Review Article

Maximizing volume in autologous breast reconstruction: stacked/conjoined free flaps

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Abstract: Since the first report of abdominally based tissue breast reconstruction with a free flap of rectus abdominis muscle to reconstruct mastectomy defects, autologous breast reconstruction has continually increased in popularity due to improved cosmesis, patient satisfaction, and quality of life. While abdominal tissue is frequently used as the principal donor site, other flap options are available, including from the buttocks, thighs, and back. Microsurgical advancements in recent years have continued to improve patient outcomes and decrease operative times. One innovative technique is the use of stacked or conjoined free flaps which can be used when more breast volume is needed than can be provided by one free flap alone. These stacked or conjoined free flaps can be used unilaterally or bilaterally and can include combinations of nearly every free flap depending on the volume of tissue desired for the reconstruction. Though these flaps are increasing in popularity, there is limited comparative data on the safety and efficacy of stacked or conjoined free flaps as compared to single free flaps. In this review, we aim to highlight the use of stacked/conjoined free flaps for autologous breast reconstruction, as well as highlight recent data on this technique and provide recommendations for its safe use.

Keywords: Free flap; autologous reconstruction; stacked flap; conjoined flap; microsurgery

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Introduction

Background

There is an increasing body of literature that reports improved cosmesis, patient satisfaction, and quality of life following autologous breast reconstruction (1-3). With this, the use of autologous tissue continues to grow for women desiring breast reconstruction following mastectomy (4). Autologous breast reconstruction may utilize tissue from a variety of donor sites throughout the body of the patient, including the abdomen, thighs, buttocks and back (5). While these numerous donor sites have been described in the literature, abdominally based free tissue transfer offers numerous advantages and has emerged as the principal donor site for autologous breast reconstruction in women with adequate abdominal tissue volume (4).

Abdominally based tissue breast reconstruction was first reported by Holmstrom when he described moving a free flap involving the rectus abdominis muscle (the transverse rectus abdominis or "abdominoplasty" flap) to reconstruct mastectomy defects (6). Since this development, abdominal based autologous reconstruction has continued to evolve, driven by improved knowledge of angiosomes and perforasomes as well as innovative derivatives of these techniques. Furthermore, the widespread training of plastic surgeons with microsurgical skills has increased the feasibility of performing autologous breast reconstruction at a broader level. Continual refinement of techniques coupled

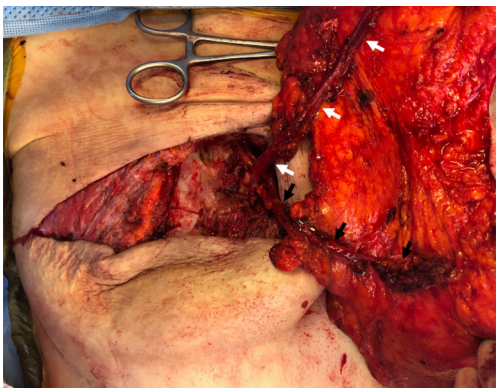

Figure 1 One DIEP flap artery anastomosed to the IMA in a retrograde fashion (white arrows), and one DIEP flap artery anastomosed to the IMA in an anterograde fashion (black arrows). DIEP, deep inferior epigastric perforator; IMA, internal mammary artery.

with the desire to meet patients' evolving demands and expectations has led to constant innovation. One challenge with abdominally based breast reconstruction is addressing patients with larger breasts—particularly in patients with disproportionate or limited available abdominal tissue (7).

Rationale and knowledge gap

The development of stacked/conjoined free flaps is one technique that evolved to address this discrepancy. The primary utility of stacked/conjoined free flaps has been supplementing extra volume for breast reconstruction and providing increased vascularity to free tissue transfers when needed (7). A recent meta-analysis reviewing a total of 26 clinical studies on stacked/conjoined breast reconstruction found that despite patients having a relatively low BMI, the mean combined flap weight for a unilateral breast was over 700 grams (7). Though useful, these stacked/conjoined flaps add more complexity and operative time to already lengthy operations. In this same meta-analysis, operative time averaged nearly 8 hours despite being performed at established microsurgical programs (7). One study has reported that operative times in stacked/conjoined flap reconstruction were significantly higher than single flap breast reconstruction (8). The risks associated with increased operative time and duration of anesthesia should be taken into consideration when performing these cases. While safe outcomes have been well-documented in the literature, there are limited data directly comparing stacked/conjoined flaps and their standard free tissue transfer counterparts (4).

Objective

In this review, we will highlight the use of stacked/conjoined free flaps as well as compile the existing data from the literature on this technique.

Nuances and applications of stacked/conjoined flaps

Considerations for use of stacked/conjoined flaps

When deciding to use a stacked/conjoined free flap for autologous breast reconstruction, several factors must be considered. As with any free flap procedure, preoperative planning is paramount for long-term success. Patients should be encouraged to reach a healthy body weight, which will help to minimize wound healing complications, as well as optimize any chronic vasculopathic diseases (e.g., diabetes mellitus). Further, strict cessation of negative behavioral activities including nicotine use which is known to have adverse effects on wound healing is recommended (9). Additionally, smoking has recently been suggested to increase flap failure in breast reconstruction underscoring the importance of controlling this modifiable risk factor (10).

Certain clinical presentations may also indicate using stacked/conjoined free flaps for autologous breast reconstruction. In massive weight loss patients, it may be challenging to find adequate tissue volume for the desired breast reconstruction using only single free flap techniques due to the abundance of skin but relative paucity of subcutaneous fat. Limited reports have found bilateral stacked free flaps to be well suited for this clinical scenario (11). Alternatively in patients with a higher body mass index (BMI), Sultan *et al.* reports that unilateral, conjoined, bipedicle deep inferior epigastric perforator (DIEP) flap breast reconstruction can be performed safely in overweight patients with no statistically significant differences in the overall incidence of major or minor complications between the high BMI and low BMI groups (12).

Most importantly, a stacked/conjoined free flap requires adequate vascular inflow and outflow to the flaps at the recipient site to successfully support the larger mass of tissue. Two options for anastomosing the flaps involve either joining the flap pedicles in "parallel" via anterograde and retrograde perfusion from two separate sets of internal mammary vessels (*Figure 1*) (13-16) or connecting the flap

pedicles in "series" via anterograde perfusion from only one internal mammary pedicle with direct anastomosis from the pedicle branch of the first flap to a pedicle branch of the second flap (17). There are challenges to both of these commonly used options. When joining the flaps in "parallel", it is not always possible to find two adequate sets of vessels for anastomosis, in addition to the increase operative time required for finding and dissecting free a second set of vessels. While interflap anastomoses in "series" require just one set of recipient vessels at the recipient site, it has been a less commonly preferred option compared to using the antegrade and retrograde internal mammary vessels by several authors due to perceived increased risk of flap complication (13,17,18). Metanalysis data, however, reveals no increased risks of any flap complications based on the choice of recipient vessels, though data is limited and more rigorous studies are required to ultimately assess this clinical question (7). Though the internal mammary vessels are commonly used, other options are available for anastomosis including appropriately sized internal mammary perforators, branches of the thoracodorsal, thoracoacromial, and lateral thoracic vessels. Other vascular considerations should be taken account for when planning including pedicle length and caliber. Flaps from the thighs may have either a smaller vessel diameter [profunda artery perforator (PAP) flaps] creating a mismatch with recipient internal mammary vessels or have a shorter pedicle length (gracilis flaps) which may limit flap positioning in the breast pocket (7).

Described options for stacked/conjoined flaps

There are various combinations of abdominal-based stacked/conjoined flaps that have been described in the literature (*Table 1*) (7). Importantly, the majority of data supporting the use of these flaps are small retrospective series or case reports from single institutions with limited comparative data. Nevertheless, early evidence supporting the safety and feasibility of stacked/conjoined flaps when indicated is promising (7). While the abdomen can be the sole donor site in stacked/conjoined flap unilateral breast reconstruction, bilateral breast reconstruction often necessitates the use of other donor sites. While the more commonly reported flap options for autologous breast reconstruction will be subsequently discussed, it should be noted that donor sites for stacked/conjoined flaps can be selected based on available donor sites and associated volume in conjunction with the patient's tolerance for donor site morbidity.

Unilateral breast reconstruction

One safe option for obtaining multiple free flaps for unilateral autologous breast reconstruction is the use of two hemiabdominal flaps as typically raised in superficial inferior epigastric artery (SIEA), DIEP or transversus rectus abdominis muscle (TRAM) reconstructions (*Figure 2*) (19-21). A single center series of 40 patients (80 flaps) reported by Beahm and Walton had no flap losses with isolated fat necrosis present in three of the 80 total flaps (19). These flaps can be maintained as one contiguous unit of tissue ("conjoined"), or the tissue separated into two distinct flaps ("stacked") before both being transferred for a unilateral reconstruction. A single center series of 63 patients undergoing unilateral bipedicled, conjoined DIEP flap reconstruction from Seth *et al.* also reported no flap losses with three operative interventions for flap salvage (22). Though both are viable options, "conjoined" flaps can have less flexibility for final contouring and shaping in the breast pocket with the added concern of pedicle kinking in certain inset positions. Thus, regardless of whether the two hemiabdominal flaps are maintained as "conjoined" or "stacked", some authors describe a preference for maintaining two separate pedicles for anastomosis in the chest (23).

An alternative option would be to maintain the two hemiabdominal flaps as one contiguous unit of tissue based on a single vascular pedicle—sometimes described as "daisy-chaining" (23). With this approach, there is a perceived higher risk of flap loss and/or fat necrosis given decreased vascular diversification (13,17,18,23). If this option is selected, perfusion across the midline must be evaluated intraoperatively using clinical signs and/or angiography, especially in patients with prior abdominal surgeries or history of radiation. Obtaining preoperative computed tomography angiography (CTA) has also proven critical to facilitate intraoperative perforator dissection and provide guidance when performing the anastomoses (24,25). Whether the two hemiabdominal flaps are divided or maintained as contiguous is largely a matter of surgeon preference (13,17,22). The decision may be influenced by the availability of recipient vessels and the need for optimum breast shaping by manipulation of the flaps during inset.

For patients who may not need the volume of two hemiabdominal flaps but need more volume than just one hemiabdominal flap can provide, many other options have been described that both include and do not include an abdominal flap as part of the configuration. Roggio *et al.*

Table 1 Brief overview of published stacked/combined free flap options for breast reconstruction

Authors	Year	Number	Reconstruction laterality	Flap combo 1	Flap combo 2	Flap combo 3	Flap combo 4	Flaps lost
Eltahir *et al.*	2022	7 patients	Bilateral	DIEP/PAP				1
Murota *et al.*	2022	1 patient	Bilateral	DIEP/LAP				0
Nakamura *et al.*	2022	1 patient	Unilateral	SIEA/SIEA				0
Haddock *et al.*	2022	79 patients	Bilateral	DIEP/PAP				–
Roggio *et al.*	2022	7 patients	Unilateral	DIEP/TUG				0
Yoo *et al.*	2022	2 patients	Bilateral	DIEP/PAP				0
Martinez *et al.*	2021	28 patients	Bilateral	DIEP/PAP				0
Haddock *et al.*	2021	2 patients	Bilateral	DIEP/LAP				0
Jo *et al.*	2022	11 patients	Unilateral	PAP/PAP				0
Haddock *et al.*	2021	50 patients	Bilateral	DIEP/PAP	msTRAM/PAP			5
Tielemans *et al.*	2021	1 patient	Unilateral	PAP/PAP				1
Yu *et al.*	2020	1 patient	Unilateral	DIEP/SIEA				0
Teotia *et al.*	2020	153 patients	Unilateral, bilateral	DIEP/DIEP	PAP/PAP	DIEP/PAP		5
Haddock *et al.*	2019	388 patients	Unilateral, bilateral	PAP/PAP	DIEP/PAP	DIEP/SIEA		3
Tessler *et al.*	2019	8 patients	Unilateral	LAP/LAP				0
Haddock *et al.*	2019	20 patients	Unilateral	PAP/PAP				0
Beugels *et al.*	2018	49 patients	Unilateral, bilateral	DIEP/SCIP	DIEP/SIEA	DIEP/LAP		2
Haddock *et al.*	2017	42 breasts	Unilateral, bilateral	DIEP/PAP	PAP/GAP	PAP/PAP		2
Parra	2017	1 patient	Unilateral	PAP/PAP				0
Haddock *et al.*	2017	21 breasts	Unilateral, bilateral	DIEP/PAP	PAP/GAP	PAP/PAP		2
Angrigiani *et al.*	2016	14 patients	Unilateral	TAP/TAP				0
Rozen *et al.*	2016	1 patient	Bilateral	DIEP/TUG				0
Patel *et al.*	2016	25 patients	Unilateral	DIEP/DIEP				1
Stalder *et al.*	2016	53 patients	Unilateral, bilateral	DIEP/DIEP	PAP/PAP	DIEP/GAP	DIEP/PAP	5
Malata *et al.*	2015	25 patients	Unilateral	DIEP/DIEP				0
Mayo *et al.*	2015	20 patients	Bilateral	DIEP/PAP				0
Park *et al.*	2015	5 patients	Unilateral	TUG/TUG				1
Koolen *et al.*	2015	28 patients	Unilateral, bilateral	DIEP/DIEP	DIEP/SIEA	DIEP/DCIA	DIEP/SCIA	0
Murray *et al.*	2015	15 patients	Unilateral	DIEP/SIEA				0
Blechman *et al.*	2013	1 patient	Unilateral	PAP/PAP				0
DellaCroce *et al.*	2011	55 patients	Unilateral	DIEP/DIEP				0
Chan *et al.*	2010	1 patient	Unilateral	DIEP/DIEP				0
Figus *et al.*	2007	1 patient	Unilateral	DIEP/SIEA				0
Ali *et al.*	2002	1 patient	Unilateral	DIEP/DIEP				0
Spear *et al.*	1994	10 patients	Unilateral	TRAM/TRAM				0

DIEP, deep inferior epigastric perforator; PAP, profunda artery perforator; LAP, lumbar artery perforator; SIEA, superficial inferior epigastric artery; TUG, transverse upper gracilis; msTRAM, muscle sparing transversus rectus abdominis muscle; SCIP, superficial circumflex iliac artery perforator; GAP, gluteal artery perforator; TAP, thoracodorsal artery perforator; DCIA, deep circumflex iliac artery; SCIA, superficial circumflex iliac artery; TRAM, transversus rectus abdominis muscle.

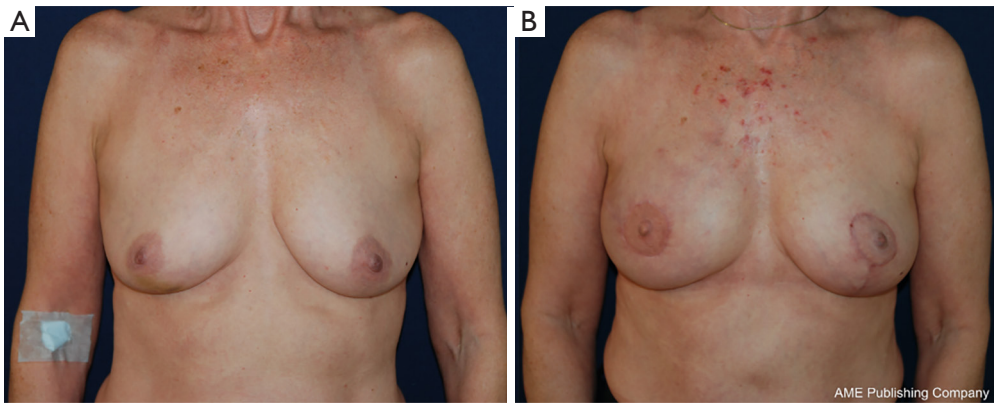

Figure 2 Pre-and post-operative photos of a patient undergoing stacked DIEP flap breast reconstruction. (A) A 59-year-old female patient with ductal carcinoma in situ of the right breast underwent unilateral skin sparing mastectomy (resected tissue weight: 325 g) with sentinel lymph node biopsy (0/5). The patient was reconstructed with stacked DIEP flaps (combined trimmed weight: 345 g) anastomosed to the IMA in an anterograde-retrograde fashion. 3-0 venous couplers were used for both DIEP flaps. (B) The patient later underwent a left mastopexy to improve breast symmetry as well as have further small breast revision surgeries, including nipple reconstruction. DIEP, deep inferior epigastric perforator; IMA, internal mammary artery.

described successfully stacking DIEP and transverse upper gracilis (TUG) flaps for unilateral breast reconstruction in seven patients (26), and multiple reports describe successfully stacking DIEP and SIEA free flaps for a patient requiring unilateral autologous breast reconstruction (27-29). Blechman *et al.* first reported the successful use of stacked PAP flaps for unilateral breast reconstruction in a patient with Poland syndrome (30), and Jo, Jeon and Han later confirmed in a series of 11 patients that PAP flaps are a viable unilateral reconstructive option in patients with normal-to-low BMIs and limited abdominal tissue (31). In single-institution series of 14 patients, Angrigiani *et al.* first reported the use stacked thoracodorsal artery perforator flaps with acceptable functional deficit of the donor site and aesthetically acceptable final scarring in all patients (32). Tessler *et al.* first demonstrated the use of stacked lateral thigh perforator flaps in eight patients (16 flaps) with 100 percent flap survival (33). Recently, a case report from Nakamura *et al.* has even reported using a bipedicled stacked SIEA flap with deep inferior epigastric artery and vein grafts to extend one of the pedicles, giving further flexibility in using bilateral SIEA flaps for unilateral breast reconstruction (34).

Bilateral breast reconstruction

Finding adequate volumes of tissue for bilateral autologous reconstruction is more challenging since the volume from the two hemiabdominal flaps must be divided amongst the bilateral chests. Numerous options have been proposed as strategies for supplementing tissue volume in augmenting the volume of these autologous reconstructions. One option that maintains a single donor site uses tissue lateral to the hemiabdominal flap that is kept in continuity but raised on its own vascular pedicle, which include the deep circumflex iliac artery, the SIEA, the superficial circumflex iliac artery, or the superior gluteal artery perforators (SGAPs) (35,36). In a study of 49 patients with 90 stacked hemiabdominal extended perforator (SHAEP) flaps, Beugels *et al.* reported no total flap losses and approximately seven percent of patients experiencing minor complications of fat necrosis, partial flap loss or hematoma (36). In these cases, the additional pedicle can be anastomosed to the primary hemiabdominal flap in series or to the mammary vessels in retrograde fashion as previously discussed.

Donor tissue for bilateral stacked/conjoined free flap breast reconstruction is not limited to the abdomen. While some of the more commonly discussed combinations are listed below, this list is not exhaustive, and any combination of free flaps can theoretically be used to meet the patient's desired breast volume within the confines of the patient's anatomy. More commonly described flap options in the literature include the combination of DIEP and PAP flaps (18,37-39), DIEP and lumbar artery perforator (LAP) flaps (40), DIEP and SGAP flaps (41), DIEP and inferior gluteal artery perforator (IGAP) flaps (42), and DIEP and TUG flaps

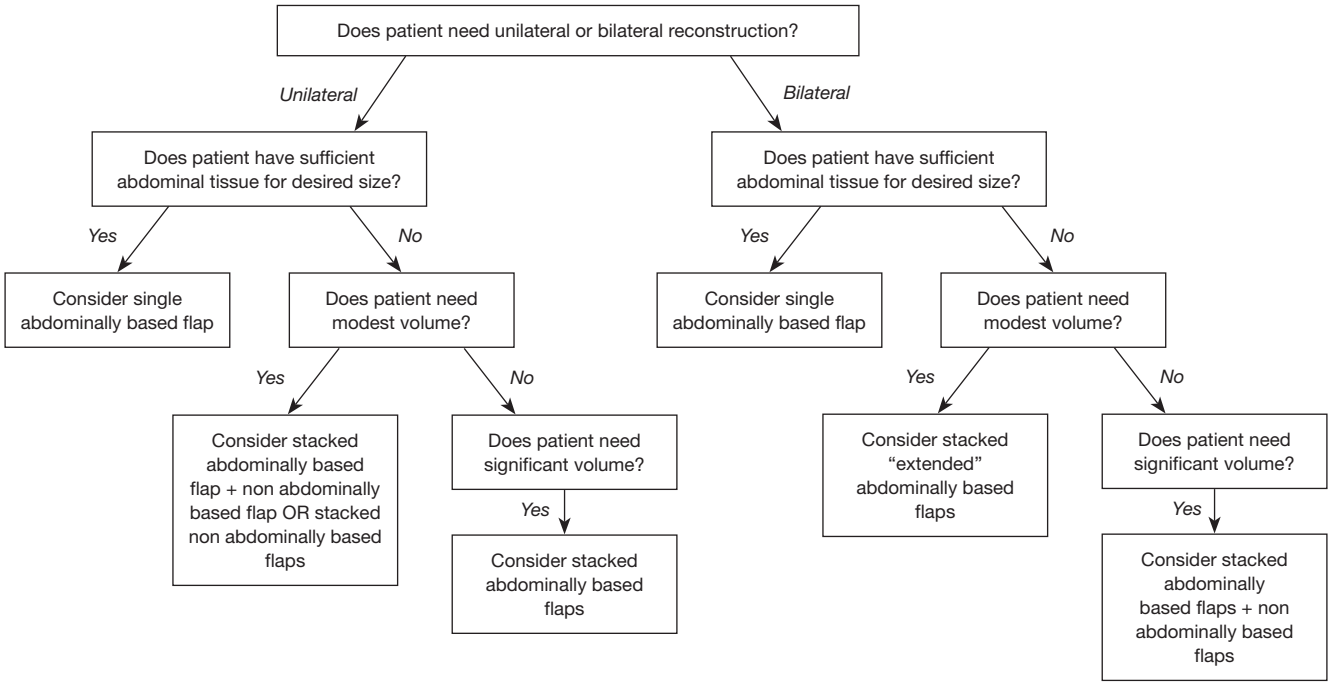

Figure 3 A general algorithm for pre-operative planning in autologous breast reconstruction. Important elements include the necessity of unilateral or bilateral reconstruction and the presence of adequate tissue at a single donor site to meet the patient's desired breast size.

(18,43). When performing four-flap reconstruction, proper consideration should be given to patient positioning and intraoperative efficiency during these lengthy procedures. Given that there may be up to four unique donor sites, patients should be adequately counseled on donor site scar burden, morbidity, and heightened risk for surgical site complications. In order to help facilitate decision making regarding these various flap options, we have constructed a general reconstructive algorithm for addressing these cases (*Figure 3*).

Comparative outcomes

Comparative data between stacked/conjoined and non-stacked/conjoined free flap breast reconstruction are limited and, in some cases, provide conflicting results. The majority of comparative data solely exists for DIEP flap breast reconstruction. A single institution study from Tomouk *et al.* of 130 patients undergoing DIEP flap breast reconstruction reported that no patients in the bipedicled group developed complications requiring repeat surgery or readmission and that donor site morbidity of bipedicled unilateral DIEP breast reconstructions does not increase compared to unipedicled unilateral and unipedicled bilateral DIEP breast reconstructions (44). However, Xu, Dong and Wang reported in 113 DIEP breast reconstruction patients that overall fat necrosis occurred more frequently in patients receiving bipedicled DIEP reconstruction than those with unipedicled DIEP reconstruction. Despite this finding, more patients in the unipedicled group experienced partial flap loss (45). A 2021 meta-analysis of the available data by Salibian *et al.* (7) ultimately reported that stacked/conjoined flaps were associated with a lower risk of fat necrosis compared with reconstructions using a single flap, but otherwise there were no differences in flap, breast, or donor-site related complications. This observation of lower rates of fat necrosis may be secondary to the augmented vascular inflow and outflow in stacked/conjoined flaps relative to the amount of tissue thereby reducing the effective area of Holm Zone III tissue in the flap (46). It is important to note that this finding is limited given the high amount of variability in definitions for establishing fat necrosis reported amongst studies necessitating the need for uniformity in reporting (7). Haddock *et al.* reported in 388 patients with stacked unilateral PAP flaps, DIEP-PAP flaps, or double-pedicle DIEP/SIEA perforator flaps compared to 682 non-stacked/combined DIEP or PAP flaps that the stacked/combined free flap breast reconstruction

group had statistically higher deep venous thrombosis rates and take-back rates compared with the non-stacked/combined free flap breast reconstruction group (8). Another study of Haddock *et al.* reported that BREAST-Q scores in bilateral stacked DIEP-PAP patients demonstrate overall patient satisfaction that is similar to non-stacked bilateral DIEP and non-stacked bilateral PAP reconstruction patients (47). Outside of this report, descriptions of patient-reported outcomes are limited. Salibian *et al.* identified a lower rate of contralateral symmetrizing reductions in patients undergoing unilateral abdominally based breast reconstruction, which could be an important consideration for patient that like their preoperative breast size and would prefer to maintain its size and shape (4).

Conclusions

Autologous breast reconstruction has experienced many innovations since the "free abdominoplasty" flap was first described by Holmstrom in the 1970s. Performing autologous breast reconstruction with stacked/conjoined free flaps represents another advancement in this field and can be employed as a useful option for patients requiring more tissue volume than can be obtained from a single free flap alone. Though more data, especially comparative studies, are needed for definitive analysis, the use of stacked/conjoined free flaps to increase transferred tissue volume appears to represent a safe and effective tool in the microsurgeon's armamentarium for treating patients who are otherwise good candidates for autologous breast reconstruction.

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