Profunda Artery Perforator Flaps for Breast Reconstruction

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Introduction

With refinement of microsurgical techniques and perforator flap design, autologous breast reconstruction has evolved to utilize donor tissues from the lower abdomen as well as from the hips, buttock, and thighs. While use of the lower abdomen is a clear first choice for donor-site tissues, it may not be available in all cases. Use of medial and posterior thigh tissue is ideal in situations where abdominal tissue is insufficient, unavailable due to previous surgery, or body fat distribution is centered below the waist.

The profunda artery perforator (PAP) flap evolved from initial descriptions of the transverse upper gracilis flap, utilizing tissue based on the medial circumflex femoral artery and requiring muscle sacrifice. Hurwitz et al. later described the posterior thigh myocutaneous flap based on the inferior gluteal artery [1]. Agrigiani et al. subsequently described the posterior thigh perforator flap based on the profunda femoris artery [2]. The profunda artery perforator free flap finally was described for use as a free flap for burn and pressure sores [3] and later for breast reconstruction in 2010 as a viable second choice if abdominal tissue is not available [4]. The flap is based on perforating branches of the profunda femoris artery which are known to provide the dominant blood supply to the posterior thigh [5]. While initially designed as a transverse flap camouflaged in the gluteal crease, recent studies demonstrate multiple variations of aesthetic flap design based on anatomic location of the dominant perforator [6, 7].

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Anatomy

The PAP flap is based on perforators off the profunda femoris artery which provide the dominant blood supply to the posterior thigh. The profunda femoris artery branches from the common femoral artery approximately 3.5 cm distal to the inguinal ligament and spirals to reach the medial aspect of the femur. The profunda splits into medial and lateral branches before giving off perforating arteries. The medial branch gives off three perforators on average, providing a segmental blood supply to the posterior thigh. The first perforator supplies the adductor magnus and gracilis, and the second and third perforators supply the semimembranosus, biceps femoris, and vastus lateralis [5]. Perforators share a common origin in 37.5% of male patients and 18.2% of female patients [8]. For traditional transverse PAP flap design, the first perforator is the preferred pedicle to the flap.

While traditional flap design centered the skin island on proximal perforators, recent anatomic studies show that the dominant profunda artery perforator is located more distally. In studies of transversely oriented PAP flaps, Allen et al. reported that average perforator distance distal to the gluteal crease was 3.5 cm, average pedicle length was 10.6 cm, distance to midline was 6.2 cm, artery diameter range was 2.3–2.8 mm, and average flap weight was 385 g [9, 10]. Subsequent analysis of the entire posterior thigh has demonstrated the mean distance of larger, dominant perforators to be more distal. Computed tomography angiogram analysis of 100 thighs demonstrates that 85% of thighs have three or more profunda perforators, with mean perforator location 6.2 cm distal to the gluteal crease and evenly distributed between the medial and lateral thigh. Average perforator diameter at the takeoff of the profunda was 2.7 mm and average perforator length was 100.7 mm [8]. Cadaveric perfusion studies of 29 posterior thigh flaps demonstrate hot spots for dominant perforator location within 5–10 cm from the inferior gluteal crease with smaller hot spots in the upper lateral and distal posterior midline. Importantly, there were no differences in perforasome territories of proximal and distal perforators [7].

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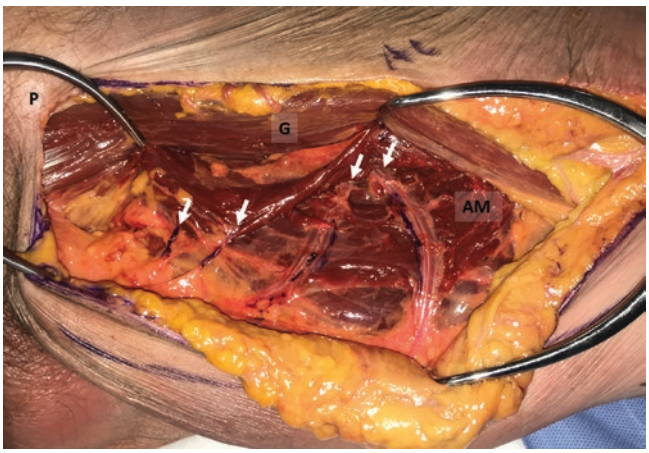


Fig. 27.1 Cadaveric dissection demonstrating four perforators exiting the adductor longus muscle. The pubic tubercle (P), adductor longus, and gracilis muscle (G) are identified, and dissection carried out subfascially over the adductor magnus (AM), where fascial exit of four perforators (white arrows) was identified. The most distal perforator is seen joining the third perforator and exits approximately 11 cm from the gluteal fold

Based on these and our own anatomic (Fig. 27.1) and imaging studies, our current flap design is centered on the location of the dominant perforator, which influences the choice for transverse, vertical, S-shaped, or oblique design. Vertically or obliquely shaped flaps additionally may allow for incorporation of more than one perforator if additional perfusion is desired for larger flaps. Adoption of the vertically oriented PAP flap has been used by St. Hilaire et al. for applications including not only breast reconstruction but also head and neck and lower extremity reconstruction [11].

Perfusion of the flap should be considered based on its perforator angiosome given the segmental nature of blood supply to the posterior thigh. Perfusion studies of circumferential thigh flaps harvested from 10 cadavers demonstrated perfusion zones of 16.7 cm × 16.5 cm (8812 cm^2) in horizontal and vertical dimension, respectively, suggesting perfusion extends lower than traditional transverse flap design [12].

Patient Selection

Indications for PAP flap use in autologous breast reconstruction are broad. Ideal candidates have body fat predominantly centered below the waist and in the upper medial thigh. Women with this body type may have a pear-shaped figure. Women who do not have abdominal tissue available due to lack of body fat, previous abdominal surgery, or abdominal liposuction may be better candidates for thigh or buttock-based flaps. Patient preference is an important additional consideration in terms of donor-site scars.

The nature and location of transverse, vertical, or oblique medial thigh scars can be designed along traditional approaches of aesthetic vertical or transverse medial thigh lift techniques with slight modifications. The planned donor-site scar should be discussed with the patient as part of the preoperative consultation. Finally, all patients should undergo preoperative imaging by magnetic resonance angiography (MRA) or computed tomography angiography (CTA) to identify the presence and location of suitable perforators.

Preoperative Planning

Once a patient is selected to undergo breast reconstruction with the PAP flap, preoperative planning begins with imaging to identify dominant perforators for flap harvest. Our preferred imaging technique is MRA, due to superior image quality and ease of mapping intramuscular perforator course; CTA alternatively may be used if MRA is unavailable or otherwise contraindicated (Fig. 27.2). Perforators off the profunda femoris are mapped in reference to the distance distal to the gluteal fold and posterior to the posterior border of the gracilis muscle. For a transverse PAP flap, proximal perforators are chosen, generally within 3–6 cm of the gluteal crease. For a vertical or oblique PAP flap, more distal perforators are generally chosen and the flap oriented accordingly.

Transverse PAP Design

Preoperative markings are performed the day before surgery in the office (Fig. 27.3a). Markings begin with the patient standing and the inferior gluteal crease is marked. The superior flap border is marked 1 cm inferior to the gluteal crease. A pinch test is performed to determine the width of the flap, generally 6–7 cm, and a second mark is made distal to the first line, denoting the inferior border of the flap. The patient is then moved to a supine position with the thigh abducted. The anterior extent of the flap is then marked, medial to the femoral triangle and just posterior to the adductor longus muscle. A crescent-shaped design is then marked approximately 26 cm × 7 cm. The perforator location is then identified and marked based on preoperative mapping of its predicted location and confirmed with a handheld Doppler. The medial perforator has been favored traditionally based on its location and ease of harvest [4]. Perforator location can be confirmed also in the prone position. The key perforator for a transverse flap is generally 3–6 cm below the gluteal crease and within 4 cm of the posterior border of the gracilis.

Vertical PAP Design

When key perforators are predicted to be more inferiorly located or a patient demonstrates medial thigh laxity in the transverse plane, a vertical or oblique flap design may be preferred. Design of a vertical flap generally results in a scar slightly posterior to the standard location of an aesthetic vertical thigh lift incision (Fig. 27.3b). Markings start again with demarcation of the gluteal crease. With the thigh in

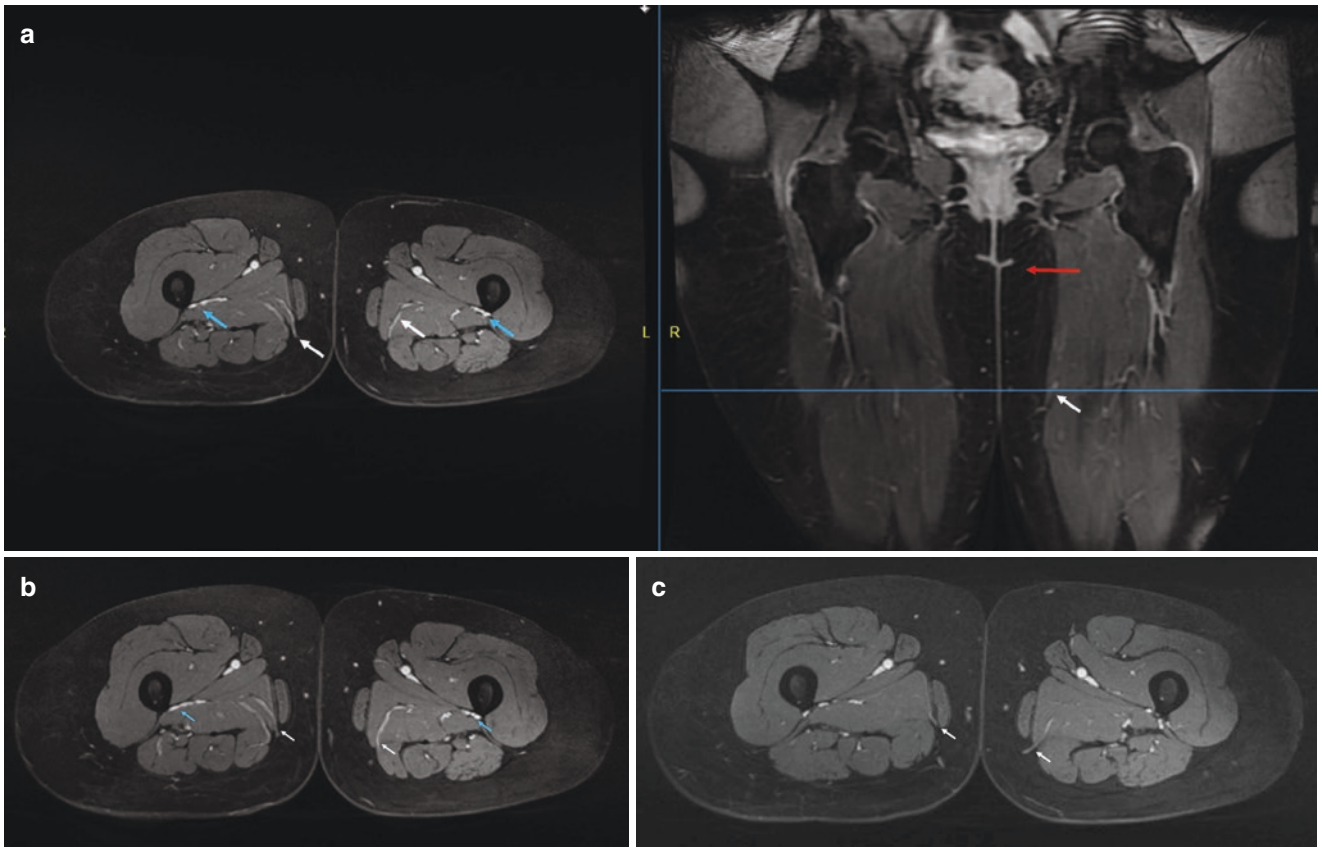


Fig. 27.2 Magnetic resonance angiography (MRA) for preoperative identification of profunda artery perforators. Perforators (white arrows) can be seen branching off the profunda artery (blue arrows), traversing adductor magnus muscle, and exiting adductor fascia posterior to the gracilis muscle. Axial images are used for perforator selection and can be correlated to coronal slices (**a**) to determine the location of perforator exit relative to the gluteal crease (red arrow). Axial images can be used to identify additional more distal perforators entering the posterior thigh (**b**, **c**)

abduction, the tendon of the adductor longus muscle is identified at its insertion on the pubic tubercle. The gracilis borders are identified medial to the adductor longus. The key perforator is then identified based on predicted location from preoperative imaging and confirmed by handheld Doppler. A series of perforators may be identified posterior to the gracilis, defining the axis of the flap. The anterior border of the flap follows the posterior gracilis border. The posterior border is then estimated based on a pinch test to estimate the maximal amount of tissue that can be safely taken, generally a maximum of 6–7 cm. It is important to avoid making the anterior border of the flap too anterior, resulting in missing the perforators or requiring a prohibitively wide flap and resultant tight skin closure.

Surgical Technique

The patient is placed in the lithotomy position, and the lower extremities are prepped into the field. Alternatively, the patient may be placed supine with thighs abducted in a "frog-leg" position; our team has adopted the lithotomy position to allow for easier donor-site closure. A two-team approach is then used throughout the case for simultaneous exposure of recipient vessels with flap harvest.

A video showing the preoperative marking and flap harvest is available as supplemental digital content (Video 27.1).

Transverse PAP Harvest

For the transverse PAP flap, the anterior incision is made and deepened down to deep thigh fascia (Fig. 27.4). Beveling is avoided along the superior incision to prevent hollowing of ischial fat pads and interfering with normal gluteal contour; inferiorly, slight beveling may be performed depending on desired flap volume and perforator location. Anteriorly, the femoral triangle is avoided. The flap is then elevated anterior to posterior superficial to fascia until reaching the posterior border of the gracilis muscle, at which point the fascia is incised. Dissection is then carried out deep to fascia of the gracilis and adductor magnus. Subfascial dissection is continued until the key perforator is identified at which point intramuscular dissection is performed until reaching the origin of the perforator off of the profunda femoris artery. Average pedicle length is 8–12 cm. Once the perforator is

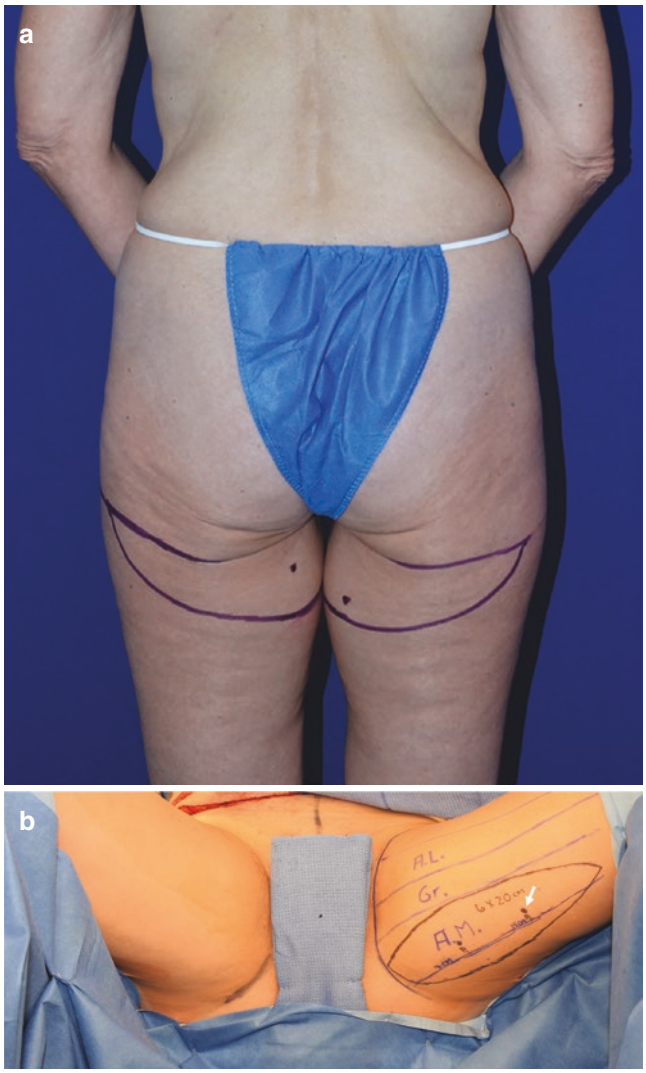


Fig. 27.3 Flap markings for transverse PAP flap (**a**) and vertical PAP flap (**b**) design. Transverse PAP flap markings are marked with superior border within 1 cm of the gluteal crease, lower border 6–7 cm inferior to the superior border, extending laterally to the border of the crease and medially to the medial aspect of the femoral triangle. The vertical PAP flap can be marked pre- or intraoperatively. Shown in **b** is intraoperative flap markings, with the anterior border of the flap centered along the posterior border of the gracilis muscle (G) and flap centered along a vertical axis of perforator exit from the adductor muscle (AM). The most distal perforator is 14 cm distal to the gluteal fold (white arrow)

captured, posterior incisions are completed and the flap is isolated. The thigh is then closed in layers over a closed suction drain. The flap may be coned for creation of one breast or stacked with the contralateral PAP or another flap such as the DIEP for volume enhancement [13]. The internal mammary vessels are the most common recipient vessel.

Vertical PAP Harvest

For the vertical, oblique, or S-shaped design, the anterior incision is made along the posterior edge of the gracilis muscle (Fig. 27.5). The incision is deepened to fascia and beveled anteriorly to capture additional fat if desired. The saphenous vein lies anteriorly and should be preserved. Once the posterior border of the gracilis muscle is identified, the fascia is vertically incised and dissection is carried deep to fascia of the adductor magnus. The key perforator is identified in addition to proximal and distal perforators. If more than one perforator is maintained with the flap, intra-flap perforator anastomosis may be performed to a side branch of the dominant perforator. Intramuscular dissection is performed, and the perforator is dissected back to the source vessel. The posterior incision is made and flap isolated. Because the profunda gives a segmental blood supply to the posteromedial thigh, ICG angiography may be used at this point to confirm the angiosome territory. Similar as for the transverse design, the thigh is then closed in layers over a closed suction drain. The flap may be coned for creation of one breast or stacked with another flap for volume enhancement. The internal mammary vessels are the most common recipient vessel. The flap may be sensitized based on branches of the posterior femoral cutaneous nerve found in the subfascial plane of the posterior mid-thigh.

Technical Variations

Skin paddle design may vary based on the nature and location of the patient's fat distribution, skin laxity, and key perforator location. For women with horizontal laxity, a vertical pattern may be desirable. For patients with upper medial thigh fat predominance with vertical laxity or desire for scar following the gluteal fold, a transverse pattern may be chosen. After massive weight loss or to capture more volume, a fleur-de-lis pattern may be chosen.

Postoperative Care

Standard postoperative free flap monitoring is performed. The patient is able to ambulate by the first postoperative day. Compressive garments may be applied to help with postoperative swelling to the thigh. The drains may be removed after they put out less than 30 cc a day for 2 consecutive days. Strenuous exercise may be started at week 6.

Postoperative complications with flap vascularity are rare. Occasionally fat necrosis may be seen in distal tips of the flap furthest from the perforator angiosome. The segmental nature of posteromedial thigh vascularity should be respected during flap harvest, and perfusion can be studied intraoperatively with ICG angiography to avoid potential fat necrosis. Unfavorable donor-site complications may occur as a result of tension or tight closure, resulting in dehiscence and secondary intention healing. Complications reported by Allen et al. in a report of 164 consecutive PAP

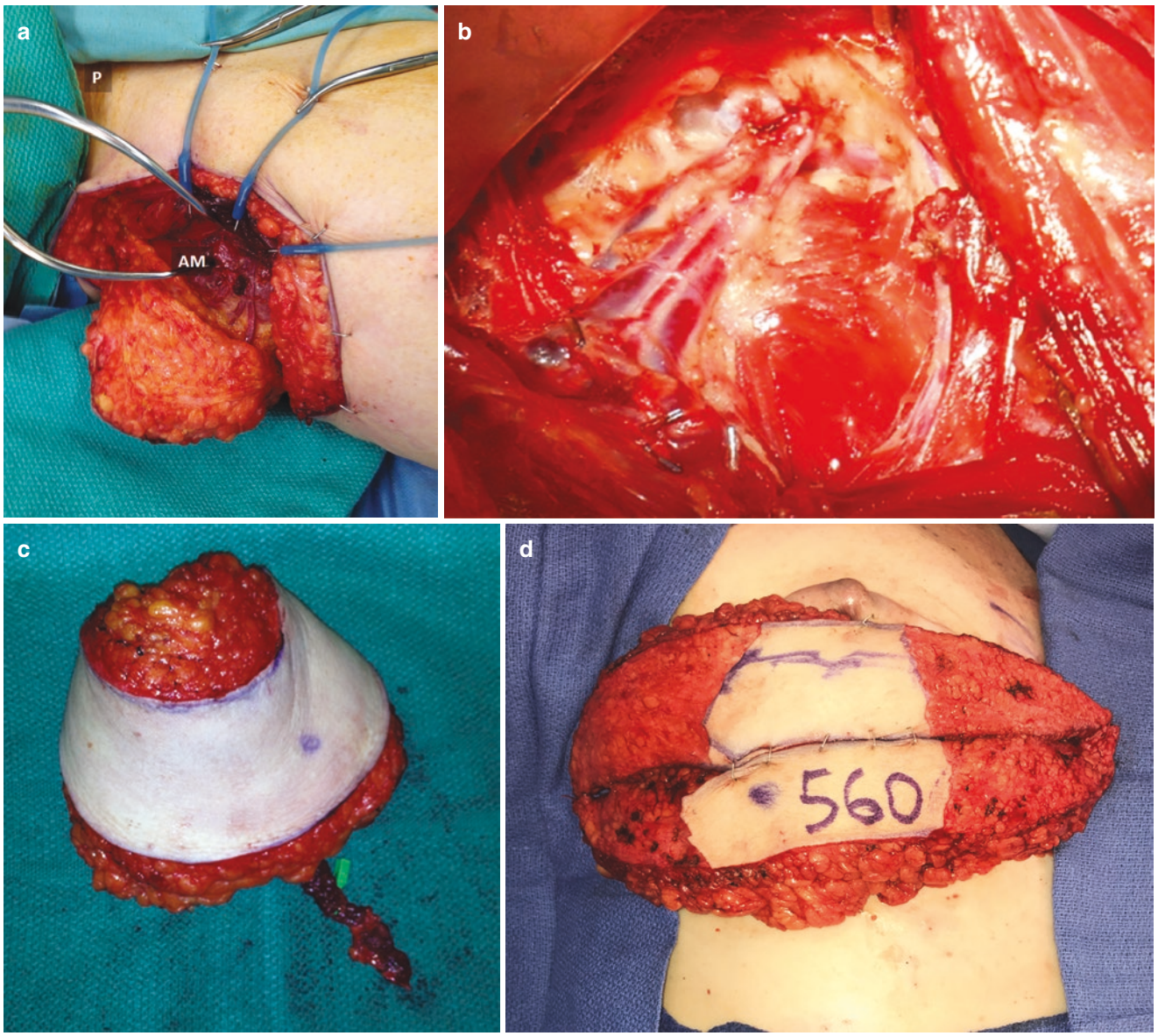
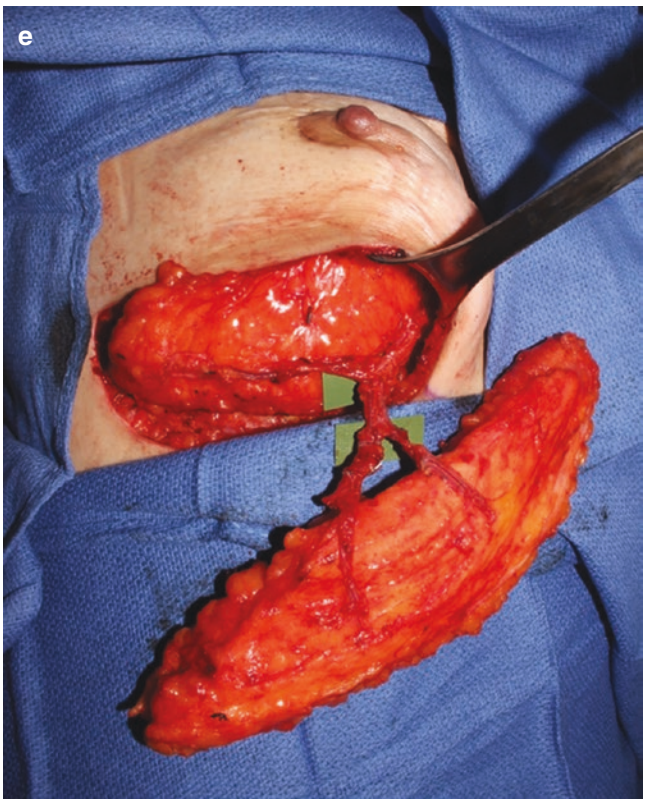


Fig. 27.4 Transverse PAP flap harvest. The pubic tubercle (P) and adductor magnus (AM) muscle is marked. The flap is harvested anteriorly to posteriorly along a crescent centered just below the gluteal crease, capturing proximal perforators. The anterior incision is made medial to the femoral triangle and dissection carried subfascial once reaching the posterior border of the gracilis muscle. The perforator is identified exiting the fascia of the adductor magnus muscle (**a**, **b**). Intramuscular dissection is performed and the posterior incisions completed. Once harvested, the flap may be coned to re-create the projection and appearance of the breast (**c**). The flap also may be stacked for volume augmentation and shape. (**d**) Stacked PAP flap with anastomosis to antegrade and retrograde internal mammary vessels in unilateral breast reconstruction. (**e**) Stacked DIEP-PAP flap with intra-flap anastomosis



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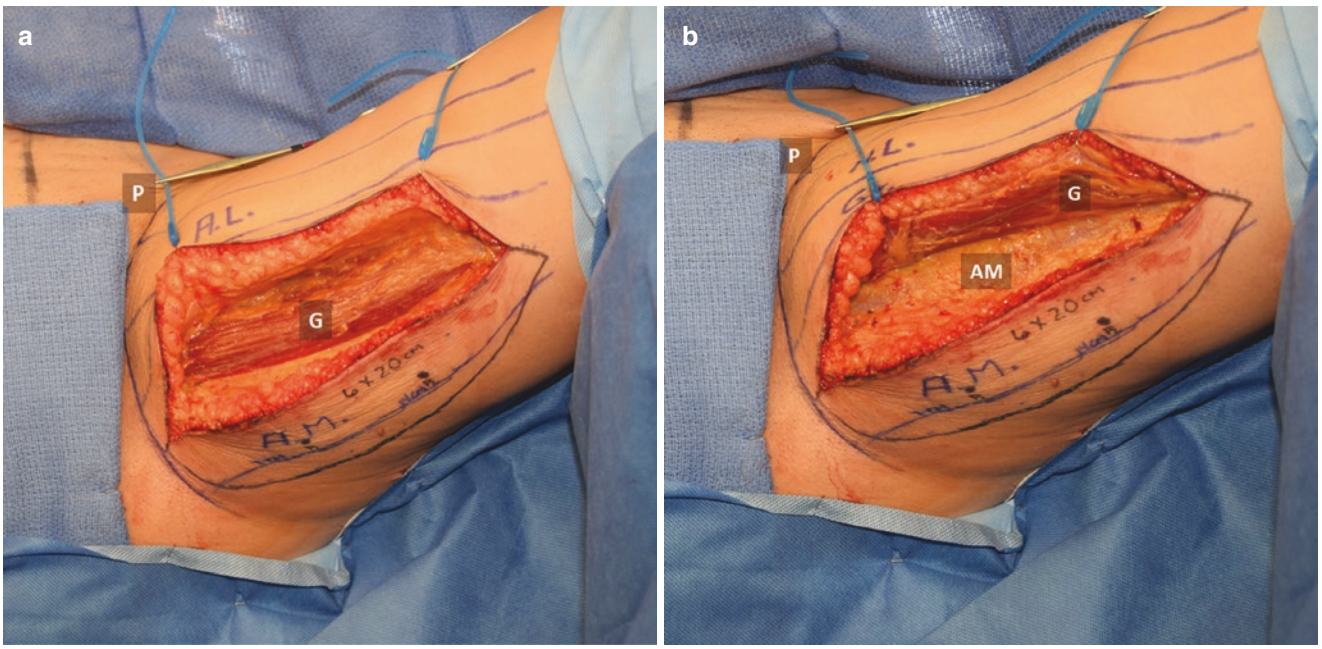

Fig. 27.5 Vertical PAP flap harvest. The pubic tubercle (P), adductor longus (AL), and gracilis (G) muscle borders are marked. Incision is made along the posterior border of gracilis (G) and carried down to the deep fascia (**a**). The gracilis muscle is elevated and adductor magnus (AM) identified (**b**). Dissection is carried out in the subfascial plane over adductor magnus and perforating vessels identified. Intramuscular dissection is carried out back to the takeoff of the perforator from the profunda femoris (**c**). The thigh is closed in layers over a closed suction drain (**d**). Dimensions of the vertical flap are 20 × 6 cm (**e**)

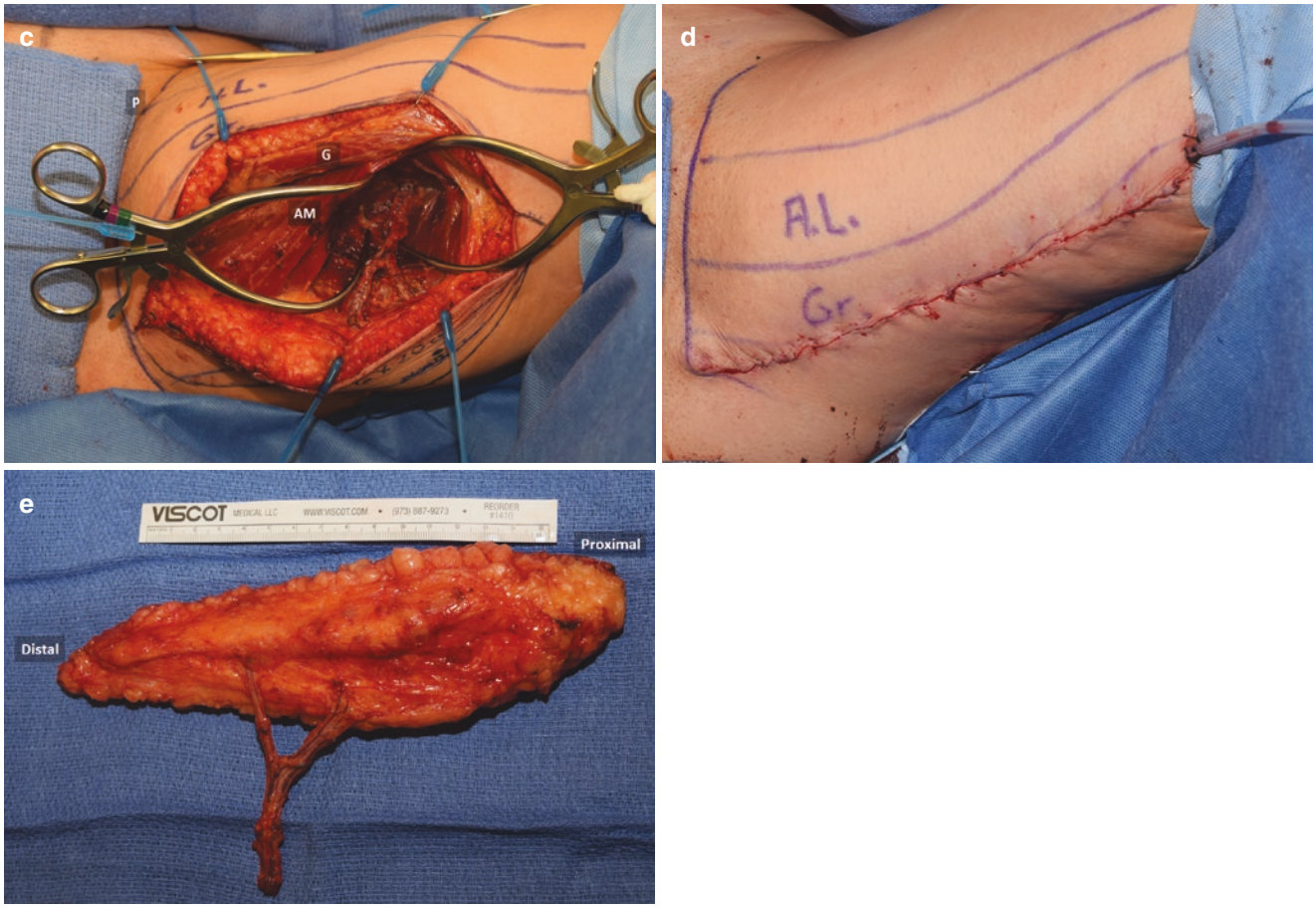

Fig. 27.5 (continued)

flaps include fate necrosis (7%), flap loss (<1%), seroma (6%), hematoma (1.9%), and hematoma (1.9%) [14–16]. There were no secondary operations performed for thigh contouring [4]. The possibility of injury to the posterior femoral cutaneous nerve is present and avoided by supra-fascial dissection in the mid-thigh once the key perforator is identified.

Clinical Cases

Case 1

A patient with BRCA1 gene mutation who underwent bilateral nipple-sparing mastectomy and immediate reconstruction with bilateral transverse PAP flap (Fig. 27.6).

Fig. 27.6 A patient with BRCA1 treated with nipple-sparing mastectomy and transverse PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

Case 2

A patient with history of right partial mastectomy and radiation for breast cancer presenting several years later with a second right breast cancer. She additionally had been previously treated for endocervical cancer with hysterectomy, lymphadenectomy, and adjuvant radiation therapy. She was treated with bilateral nipple-sparing mastectomy and immediate transverse PAP flap reconstruction (Fig. 27.7).

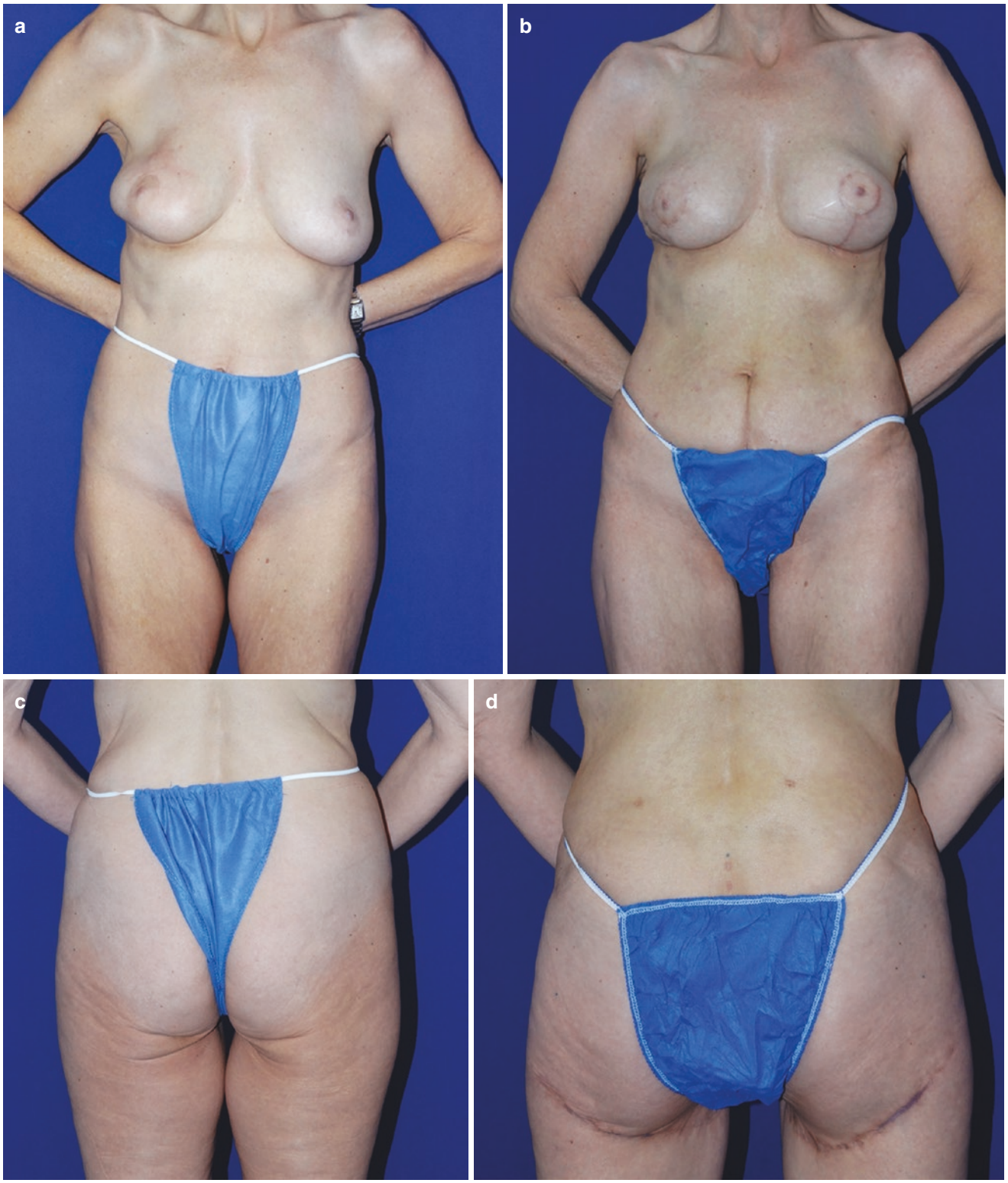

Fig. 27.7 A patient with history of right partial mastectomy and radiation and new right breast cancer treated with bilateral mastectomy and transverse PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

Case 3

A patient with history of left breast cancer for which she was treated with mastectomy and DIEP flap reconstruction. Several years later, she presented with a high-risk gene mutation for which she underwent nipple-sparing prophylactic mastectomy and immediate stacked vertical PAP reconstruction (Fig. 27.8).

Fig. 27.8 A patient with history of left mastectomy and stacked DIEP reconstruction now treated for genetic high risk with prophylactic mastectomy and stacked PAP vertical flap reconstruction. (**a**) Preoperative photo; note history of left DIEP flap. (**b**) Postoperative. (**c**–**e**) Postoperative posterior thigh views

Case 4

A patient with left breast cancer treated with bilateral mastectomy and stacked bilateral DIEP-PAP flap reconstruction. The pedicle for the PAP flap was anastomosed to a branch of DIEP and the entire flap inset to allow the DIEP flap to reconstruct the superior pole and the PAP flap to fill out the lower pole (Fig. 27.9).

Conclusions

The PAP flap has become an accepted secondary option for autologous breast reconstruction when the abdomen is not available for use. The flap provides a long pedicle, excellent vessel diameter and match to common recipient sites. Preoperative imaging should be used to guide perforator selection and flap design. The dominant perforator is vari-

Fig. 27.9 A patient with left breast cancer treated with mastectomy and bilateral stacked DIEP-vertical PAP flap reconstruction. (**a**, **c**) Preoperative. (**b**, **d**) Postoperative

able and patient-specific. Flap design can be tailored to volume requirements and aesthetic principles to guide optimal outcomes. Donor-site morbidity is low, and scarring is well concealed in the gluteal fold or medial thigh. Given its reliable blood supply and ability to cone or stack flaps for creation of a natural-appearing breast, the PAP flap is an excellent choice for breast reconstruction in selected patients.

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