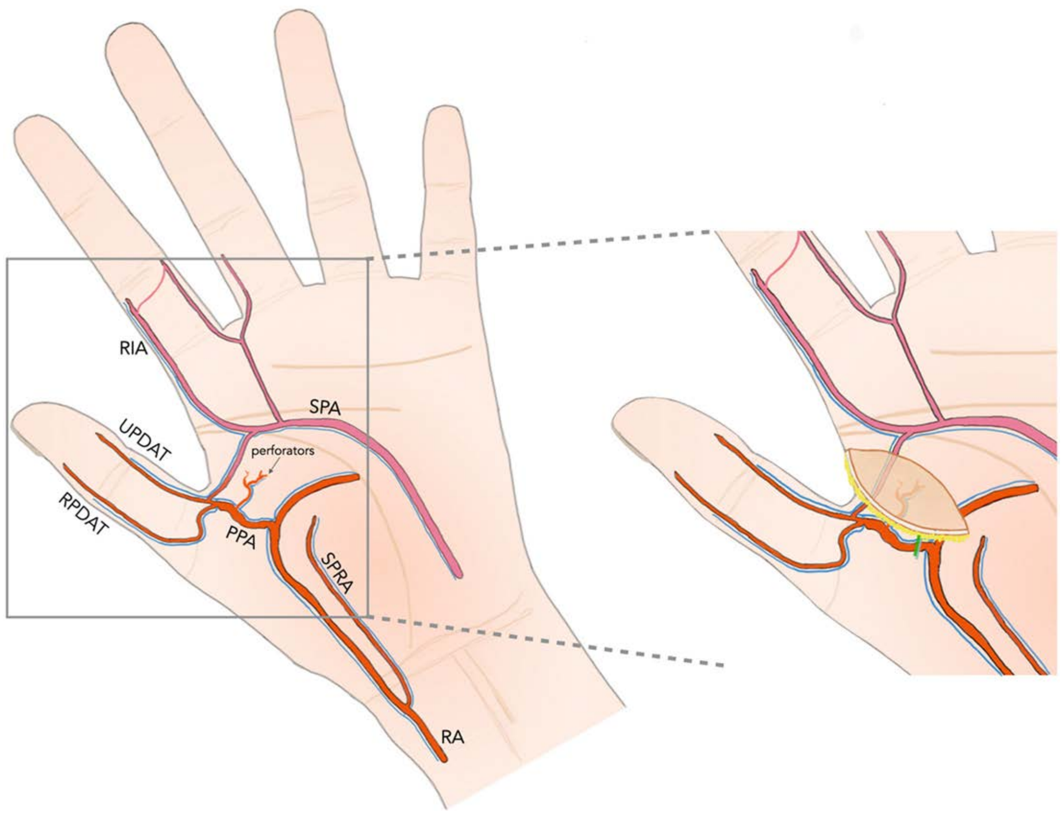

Fig. 8. (Type B) RMP flaps are designed close to the first web space when the SPA is mainly formed by the ulnar artery and the RIA bifurcates from the SPA. The flap is nourished by the terminal branch of the SPA and the dorsal-palmar anastomosis of the thumb's arteries. The PPA is the perforator origin. RA, radial artery.

the following instructions. First, when planning an RMP flap, the axis of the second metacarpal bone should serve as the key skin surface landmark for cutaneous perforators. This approach is consistent with that taken by several surgeons reporting the use of RMP flaps.[6,23] Thus, the flap pedicle will be located at or around the middle point of the axis of the second metacarpal bone. Our study also showed that there was at least 1 cutaneous perforator in a 23.2-mm diameter circle in all patients (Figs. 2, 4, 5). By including this circle in the flap, one could potentially design the RMP flap without preoperative perforator mapping.

Second, the RMP flap can be designed as either a longitudinal-type reverse-flow pattern flap that is designed parallel to the thenar crease[7] or as a triangular or elliptically shaped transverse-type flap that is designed along the distal palmar crease.[6,14] The size of the flap that can be safely elevated generally ranges from 2 to 4 cm in width and 2.5 to 6 cm in length, as reported by Kim and Hwang[6] and Kim et al.[15]

Third, nerve branches should be incorporated into the flap design to improve sensory outcomes. The midpalmar skin is relatively sensitive because it is supplied by 3 to 5 cutaneous nerve branches from each of the palmar digital nerves (PDNs).[4] In particular, the RMP region is supplied by several branches from the radial PDN of the index finger[4] and the PDN of the thumb.[6] The PDN of the index finger is bifurcated from the radial side of the median nerve at the distal margin of the flexor retinaculum, runs over the flexor tendons, and becomes superficial in the distal palm.[24] Thus, to avoid any sensory deficits, it will be necessary to identify the points where the PDN emerges at the superficial fascia by careful dissection under a surgical loupe or a microscope. Omokawa et al[7] reported that after innervated RMP flap transfer, sensory recovery is indicated by a moving 2-point discrimination of 6 mm.

Fourth, because the RMP region is ubiquitously supplied by at least 1 of 3 source vessels, it is possible to raise the RMP flap as a pedicled flap or propeller perforator flap for reconstructing defects on the radial side of the hand (thumb, first web space, and index finger).[5–7,13,14] When the source vessel is divided during flap elevation, the vascular pedicle lengthens, allowing the flap to reach as far as the tip of the thumb. Conversely, when using a perforator-based pedicle, the flap is particularly useful for releasing scar contracture in the first web space. Our study supports these findings and, in fact, suggests that having multiple potential sources makes the RMP flap particularly reliable as a pedicled or propeller flap. Thus, if the perforators arise from the terminal branch of the SPA (type A), the flap can be skeletonized by ligating the ulnar side of the terminal branch of the SPA. In these cases, the RMP flap is supplied by the UPDAT/RPDAT (Fig. 7). However, if the PPA/UPDAT/RPDAT is the perforator source (type B),

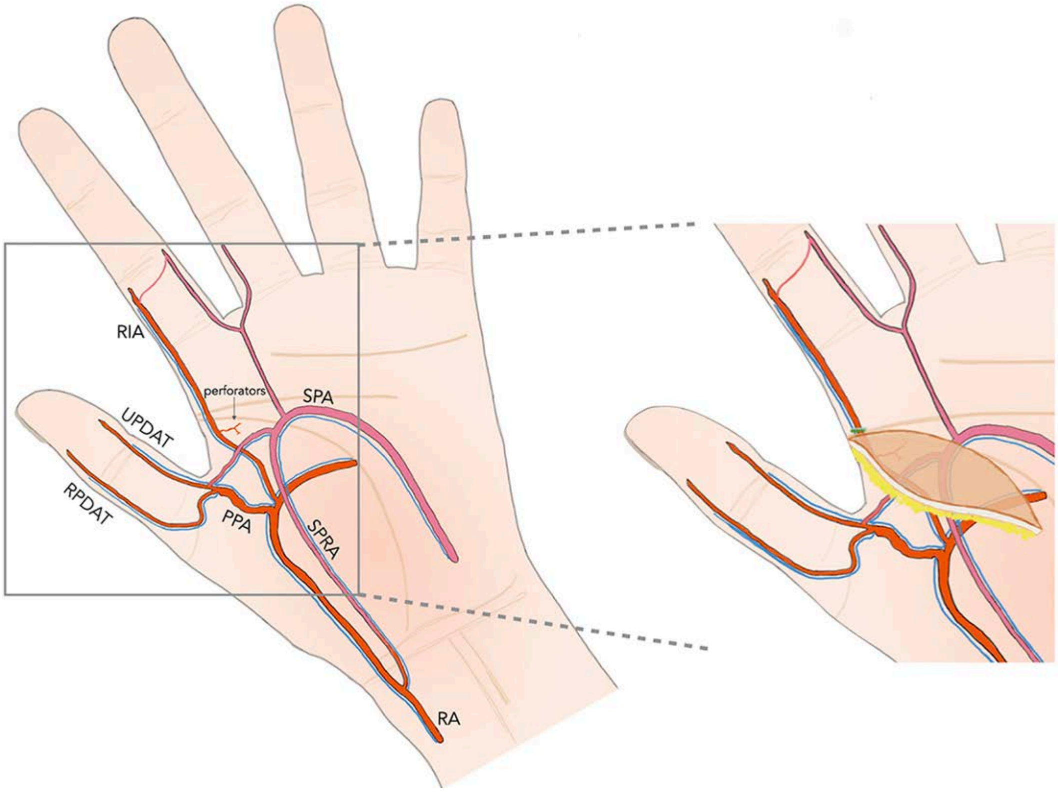

Fig. 9. (Type C) RMP flaps are designed parallel to the thenar crease and require bifurcation from the RIA for thumb reconstruction. Ligation of the distal RIA and proximal RIA increases flap rotation range, allowing the flap to reach the index finger. RA, radial artery.

only the PPA is ligated, leaving the flap being nourished by the terminal branch of the SPA and the dorsal-palmar anastomosis of the arteries of the thumb. The flap is designed close to the first web space, with its pivot point at the intersection between the terminal branch of the SPA and the palmar digital arteries of the thumb (Fig. 8).[7] Finally, if the perforators bifurcate from the RIA (type C), the pivot point of the flap is at the proximal phalangeal level.[7] For thumb reconstruction, the distal RIA must be ligated. The pedicle of the flap is dissected distally and the flap is supplied by the RIA (Fig. 9). Thus, various types of RMP flaps can be designed and harvested due to their reliable blood supply.

Fifth, there are 2 types of venous systems available for the RMP flap, namely, a subcutaneous vein or the concomitant vein of the SPA, RIA, and the palmar arteries of the thumb. Either should be included in the flap. Theoretically, the artery is usually accompanied by 1 or 2 concomitant venae.[25] To the best of our knowledge, MDCT or other precise imaging has not been performed for the concomitant venae of these perforators. However, we observed that vessel-like structures that may be venae accompanied the perforators.

Study Limitation

This study had several limitations. First, only 30 cases were examined. This reflects technical difficulties when conducting MDCT angiography on the living body: indeed, more than a third of our potential cases had to be excluded due to inadequate MDCT. Nonetheless, our sample size is larger than those in other studies on RMP perforators (n = 15 in both).[6,7] Second, because the resolution of P-CTA is modest, we may have missed tiny (<0.5 mm diameter) perforators and their concomitant veins. Further progress in computed tomography angiography that results in higher resolution will help reduce this limitation in the future. Nonetheless, the inability to detect smaller perforators is unlikely to cause clinical problems because many plastic surgeons recommend to use perforators that have a diameter of at least 0.5 mm.[26]

CONCLUSIONS

Our P-CTA study with MDCT showed that all 30 cases had at least 1 reliable perforator in the radial RMP area. As a result of our findings, we have presented guidelines that will assist plastic surgeons to easily and safely design and harvest the RMP flap, potentially without requiring preoperative perforator mapping.

Shimpei Ono, MD, PhD
Department of Plastic, Reconstructive and Aesthetic Surgery
Nippon Medical School
1-1-5 Sendagi Bunkyo-ku
Tokyo 113-8603, Japan
E-mail: s-ono@nms.ac.jp

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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