Journal of Plastic, Reconstructive & Aesthetic Surgery 89 (2024) 164–173

The profunda artery perforators: Anatomical study and radiological findings using computed tomography angiography in patients undergoing PAP flap breast reconstruction

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Received 24 May 2023; Accepted 6 December 2023

KEYWORDS
PAP flap;
Breast reconstruction;
Computed tomography angiography

Summary *Background:* The popularity of the profunda femoris artery perforator (PAP) flap is increasing; however, knowledge concerning the standardization of radiological findings and their clinical implications is limited. We evaluated the radiological architecture of posterior thigh perforators using Computed Tomography Angiography (CTA) to identify landmarks to facilitate flap dissection.
Methods: A retrospective study was conducted on 35 patients who underwent unilateral breast reconstruction with a PAP flap. The preoperative CTA scans were analyzed, and the perforator characteristics were evaluated. The perforators were mapped using a Cartesian coordinate system. Data were normalized by anatomical landmarks and overlapped. Perioperative and postoperative results were analyzed. Radiological and intraoperative were compared.

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https://doi.org/10.1016/j.bjps.2023.12.006

Results: Two CTA scans were excluded; 66 thighs were examined. The mean perforator number was 3.2. The mean diameter of chosen perforators was 2.7 mm (DS ± 0.6 mm) at the origin, 2.2 mm (DS ± 0.4 mm) at the adductor space midpoint, and 1.7 mm (DS ± 0.3 mm) at the deep fascia. The mean adipose tissue thickness was 3.35 cm (DS ± 0.94) at the deep fascia and 3.59 cm (DS ± 1.19) at the adductor space midpoint. Intraoperatively, the perforator was located 3.22 cm (DS ± 0.87) from the posterior border of the gracilis muscle and 8.98 cm (DS ± 1.44) from the inferior gluteal crease. A radiological area located 9.33 cm (DS ± 4.81) from the y-axis and 7.48 cm (DS ± 1.88) from the x-axis was identified.

Conclusions: CTA using the volume-rendering technique is a valuable method to study in vivo the radiological anatomy of the posterior thigh perforators.

The deep inferior epigastric artery (DIEP) perforator flap is considered the first choice for free autologous tissue breast reconstruction.[1] The DIEP flap provides an adequate amount of skin and subcutaneous fat, ideal for replacing the missing breast tissue. However, when the abdominal donor tissue is insufficient, there are contraindications, or the patient refuses to avoid an abdominal scar, alternative perforator flaps can be considered.[2-4] The superior gluteal artery perforator, inferior gluteal artery perforator, transverse upper gracilis (TUG), and lumbar perforator flaps have been advocated as choices, all of them with benefits and drawbacks.[5-7]

In the last decade, the profunda femoris artery perforator (PAP) flap has gained popularity within the field of reconstructive surgery for different purposes and represents a good option for breast autologous reconstruction.[8] Posterior thigh flaps were first described by Conway et al.[9] in 1947 and by Hurwitz[10] in 1980. Song et al.[11] in 1984 used it as a free flap, whereas in 2001, Angrigiani et al.[12] described the posterior thigh flap as a perforator flap. Finally, Allen et al.[13] in 2012 was the first to use it for breast reconstruction. Since then, the role of the PAP flap in breast reconstruction has been expanding because of sufficient soft tissue volume, long and sizable pedicle length, optimal vascular resistance, good texture, and hidden donor-site scar.[14]

However, compared with the lower abdominal region, the posterior thigh anatomical region has been much less studied as compared with perforators and blood perfusion. Even if findings regarding radiological[15-17] and surgical anatomy and the location of the profunda femoris perforators[18-26] have been reported, there is limited knowledge on how to standardize radiological results and their clinical effects on the conventional flap design and harvesting. On the basis of these factors, this study aims to assess the radiological anatomy of the posterior thigh perforators and provide an additional helpful method for surgical planning.

Methods

Study design

We conducted a retrospective, single-blinded, anatomical study on a consecutive series of cases of unilateral breast reconstruction with the PAP flap performed on females (> 18 years old) who underwent surgery between January 1, 2018 and April 30, 2019. We retrospectively investigated the fully de-identified preoperative computed tomography angiographies (CTAs) archived in our institutional records. Exclusion criteria were previous thigh or perineal-gluteal surgical procedures, known vascular anomalies, or paraplegia. Being a retrospective analysis of service activity, this study was deemed exempt from our Institutional Review Board, and no informed consent was required. The principles outlined in the Declaration of Helsinki, as well as all applicable laws and ethical standards, have been followed during the conduction of this study. Information on demographic data, body mass index (BMI), side of flap harvest, intraoperative findings, perforator characteristics, flap weight, operative time, and complications were recorded prospectively at the time of surgery.

Flap harvest

The profunda artery perforator flaps were harvested with the skin paddle oriented transversely.[27] During the marking of patients, two positions were employed: standing and lying in the frog leg position. In the standing position, markings were made at the inferior gluteal crease and the midline of the posterior thigh. In the frog leg position, the superior border of the skin flap was positioned 1 cm above, or at the level of, the inferior gluteal crease. The anterior apex of the skin flap was extended to the level of the anterior labial commissure, whereas the posterior apex of the skin flap did not extend beyond the midline of the gluteal crease. The width of the skin paddle varied depending on the amount of skin required in the reconstructed breast but typically measured up to 6 cm in width. With the patient in the lithotomy position, all surgeries were performed with a two-team approach, with one team harvesting the flap and the other team preparing the recipient site at the breast. The dissection was carried out from supero-anterior to infero-posterior. Perforators were found and dissected within the adductor magnus muscle below the inferior border of the gracilis muscle. Pedicle dissection was completed when the vessels had a sufficient diameter to match the internal mammary vessels. With the inferior border of the gracilis muscle and the inferior gluteal fold as landmarks, the chosen perforator's location was measured intraoperatively. Consequently, we verified if the chosen perforator was the one identified with the CTA.

Imaging analysis

Preoperative serial axial CTA scans with the Toshiba scanner Aquilion Prime TSX-303A iCT were performed on all patients who underwent free autologous breast reconstruction with a PAP flap. A 0.5-mm-thick slice was used and was analyzed by Horos (Open Source Software, Horosproject.org, v 3.3) from the upper abdomen to the superior edge of the patella, after the patients had been given a bolus of intravenous iodine-based contrast material at 3.5–4.5 mL/s (Lomeron 400 mg/mL or Ultravist 370 mg/mL). The patients were scanned while lying supine with their toes pointed upward, both lower limbs straight and fully adducted. The images were reconstructed to coronal, sagittal, and 3-D views and with maximum intensity projection by Vista application.

The perforators' number was recorded, and among them, the most suitable perforator was identified for flap harvest. Perforators located 15 cm below the inferior gluteal crease were excluded. The thickness of adipose tissue was measured at two points: at the level of the deep fascia near the perforator and at the level of the midpoint of the adductor space.

A Cartesian coordinate system was used to map the location of the perforators, with the origin set at the greater trochanter. The distance between the greater trochanters represents the abscissa (x) axis, whereas the distance between the greater trochanter and the lateral epicondyle serves as the ordinate (y) axis. The perforator endoluminal diameter was measured at three points: (A) deep fascia, (B) the midpoint of the adductor space, and (C) the origin from the profunda artery. To compare all the evaluated data, the perforator's location along its course (at the deep fascia, at the midpoint of the adductor space, and at the origin of the perforator) was normalized, 0–100 scale, by anatomical landmarks (inter-greater trochanter distance for the x-axis and greater trochanter-lateral epicondyle distance for the y-axis).

All the normalized data were reported and overlapped to a second quartile or the 50th percentile of standard female thighs represented in the volume-rendering image of a CTA. Consequently, we identified on the medial aspect of the thigh a radiological area where the majority of suitable profunda artery perforators were located.

Descriptive statistics were calculated, including mean values, standard deviations, and ranges for continuous variables; Sigma Stat 4.0 and Sigma Plot 14.0 software (Systat Software Inc, Nevada, USA) and IBM SPSS Statistics 24 (IBM, Armonk, New York, USA) were used for all statistical analyses. In cases where the dissected perforator was the same as the one identified in the CTA scan, we retrospectively measured on the CTA scan the perforator's localization from the posterior margin of the gracilis and the inferior gluteal fold.

Results

Clinical and intraoperative data

A total of 35 female patients underwent unilateral breast reconstruction with a PAP flap. The mean age was 42.35 (range 26–58) years, and their average BMI was 21.11 ± 8.6. All patients were Caucasian.

Average operative time was 287.25 ± 46.50 min including mastectomy operation time. Patients' mean hospitalization was 6.77 ± 3.04 d.

On the basis of the best perforator and adipose thickness side 16 PAP (45.7%) were harvested from the left side, with the perforator placed 3.24 cm (DS ± 0.98) from the gracilis muscle's posterior border and 9.05 cm (DS ± 1.21) from the inferior gluteal crease. On the right side, 19 PAP (54.4%) were harvested and we measured the distances to the posterior gracilis margin, and the inferior gluteal crease as follows: 3.2 cm (DS ± 0.76) and 8.92 cm (DS ± 1.67), respectively. The average location was 3.22 cm (DS ± 0.87) from the posterior gracilis muscle margin and 8.98 cm (DS ± 1.44) cm from the inferior gluteal fold (Table 1). The average flap weight was 221.08 g (DS ± 67.36).

The surgeon identified the most suitable perforator intraoperatively, and all of the chosen perforators were dissected through an intramuscular course. Among the 33 flaps that had an available CTA (2 CTA scans were excluded), in 24 cases (72.7%), the chosen perforators were the same perforators that were identified with the CTA. In two flaps, two perforators connecting in a Y-fashion were harvested to supply the flap perfusion (Figure 1).

The postoperative course was uneventful for all patients. No flap losses or significant fat necrosis were recorded. Only two patients (5.7%) presented complications: one patient (2.8%) required revision surgery because of the wound dehiscence at the donor site; the other (2.8%) developed a seroma at the donor site, which was managed at the outpatient clinic with puncture aspiration.

CTA findings

Thirty-three CTA scans were analyzed and two patients' scans were excluded because the hyperkinetic blood flow did not allow visualization of perforators. Sixty-six thighs were examined by two blinded specialists, a plastic surgeon, and a radiologist. Multiple musculocutaneous perforators (n = 170) and fewer septocutaneous ones (n = 16) were identified, all of them ran through the adductor magnus muscle and obliquely in a posterior direction (Figure 2).

The average number of perforators for each thigh was 3.2 (DS ± 1.02). A major perforator with the best diameter and best course was found in all CTA scans. These perforators were followed, their course was analyzed, and the diameter was measured at three points (Figure 3). We measured an average diameter of 2.7 mm (DS ± 0.6 mm) at the origin from the profunda femoris artery, 2.2 mm (DS ± 0.4 mm) at the midpoint of the adductor space, and 1.7 mm (DS ± 0.3 mm) at the emergency from the deep fascia (Table 2). Where the major perforator pierced the deep fascia, the adipose tissue average thickness was 3.35 cm (DS ± 0.94, range: 1.41–5.36 cm), and in the adductor space the midpoint was 3.59 cm (DS ± 1.19, range: 1.1–6.39 cm). A statistical correlation was found, t-test ($p < 0.0001$), between the adipose thickness of the medial thigh and the number of perforators from the profunda

Table 1 Detailed data of the chosen perforators' intraoperative location (cm) with the gracilis muscle's posterior border and the inferior gluteal fold as landmarks.

Left thigh			Right thigh		
PAP no.	Chosen peroforator distance (cm) from posterior gracilis muscle margin	Chosen peroforator distance (cm) from inferior gluteal fold	PAP no.	Chosen peroforator distance (cm) from posterior gracilis muscle margin	Chosen peroforator distance (cm) from inferior gluteal fold
1	4.6	8.5	1	3.4	8.3
2	3.6	9.2	2	2.7	7
3	3.3	10	3	3.6	7.2
4	4.8	7	4	1.8	8.8
5	3.2	9.8	5	4.2	7.3
6	2.8	9	6	3.2	7.8
7	2	7.5	7	3	8.5
8	3.8	9.2	8	2.5	11.8
9	1.9	8.4	9	3.2	8.9
10	2.7	10.3	10	2.8	9.6
11	3	7.2	11	3.3	10
12	4.7	8.1	12	4.5	11.3
13	1.6	11	13	2.6	8.2
14	3.5	9.6	14	3.3	10.3
15	2.4	10.8	15	4.8	6.5
16	3.9	9.3	16	3.4	10.5
			17	2.7	6.3
			18	2.2	11
			19	3.6	10.2

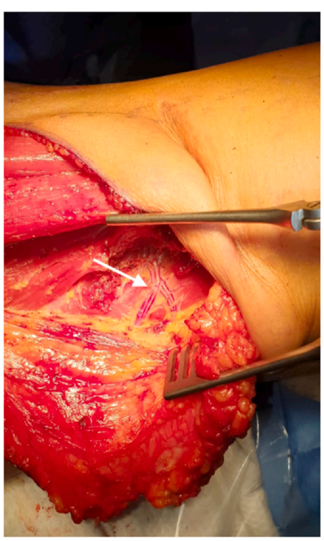

Figure 1 A Y-configuration of the second medial perforator of the profunda femoris left artery, intraoperative particular (white arrow shows the Y forking).

femoris artery, but not with the diameter of the major perforator (p = 0.0925).

Figure 4 showed the normalized data, 0–100 scale, by the anatomical landmark of each chosen perforator's location along its course whereas in Figure 5, all the normalized data were reported to a second quartile or the 50th percentile of standard female thighs represented in the volume-rendering image of a CTA. Consequently, the area with the majority of perforators was identified and localized at

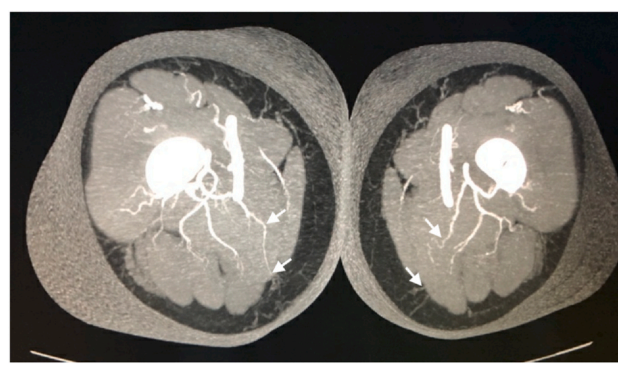

Figure 2 A Maximum Intensity Projection (MIP) imaging of the perforator of the profunda artery. They run through the adductor magnus muscle and obliquely in a posterior direction, mostly with the intramuscular pattern. The white arrow shows the intramuscular pattern in the middle point of the adductor magnus muscle, and the second arrow is the point at which perforators pierced the deep fascia.

9.33 cm (DS ± 4.81) from the inter-great trochanter line on the ordinate axis, and at 7.48 cm (DS ± 1.88) from the greater trochanter-lateral epicondyle line on abscissa axis. A Y-configuration was revealed for 17 perforators, approximately 1–2 cm into the adductor magnus muscle. This configuration was present in 25.75% of the thighs and was supplied by a second medial branch of the profunda femoris artery. We also found that eight of these perforators, when originating from the first medial branch of the profunda femoris artery, crossed the muscle and then ran obliquely in a posterior-upper direction. A rather constant anastomosis

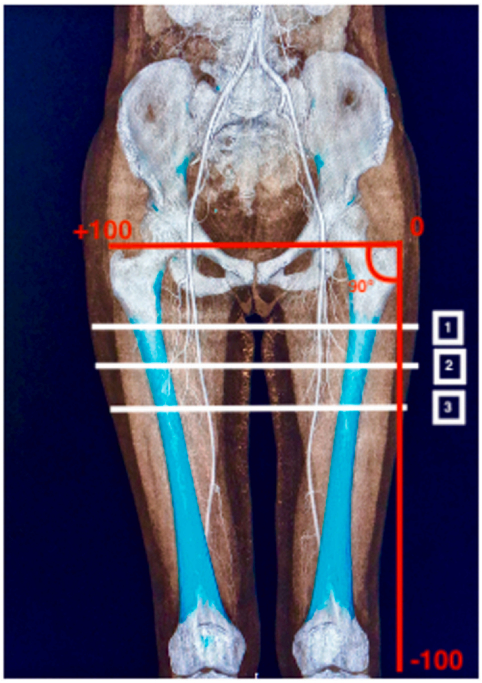

Figure 3 Computed Tomography Angiography (CTA) volume rendering image of standardized female tights of the second quartile or 50th percentile (Q2). Measurements were normalized, 0-100 scale, by anatomical landmarks (inter-greater trochanter, greater trochanter-lateral epicondyle distance). The Cartesian coordinate system (red line) was made setting to zero at the greater trochanter (red 0), abscissa axis (horizontal red line) at inter-greater trochanter space, and ordinate axis (vertical red line) at the greater trochanter-lateral epicondyle distance. The white line and corresponding number highlight the anatomical points of study in which all analyzed perforator vessels of the profunda femoris artery (PFA) diameter and Cartesian coordinates data were collected. The first white line shows the first point (1) at emergency from PFA, the second line shows the second point (2) of perforator detection and analyzes at adductor space, and the last line the point (3) where the major perforator pierces deep tight fascia.

was noted between the first or the second-deep femoral perforating artery and a posterolateral branch of a fascia-lata muscle perforator.

CTA data of the location of the 24 perforators identified and consequently dissected intraoperatively are available in Table 3.

Discussion

It is widely acknowledged that the posterior thigh's radiological vascular architecture is constant.[5,8,14-18] However, there is limited evidence in the literature about the medial thigh profunda artery perforators. Although studies addressed radiological and surgical anatomy and the location of the profunda femoris perforators have been recorded, there has been limited knowledge on how to standardize radiography results and their implications in surgical planning.

Compared with the study conducted by Ahmadzadeh et al.,[22] which reported an average of five suitable perforators with a sizable perforasome located between the inferior gluteal fold and 15 cm distal to that site, we found a smaller number of suitable perforators (mean: 3.2). Our findings are similar to the ones of Haddock et al.,[28] where an average of 3.3 perforators were identified and to the ones of Zeltzer et al.[29] where an overall average number of 2.5 $\pm$ 1.03 perforators was seen per thigh.

Among all the perforators, the authors identified the best perforator intraoperatively in all the cases.

According to Haddock et al.,[28] the perforators had an oblique and posterior course through the adductor magnus muscle.

Ramirez et al.[30] in 1984 first demonstrated that the posterolateral fascia-lata flap received branches from the first deep femoral perforating artery quite constantly and we confirmed their findings. As already shown by Cormack and Lamberty's,[31] the profunda femoris perforating arteries provide the majority of the blood flow to the skin of the posterior thigh. Moreover, the CTA scan's analysis of the perforator demonstrated that a valid profunda femoris perforator with suitable pedicle length and diameter is constantly present, making the PAP flap a valuable tool in reconstructive surgery.

Their course and size were easily traced on the angiogram, and the reported Y-conformation of the perforator is also reported in an anatomical cadaver study conducted by Saad et al.[5] Ahmadzadeh et al.[22] proposed to call these arteries "perforating" to avoid any confusion with the current commonly used word perforator with reference to any vessel that enters the subfascial area through a fenestration in the deep fascia.

Flaps have also been given a nomenclature classification: the profunda femoris flap would be denoted as PFAP-*bf*, PFAP-*sm*, or PFAP-*s*, depending on whether the profunda femoris artery perforator flap (PFAP) is raised on perforators piercing the biceps femoris muscle (*bf*), semimembranosus muscle (*sm*), or fascia (*s*), respectively.[22]

The Cartesian coordinate system used in our study is different from Haddock's[28] work in which the midline and gluteal fold are set to zero on the x- and y-axes, respectively, to represent the location and different from Zeltzer's[29] work in which the x-axis is formed by a line horizontally drawn at the level of the highest point of the symphysis pubis and the y-axis by a line perpendicular to the x-axis and passing through the middle of the upper border of the patella.

The PAP flap is an excellent option for autologous breast reconstruction, providing soft and pliable tissue even for skinny patients with inadequate abdominal tissue. Compared with the TUG flap, another viable alternative from the medial thigh, the PAP flap involves no muscle sacrifice, and it is dissected further from the lymphatics, resulting in less donor-site morbidity. Furthermore, the PAP flap offers a higher volume of tissue, with more posterior and well-hidden donor scar. The vascular pedicle is significantly longer and the caliber's vessels larger, making it our preferred choice for breast reconstruction over the TUG flap.[32]

Several skin paddle designs may be employed according on the surgeon's preferences, the patient's characteristics,

Table 2 Detailed data for each patient are given with the mean diameter of the studied perforator vessels for each thigh at precise points. (DIAM. 1 = Diameter at its origin from the profunda femoris artery; DIAM. 2 = Diameter at the middle point of the adductor space; DIAM. 3 = Diameter at the point it passes through the deep fascia).

Patient	Left thigh				Right thigh			
	Perforator no.	Diameter 1	Diameter 2	Diameter 3	Perforator no.	Diameter 1	Diameter 2	Diameter 3
1	4	3.5	2.3	1.2	5	2.8	2.2	1.6
2	4	2.7	2.5	1.5	4	3.1	2	1.8
3	3	3.7	2.9	2.2	3	2.6	1.8	1.6
4	4	4.2	3.3	2.8	3	4.2	3.1	2.8
5	4	3.5	3	2.7	5	2.9	3.5	2.3
6	4	3.5	2.3	1.2	5	2.8	2.2	1.6
7	2	2.5	2	1.4	2	2.9	1.9	1.6
8	3	2.5	2.5	1.7	4	2.4	2	1.4
9	3	2.2	1.9	1.5	4	2.5	1.9	1.9
10	4	3.4	2.1	1.7	3	3	2.4	1.8
11	4	2.8	2	1.5	3	4.1	2.3	1.7
12	1	2.6	2	1.7	3	2.9	2.4	1.9
13	2	2.5	1.9	1.6	3	2.8	2.1	1.9
14	3	2.8	2.5	1.7	1	2	1.4	1
15	3	2.1	1.8	1.6	5	2.5	2.3	2
16	5	2.5	1.7	1.6	2	2.6	2.2	1.7
17	2	3.3	2.3	1.6	3	2.8	2	1.7
18	5	2.8	2.3	1.6	5	2.6	2	1.9
19	2	2.2	1.9	1.7	3	2.6	1.9	1.6
20	3	2.8	2	1.8	4	3.4	2.9	1.8
21	3	2.8	1.9	1.5	4	2.9	2.4	1.6
22	4	2.7	1.9	1.2	3	2.5	2.2	1.9
23	2	2	1.7	1.6	3	2	1.7	1.5
24	2	1.9	2.1	1.3	2	2.7	1.7	1.8
25	2	2.3	2.1	1.7	2	2.4	1.8	1.4
27	4	4	2.2	1.6	3	2.2	2.1	1.6
28	4	1.9	1.8	1.7	3	2.3	2	1.5
29	3	3	2	1.5	2	2.5	1.8	1.8
30	2	2.6	2.1	1.8	4	2.3	2.3	1.5
31	4	2	1.9	1.6	4	2	2.01	1.4
32	3	2.8	2.5	1.7	1	2	1.4	1
33	2	2.3	2.1	1.7	2	2.4	1.8	1.4

and the position of the perforator.[33] The author's preferred design[27] involves a transverse narrower skin island with the chosen perforator included within the adipose tissue. Dissection is carried out by undermining the medial thigh skin from the flap's adipose tissue and dissecting it above the gracilis muscle fascia. This technique permits the reduction of the risk for lower migration of the donor-site scar, less asymmetry between the thighs, no visible scar anteriorly, and less visible scar posteriorly. Moreover, by avoiding the extension of the skin paddle beyond the midline of the posterior thigh, the risk of injuring the posterior cutaneous femoral nerve is reduced (Figure 6).

Analyzing the normalized, overlapped data reveal a consistent distribution of source artery perforators, which may contribute to a more precise flap design. Moreover, on the basis of the intraoperative findings routinely recorded in a prospective manner, the CTA-identified radiological area aligns with the region where surgeons focused on perforator dissection providing further evidence of the accuracy of CTA using the volume-rendering technique[34,35] as a reliable method to radiologically identify and evaluate the perforator of choice on which to harvest the PAP flap.

Within the 33 flaps that had an available CTA scan, in 24 cases, the perforator selected was the same as the one identified in the CTA scan. The concordance between the CTA findings and the perforator selected by the surgeons was 72.7%.[36,37]

Among the remaining cases, eight perforators were selected on the basis of their more advantageous central location in relation to the flap. The remaining perforator was not identified preoperatively by the CTA scan. Therefore, the sensitivity of CTA for this data was 96.9%. Being a retrospective analysis, we have not assessed if all the perforators visualized in CTA were present intraoperatively.

The correlation between these two data underlie the high importance of preoperative CTA scan analysis.

Furthermore, as to these 24 flaps, the position of the perforator from the intergluteal fold and the posterior margin of gracilis muscle were retrospectively measured in the CTA scans and compared with the intraoperative ones.

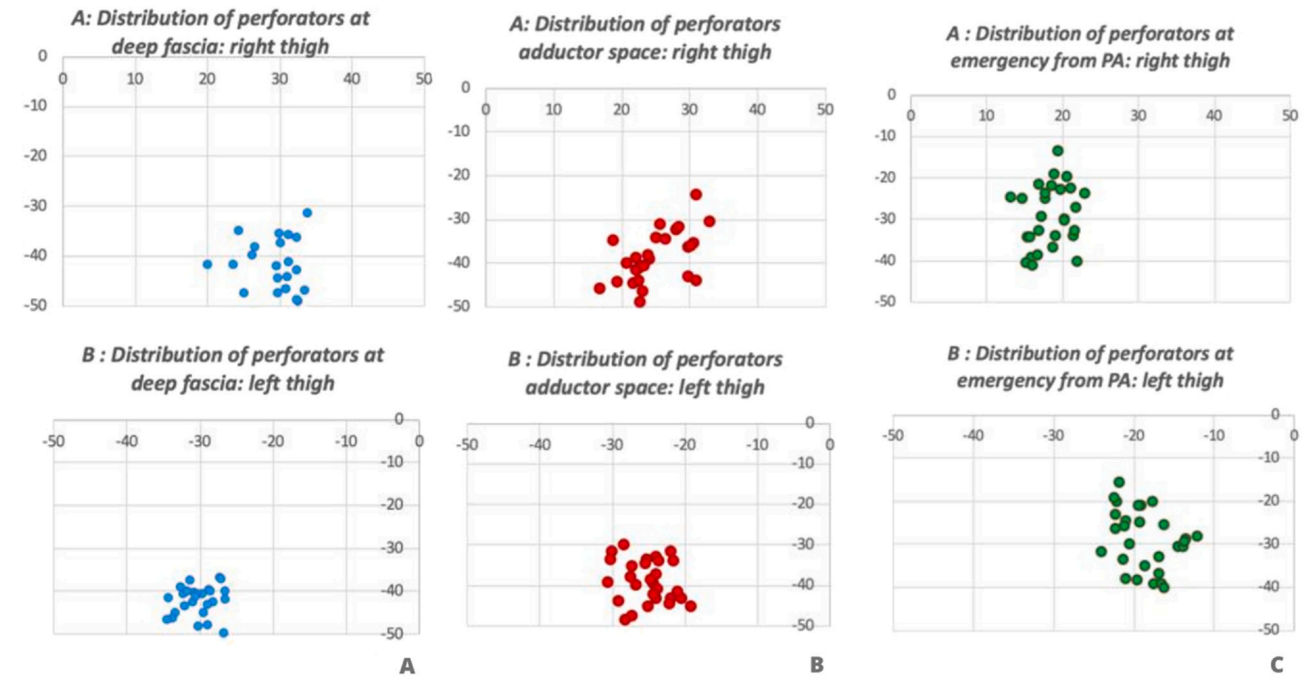

Figure 4 Diagrammatic representation of the Computed Tomography Angiography (CTA) of standardized tights, showing the anatomical localization and distributions of all major analyzed perforators vessels of the profunda femoris artery (PFA) and their relationship at adductor space (A) right thigh, (B) left thigh. Bony landmarks (Greater trochanter, lateral epicondyle) were used as referrals. Measurements were normalized, 0-100 scale, by anatomical landmarks: inter-greater trochanter distance for the abscissa (x) axis; greater trochanter-lateral epicondyle distance represents the ordinate (y) axis. (a) Normalized distribution data of each major perforator at deep tight fascia (A) left thigh, (B) right thigh. Each red dot shows a normalized coordinate (x;y) of the major perforator of a tight at the deep tight fascia. (b) Normalized distribution data of each major perforator at adductor space (A) left thigh, (B) right thigh. Each red dot shows a normalized coordinate (x;y) of the major perforator of a tight at adductor space. (c) Normalized distribution data of each major perforator at emergency from PA (A) left thigh, (B) right thigh. Each red dot shows a normalized coordinate (x;y) of the major perforator of a tight at emergency from PA.

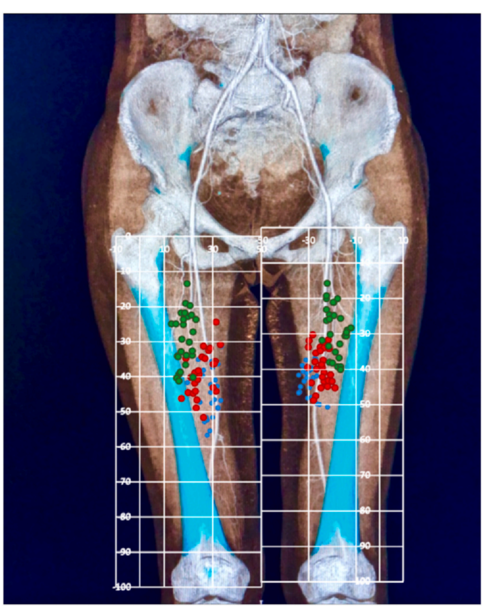

Figure 5 Computed Tomography Angiography (CTA) volume rendering image of standardized female tights of the second quartile or 50th percentile (Q2), showing the anatomical localization and distributions of all analyzed perforators vessels of the profunda femoris artery (PFA) and their relationship at deep tight fascia (blue dots), at adductor space (red dots), and at emergency from PFA (green dots).

Intraoperatively, perforators were found at an average of 0.92 cm difference from the location identified with the CTA scan. Our findings agree with Garvey et al.[38] and Kim et al.[39] confirming that the discrepancies between CTA and intraoperative findings could be because of operator-biased intraoperative measurements or correlated with the CTA scan technique. Anyhow, the sensitivity and sensibility of the CTA scan in identifying the profunda artery perforator location should be better assessed prospectively within a larger population.

CTA that employs the volume-rendering technique allows physicians to map the anatomical characteristics of the suitable perforators, including their origin, course, and emerging site. The 3-D image reconstruction helps surgeons choose the best flap design and surgical approach. Furthermore, it might be helpful to assess additional specific preoperative information such as the perforator's caliber and the thickness of the adipose tissue. The average thickness of the adipose tissue was 3.35 cm (DS ± 0.94 cm) at the site where the major perforator pierced the deep fascia. According to Greige et al.,[40] the preoperative measurement of the flap thickness can predict the flap weight, preventing the need for revision surgery to achieve symmetry or the augmentation of the reconstructed breast with an additional flap or lipofilling. On the basis of these considerations, the surgeon can plan the flap design and select the "best thigh" for the flap harvest by accurately assessing the adipose thickness and perforator distribution. For these reasons, we

Table 3 Detailed data of the distance (cm) of the most suitable perforator identified with the CTA scan from the gracilis muscle's posterior border and the inferior gluteal fold. Measurements were calculated retrospectively on CTA scans.

	Left thigh			Right thigh	
PAP no.	Chosen perforator distance (cm) from posterior gracilis muscle margin	Chosen perforator distance (cm) from inferior gluteal fold	PAP no.	Chosen perforator distance (cm) from posterior gracilis muscle margin	Chosen perforator distance (cm) from inferior gluteal fold
1	4.2	7.8	1	3.8	6.9
3	4.8	9	2	3.7	8.2
4	3.7	7.9	3	4.1	8.2
5	3.2	9.6	4	2.5	6.5
6	3.3	10.6	5	3	6.9
7	2.9	6.5	6	4	6.9
8	2.6	8.6	7	3	7.9
9	3.1	9.8	9	4.1	7.4
11	2.2	7.7	11	4.5	9.5
12	3	7.2	13	2.9	7
14	2.2	8.4	14	2	9.4
			16	1.7	9.3
			19	4	9.4

Figure 6 Preoperative (A, B, C) and postoperative (D, E, F) views of a 46-year-old patient who underwent a right nipple-sparing mastectomy and left thigh PAP flap immediate breast reconstruction. Previous quadrantectomy on the left side.

consistently have employed CTA in the preoperative evaluation. Even though previous studies in this field have predominantly relied on cadaver dissections,[25,26] to the best of our knowledge, this is the first study that evaluated in vivo a normalized, reproducible radiological region employing CTA with a volume-rendering technique where the best profunda artery perforator can be identified along its course within the adductor magnus muscle.

We believe that the application of a preoperative CTA with a volume-rendering technique facilitates physicians in preoperative planning. This lowers the rate of intraoperative flap design changes, complications, and the number of revision surgeries, which positively impacts the healthcare system's costs and causes less psychosocial distress for the patients.

The limitations of this study are its retrospective nature and the small sample size of a cluster of patients with low BMI. Therefore, the initial promising outcomes must be validated prospectively using this technique as a step in preoperative planning.

Conclusions

CTA using the volume-rendering technique is a valuable method to study in vivo the radiological anatomy of the posterior thigh perforators. Through the overlay of the normalized data based on bone landmarks, a consistent distribution pattern of perforators was observed. The area where the most suitable perforators are located was identified, which may contribute to a more precise flap design. Moreover, we suggest that CTA using the volume-rendering technique holds potential in preoperative planning because it is a reliable and reproducible method to radiologically identify and evaluate the characteristics of the perforators.

The concordance between the perforator evaluated with the CTA and that dissected by the surgeon highlights the importance of the CTA before surgery.

Ethical approval

Not required.

Funding

None.

Declaration of Competing Interest

Authors disclose any financial and personal interest to declare in relation to the content of this article.

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