Radiographic Study Evaluating Perforator Vessels in the Ischiorectal Fossa for Safe Elevation of Island Flaps

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Background: Perforator flaps based on the ischiorectal fossa (IRF) (ie, internal pudendal artery perforator flaps) are useful for perineal reconstruction. The three-dimensional characterization of perforator arteries in the IRF remains unclear, as the IRF contains thick adipose tissue as well as organs, such as the rectum, vagina, and urethra. This study aimed to evaluate perforators in the IRF to guide the safe elevation of skin flaps designed based on the IRF.

Methods: IRF vessels were examined in 200 bilateral computed tomography angiography scans performed in 100 patients. We examined branching patterns arising from the internal iliac artery and the origins of the skin perforators in the IRF.

Results: The branching patterns of the internal iliac artery were divided into three groups: perforators derived exclusively from the internal pudendal artery (78%), perforators derived from the internal pudendal artery and the inferior gluteal artery (18%), and perforators derived exclusively from the inferior gluteal artery (4%). The average number of perforators in the IRF was 1.5 ± 0.7. The number of perforators was significantly higher in women than in men. The perforator arteries were found exclusively around the medial and dorsal sides of the ischial tuberosity.

Conclusions: We found that perforators in the IRF were stable. All cases had more than one skin perforator, which was mainly derived from the internal pudendal artery. Although perforators cannot be identified during flap elevation because the fatty tissue in the IRF is very thick, physicians must focus on preserving the perforator-containing fatty tissue around the ischial tuberosity. *(Plast Reconstr Surg Glob Open 2022;10:e4561; doi: 10.1097/GOX.0000000000004561; Published online 11 October 2022.)*

INTRODUCTION

The appropriate use of skin perforator flaps offers a host of safe and reliable procedures within reconstructive plastic surgery.[1,2] Gluteal fold flaps, which are nourished with skin perforators from the internal pudendal artery, have been reported to be useful for perineal reconstruction.[3,4] Different shapes and forms of skin flaps based on the ischiorectal fossa have been evaluated and described in studies and case reports regarding internal pudendal artery perforator flaps.[5–7] The key to the safe elevation of these flaps is vascularization from skin perforators in the ischiorectal fossa (the triangle formed by the ischial tuberosity, apex of the coccyx, and vaginal orifice or scrotum).[4,5] Previous publications of the internal pudendal artery have reported that this artery branches from the internal iliac artery and divides into the inferior rectal artery and the perineal artery in the ischiorectal fossa to nourish the skin around the perianal area and the perineum.[8,9] However, details of the internal pudendal artery and skin perforators in the ischiorectal fossa are still obscure, as the fossa is a deep space between the perineal skin and the pelvic diaphragm that is filled with thick fatty tissue and likewise contains organs, such as the rectum, vagina, and urethra.[10] In this study, we used computed tomography angiography to safely elevate perforator flaps designed based on the ischiorectal fossa to comprehensively examine the branching patterns of the internal pudendal artery as well as those of the perforator arteries throughout the ischiorectal fossa in our presenting patients.

METHODS

We analyzed computed tomography (CT) data presented in Digital Imaging and Communications (DICOM) format. We performed CT colonography after administering intravenous contrast material for colon screening at the Department of Surgery at the Tokushima University Hospital from January 2015 to December 2018. A standardized imaging protocol was applied with an iopamidol dosage of 370 mg/mL (Iopamiron 370, Bayer Yakuhin Ltd, Osaka, Japan). The injection rate was 5 mL/s, and the total injection amount was 80–100 mL for each patient. Data were based on bilateral samples with 1-mm slice thickness and were evaluated using Aquilion One 320-slice CT scanners (Canon Medical Systems, Tokyo, Japan). CT data were obtained from 200 bilateral scans (sides) of 100 cases (men, n = 50; women, n = 50). Patients who underwent treatment for colorectal cancer were excluded from this study because of the impact of colorectal cancer on the vascular system in the pelvis.

This study was approved by the Clinical Research Ethics Review Committee of the Tokushima University Hospital and was conducted in accordance with the principles of the Declaration of Helsinki and its later amendments.

Branching Patterns

In this study, we first analyzed the branching patterns of the internal pudendal artery, superior gluteal artery, and inferior gluteal artery, all of which branch from the internal iliac artery in the pelvis. Second, we counted the perforator arteries appearing in the ischiorectal fossa between the small sciatic foramen and the superficial and deep perineal muscles and then travel toward the skin (Fig. 1). Vessels with a diameter of 1 mm or greater at the thickest part were recognized as perforator arteries. The inferior rectal artery traveling to the rectum was excluded from the present evaluation.

The points of perforators emerging to the ischiorectal fossa were mapped on a two-dimensional grid and expressed as two axes reaching from the pubic symphysis to the ischial tuberosity as well as from the coccyx to the ischial tuberosity. The two distances on the two axes were expressed as ratios with respect to the patient's height.

Statistical Analysis

Descriptive data were expressed as means ± SDs. These descriptive statistics were calculated using two-tailed Student t-tests as appropriate. In addition, the chi-squared test of independence was implemented to determine whether there was an association between male and female participants. Significance was set at a two-sided P value of less than 0.05.

RESULTS

Characteristics of Patients

The age of the enrolled patients ranged from 37 to 93 (average age: all patients, 67.5; men, 68.1; women, 66.9) years. For all patients, the body mass index, calculated in kg/m², ranged from 16.7 to 32.7 (average: 23.2) kg/m². The average body mass index values of the male and female participants were 23.4 and 22.9 kg/m², respectively. Age and body mass index were not significantly different when comparing men and women.

Takeaways

Question: Are perforators in the ischiorectal fossa (IRF) stable? Where do perforators come from? Where is the exact location of perforators? Do perforators have any characteristics for safe elevation?

Findings: Perforators were stable and came from internal pudendal artery and/or inferior gluteal artery. Perforators were found exclusively around the medial and dorsal sides of the ischial tuberosity.

Meaning: To safely elevate island skin flaps on IRF, the base of skin flaps should be placed on the medial-dorsal aspect of the ischial tuberosity.
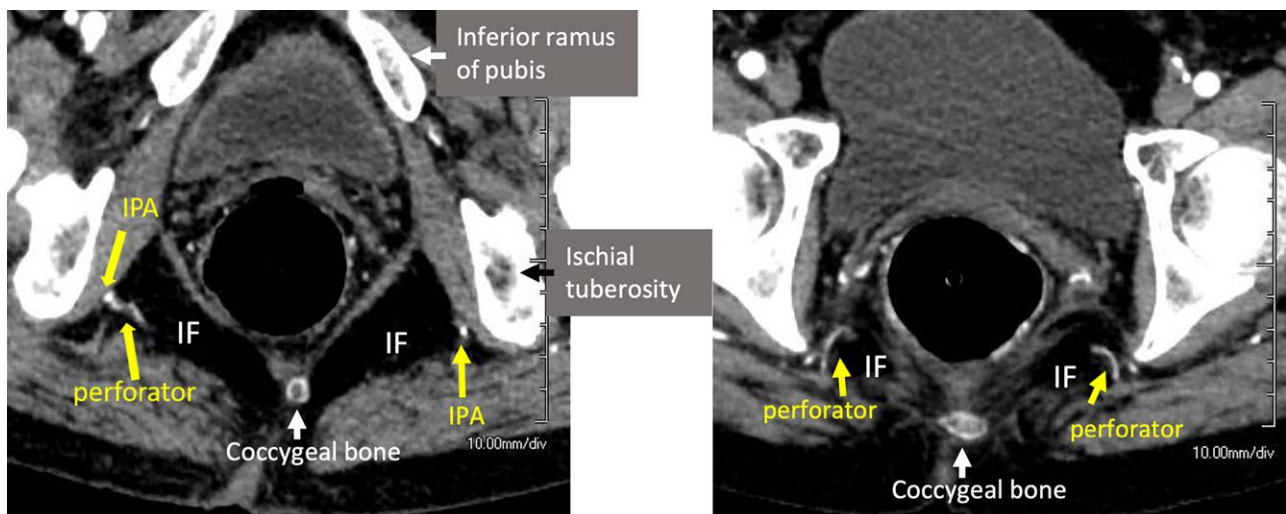
Fig. 1. CT images of the IPA and perforators arising from the IPA in the IF. IPA, internal pudendal artery; IF, ischiorectal fossa.

Branching Patterns

The branching patterns of the internal pudendal artery, superior gluteal artery, and inferior gluteal artery were divided into groups A, B, and C (Fig. 2). In group A, the inferior gluteal artery and internal pudendal artery had a common trunk arising from the internal iliac artery. In group B, the superior gluteal artery and the inferior gluteal artery had a common trunk arising from the internal iliac artery. In group C, the superior gluteal artery, inferior gluteal artery, and internal pudendal artery had a common trunk arising from the internal iliac artery; 75%, 20%, and 5% of the patients were divided into groups A, B, and C, respectively.

Skin Perforators in the Ischiorectal Fossa

We found 338 perforators in the ischiorectal fossa in 200 sides (100 participants). All evaluated patients had one or more perforators in the ischiorectal fossa. These perforators were derived from the internal pudendal or inferior gluteal arteries. Moreover, 293 (86.7%) and 45 (13.3%) perforators were derived from the internal pudendal and inferior gluteal arteries, respectively. The mean numbers of skin perforators in groups A, B, and C were 1.7 ± 0.7, 1.6 ± 0.8, and 2.3 ± 0.7, respectively. No significant differences were noted in the numbers of perforators when comparing groups A, B, and C.

Patients were divided into the following three types according to the origins of the perforators in the ischiorectal fossa. Type I presentations were defined as cases with skin perforators derived exclusively from the internal pudendal artery, type II presentations had skin perforators derived from both the internal pudendal artery and the inferior gluteal artery, and type III presentations had perforators derived exclusively from the inferior gluteal artery (Fig. 3). The numbers of sides and perforators in type I, II, and III presentations are presented in Table 1. The mean number of perforators was significantly higher in type II than in type I or III presentations ($P < 0.05$). No specific trends were found in the relationship between the branching group of the internal iliac artery (groups
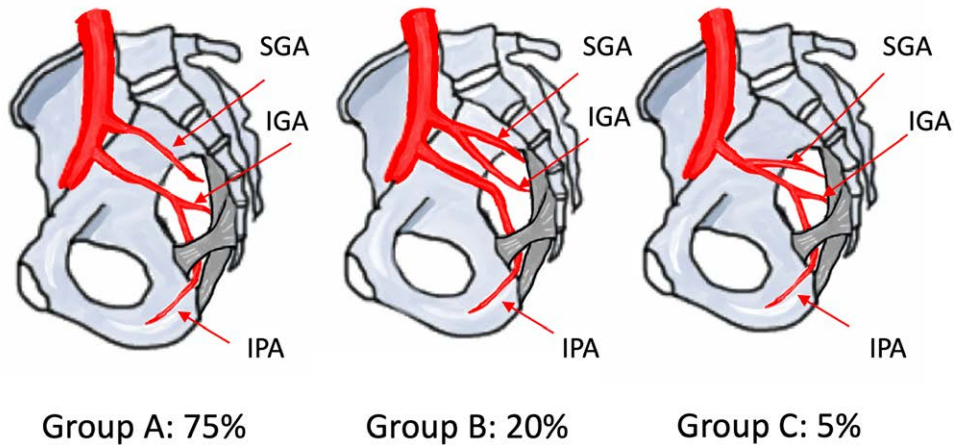
Fig. 2. A depiction of the branching patterns of the internal iliac artery. IGA, inferior gluteal artery; IPA, internal pudendal artery; SGA, superior gluteal artery.

Fig. 3. Presentation types with respect to different origins of perforators in the ischiorectal fossa. Type I, perforators are derived exclusively from the IPA; type II, perforators are derived from the IPA and the inferior SGA; type III, perforators are derived exclusively from the SGA. IPA, internal pudendal artery; SGA, superior gluteal artery.

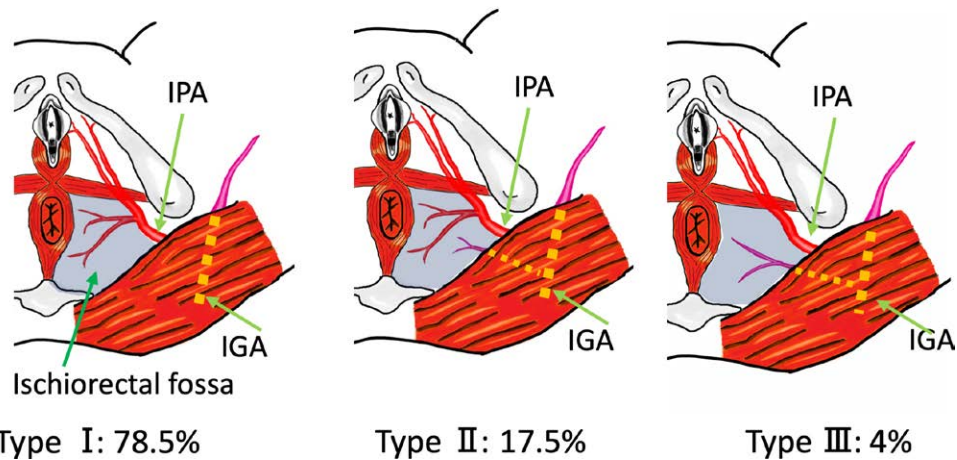**Table 1. Total Number of Perforators and Total Number of Bilateral Sides with Type I, II, and III Presentations**

	Type I			Type II			Type III		
	Perforators (N)	Sides (N)	Mean	Perforators (N)	Sides (N)	Mean	Perforators (N)	Sides (N)	Mean
Total	242	157	1.5	87	35	2.5*	9	8	1.1
Derived from the IPA	242	157	1.5	51	35	1.5			
Derived from the IGA				36	35	1.0	9	8	1.1

Mean values indicate the number of perforators per side.
*$P < 0.05$.
IGA, inferior gluteal artery; IPA, internal pudendal artery.

A, B, and C) and the type of skin perforator (types I, II, and III).

As a result of mapping the emerging points of the skin perforators to the ischiorectal fossa, we determined that perforators arising from the internal pudendal artery were found on the medial side of the ischial tuberosity. Conversely, perforators from the inferior gluteal artery were found on the medial and dorsal sides of the ischial tuberosity (in contrast to those of the internal pudendal artery) (Fig. 4).

Relationship between the Number of Skin Perforators and Sex

There were 338 perforators, of which 134 and 204 were found in men and women, respectively. The mean numbers of perforators on each side in men and women are presented in Table 2. The mean number of perforators was significantly higher in women than in men ($P < 0.01$). In male patients, the numbers of perforators derived from the internal pudendal artery and the inferior gluteal

Table 2. Total Number of Perforators Found in the Ischiorectal Fossa by Origin and Sex

	Derived from the IPA	Derived from the IGA	Total (mean)
Total	293/ 200	45/200	338/200 (1.7)
Men	120/ 100	14/100	134/100 (1.3)
Women	173/ 100	31/100	204/100 (2.0*)

Each column shows the number of perforators/the number of investigated sides. The mean values represent the number of perforators per side. Chi square test, not significant; Student *t*-test.
*$P < 0.01$.
IGA, inferior gluteal artery; IPA, internal pudendal artery.

artery were 120 and 14, respectively. In female patients, the numbers of perforators derived from the internal pudendal artery and the inferior gluteal artery were 173 and 31, respectively. No significant differences were observed between men and women in terms of whether the penetrating branches were derived from the internal pudendal artery or the inferior gluteal artery.

The number of perforators found in the ischiorectal fossa ranged from one to four within each side. The numbers of sides with one, two, three, or four perforators are presented in Table 3. We observed a significant difference between men and women concerning the number of skin perforators ($P < 0.01$).

The numbers of sides with type I, II, and III presentations analyzed by sex are presented in Table 4. Significant differences were observed between men and women concerning the origins of the perforators. Type II presentation
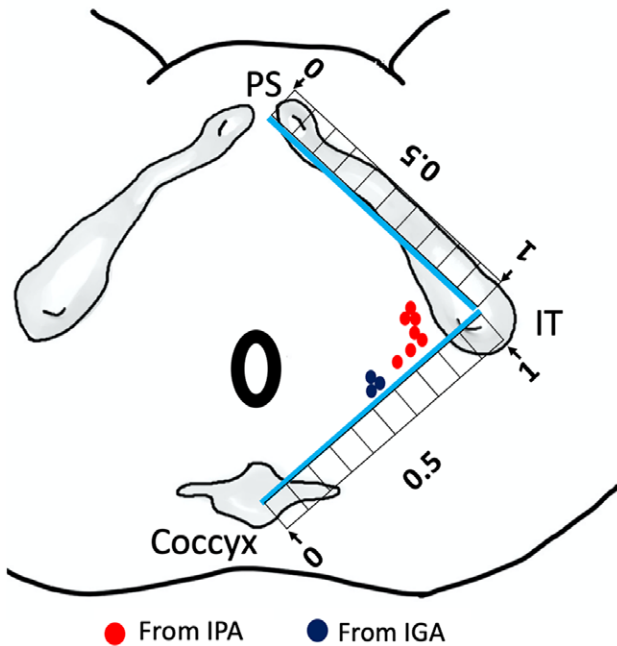
Table 3. Numbers of Perforators Found on Each Side of the Ischiorectal Fossa and the Number of Evaluated Bilateral Sides in Total and by Sex

Perforators in Each Side	1 Perforator	2 Perforators	3 Perforators	4 Perforators	Total
Total sides	91	82	24	3	200
Sides in men	69	28	3	0	100
Sides in women	22	54	21	3	100

Chi-squared test: $P < 0.01$.

Table 4. Number of Bilateral Sides with Perforators with Type I, II, and III Presentations in Total and by Gender

	Type I	Type II	Type III	Total
Total	157	35	8	200
Men	87	6	7	100
Women	70	29	1	100

Chi-squared test: $P < 0.01$.

Fig. 4. Points of perforators emerging to the ischiorectal fossa found in this study. They are expressed as two axes reaching from the PS to the IT as well as from the coccyx to the ischial tuberosity. The distances are expressed as ratios with respect to the patient's height. IPA, internal pudendal artery; IGA, inferior gluteal artery; PS, pubic symphysis; IT, ischial tuberosity.

was found more frequently in women than in men, whereas type I and III presentations were likewise found more frequently in men than in women. We found no significant differences in the number of perforators on the left and right side scans when comparing men and women.

Representative Case Presentation

Case 1

A 56-year-old man developed a right ischial pressure sore due to a spinal cord injury (Fig. 5). He underwent several surgical procedures to repair the ischial pressure sore. A flap nourished by perforator arteries in the ischiorectal fossa (which we term the internal pudendal artery perforator thigh flap) was designed on the thigh. The flap was carefully elevated containing the fatty tissue on the medial and dorsal sides of the ischial tuberosity. The flap was well vascularized and successfully transplanted to the defect.

Case 2

A 59-year-old woman developed a rectovaginal fistula following an operation for rectal cancer (Fig. 6). After debridement of the fistula, a flap nourished by perforator arteries in the ischiorectal fossa was designed along the gluteal fold. The flap was carefully elevated, containing

the fatty tissue on the medial and dorsal sides of the ischial tuberosity. The blood circulation of the flap was good.

DISCUSSION

As novel findings, this study revealed (1) the relationship among the skin perforators in the ischiorectal fossa and the branching patterns of the internal iliac arteries, (2) participation of the internal gluteal artery in the blood supply to the ischiorectal fossa, (3) difference in the number of perforators between men and women, and (4) the position of perforator vessels in the ischiorectal fossa.

The common perforator flaps are elevated after identification of the perforator vessels, but the deep and thick adipose tissue in the ischiorectal fossa makes it difficult to have direct observation for the perforator vessels.[4,5] The thick adipose tissue allows the rotational movement of the skin flap based on the ischiorectal fossa by detaching the adipose tissue containing the perforator vessels from the surrounding area without direct visualization of the perforator vessels.[4-6] This method of skin flap movement is also employed in the perforator flap on the gluteus maximus, which has a thick adipose tissue on the muscle.[11,12] In cases of adipose tissue dissection for rotational movement
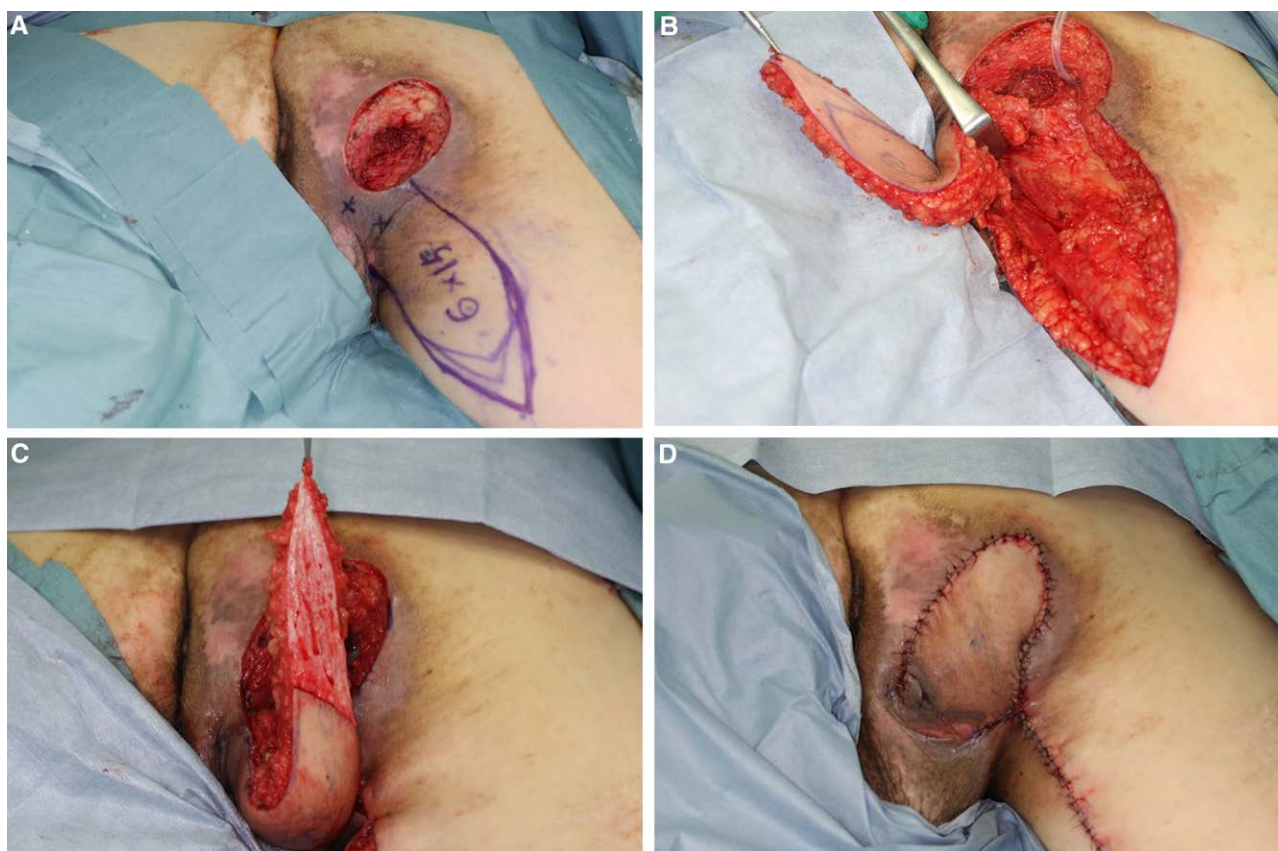

Fig. 5. Case 1 is of a male patient with an ischial pressure sore undergoing transplantation of a perforator flap from his thigh. Flap design (6×15 cm) and X marks of the arterial sounds heard by a Doppler flow meter on the ischiorectal fossa can be observed (A). The ischial tuberosity is exposed in the debrided ulcer. Fatty tissue of the flap pedicle is based on the medial and dorsal sides of the ischial tuberosity (B). The skin of the distal part of the flap is denuded to fill in the defect on the ischial tuberosity (C). We note the favorable color of the bleeding on the denuded flap. The flap is transplanted to the defect (D).
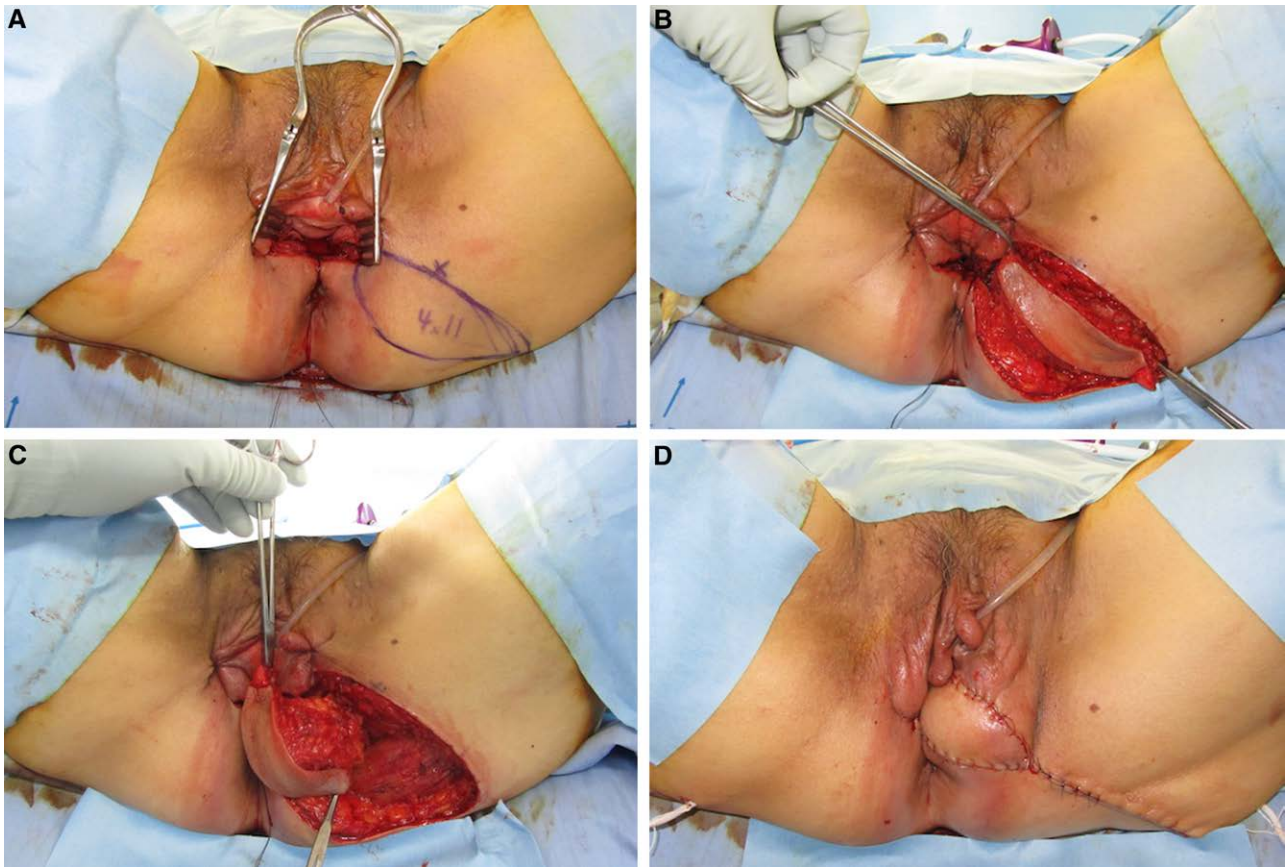
Fig. 6. Case 2 is of a female patient with a rectovaginal fistula undergoing transplantation of a perforator flap from her gluteal fold. Flap design (4 × 11 cm) and an X mark indicating the ischial tuberosity can be identified (A). The flap is elevated and rotated toward the defect site based on the fatty tissue connecting with the medial and dorsal sides of the ischial tuberosity (B, C). The distal side of the flap is thinned and sutured to the defect in the vagina (D).

of skin flaps, the location of the perforator vessels and the direction of dissection is of paramount importance to avoid damaging the perforator vessels. Furthermore, because of the deep adipose tissue in the ischiorectal fossa, the location of arterial sounds at the skin surface, heard by Doppler flowmeter, may not accurately reflect the location of perforator vessels deep in the adipose tissue. Our findings are useful with regard to adipose tissue preservation during safe elevation and rotation of the ischiorectal fossa-based perforator skin flap.

The patterns and their associated percentages concerning branching patterns of the internal iliac arteries found in this study are thought to be reliable, as these results are almost completely consistent with those obtained from cadaver dissections in a previous report.[13] In our study, no patients lacked both an internal pudendal artery and an inferior gluteal artery. This was a novel finding in the present report. Thus, to the best of our knowledge, our study was the first to reveal that the branching patterns of the internal pudendal artery and the inferior gluteal artery did not affect the origins and numbers of perforator arteries in the ischiorectal fossa.

Our results revealed that the internal pudendal artery was the dominant source of blood supply in the ischiorectal fossa. Variant cases (ie, type III presentations) with

perforators derived only from the inferior gluteal artery were observed in a total of only 4% of all cases. However, type II presentations (ie, with perforators derived from the internal pudendal artery and the inferior gluteal artery) were found in 17.5% of the cases. Especially, the perforator arteries were derived from the inferior gluteal artery in 21.5% of the enrolled cases. Thus, we believe that the inferior gluteal artery is an anatomical variation and an important source of blood supply for perforator flaps located in the ischiorectal fossa.

The internal pudendal artery exits the pelvis just above the sciatic spine, reaches the backside of the ischiorectal fossa, and then runs forward inside the pudendal canal along the ischial tuberosity. The internal pudendal artery in the pudendal canal is located deep in the ischiorectal fossa, runs forward to the urogenital diaphragm, and ultimately becomes the perineal artery. In the 1990s, axial flaps nourished by the perineal artery were developed and termed pudendal thigh flaps[14,15] and perineal artery axial flaps.[16,17] Following this (in the 2000s), the era of fasciocutaneous flaps containing axial vascularities transitioned to the era of perforator flaps nourished by perforator arteries. Perforator flaps around the ischiorectal fossa have been reported as internal pudendal artery perforator flaps in some studies.[5,6] Comprehensive information

concerning the locations of the skin perforators is vital for flap designs and surgical procedures with respect to the safe elevation of perforator flaps.

The inferior gluteal artery exits the pelvis and enters the gluteal region inferior to the piriformis muscle with the sciatic nerve. This artery comprises three types of branches: muscular branches to the gluteal maximus and hamstring muscles, anastomotic branches to the medial femoral circumflex artery, and a terminal fasciocutaneous branch with the posterior cutaneous nerve of the thigh.[18] Anatomical and clinical studies regarding perforators derived from the inferior gluteal artery have been conducted on the surface of the gluteal maximus to elevate the perforator flaps.[19,20] However, perforator vessels inside the ischiorectal fossa have not received much attention to date.[10]

Various forms of perforator flaps can be elevated in the ischiorectal fossa. The most valuable advantage of these types of flaps is that the pedicle vessels are near the defect sites. Safe dissection around the vascular pedicle in the ischiorectal fossa is essential to move the flap to the defect site. This study revealed that the perforator arteries in the ischiorectal fossa were derived from both the internal pudendal artery and the inferior gluteal artery, with origins on the medial and dorsal sides of the ischial tuberosity. Therefore, we must give precedence to preserving the fatty tissue around this area during flap elevation.

We found a higher number of perforators in women than in men, with a significant difference observed between sexes. The other major findings of this study were that type II presentation was significantly more common in women than in men and that perforator vessels were more common in type II presentations than in type I and III presentations. We believe that these findings are all mutually associated. Namely, the pelvic space and the ischiorectal fossa in women are larger than those of men, and the vagina is adjacent to the rectum. These factors may affect the differences in the number of perforators between men and women, as observed in the current study. Sex-specific differences in the anatomical distributions of perforators derived from the internal pudendal artery have been found throughout the entire perineal region, which includes the perineal arterial supply.[10] To the best of our knowledge, this study is the first report concerning sex-specific differences in blood supply that has been limited to the ischiorectal fossa.

This study has two limitations. First, computed tomography angiography was performed in the supine position, such that the skin around the ischiorectal fossa was folded and bent between the thigh and buttocks. Thus, the distribution of the perforator arteries close to the skin could not be analyzed because the skin around the ischiorectal fossa could not be expanded. Second, given the resolution of the CT images used in this study, we have not been able to observe blood vessels less than 1 mm.

CONCLUSIONS

In this study, we found that perforator arteries arising from the internal pudendal artery and the inferior gluteal artery could be observed in the ischiorectal fossa in all cases upon computed tomography angiography. The internal pudendal artery predominantly supplies blood in this region. However, the inferior gluteal artery likewise contributes to the blood supply because 21.5% of the enrolled cases had perforator arteries derived from the inferior gluteal artery. We found that women had a higher number of perforators than men. We conclude that a safe elevation of the perforator flap on the ischiorectal fossa can be achieved even in male patients when surgeons pay close attention to the perforators included in the fatty tissue on the medial and dorsal sides of the ischial tuberosity.

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