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Gender-specific Anatomical Distribution of Internal Pudendal Artery Perforator: A Radiographic Study for Perineal Reconstruction

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Background: Cancer, trauma, infection, or radiation can cause perineal defects. Fasciocutaneous flaps based on perforator vessels (PV) from the internal pudendal artery (IPA) provide an ideal reconstructive option for moderate defects. We hypothesized that, due to gender differences in the pelvic-perineal region, the anatomical distribution of PV differs between genders.

Methods: Computed tomography angiographies from male and female patients without pelvic-perineal pathologies were retrospectively analyzed to study the vascular anatomy of the IPA. The number, size, type, and distribution of PV were recorded and compared between genders. Four anatomical regions were defined to describe the distribution of PV on each perineal side: anterior (A), anterior-central (AC), central-posterior (CP), and posterior (P).

Results: A total of 63 computed tomography angiographies were analyzed (men, 31; women, 32). Each IPA provides 2 ± 1 PV and 5 ± 2 terminal (cutaneous) branches: in both genders, 85% of PV are septocutaneous (15% musculocutaneous). In women, 70.5% of PV are located in AC, 28.2% in CP, 1.2% in A, and 0% in P; average diameter of the PV is 2.4 ± 0.3 mm. In men, 53.7% of PV are located in CP, 43.1% in AC, 3.3% in A, and 0% in P; average diameter of the PV is 2.8 ± 0.5 mm. Gender-specific differences in anatomical distribution of PV are significant ($P < 0.001$).

Conclusions: Number, size, and type of terminal branches of PV of the IPA are consistent between genders, but their distribution is different, with women having an anterior predominance. Knowledge of gender-specific anatomy can guide preoperative planning and intraoperative dissection in flap-based perineal reconstruction (*Plast Reconstr Surg Glob Open* 2020;8:e3177; doi: [10.1097/GOX.0000000000003177](https://doi.org/10.1097/GOX.0000000000003177); Published online 29 October 2020.)

INTRODUCTION

The perineum is an anatomically and functionally complex region. Several conditions, ranging from cancer to trauma or pressure injuries,¹ infection, radiation, congenital to gender-affirming surgery, can lead to the need for perineal reconstruction and function restoration.

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Although each of the conditions mentioned above has a relatively low incidence, collectively they represent a common surgical scenario. Cancer is the most frequent cause of perineal defects, directly (colorectal adenocarcinoma, anal squamous cell carcinoma, vulvar and vaginal squamous cell carcinoma, or Paget's disease) or indirectly (radiation therapy for pelvic tumors). For example, over 6000 vulvar cancers are diagnosed every year in the United States (0.7% of all cancers in women and 6% of all cancers affecting the female reproductive system). Other conditions, such as Fournier's gangrene, are more rare (incidence, 1.6 per 100,000 men in the United States) but associated with a high morbidity and mortality (7.5% fatality rate).²

The variety and severity of these conditions, as well as their impact on patients' function (including sexual) and quality of life, highlight the importance of proper defect reconstruction and function restoration. Proper perineal reconstruction

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has been associated with high patient satisfaction,^{3,4} although preinjury function and quality of life are not fully recovered.

Several reconstructive techniques are currently available, including direct wound closure and skin grafts, local or pedicled flaps, and microsurgical free flap reconstruction.^{3,5–11} Pedicled fasciocutaneous flaps have shown to be a less invasive and ideal option to repair moderate perineal defects.^{5,12–14} Possibly, they could also be adopted for smaller defects because direct wound closure, skin grafts, and local flaps have been associated with poor outcomes due to wound dehiscence, scarring, anatomical disruption, and functional restriction.^{3,5–7,15–18} Among fasciocutaneous flaps, those based on the internal pudendal artery (IPA) system and its branches (eg, perineal artery) have been frequently used and have been associated with optimal outcomes, as they provide an ideal restoration of native tissue structure, limited scarring, function restoration, and retention of sensation.^{1,4,12,19–29} Examples of IPA perforator flaps (IPAP flaps) include the “Lotus petal” flap (Gluteal-fold flap) and the “Singapore” flap (Pudendal thigh fasciocutaneous flap).^{19,20,22,30–34}

Despite the extensive use of flaps based on the IPA system, only limited studies have investigated and described its vascular anatomy in detail.^{20,35–37} Most of these studies have been based on few cadaveric dissection and have only reported the branching structure of the system, without information on its anatomical localization and distribution.^{36,37} A more accurate knowledge of the anatomical localization and distribution^{36,37} of the perforator vessels branching from the IPA can guide preoperative planning, facilitate safer intraoperative identification, and allow more extended dissection of larger flaps based on this system. In addition, it can help expand the use of free-style perforator flaps based on the IPA system in perineal reconstructions.¹²

The goal of this study was to use radiographic imaging to define the anatomical distribution of the perforator vessels of the IPA in both genders. We hypothesize that, due to gender differences in the anatomy of pelvic–perineal region and of external genitalia, the anatomical distribution of the perforator vessels differs between genders.

MATERIAL AND METHODS

Study Design and Approval

We designed a retrospective anatomical study investigating fully de-identified radiographic images archived in our institutional records. The study was retrospective and 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.

Computed tomography angiographies (CTAs) performed on adults (>18 years old; men and women) not affected by pelvic or perineal pathologies were included and retrospectively assessed. Exclusion criteria were previous pelvic or perineal surgical procedures, known vascular anomalies, or paraplegia. Information regarding patients' gender, body mass index (BMI), and side of the imaging measurements was collected.

Imaging Analysis

CTAs of the abdominal-pelvic area were analyzed by Horos (Open Source Software, Horosproject.org, v 3.3) to investigate the vascular system of the IPA bilaterally. The following parameters were assessed: presence of the IPA, the diameter of the IPA at the inlet of the lesser sciatic foramen (pudendal canal), the number of perforator vessels branching from each IPA, their type/course (musculocutaneous or septocutaneous), the location of their origin, reported in percentage, and their diameter (ie, both at the origin and where they pierce the pudendal canal) (Fig. 1A).

Any anatomical variation of that regional vascular system was also recorded. The localization of the vessels was defined using the Cartesian system, considering the anus as the origin point (point 0.0).³⁵ The distance of each perforator vessel from the anus was calculated on each main axis (ie, x and y): all data were normalized then adapted to a 50th percentile pelvis (constant interischial distance) and expressed as percentage of the distance between the anus and each ischial tuberosity (Table 1). To account for variations in patient positioning, the interischial line was used to create a standardized Cartesian plane, imagining patients placed in a horizontal supine position.

Identification of Distribution Areas

To provide a more surgically relevant anatomical knowledge, we segmented the distribution areas of the perforator vessels of the IPA in 4 separate regions on each side, identified by easily recognizable and standardized anatomical landmarks. The following landmarks were established: the ischial tuberosities (laterally), the midline (medially), the anus (posteriorly), and the proximal origin of the urethra (bladder outlet; anteriorly). The triangle having as anterior edge the urethra, posterior edge the anus, and lateral edge the ischial tuberosity was divided in 2 equal parts to define the anterior (A) and the anterior-central (AC) regions. The triangle having as anterior edge the anus, posterior edge the posterior cutaneous border, and lateral edge the ischial tuberosity was divided in 2 equal parts to define the posterior (P) and the central-posterior (CP) regions (Fig. 1B, C).

Data and Statistical Analysis

Data were measured and analyzed by 2 independent investigators, both experienced in the vascular anatomy of the region of interest. All measurements were performed in millimeters.

Sample size was calculated assuming a 30% difference in percentage distribution of perforators vessels between genders in at least one of the regions of interest (α , 0.05; power, 95%). Descriptive statistics (mean, SD) were used to report outcomes. A χ^2 test was performed to assess if significant differences in the distribution of perforator vessels (4 regions of interest) between the 2 genders occurred (applied level of significance $P < 0.05$). χ^2 test was used to assess the difference between the percentages of the perforators located in each predetermined triangles, turning it in a nonparametrical variable. Sigma Stat 4.0 and Sigma Plot 14.0 software (Systat Software Inc, Nev.) and IBM SPSS Statistics 24 (IBM, Armonk, N.Y.) were used for all statistical analyses.

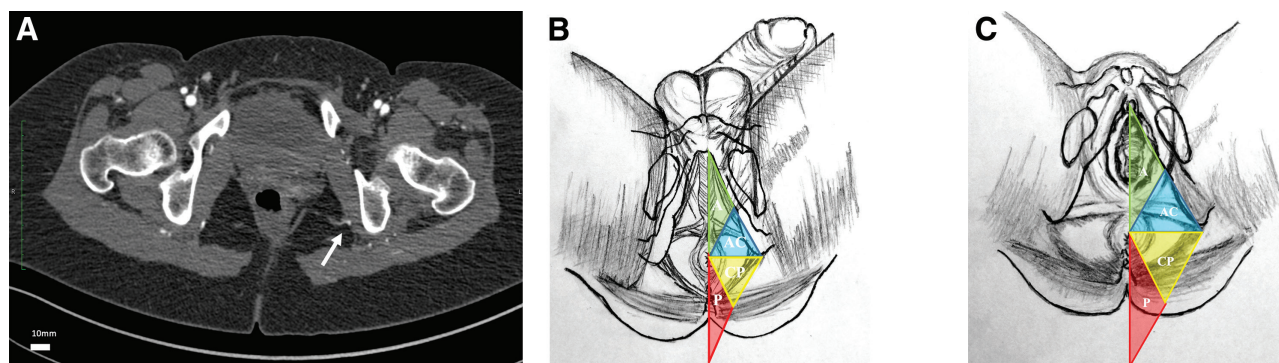


Fig. 1. A, CTA showing a perforator vessel originating from the IPA. The white arrow shows the point where septocutaneous perforator originates from the IPA. B, C Segmentation of the anatomical localization and distribution of perforator vessels of the IPA in 4 regions: anterior (A), anterior-central (AC), central-posterior (PC), and posterior (P). Landmarks used for segmentation include the ischial tuberosities laterally, the midline medially, the anus posteriorly, and the proximal origin of the urethra (bladder outlet) anteriorly. A and AC regions represent ischio-rectal fossa; they are divided by the bisector of the angle formed by anus-urethra and anus-ischiatic tuberosity lines. P and PC triangles are the specular reflection of A and AC, in the posterior region.

Table 1. Demographic and Anatomical Data from the Study

Variable	Men	Women	P
Demographics			
Sample size (N)	31 (31/63; 49%)	32 (32/63; 51%)	>0.05
Age, y (range)	45.65 (6–68)	57.25 (28–71)	<0.05
BMI < 25	19	12	>0.05
25 ≤ BMI < 30	10	14	>0.05
30 ≤ BMI < 35	0	5	<0.05
BMI > 35	2	1	>0.05
Perforator vessels analyzed (N)	281	354	>0.05
General anatomy			
Posterior inter ischial tuberosities distance, mm	100.2 ± 10	112.4 ± 12	>0.05
Urethra–anus distance, mm	39.4 ± 8.5	45.8 ± 8	<0.05
Vascular anatomy of the IPA			
Diameter at origin, mm	2.8 ± 0.5	2.4 ± 0.3	>0.05
Perforator vessels per IPA (n)	2 ± 1	2 ± 1	>0.05
Perforators originating from the IPA, %	92.9%	96.6%	>0.05
Perforators originating from the IGA, %	7.1%	3.4%	<0.05
Vascular anatomy of the perforator vessels			
Diameter at origin, mm	1.7 ± 0.3	1.6 ± 0.3	>0.05
Diameter at point piercing pudendal canal, mm	1.4 ± 0.3	1.4 ± 0.2	>0.05
Terminal cutaneous branches	5 ± 2	5 ± 2	>0.05
Course: septocutaneous/musculocutaneous, %	84%/16%	85%/15%	>0.05
Anatomical distribution of the perforator vessels			
Anterior region (A), %	3.3%	1.3%	<0.05
Anterior-Central region (AC), %	43.1%	70.5%	<0.001
Central-Posterior region (CP), %	53.7%	28.2%	<0.001
Posterior region (P), %	0%	0%	>0.05
Distance from the anus on the coronal plane [anus-ischial tuberosity line], mm; %	30.6 ± 7.2 mm; 60.4 ± 12%	39.1 ± 6.6 mm; 70.6 ± 11%	<0.05
Distance from the midline on the sagittal plane [from the anus-ischial tuberosity line], mm	11.6 ± 7.3 mm	12.9 ± 7.6 mm	>0.05

A $P < 0.05$ was considered significant.

RESULTS

Characteristics of the Population

A total of 63 CTAs were analyzed (31 men and 32 women). Their mean age was 48.6 (range, 6–71) years, and their average BMI was 24.11 ± 12.6 . There was a statistically significant difference in age between the 2 groups [men, 45.7 (6–68); women, 57.3 (28.71)] ($P < 0.05$). The 2 groups were homogeneously represented in most ranges of BMI, although there was a statistically significant difference in the Obese-Class I range (BMI, 30–35), which had no male subjects and 5 female subjects ($P < 0.05$). All patients were white (Table 1).

The mean width (posterior inter ischial tuberosities distance) and height (urethra–anus distance) of the pelvis were 112.4 ± 12 and 45.8 ± 8 mm in women and 100.2 ± 10 and 39.4 ± 8.5 mm, respectively, in men (Table 1).

Vascular Anatomy of the IPA

At the inlet of the lesser sciatic foramen (pudendal canal), the IPA had a diameter of 2.4 ± 0.3 mm in women and of 2.8 ± 0.5 mm in men (Table 1).

In both genders, a total of 2 ± 1 perforator vessels providing vascularization to the perineal tissues were identified. Perforator vessels originated 96.6% of times from the IPA in women and in 92.9% in men ($P < 0.05$). Perforator

vessels originated from the inferior gluteal artery system (IGA) in 7.1% of cases in men. The difference between genders in the percentage of perforator vessels originating from the IGA was statistically significant ($P < 0.05$) (Table 1; Fig. 2).

No statistically significant difference regarding the mean diameter of perforator vessels neither at their origin (1.6 ± 0.3 mm in women and 1.7 ± 0.3 mm in $P > 0.05$) nor where they pierce the pudendal canal (1.4 ± 0.2 and 1.4 ± 0.3 mm, in women and men, respectively, $P > 0.05$) occurred (Table 1). These measures account for both musculocutaneous and septocutaneous branches. Musculocutaneous branches seem to be larger in diameter in men, although we did not formally and quantitatively analyze this variable.

Each IPA supplied 5 ± 2 terminal cutaneous vascular branches in both genders (ie 85% in women and 84% in men had a septocutaneous course). All musculocutaneous perforator vessels crossed the gluteus maximus muscle in proximity to its inferior medial margin.

Anatomical Distribution of Perforator Vessels of the IPA

In women, 70.5% of the perforator vessels pierced the pudendal canal in the AC region, 28.2% in the CP region, 1.3% in the A region, and 0% in the P region (Table 1; Fig. 2). In men, 53.7% of the perforator vessels pierced the pudendal canal in the CP region, 43.1% in the AC region, 3.3% in the A region, and 0% in the P region (Table 1; Fig. 3). Differences in the anatomical distribution both within genders and between genders were statistically significant ($P < 0.001$, each AC and CP region).

Using the anus as reference point, perforator vessels on average were at a distance of 39.1 ± 6.6 mm on the coronal plane (anus-ischial tuberosity line; $70.6 \pm 11\%$ of the entire line) and of 12.9 ± 7.6 mm on the sagittal plane (from the anus-ischial tuberosity line) in women. In men, the location of the perforator vessels was at a distance of 30.6 ± 7.2 mm on the coronal plane ($60.4 \pm 12\%$ of the entire line) and of 11.6 ± 7.3 mm on the sagittal plane (Table 1).

Anatomical Variations

In one case (0.7% of the analyzed subjects) the IPA was absent on one side. In this case, we detected several collateral vessels branching from the IGA and running inside the pudendal canal before piercing it to provide terminal branches. We also noticed a vessel originating from the anterior division of the internal iliac artery and running directly from the inner pelvis to the perineal region near the urethra: this vessel gave origin to the deep artery of the penis, the posterior scrotal artery, and the dorsal artery of the penis.

DISCUSSION

In this study, we described the vascular anatomy of the IPA system and the anatomical localization and distribution of its perforator vessels, highlighting similarities and differences between genders. Our results demonstrated that this vascular system is mostly constant and reliable, with small variations. Although perineal perforator vessels are similar between genders for number, course, and



Fig. 2. CTA showing a perforator vessel originating from the IGA.

diameter, they significantly differed for anatomical localization and distribution. They also showed a significant difference in origin, as in men a higher percentage of vessels branches from the IGA (although vessels originating from the IGA are a minority in both genders). Gender-specific differences in the anatomy of the pelvis and perineum likely accounted for these findings.

Fasciocutaneous flaps based on the IPA (IPAP flaps) were initially described over 40 years ago, by Wee and Joseph, and have been later adopted, optimized, and modified (“Lotus petal flap,” “Singapore flap,” etc.) by several other investigators.^{12–14,19,20,25,27,30,33,34,37–46} The advantages (and disadvantages) of these nonaxial pattern flaps are well known.^{12–14,20,25,27,30,33,34,37–46} Their use has been suggested as an ideal option for the reconstruction of moderate to moderate-severe perineal defects that do not cross the midline (eg, semi-vulvar reconstruction), and that do not require the “bulkiness” of more invasive muscle or musculocutaneous flaps (eg, gracilis flap, rectus abdominis muscle flap, etc.), and that cannot be repaired with minor local techniques.^{3,5,9,13,14,19,22,47–51} These flaps are considered reliable and effective. In fact, a success (flap survival) rate of over 85% and an 80%–100% rate of patient satisfaction were reported.^{9,52} They can be designed in different variations (eg, transposition, rotation, V-Y advancement, rhomboid) and can be sensate, with innervation from the posterior labial nerve and the perineal branches of the posterior cutaneous nerve of the thigh.^{19,20,27,39,53–55} Donor sites up to 7 cm in the gluteal fold can be closed primarily, and staged reconstruction with a multizone design can be planned. Despite concerns that the flap could increase lymphatic spreading after tumor removal, current clinical evidence suggests its safety in post-oncological reconstructions.^{9,19} Altogether, literature and clinical experience strongly support the use of IPA-based flaps in perineal reconstruction.^{3,5,9,13,14,49–51}

Despite extensive clinical use, anatomical description of the IPA system and of its perforators has been limited to few reports based on cadaveric dissections.^{20,36,37} In addition, gender-specific differences in the system and anatomical distribution of perforator vessels originating from the IPA have not been described before. This information is critical to guide preoperative flap planning and design, and to facilitate intraoperative flap dissection; a more robust

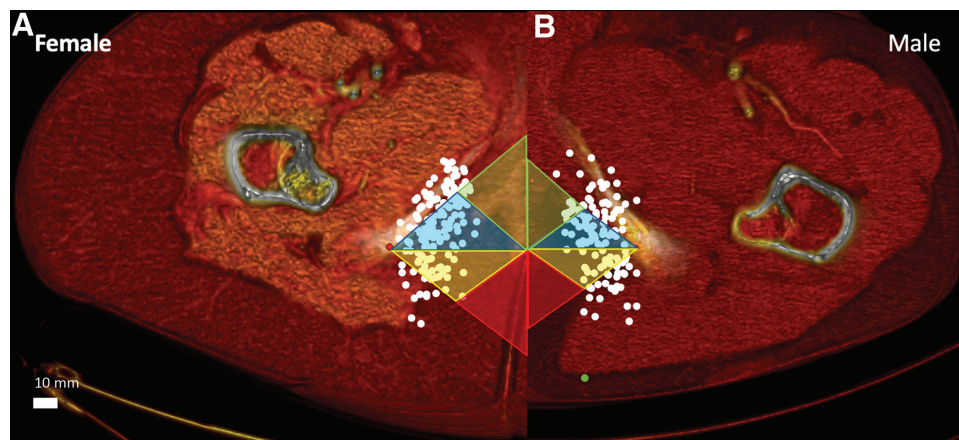


Fig. 3. CTA volume rendering image of a standardized women (A) and men (B) pelvis, showing the anatomical localization and distributions of all analyzed perforator vessels of the IPA and their relationship with the 4 regions of interest: anterior (A), anterior-central (AC), central-posterior (PC), and posterior (P).

knowledge of the anatomy of IPA system could help expand its safe and effective use in perineal reconstructions.

The IPA is located deep within the pudendal canal and is commonly preserved. An average of $2 (\pm 1)$ vessels perforate the pudendal canal and cross through the ischio-anal adipose tissue dividing in approximately $5 (\pm 2)$ terminal cutaneous branches on which the flaps are designed. Hashimoto et al^{12,28,37} suggested that IPA has only direct perforator vessels, surrounded by adipose tissue and no fascia. The absence of fascia inside the adipose layer of the ischio-anal fossa can increase the difficulty of the dissection in the lack of precise anatomical landmarks and knowledge. In addition, we report that both musculocutaneous branches (15%–16%) and septocutaneous branches can originate in the ischio-anal fossa, and that in 3%–7% of cases these vessels branch from the IGA.

Based on clinical experience, previous reports suggested that vascular pedicles are located in the ischio-anal fossa, delimited posteriorly by anus, laterally by the ischial tuberosity, and anteriorly the vaginal orifice.¹² Our work shows that, although most vessels generally cross this area, their exact distribution can be different, and significantly differ between genders. The percentage of perforator vessels originating outside the ischio-anal fossa was significantly high in both genders: in fact, only 28% of perforator vessels in women and 54% in men (54%) are located posteriorly to the ischio-anal line. These findings confirm previous hypotheses that some perforator vessels may be found over the gluteus maximus muscle and that the vascular network of this area is particularly reliable.^{12,19,28,32,37} From our findings, we suggest the following sequence:

1. Trace a first line connecting the anus and the ischial tuberosity, a second vertical passing through the anus and urethra. Connect Ischial tuberosity and urethra.
2. Draw the bisector of the angle formed in point 1, identifying A and AC triangles.
3. These 2 triangles should be mirrored over the first line traced, identifying P and CP triangles.
4. The flap can have different shapes depending on the defect, as previously mentioned.

5. AC and CP are the area of maximum concentration of perforators, which should be included in the pedicle and carefully dissected.

Surgically, since these vessels have a lateral-to-medial course toward external genitalia and the midline, a less-aggressive dissection in the ischio-anal fosse can most frequently preserve the integrity of the pedicle and allow the survival of the flap; yet, a higher anatomical knowledge could allow harvesting longer pedicles with better vascularization of the flap.

As previously suggested, we believe that preoperative identification of perforator vessels can rely on a handheld Doppler, without the need for CTAs.^{12,28} As observed here, anatomical variations are rare (<1%) and still allow for perforator vessels to be found in the ischio-anal fossa. Preoperative CTA could help identify whether the IPA or the IGA provides the best perforator vessels, and hence allow a better flap design with a longer pedicle and a larger skin island: we suggest limiting this approach to cases requiring larger flaps or pedicles longer than usual.

This study has limitations. Patients' position while acquiring CTAs is different from their intraoperative position (lithotomy position): this could mildly alter some measurements provided here. In addition, our population is relatively homogenous in terms of race, BMI, and age: although we do not expect significant differences based on race, BMI could impact the diameter and number of perforator vessels, as previously shown by our group and others.^{56,57} Over 30% of male subjects and nearly 63% of female subjects in this study were overweight or obese. Of note, there was a slightly higher, yet significant, representation of moderately obese (Class I) female subjects in our study population, compared with male subjects. Some anatomical measurements might change with age, especially in female subjects (age-related structural pelvic adaptations): importantly, the average age of our female subjects was relatively high (57.3 years). In patients with pathological conditions, the local anatomy (including vascular) could also be altered.

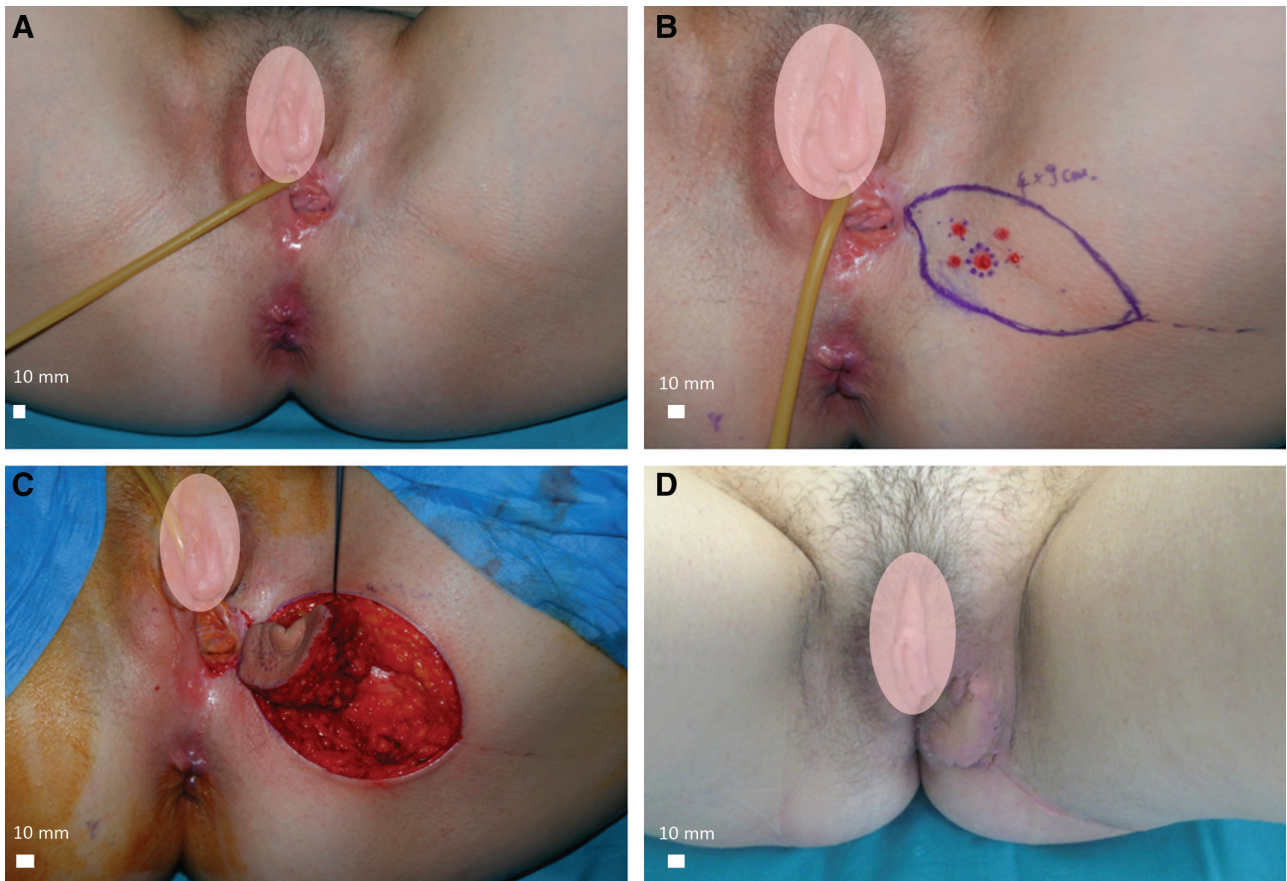


Fig. 4. A case of a 43-year-old female patient with a perineal leiomyosarcoma. After the surgical resection with wide margins (A), we designed a fasciocutaneous flap based on the perforator vessels of the IPA: we located the flap along the gluteal crease and marked the perforators vessels identified in the central-posterior region using a handheld Doppler device (B). C, Intraoperative dissection of the flap shows the pedicle of the perforator vessel. D, Postoperative outcome at 28 months shows optimal perineal reconstruction with preservation of function.

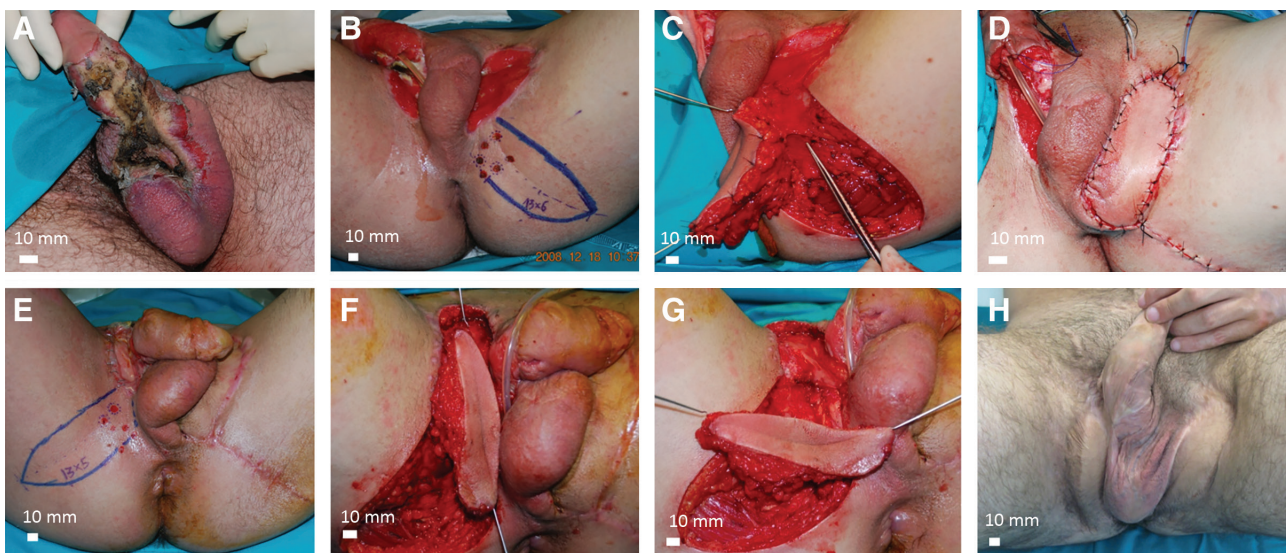


Fig. 5. A case of a 52-year-old male patient with an electric fulguration of the external genitalia and the perineum, reconstructed with staged bilateral fasciocutaneous propeller flaps based on the perforator vessels of the IPA. A–D show the first stage of reconstruction, whereas E–H show the second stage of reconstruction performed after 3 months from the first surgery. In both cases, the flap was designed along the gluteal crease and rotated 180 degrees. Postoperative outcome at 18 months shows optimal perineal reconstruction with preservation of function.

This study did not investigate the venous and lymphatic drainage of the region. Finally, although we can anecdotally report that this anatomical knowledge has had a positive benefit on our surgical procedures, we have not yet formally analyzed the impact of improved anatomical knowledge on surgical and clinical outcomes (Figs. 4, 5). All these limitations will need to be addressed in future clinical studies.

CONCLUSIONS

This study provides an accurate description of the vascular system of the IPA and its perforator vessels, reporting their anatomical localization and distribution and identifying gender-specific differences. Compared with previous reports, we showed a higher diversity in the origin (minor contribution of the IGA), course (presence of musculocutaneous branches), and distribution (high percentage of vessels outside the ischial-anal fossa) of perforator vessels supplying the perineum. We hope this knowledge will support surgeons in the preoperative planning and the intraoperative dissection of flaps based on the IPA for perineal reconstruction, ultimately leading to improved flap design (skin island size, pedicle length), safety (survival), and use (shorter operative time, broader use as free-style loco-regional flaps).

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