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ORIGINAL ARTICLE
Breast

# The Preferred Design of the Profunda Artery Perforator Flap for Autologous Breast Reconstruction: Transverse or Diagonal?

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**Background:** Since its introduction for autologous breast reconstruction in 2010, the profunda artery perforator (PAP) flap has emerged as a preferred choice when an abdominal flap is suboptimal. The traditional transverse design (tPAP) was popularized, given the inconspicuous donor scar. A diagonal design (dPAP) has since evolved to address some of the shortcomings of the tPAP. The authors aimed to compare outcomes of tPAP/dPAP flaps harvested for breast reconstruction by a single surgeon.

**Methods:** A retrospective review was conducted from 2017 to 2022 of patients undergoing tPAP versus dPAP-based breast reconstruction by a single surgeon at a tertiary cancer center. Patient variables and operative variables were assessed. Need for additional symmetrizing breast procedures were compared. Complications and BREAST-Q patient-reported outcome measures were analyzed.

**Results:** Thirty-nine flaps were used to reconstruct 35 breasts in 24 patients. Average follow-up for the group was 1.8 years. The groups were similar with respect to demographics. The majority of dPAP flaps had two perforators, whereas most tPAP flaps had one perforator. The dPAP flaps had greater average weights, width, and overall surface area. There were no cases of partial/total flap loss. Complications and PROM results were similar between the two groups.

**Conclusions:** The dPAP design allows for a larger skin paddle and greater tissue harvest and capture of cutaneous perforators, without increasing the risk of complications or compromising satisfaction. It should be considered as a viable option in patients unable to undergo abdominal-based reconstruction. Additional patients and multi-institutional efforts are necessary to better compare advantages of either design. *(Plast Reconstr Surg Glob Open 2023; 11:e5188; doi: 10.1097/GOX.0000000000005188; Published online 23 August 2023.)*

## INTRODUCTION

Advances in microsurgical techniques in autologous breast reconstruction have led to decreased operative time, length of stay, and morbidity.[1] Additionally, autologous reconstruction allows for natural appearing breasts while avoiding risks associated with implant-based reconstruction, including capsular contracture, malposition, and exposure. In fact, autologous breast reconstruction has been shown to lead to higher patient satisfaction.[2] Although the abdomen remains the gold standard donor site,[3] alternative sources must be considered in patients with extensive prior abdominal surgery, scant abdominal tissue, history of abdominoplasty, a desire for future pregnancy, or an aversion to abdominal scars. The potential for abdominal core weakness may also be a significant issue, particularly for the athletic or physically active patient.

The profunda artery perforator (PAP) flap was conceived as a derivation from various pedicled and fasciocutaneous free flaps of the thigh. Song and colleagues described a posterior thigh flap for reconstruction of head and neck burn contractures.[4] Angrigiani et al were the first to provide detailed descriptions of the PAP flap harvest as well as perforator anatomy and reliability

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*Received for publication May 30, 2023; accepted June 27, 2023.*



DOI: 10.1097/GOX.0000000000005188

Disclosure statements are at the end of this article, following the correspondence information.

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through latex injections in cadaveric specimens.[5] In 2012, Allen Sr heralded a shift in the realm of autologous breast reconstruction when he first described the utility of PAP flaps in this setting.[6] Since the initial description of 27 patients, the PAP flap has become the senior author's favored alternate donor site when abdominal tissue harvest is unavailable or contraindicated.

Allen's original description of the PAP flap for breast reconstruction designed the flap in a transverse dimension (tPAP), with the donor site scar well concealed in the inferior gluteal crease (IGC).[6] However, a transverse closure is often under significant tension, which may limit flap width and risk dehiscence. Dayan and colleagues had subsequently described the diagonal upper gracilis flap oriented along Langer's lines to address these issues, yielding a wider flap with reliable healing.[7] More recently, Dayan and Allen Jr applied the diagonal skin paddle design to the PAP flap (dPAP).[8] This modified skin paddle orientation captures additional cutaneous perforators while the resulting donor site defect can be closed along the line of least tension, allowing the flap to support a wider skin paddle. The reliability and ease of capturing numerous perforators with a dPAP may prove beneficial if a perforator is inadvertently injured at the time of harvest or if preoperative imaging is not available. Also, the diagonal design is better able to include the fat of the posteromedial thigh, which is ideal in consistency for breast reconstruction. Unlike the scar that accompanies a tPAP, compression of a dPAP incision while sitting is less of a concern, decreasing potential wound sequelae and/or chronic paresthesia.

Donor site complications after PAP flap harvest include seroma, hematoma, wound dehiscence, wound infection/cellulitis, and chronic pain.[9] The complication rates at the donor site have been previously published, but the results of these studies have been limited to an examination of tPAP flaps.[9–14] The purpose of this study was to analyze the senior author's (R.J.A., Jr) early experience and results with autologous breast reconstruction using PAP flaps, as well as compare demographics, operative details, complication rates, and patient-reported outcome measures (PROMs) between patients reconstructed with tPAP and dPAP flaps. We hypothesized that the dPAP flap design allows for a larger skin paddle and overall volume, without increasing the risk of complications or compromising patient satisfaction.

## METHODS

Approval for this study was provided by the institutional review board at Memorial Sloan Kettering Cancer Center. A retrospective review was conducted from a prospectively maintained database of all patients who underwent PAP flap breast reconstruction by the senior author (Robert Allen Jr.) from 2017 to 2022 at Memorial Sloan Kettering Cancer Center. These procedures were performed either in an immediate or delayed setting. One patient who underwent a fleur-de-lis PAP was excluded for the purpose of this study.

The method of harvesting the tPAP is as originally described by Allen and colleagues.[6] With regard to the dPAP, the patient is typically assessed in the preoperative area while standing (Fig. 1A–D), and skin markings are made. The gracilis and adductor longus muscles are marked as important landmarks, as is the IGC. After confirmation of perforator status via advanced imaging modalities, typically with magnetic resonance angiography, the cutaneous perforators are confirmed with a Doppler probe, and markings are made for intraoperative reference. The anterior marking of the dPAP should be placed along the posterior border of the gracilis muscle. The anterior mark curves posteriorly starting approximately 8 cm distal to the IGC. A pinch test along the resting skin tension lines is then used to make the posterior marking, and the ellipse is completed to include the PAP perforator, which runs through the adductor magnus muscle. For flap harvest, the patient can be placed in lithotomy, or in a frog-leg or split-legged position (Fig. 1E). Dissection then proceeds at the thigh through an anterior incision. The fascia investing the gracilis muscle is entered, and the muscle is retracted anteriorly. The adductor magnus fascia is then exposed posterior to the gracilis, incised, and dissection proceeds posteriorly/laterally in the subfascial plane until the perforators are identified. Intramuscular dissection of the perforators then proceeds in a standard fashion until adequate length is achieved or the profunda artery is encountered. When pedicle length is deemed sufficient and the vessels are confirmed to be of suitable caliber for microsurgical transfer, the pedicle is divided. The remainder of the incisions can then be made, and the flap transferred to reconstruct the mastectomy defect, or the flap can be allowed to perfuse through posterior perforators until the recipient site is ready (Fig. 2A). Microsurgical anastomosis is then performed in a standard fashion, typically to the antegrade internal mammary artery and vein. The tissue is then shaped and molded to match the breast footprint, and tacking sutures are placed to secure the flap into the breast envelope. Donor sites are closed in a multilayered fashion, with one closed-suction drain placed in each donor site within the muscle beds (Fig. 2B). A skin paddle is used for postoperative monitoring (Fig. 2C). Long-term postoperative follow-up shows excellent symmetry of the breasts and well-hidden donor site scars (Fig. 3).

Subgroup analysis was performed comparing two groups: tPAP and dPAP patients. Data regarding patient

### Takeaways

**Question:** What is the optimal design of the profunda artery perforator (PAP) flap for autologous breast reconstruction?

**Findings:** This is a retrospective review that showed that diagonal PAP flaps allow for greater tissue harvest without increasing the risk of donor site complications.

**Meaning:** In comparison with transverse PAP flaps, diagonal PAP flaps provide significantly more tissue while avoiding significant donor site complications, and thus remain an excellent option when abdominal-based tissue is unavailable.

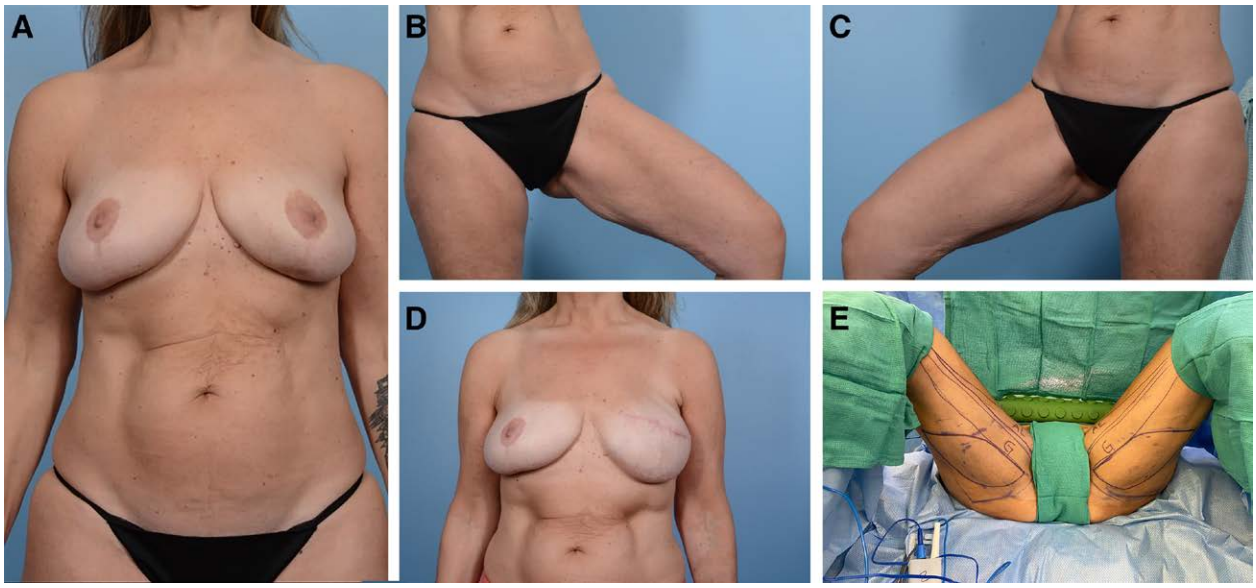


**Fig. 1.** Patient case photographs. A, Preoperative appearance of the breasts/abdomen. Note the well-healed Wise pattern incisions on bilateral breasts from previous reduction mammoplasty. Patient has inadequate abdominal donor site for autologous breast reconstruction. B, Preoperative appearance of the left inner thigh demonstrating adequate posteromedial thigh tissue and laxity. C, Preoperative appearance of the right inner thigh demonstrating adequate posteromedial thigh tissue and laxity. D, Appearance of left breast following mastectomy and reconstruction with a prepectoral tissue expander. E, Intraoperative positioning in lithotomy with markings delineating the location of the adductor longus (AL) muscle, gracilis (G) muscle, and a 21 × 9.5 cm anticipated skin paddle on the left (21 × 9.5 cm on the right) .

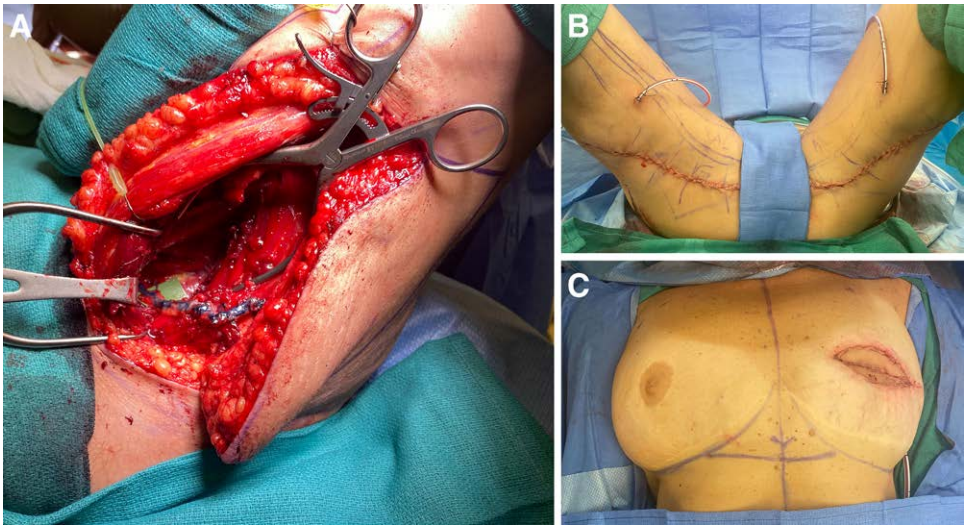


**Fig. 2.** Patient case photographs. A, After the anterior skin incision is made, the gracilis fascia is incised and retracted anteriorly. The fascia investing the adductor magnus is incised, facilitating a subfascial dissection until adequate pedicle length is achieved or the profunda artery is reached. A suitable perforator was selected (marked with methylene blue) and a bulldog clamp was placed on the perforator, after which the vessel was clipped and divided, whereas the posterior skin attachment is left intact until ready for flap harvest. B, Appearance of bilateral donor sites after wound closure over closed-suction drains. Note the tension-free closure. C, The flaps were transferred to the left chest in a stacked fashion. The left dPAP flap was anastomosed to the antegrade internal mammary system, whereas the right thigh flap was coapted to the retrograde internal mammary vessels. The flaps were selectively de-epithelialized, inset into the mastectomy defect to create a youthful breast mound, and a skin paddle is used to monitor both flaps. The original mastectomy weight was 383 g, whereas the PAP flaps weighed 243 g (L) and 230.5 g (R).

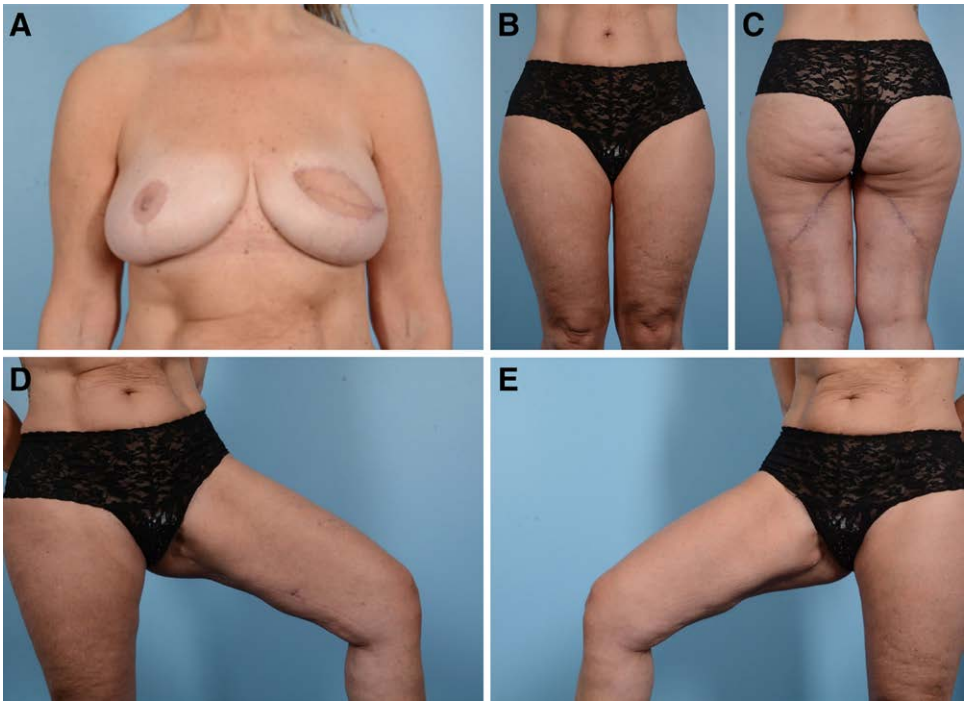


**Fig. 3.** Postoperative patient photographs. A, Three-month postoperative appearance of the breasts. Note the excellent symmetry of the breasts. B, Three-month postoperative appearance of the thighs (anterior view). C, Three-month postoperative appearance of the thighs (posterior view). D, Three-month postoperative appearance of the left inner thigh. E, Three-month postoperative appearance of the right inner thigh.

demographics, medical comorbidities, risk factors, and systemic therapies (chemotherapy, radiation) were reviewed. Reasons for undergoing PAP flap autologous reconstruction, as opposed to other methods of breast reconstruction, were reviewed. Surgical variables, including operative time, flap size/weight, pedicle length/caliber, and number of perforators, were also assessed. Any need for additional breast procedures, including fat grafting, implant augmentation, mastopexy, and mammoplasty, was compared between the groups. Donor and recipient site complications were reviewed. Mastectomy skin flap necrosis (MSFN) was defined as either epidermolysis or partial/full thickness necrosis of the skin flaps. Wound dehiscence was defined as superficial skin dehiscence of the suture line at either the recipient or donor site, which did not require operative intervention or revision. PROMs were evaluated via comparison of BREAST-Q scores for both cohorts. BREAST-Q surveys were administered at the following intervals as part of routine clinical care: preoperatively, 2 weeks postoperatively, 6 weeks postoperatively, 3 months postoperatively, 6 months postoperatively, 1 year postoperatively, 2 years postoperatively, and 3 years postoperatively.

Summary statistics for continuous variables were calculated, and student *t* test was used for demographic comparisons. The Mann-Whitney U test was used for BREAST-Q score comparisons. Fisher exact test was used to compare categorical variables. Statistical significance was set to 0.05, and all analyses were completed using R statistical software (version 4.2.0).

## RESULTS

Supplemental Digital Content 1 provides a comparison of patient demographics between the two cohorts. [**See tables, Supplemental Digital Content 1,** which displays (a) patient demographics, (b) operative time, (c) operative details, (d) complication rates. **http://links.lww.com/PRSGO/C716.**] The mean age at surgery was 46.4 years, with an average follow-up period of 644.4 days (1.8 years). The average body mass index for the whole group was 25.9 kg per $m^2$. A total of nine patients (37.5%) underwent neoadjuvant chemotherapy, whereas six patients (25%) received systemic chemotherapy in the adjuvant setting. In terms of radiation to the affected breast/chest wall, 37.5% (n = 9) had radiotherapy delivered in the adjuvant setting. No patient received neoadjuvant radiation. The reasons for selecting a PAP flap for reconstruction, as opposed to an abdominal donor site, were as follows: prior abdominoplasty (25%, n = 6), patient aversion to abdominal scarring (4.2%, n = 1), patient desire for future pregnancy (4.2%, n = 1), history of prior abdominal flap (4.2%, n = 1), prior extensive abdominal surgery and/or scarring (16.7%, n = 4), prior failed abdominal flap (4.2%, n = 1), and scant abdominal tissue (41.7%, n = 10). All demographic variables examined were similar between the groups, with no statistical difference noted on analysis ($P > 0.05$ for all). Although tPAP flaps took longer to harvest on average (9.8 versus 7.5 hours), this was not found to be statistically significant ($P = 0.059$). The faster harvest with a dPAP flap is likely a reflection of increasing surgeon experience

as well as the inherently greater exposure of the adductor magnus and its fascia with dPAP flaps. This allows for more efficient perforator identification and dissection. There were no significant differences in average operative time between groups when comparing unilateral/bilateral and stacked/nonstacked cases (Supplemental Digital Content1b, **http://links.lww.com/PRSGO/C716**).

Supplemental Digital Content 1c (**http://links.lww.com/PRSGO/C716**) highlights the operative details for our patient population. A total of 39 flaps were used to reconstruct 35 breasts in 24 patients. On average, dPAP flaps weighed more (389.2g versus 281.5g, $P = 0.003$). With respect to skin paddle size, dPAP flaps (10.2cm) were wider than tPAP flaps (6.9cm) ($P < 0.001$) and had a larger skin paddle surface area (234.8$cm^2$ versus 150.9$cm^2$, $P < 0.001$). Mean pedicle length was 10.4cm for the dPAP group and 9.9cm for the tPAP group ($P = 0.206$). The dPAP flaps were more likely to have two or more perforators (68.4%, n = 13) as compared with tPAP flaps (40%, n = 8), although this lacked statistical significance ($P = 0.11$). The average size of the vena comitans associated with the flap pedicle was 2.8mm for both cohorts ($P = 0.9$). 15.4% of dPAP patients (n = 2) and 54.5% of tPAP patients (n = 6) underwent stacked flap reconstruction. The breakdown of secondary flap choice for placement in a stacked configuration was as follows: PAP (ie, stacked PAP flaps in one mastectomy defect, 33.4%, n = 4), single/two perforator deep inferior epigastric perforator (58.3%, n = 7), and muscle sparing-transverse rectus abdominis myocutaneous (ms-TRAM, 8.3%, n = 1). The number of additional procedures between the groups was similar ($P = 0.44$), with no difference with respect to the need for fat grafting ($P = 1.0$), implant augmentation ($P = 0.48$), mastopexy ($P = 0.33$), or mammoplasty ($P = 1.0$).

Supplemental Digital Content 1d (**http://links.lww.com/PRSGO/C716**) details the complication rates at both the recipient and donor sites for our cohorts. There was no difference in the rate of abscess ($P = 1.0$), flap congestion ($P = 1.0$), flap ischemia ($P = 0.46$), hypertrophic scarring ($P = 0.46$), MSFN ($P = 1.0$), seroma ($P = 1.0$), wound dehiscence ($P = 0.65$), or cellulitis ($P = 0.46$) between the groups. There were no instances of full-thickness MSFN in our cohort. One patient in each group had partial thickness skin edge necrosis that was managed nonoperatively. No patient in either cohort developed fat necrosis. There were no instances of partial or total flap loss in our patient population (100% flap success rate).

PROMs were assessed with BREAST-Q surveys administered at the aforementioned intervals. Modules assessing satisfaction with breasts, as well as adverse effects of radiation, physical well-being of the chest, psychosocial well-being, and sexual well-being were compared between the two cohorts (Fig. 4). [**See tables, Supplemental Digital Content 2,** which displays (a) BREAST-Q: Satisfaction with Breasts module, (b) BREAST-Q: Adverse Effects of Radiation module, (c) BREAST-Q: Physical Well-Being of the Chest module, (d) BREAST-Q: Psychosocial Well-Being module, and (e) BREAST-Q: Sexual Well-Being module. **http://links.lww.com/PRSGO/C717**.] (**See figure, Supplemental Digital Content 3,** which displays box-plot representation of Adverse Effects of Radiation module. **http://links.lww.com/PRSGO/C718**.) (**See figure, Supplemental Digital Content 4,** which displays box-plot representation of Physical Well-Being of the Chest module. **http://links.lww.com/PRSGO/C719**.) (**See figure, Supplemental Digital Content 5,** which displays box-plot representation of Psychosocial Well-Being module. **http://links.lww.com/PRSGO/C720**.) (**See figure, Supplemental Digital Content 6,** which displays box-plot representation of Sexual Well-Being module. **http://links.lww.com/PRSGO/C771**.) There were no statistically significant differences in BREAST-Q scores (for all modules) between tPAP and dPAP flap patients at any time interval that was assessed ($P > 0.1$ for all).

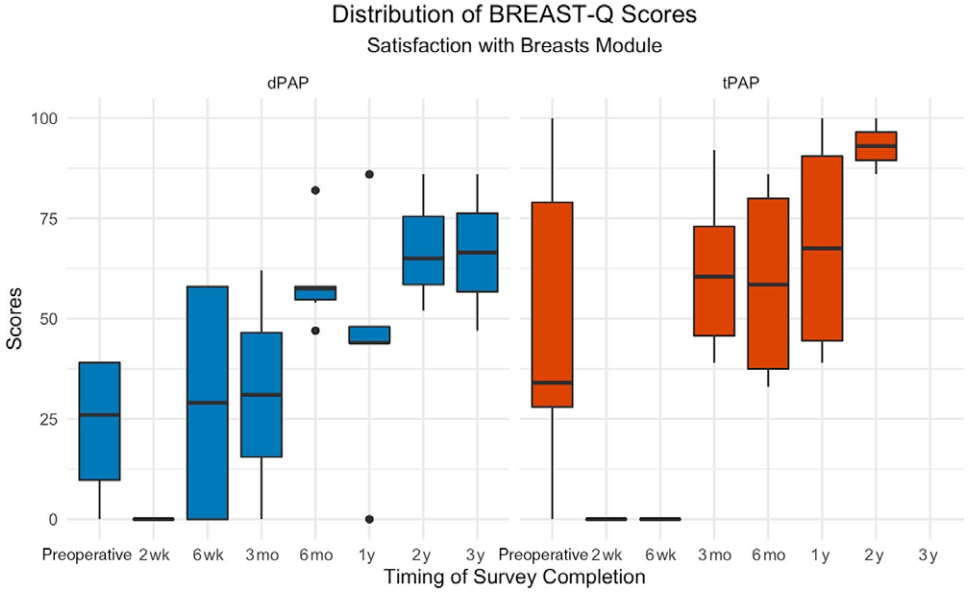


**Fig. 4.** Box-plot representation of Satisfaction with Breasts module.

## DISCUSSION

For autologous breast reconstruction, the deep inferior epigastric perforator flap remains the donor tissue of choice across many institutions, citing excellent outcomes, reliability, and minimal donor site morbidity.[15–18] However, when an abdominal donor site is unavailable or contraindicated, the reconstructive surgeon must explore secondary tissue sources. The PAP flap has become the leading alternate flap choice in our institution. In our experience, it provides ample volume for autologous breast reconstruction, even in patients with a low body mass index who do not have adequate abdominal donor tissue.[11–14] Additionally, the vessels are consistent in nature, with each source artery (profunda femoris) supplying at least two suitable perforators, with one study showing that a single thigh may contain up to five cutaneous perforators.[19] The pedicle averages 11–13 cm in length and is of excellent caliber for microvascular anastomosis, with the perforating arterial branch and its associated vena comitans being more than 2 mm in size.[13,19–28] The authors' early results presented in this study show that dPAP flaps consistently provide a larger amount of tissue and larger skin paddle than tPAP flaps, without increasing complication rates or compromising patient satisfaction. With regard to the tPAP flap, the maximum width of the skin paddle is typically ~6–8 cm, limiting the amount of tissue that can be harvested. Additionally, despite being able to hide the tPAP donor scar in the IGC, there is a significant amount of tension on the incision, potentially increasing the risk of wound complications. Lastly, patients may compress the incision when sitting, a factor which may further potentiate wound complications and/or lead to chronic posterior thigh paresthesia from damage to the posterior cutaneous nerves.[9] The additional tissue afforded by a diagonally oriented PAP flap will allow the surgeon to address a wider volumetric range of breast defects, thus increasing its reconstructive potential. Additionally, the larger skin paddle design may prove beneficial in delayed reconstruction cases that require extensive skin resurfacing.

Previously published studies have largely focused on the original transverse design of the PAP flap. In 2016, Allen Sr and colleagues reviewed their initial experience with 164 flaps used to reconstruct 96 patients.[9] Cited complications in this study were as follows: hematoma (1.9%), seroma (6.0%), fat necrosis (7.0%), and donor site wound dehiscence (3.6%). They noted a 3% takeback rate and one instance of flap loss. Haddock et al assessed their results with PAP flap breast reconstruction in 2017.[12] They recorded one partial flap loss and two cases of total flap loss out of 101 flaps used to reconstruct 96 breasts. Donor site complications included cellulitis (5.9%) and wound dehiscence (10.9%). Haddock then expanded on his results in 2020 and examined 265 total PAP flaps.[13] The total flap loss rate was 3%, with the following donor site complications: seroma (4.5%), hematoma (2.6%), infection (4.9%), and significant wounds requiring negative pressure dressing or procedure(s) (6.8%). Lastly, in one of the larger examinations of PAP flaps, Qian and colleagues performed a systematic review of 12 studies that included a total of 516 PAP flaps used to reconstruct 327 patients.[29] The reported flap success rate was 99% (1% rate of total flap loss) and 2% of patients experienced partial flap loss. The pooled donor site complications were wound dehiscence (6%), seroma (2%), and hematoma (1%).

Our early results show a 100% flap success rate with no cases of partial/total flap loss or clinically apparent fat necrosis. The rates of our cohort's complications, including donor site seroma (25%, tPAP = 3, dPAP = 3), wound dehiscence (25%, tPAP = 2, dPAP = 4), cellulitis (4.2%, tPAP = 1), and hypertrophic scarring (4.2%, tPAP = 1) show slight heterogeneity in comparison with the rates cited in the historical studies by Allen Sr and Haddock, likely a reflection of our small sample size (total n = 24). None of the patients who experienced donor site complications in our cohort required surgical intervention, and all were managed conservatively with excellent outcomes. Additionally, there were no instances of significantly increased risk of complications in comparing diagonal and transverse PAP flap harvest in our cohort.

When compared with another popular thigh-based option, such as the gracilis flap and its variants (ie, diagonal upper gracilis, transverse upper gracilis), the PAP flap spares muscle harvest. Dissection of the PAP flap occurs away from the draining lymphatics of the lower extremity, decreasing the potential for dead space and subsequent lymphedema/seroma.[8,9] As expected, the advantages of the dPAP over the tPAP in terms of flap dimensions are also true compared with the transverse upper gracilis flap.[7] The PAP has a larger caliber vessel compared with the gracilis pedicle, and also has a longer pedicle, although the effective pedicle length is similar given the more central location of the PAP perforators. Additionally, the PAP flap captures the fat of the posteromedial thigh, which is ideal in consistency for insetting and shaping into a youthful breast mound.

The PAP flap is ideally harvested with patients positioned in lithotomy, but a split-leg bed is another option. This facilitates a two-team approach, allowing the mastectomy and/or preparation of the recipient vessels to proceed simultaneously with flap dissection. Additionally, after the main perforator is ligated, the PAP flap remains attached via posterior skin attachments that can maintain adequate tissue perfusion (Fig. 2A). When the group preparing the recipient vessels at the chest is ready for microvascular transfer, the remaining skin attachments of the PAP flap are divided and the flap is prepared for transfer, thus minimizing ischemic time, and optimizing the workflow of the operative teams.

The authors recognize several limitations to this study, including those inherent to a retrospective design. Further, although this is the first reported series comparing dPAP and tPAP flaps for breast reconstruction, the total number of patients is small, and a greater number may uncover additional findings and/or differences between the groups. The analysis of patient-reported outcomes is underpowered, and the results should be viewed in light of this. Despite these limitations, the single-surgeon and

single-institutional experience of this study minimizes any variability of patient selection, technique, and perioperative care. Large-scale, multi-institutional studies are required to further assess and compare the differences and potential benefits between the geometric modifications of the PAP flap. Additionally, a validated assessment of patients' satisfaction of the donor site aesthetic result should be performed.

## CONCLUSIONS

The presented findings on PAP flap based autologous breast reconstruction demonstrate that dPAP flaps are, on average, larger in volume and allow for a larger surface area skin paddle to be harvested when compared with tPAP flaps. The orientation of the diagonal flap along Langer's lines allows for reduced tension at the donor site closure. Complication rates are similar between the two geometric modifications of the PAP flap. PROMs are not compromised with the increase in flap size afforded by the diagonal design, with similar results in all BREAST-Q survey domains between dPAP and tPAP flap patients. We believe that the larger volume and skin paddle inherent to dPAP flaps increases its reconstructive potential following mastectomy, particularly in a delayed setting. Further multi-institutional efforts with recruitment of additional patients are required for a more comprehensive comparison between PAP flap types.

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## DISCLOSURES

*The authors have no financial interest to declare in relation to the content of this article. This research was funded in part through the NIH/NCI Cancer Center Support Grant P30 CA008748, which supports Memorial Sloan Kettering Cancer Center's research infrastructure.*

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