

Using the Retrograde Internal Mammary System for Stacked Perforator Flap Breast Reconstruction: 71 Breast Reconstructions in 53 Consecutive Patients

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Background: Abdominal tissue is the preferred donor source for autologous breast reconstruction, but in select patients with inadequate tissue, additional volume must be recruited to achieve optimal outcomes. Stacked flaps are an effective approach in these cases, but can be limited by the need for adequate recipient vessels. This article reports outcomes for the use of the retrograde internal mammary system for stacked flap breast reconstruction in a large number of consecutive patients.

Methods: Fifty-three patients underwent stacked autologous tissue breast reconstruction with a total of 142 free flaps. Thirty patients underwent unilateral stacked deep inferior epigastric perforator (DIEP) flap reconstruction, five had unilateral stacked profunda artery perforator flap reconstruction, one had bilateral stacked DIEP/superior gluteal artery perforator flap reconstruction, and 17 underwent bilateral stacked DIEP/profunda artery perforator flap reconstruction. In all cases, the antegrade and retrograde internal mammary vessels were used for anastomoses. In situ manometry studies were also conducted comparing the retrograde internal mammary arteries in 10 patients to the corresponding systemic pressures.

Results: There were three total flap losses (97.9 percent flap survival rate), two partial flap losses, four reexplorations for venous congestion, and three patients with operable fat necrosis. The mean weight of the stacked flaps for each reconstructed breast was 622.8 g. The retrograde internal mammary mean arterial pressures were on average 76.6 percent of the systemic mean arterial pressures.

Conclusions: The results demonstrate that the retrograde internal mammary system is capable of independently supporting free tissue transfer. These vessels provide for convenient dissection and improved efficiency of these cases, with successful postsurgical outcomes. (*Plast. Reconstr. Surg.* 137: 265e, 2016.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

The deep inferior epigastric perforator (DIEP) flap, because of its ample tissue, reliable vascular anatomy, minimal donor-site

morbidity, and reasonable aesthetic outcomes, has been well established as an excellent tissue source for autologous breast reconstruction. In most patients, the abdominal donor site provides ample volume for an adequate result. However, in select patients with inadequate abdominal tissue, additional volume must be recruited to achieve optimal outcomes. Stacked DIEP flaps, stacked profunda artery perforator flaps, and stacked DIEP/profunda artery perforator flaps are effective reconstructive options in such cases.¹⁻⁸

Stacked flap procedures are technically demanding, however, and are complicated by the need for multiple recipient vessels. Well-described

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options include the antegrade internal mammary system, the thoracodorsal system, internal mammary perforators, the serratus vessels, the subscapular system, and branches off of the primary flap pedicle.^{2,5,6,9–11} However, aside from the antegrade internal mammary system, the established standard for single-flap anastomoses, these options each present unique disadvantages (e.g., inconvenient anatomy, potentially compromised vessels, or suboptimal inflow or outflow) when used in stacked flap reconstruction.

A number of reports describe the successful use of the retrograde internal mammary system as recipient vessels for stacked flaps.^{3,4,7–9,12} However, consistent use of these vessels has been limited, and there is often concern expressed over both the perfusion pressure of the retrograde arterial system, and the ability of the venous system to drain effectively in a retrograde manner.^{8,12} However, use of the retrograde internal mammary system provides numerous advantages for stacked flap procedures. Only a single site of dissection is required to obtain both sets of recipient vessels, saving time and decreasing morbidity. The retrograde internal mammary system is anatomically consistent, and there is excellent size match with the flap vessels for anastomosis.^{8,12} In addition, the proximity of both recipient vessels to each other and to the midline facilitates optimum inset.

The use of the retrograde internal mammary vessels in stacked flap breast reconstruction has the potential to increase operative efficiency, decrease morbidity, and ultimately improve the reconstructive outcomes in a select patient population. We present here our experience using the retrograde internal mammary system as recipient vessels in stacked perforator flap breast reconstruction.

PATIENTS AND METHODS

Clinical Series

Between December of 2010 and December of 2014, 53 consecutive patients underwent autologous tissue breast reconstruction using stacked perforator flaps with combined antegrade internal mammary/retrograde internal mammary arterial and venous microvascular anastomoses. Patients were selected for these procedures by the senior authors (A.S., R.A.) based on a combination of clinical factors including, but not limited to, preoperative breast size relative to volume of tissue available at the preferred abdominal donor site, and patients' reconstructive goals. Many of these patients have a thin build with larger breasts,

or may have had previous implants. A total of 142 free flaps were used in several possible combinations. Retrospective data were collected and analyzed regarding flap weight, mastectomy weight, expander or implant volume, and any complications encountered. Patient follow-up ranged from 4 to 27 months after the primary reconstructive procedure. All procedures were performed by the senior authors (A.S., R.A.), and all content and procedures described within conform to the principles outlined in the Declaration of Helsinki.

Flap Harvest

Preoperative contrast-enhanced computed tomographic scans were obtained for all patients to identify target perforators before dissection. All patients remained in the supine position throughout the entire procedure for each flap described (with the exception of the single patient who underwent reconstruction using superior gluteal artery perforator flaps). For profunda artery perforator harvest, all of the patients included in this study were placed in the frog-leg position, with each flap harvested sequentially by a single surgeon. This positioning permitted a second reconstructive surgeon to harvest the DIEP flaps while the oncologic surgeon performed the ablative portion of the procedure.

Recipient Vessel Preparation

The third intercostal space was accessed through the mastectomy site, and the fibers of the pectoralis major muscle were divided to access the chest wall. The perichondrium of the third and fourth ribs was incised along with the intercostal fascia and muscle, and raised lateral to medial, while the internal mammary vessels were carefully inspected. Once the vessels were identified, they were isolated through the full length of the exposed interspace. If additional vessel length was required, portions of either the third or fourth rib were removed with a rongeur to extend the dissection. At the time of flap transfer, the internal mammary vessels were clamped and divided, providing both an antegrade and a retrograde system available for anastomosis.

In Situ Internal Mammary System Pressure Recordings

Fifteen retrograde internal mammary arteries and veins were studied in 10 consecutive patients undergoing either unilateral or bilateral perforator flap breast reconstruction. After the internal mammary vessels were isolated in each patient,

Table 1. Patients with Unilateral Breast Reconstructions

Diagnosis	Age (yr)	Sex	BMI (kg/m ²)	Procedure	Timing	Length of Procedure (hr:min)	Inpatient Stay (days)	Mastectomy		Difference (g)	Difference (%)	Complications
								Weight (g)	Volume (cc)			
History of DCIS and failed implant reconstruction	34	F	24.7	Stacked DIEP	Immediate	5:14	4	300 cc	575	+275	+91.7	None
Invasive ductal carcinoma	50	F	20.5	Stacked DIEP	Immediate	4:38	5	550 g	606	+56	+10.2	None
Invasive ductal carcinoma	42	F	25.1	Stacked DIEP	Immediate	6:14	3	857 g	740	-117	-13.7	None
Invasive ductal carcinoma	58	F	30	Stacked DIEP	Delayed	4:13	4	550 g	606	+56	+10.2	None
Phyllodes tumor	46	F	30.6	Stacked DIEP	Immediate	3:13	5	718 g	922	+204	+28.4	None
Invasive ductal carcinoma	60	F	28.3	Stacked DIEP	Immediate	4:52	4	534 g	754	+220	+41.2	None
Invasive ductal carcinoma	50	F	31.2	Stacked DIEP	Immediate	3:57	5	—	690	—	—	None
Invasive metaplastic carcinoma	52	F	23.4	Stacked DIEP	Delayed	3:42	5	390 g	366	-24	-6.2	None
History of squamous cell carcinoma and failed implant reconstruction	69	F	22.5	Stacked PAP	Delayed	5:54	5	450 cc	510	+60	+13.3	Donor-site dehiscence
Invasive ductal carcinoma	71	F	26	Stacked DIEP	Immediate	3:30	5	446 g	634	+188	+42.2	None
Invasive ductal carcinoma	58	F	30.6	Stacked DIEP	Immediate	3:19	4	476 g	586	+110	+23.1	Loss of both flaps
Invasive ductal carcinoma	49	F	26.2	Stacked DIEP	Delayed	3:45	3	650 cc	720	+70	+10.8	None
Invasive ductal carcinoma	48	F	32.9	Stacked DIEP	Delayed	4:5	4	636 g	1195	+559	+87.9	Breast wound dehiscence, operable fat necrosis
DCIS	62	F	21.8	Stacked DIEP	Immediate	3:38	4	333 g	436	+103	+30.9	None
Invasive ductal carcinoma	57	F	36.3	Stacked DIEP	Immediate	4:3	3	1348 g	1214	-134	-9.9	None
Lobular carcinoma in situ	66	F	26.2	Stacked DIEP	Immediate	3:30	4	667 g	624	-43	-6.4	None
Invasive ductal carcinoma	38	F	25.8	Stacked DIEP	Immediate	6:35	4	501 g	650	+149	+29.7	None
Remote history of breast cancer	58	F	30.6	Stacked DIEP	Delayed	3:50	4	—	1352	—	—	None
Strong family history of breast cancer	39	F	21.6	Stacked PAP	Delayed	4:37	4	132 g	316	+184	+139.4	None
Invasive ductal carcinoma	37	F	26.6	Stacked DIEP	Delayed	4:19	3	650 cc	951	+301	+46.3	None
Poland syndrome and failed implant reconstruction	46	F	32.9	Stacked DIEP	Delayed	3:52	4	—	790	—	—	Partial skin necrosis of flap
Invasive ductal carcinoma	59	F	23.9	Stacked DIEP	Immediate	6:50	4	834 g	611	-223	-26.7	None
History of breast cancer	54	F	24.9	Stacked DIEP	Delayed	3:55	7	—	—	—	—	Reexploration for venous congestion
DCIS	61	F	28.4	Stacked DIEP	Immediate	5:28	6	839 g	943	+104	+12.4	Reexploration for hematoma
Invasive ductal carcinoma	48	F	26.6	Stacked DIEP	Immediate	4:44	5	230 g	366	+136	+59.1	None
History of breast cancer and failed implant reconstruction	51	F	21.6	Stacked DIEP	Delayed	3:26	3	227 g	405	+178	+78.4	None
Invasive ductal carcinoma	79	F	23	Stacked DIEP	Immediate	3:11	4	832 g	720	-112	-13.5	None
History of remote breast cancer and <i>BRCA</i> ⁺	56	F	21.9	Stacked PAP	Immediate	5:0	3	175 g	334	+159	+90.9	None
Inflammatory breast cancer	54	F	27.4	Stacked DIEP	Delayed	3:13	3	—	543	—	—	None
DCIS	58	F	24.7	Stacked DIEP	Immediate	4:40	3	300 g	734	+434	+144.7	None

(Continued)

Table 1. (Continued)

Diagnosis	Age (yr)	Sex	BMI (kg/m ²)	Procedure	Timing	Length of Procedure (hr:min)	Inpatient Stay (days)	Mastectomy				
								Weight (g) or Implant Volume (cc)	Combined Flap Weight (g)	Difference (g)	Difference (%)	Complications
Invasive ductal carcinoma	51	F	27.2	Stacked PAP	Delayed	5:15	5	—	—	—	—	None
Invasive ductal carcinoma	55	F	35.2	Stacked DIEP	Immediate	3:48	4	961 g	1021	+60	+6.2	None
Invasive ductal carcinoma	45	F	32.3	Stacked DIEP	Immediate	4:6	4	1417 g	1211	-206	-14.5	None
Invasive ductal carcinoma	58	F	31.2	Stacked PAP	Delayed	4:53	6	—	651	—	—	Loss of retrograde flap
Infiltrating ductal carcinoma	75	F	20.2	Stacked DIEP	Delayed	3:54	5	—	—	—	—	None

BMI, body mass index; DCIS, ductal carcinoma in situ; F, female; SGAP, superior gluteal artery perforator; PAP, profunda artery perforator.

BMI, body mass index; DCIS, ductal carcinoma in situ; F, female; SGAP, superior gluteal artery perforator; PAP, profunda artery perforator.

an 18-gauge angiocatheter was inserted into the lumen at the distal stump of both the retrograde internal mammary artery and retrograde internal mammary vein. The catheter was connected to a pressure transducer, and systolic and diastolic arterial pressures were recorded at 10-second intervals for 1 minute, and then averaged to obtain the final value. Brachial cuff sphygmomanometry pressures were recorded simultaneously for comparison.

Statistical Analysis

Statistical analysis was performed on the data using a two-tailed *t* test to evaluate the difference between mean retrograde internal mammary and brachial recordings. Statistical significance was set at a value of $p < 0.05$.

RESULTS

Clinical Series

Fifty-three patients underwent stacked flap breast reconstruction with a total of 142 flaps. All planned internal mammary vessel anastomoses were successfully completed at the time of the primary procedure. Unilateral stacked DIEP flap reconstruction was performed on 30 patients (Table 1 and Fig. 1). In these procedures, the DIEP flaps were left intact at the midline, folded at inset, and anastomosed as bipediced constructs to the antegrade internal mammary and retrograde internal mammary vessels (Fig. 2). Among these patients, there were 20 immediate reconstructions and 10 delayed reconstructions. In five cases, there were no documented mastectomy data available. Flap weights were also unavailable in one of these patients. Patients in whom all relevant data were not available were excluded from the calculations described in Table 2. To simplify analysis, mastectomy weights and implant volumes were combined and averaged to obtain an estimate of the breast tissue that required reconstruction.

For the 23 patients that were included in the calculations for this group, the mean mastectomy weight or implant volume was 635.3 g or cc (Table 2). Combined flap weights ranged from 366 to 1352 g, with a mean combined flap weight of 732.9 g, for a difference of 97.9 g (+27.6 percent). Procedural time ranged from 3 hours 11 minutes to 6 hours 50 minutes, with a mean of 4 hours 15 minutes, and mean inpatient stay was 4.2 days, with a range of 3 to 7 days. Postoperative complications included one failed bipediced flap construct (both flaps), one incident of delayed



Fig. 1. A 46-year-old woman diagnosed with left phyllodes tumor, shown preoperatively (*above*). The patient underwent left nipple-sparing mastectomy with immediate bipedicle stacked DIEP flap reconstruction using both the antegrade and retrograde internal mammary vessels. The patient is shown 1 month after the first stage of reconstruction (*center*). The mastectomy weight was 718 g, and the stacked flap weight was 922 g. Procedural time was 3 hours 13 minutes, and the patient suffered no complications. Three months after the initial operation, the patient underwent the second stage of reconstruction, including excision of the flap skin paddle and donor-site scar revision, and is pictured 1 month after that procedure (*below*).

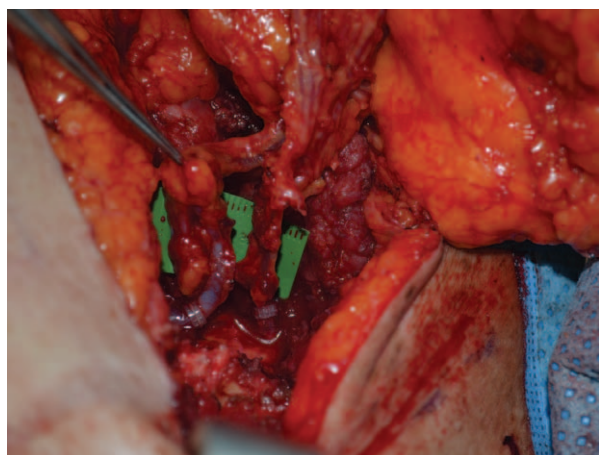


Fig. 2. Antegrade and retrograde internal mammary recipient vessel anastomoses in situ during breast reconstruction using a bipediced deep inferior epigastric perforator construct. Veins were anastomosed using coupler devices as pictured, and arteries were anastomosed using 9-0 nylon suture in a running fashion.

recipient-site wound healing, one incident of operable fat necrosis, one partial flap loss, and one patient who experienced delayed wound healing at the abdominal donor site (Table 3).

Unilateral stacked profunda artery perforator flap reconstruction was performed on five patients (Table 1). Each flap was inset as a separate construct, with one flap positioned at the superior pole of the breast and anastomosed to the retrograde internal mammary system, and one flap positioned at the inferior pole and anastomosed to the antegrade internal mammary system. There were four delayed reconstructions and one immediate reconstruction. Mastectomy weights were unavailable for two of the patients, and combined flap weight was unavailable for one patient. For

the three patients included in the analysis, the mean mastectomy weight or implant volume in this group was 252.3 g or cc (Table 2). The combined flap weights ranged from 316 to 651 g, with a mean of 420.0 g, for a difference of 167.7 g (+88.6 percent). Procedural time ranged from 4 hours 37 minutes to 5 hours 54 minutes, with a mean of 5 hours 8 minutes; and the mean length of inpatient stay was 4.6 days, with a range of 3 to 6 days. There was a total of one flap loss (retrograde anastomosis), one recipient-site hematoma, and one incident of delayed healing at the donor site (Table 3).

Immediate reconstruction was performed on one patient using bilateral, stacked, combined DIEP, and superior gluteal artery perforator flaps (Table 4). The DIEP flap was inset superiorly and anastomosed to the retrograde internal mammary system, and the superior gluteal artery perforator flap was inset inferiorly and anastomosed to the antegrade internal mammary system. The mean mastectomy weight was 376.5 g, and the mean combined flap weight for each breast was 580.0 g, with a mean difference in weight for each breast of 203.5 g (+54.7 percent) (Table 2). Procedural time was 10 hours 57 minutes, and length of inpatient stay was 4 days. All flaps survived, although the patient did experience some mastectomy flap necrosis bilaterally (Table 3).

Bilateral stacked, combined DIEP, and profunda artery perforator flap reconstruction was performed in 17 patients (34 breasts) (Table 4 and Fig. 3). In these patients, the DIEP flaps were inset in the superior position and anastomosed to the retrograde internal mammary system, and the profunda artery perforator flaps were coned, inset

Table 2. Mean Values for All Patients

Reconstruction	No. of Patients	No. of Flaps	BMI	Procedural Time (hr:min)	Inpatient Stay (days)	Mastectomy Weight (g) or Implant Volume (cc)	Combined Flap Weight (g)	Difference (%)
Bilateral								
Stacked DIEP/PAP	17	68	23.0 ± 2.4	8:14 ± 1:53	4.9	442.4 ± 208.3*	559.9 ± 206.9*	117.5 ± 119.2* (44.6 ± 61.8*)
Stacked DIEP/SGAP	1	4	21.7	10:57	4.0	376.5 ± 54.4	580.0 ± 53.7	203.5 ± 0.7 (54.7 ± 8.1)
Unilateral								
Stacked DIEP	30	60	27.3 ± 4.3	4:15 ± 58	4.2	635.3 ± 310.2*	732.9 ± 252.9*	97.9 ± 189.2* (27.6 ± 41.3*)
Stacked PAP	5	10	24.8 ± 4.3	5:8 ± 29	4.6	252.3 ± 172.5*	420.0 ± 164.8*	167.7 ± 14.2* (88.6 ± 51.9*)
Total	53	142	25.6 ± 4.2	8:23 ± 1:56 (bilateral) 4:23 ± 58 (unilateral)	4.5	507.8 ± 270.9*	622.8 ± 238.5*	114.9 ± 147.3* (40.3 ± 53.8*)

BMI, body mass index; PAP, profunda artery perforator; SGAP, superior gluteal artery perforator.

*Only patients with complete data were included in calculations.

Table 3. Complications

Reconstruction	Donor-Site Wound Healing	Recipient-Site Wound Healing	Recipient-Site Hematoma	Operable Fat Necrosis	Reexploration for Vascular Compromise	Partial Flap Loss	Total Flap Loss
Bilateral							
Stacked DIEP/PAP	0	0	1	2	3	1	0
Stacked DIEP/SGAP	0	2	0	0	0	0	0
Unilateral Reconstruction							
Stacked DIEP	1	1	0	1	1	1	2
Stacked PAP	1	0	1	0	0	0	1
Total	2 (3.8%)*	3 (4.2%)†	2 (2.8%)‡	3 (4.2%)‡	4 (5.6%)‡	2 (1.4%)‡	3 (2.1%)‡

PAP, profunda artery perforator; SGAP, superior gluteal artery perforator.

*Percentage of total patients.

†Percentage of total reconstructed breasts.

‡Percentage of total flaps.

in the inferior pole position, and anastomosed to the antegrade internal mammary system. There were 19 immediate reconstructions and 15 delayed reconstructions. Mastectomy weights and flap weights were not available for three of the reconstructions. For the 31 reconstructions in which full data were available, the mean mastectomy weight or implant volume was 442.4 g or cc (Table 2). The mean combined flap weight for each reconstructed breast ranged from 337 to 1184 g, with a mean of 559.9 g, for an average difference of 117.5 g (44.6 percent). The procedural time for this group ranged from 5 hours 31 minutes to 11 hours 5 minutes, with a mean of 8 hours 14 minutes; and the mean length of inpatient stay was 4.9 days, with a range of 4 to 7 days. There were no total flap losses, one partial flap loss, three reexplorations because of venous congestion, two instances of operable fat necrosis (one antegrade profunda artery perforator flap and one retrograde DIEP flap), and one recipient-site hematoma that required drainage (Table 3).

In total, 139 of 142 flaps survived, for an overall success rate of 97.9 percent (Table 3). For the stacked DIEP flap construct lost in its entirety, both the antegrade and retrograde veins were thrombosed at reexploration. That patient's case had been complicated by hematoma, which likely played a role in the ultimate failure of the flaps. For the failed retrograde profunda artery perforator flap, there was also venous thrombosis found at reexploration, although no discernible contributing factors were identified. The mean mastectomy weight or implant volume for all patients included in calculations was 507.8 g or cc, and the mean combined weight of the stacked flaps was 622.8 g per breast, for a mean difference of 114.9 g (40.3 percent) (Table 2). Overall, 14 of 53 (26.4 percent) patients experienced complications of any kind, 13 of 71 (18.3 percent) reconstructed breasts had complications of any kind,

and there were 10 flap-specific complications (7.0 percent) (Table 3).

In Situ Retrograde Internal Mammary System Pressure Recordings

A total of 15 retrograde internal mammary arteries and veins were studied in 10 patients intraoperatively using a catheter-based pressure transducer as described. The mean systolic blood pressure recorded in the retrograde internal mammary arteries in these patients was 79.3 mmHg ($p < 0.001$), or 64.1 percent of the systemic measures (Table 5). The average diastolic blood pressure recorded in the retrograde internal mammary arteries was 64.2 mmHg ($p < 0.001$), or 87.3 percent of the systemic measures. The mean arterial pressure recorded in the retrograde internal mammary arteries in these patients was 69.2 mmHg ($p < 0.001$), or 76.6 percent of the systemic mean arterial pressure. The average retrograde internal mammary vein pressure recorded in these patients was 13.5 mmHg, and is comparable to the reported normal values of central venous pressure.

DISCUSSION

A number of reports in the literature discuss the use of stacked free flaps for breast reconstruction in patients that require additional volume to achieve an optimum result. Stacked DIEP flaps, stacked profunda artery perforator flaps, stacked superficial inferior epigastric artery/DIEP flaps, and several other combinations have been used for this purpose.^{1-7,9,10} These procedures have generally produced successful reconstructive results, and fill a need in select patients who are large breasted, or who simply have inadequate tissue available at any single donor site. However, they remain technically demanding and time-consuming operations, and many surgeons are hesitant to

Table 4. Patients with Bilateral Breast Reconstructions

Diagnosis	Age (yr)	Sex	BMI (kg/m ²)	Procedure	Timing	Length of Procedure (hr:min)	Inpatient Stay (days)	Mastectomy				Complications
								Weight (g) or Implant Volume (cc)	Combined Flap Weight (g)	Difference (g)	% Difference (%)	
Right DCIS	43	F	21.7	Bilateral stacked DIEP/SGAP	Immediate	10:57	4	R, 338 g; L, 415 g	R, 542; L, 618	R, +204; L, +203	R, +60.4; L, +48.9	Mastectomy flap necrosis bilaterally
Right invasive ductal carcinoma	49	F	24.2	Bilateral stacked DIEP/PAP	L, immediate; R, delayed	6:55	5	R, 550 g; L, 570 g	R, 622; L, 628	R, +72; L, +58	R, +13.1; L, +10.2	Reexploration for hematoma
Right invasive ductal carcinoma	54	F	20.6	Bilateral stacked DIEP/PAP	L, immediate; R, delayed	8:33	5	R, 166 g; L, 112 g	R, 410; L, 438	R, +244; L, +326	R, +146.9; L, +291.1	Partial loss right PAP
Right sarcoma and history of left breast cancer	62	F	20.4	Bilateral stacked DIEP/PAP	Delayed	5:31	4	R, 400 cc;—	R, 384; L, 337	R, -16;—	R, -4;—	None
Invasive lobular carcinoma	56	F	20.5	Bilateral stacked DIEP/PAP	Delayed	9:50	5	R, 421 cc; L, 397 cc	R, 404; L, 444	R, -17; L, +47	R, -4; L, +11.8	None
Invasive ductal carcinoma	51	F	22.6	Bilateral stacked DIEP/PAP	Delayed	6:30	5	R, 600 cc; L, 600 cc	R, 667; L, 706	R, +67; L, +106	R, +11.2; L, +17.7	None
Invasive lobular carcinoma	54	F	23	Bilateral stacked DIEP/PAP	Delayed	7:18	4	R, 610 cc; L, 610 cc	R, 609; L, 635	R, -1; L, +25	R, -0.2; L, +3.9	None
Invasive ductal carcinoma	52	F	24.8	Bilateral stacked DIEP/PAP	Immediate	11:5	7	R, 866 g; L, 622 g	R, 735; L, 776	R, -131; L, +154	R, -15.1; L, +24.7	Reexploration for venous congestion
Invasive ductal carcinoma	40	F	22.3	Bilateral stacked DIEP/PAP	Immediate	8:36	7	R, 170 g; L, 220 g	R, 410; L, 420	R, +240; L, +200	R, +141.2; L, +90.1	None
<i>BRCA1</i>	37	F	21.3	Bilateral stacked DIEP/PAP	Immediate	8:36	4	R, 310 g; L, 295 g	R, 393; L, 383	R, +83; L, +88	R, +26.8; L, +29.8	Postoperative transfusion
Strong family history of breast cancer	49	F	23.8	Bilateral stacked DIEP/PAP	Immediate	8:7	4	R, 242 g; L, 289 g	R, 420; L, 457	R, +178; L, +168	R, +73.6; L, +58.1	None
DCIS	54	F	23.6	Bilateral stacked DIEP/PAP	Delayed	8:14	4	—	R, 560; L, 535	—	—	Reexploration for venous congestion
Invasive ductal carcinoma	36	F	26.6	Bilateral stacked DIEP/PAP	L Immediate	10:32	5	R, 790 g; L, 830 g	R, 1136; L, 1184	R, +346; L, +354	R, +43.8; L, +42.7	None
DCIS	45	F	28.7	Bilateral stacked DIEP/PAP	R Delayed	10:48	5	R, 706 g; L, 557 g	R, 747; L, 766	R, +41; L, +209	R, +5.8; L, +37.5	None
Invasive ductal carcinoma	49	F	24.3	Bilateral stacked DIEP/PAP	Delayed	9:26	6	R, 600 cc; L, 633 g/cc*	R, 517; L, 531	R, -83; L, -102	R, -16.1; L, -16.1	None
Left DCIS	42	F	20	Bilateral stacked DIEP/PAP	Immediate	8:3	5	R, 363 g; L, 422 g	R, 407; L, 430	R, +44; L, +8	R, +12.1; L, +1.9	Reexploration for venous congestion
Invasive lobular carcinoma and right DCIS	55	F	24.2	Bilateral stacked DIEP/PAP	Immediate	6:48	4	R, 223 g; L, 289 g	R, 470; L, 458	R, +247; L, +169	R, +110.8; L, +58.5	None
DCIS	50	F	20.4	Bilateral stacked DIEP/PAP	Immediate	8:5	5	R, 252 g; L, 232 g	R, 374; L, 397	R, +122; L, +165	R, +48.4; L, +71.1	None

BMI, body mass index; DCIS, ductal carcinoma in situ; F, female; SGAP, superior gluteal artery perforator; PAP, profunda artery perforator.

*Combined mastectomy weight and implant volume.



Fig. 3. A 52-year-old woman diagnosed with right invasive ductal carcinoma shown preoperatively (*above*). The patient underwent left nipple-sparing and right skin-sparing mastectomies with immediate bilateral reconstruction performed with stacked DIEP and profunda artery perforator flaps using the antegrade and retrograde internal mammary vessels for anastomosis. The DIEP flaps were positioned superiorly and anastomosed to the retrograde vessels, and the profunda artery perforator flaps were coned and inset inferiorly and anastomosed to the antegrade vessels. The right mastectomy weight was 866 g and the left mastectomy weight was 622 g. The combined flap weight was 735 g for the right breast and 776 g for the left breast. The patient is shown 1 month after the first stage of reconstruction (*center*). Three months after the initial operation, the patient underwent the second stage of reconstruction, including partial excision of flap skin paddles, bilateral mastopexies, and right nipple-areola complex reconstruction, and is pictured 1 month after that procedure (*below*).

Table 5. Intraoperative Pressure Recordings

Patient	Systemic Systolic (mmHg)	Retrograde IMA Systolic (mmHg) (% Systemic)	Difference (mmHg)	Systemic Diastolic (mmHg)	Retrograde IMA Diastolic (mmHg) (% Systemic)	Difference (mmHg)	Systemic MAP (mmHg)	Retrograde IMA MAP (mmHg) (% Systemic)	Difference (mmHg)	Retrograde IMV (mmHg)
1	123	82 (66.7)	41	70	68 (97.1)	2	87.7	72.7 (82.9)	15.0	15
2R	130	80 (61.5)	50	80	67 (83.8)	13	96.7	71.3 (73.3)	25.4	14
2L	130	85 (65.4)	45	80	70 (87.5)	10	96.7	75.0 (77.6)	21.7	15
3	114	73 (64.0)	41	73	55 (75.3)	18	86.7	61.0 (70.4)	25.7	12
4R	132	85 (64.4)	47	68	65 (95.6)	3	89.3	71.7 (80.3)	17.6	15
4L	125	80 (64.0)	45	70	60 (85.7)	10	88.3	66.7 (75.5)	21.6	12
5R	132	85 (64.4)	47	78	60 (76.9)	18	96.0	68.3 (71.1)	27.7	15
5L	135	75 (55.6)	50	80	62 (77.5)	18	98.3	66.3 (67.4)	32.0	12
6R	110	77 (70.0)	33	69	68 (98.6)	1	82.7	71.0 (85.9)	11.7	14
6L	120	85 (70.8)	35	80	66 (82.5)	14	93.3	72.3 (77.5)	21.0	18
7	128	73 (57.0)	55	73	58 (79.5)	15	91.3	63.0 (69.0)	28.3	10
8	140	90 (64.3)	50	89	72 (80.9)	17	106.0	78.0 (73.6)	28.0	16
9	120	77 (64.2)	43	76	66 (86.8)	10	90.7	69.7 (76.8)	21.0	13
10L	112	73 (65.2)	39	65	60 (92.3)	5	80.7	64.3 (79.7)	16.4	11
10R	110	70 (63.6)	40	60	66 (110.0)	6	76.7	67.3 (87.7)	9.4	11
Mean	124.1 ± 9.5	79.3 ± 5.9 (64.1 ± 3.9)	44.1 ± 6.0*	74.1 ± 7.4	64.2 ± 4.8 (87.3 ± 9.7)	10.7 ± 6.1*	90.7 ± 7.5	69.2 ± 4.6 (76.6 ± 6.0)	21.5 ± 6.5*	13.5 ± 2.2

L, left; R, right; IMA, internal mammary artery; IMV, internal mammary vein; MAP, mean arterial pressure.

*Statistically significant ($p < 0.001$).

undertake the perceived added risk.^{2,9} Thus, optimization of procedural efficiency would be a step toward making these procedures more accessible for reconstructive surgeons at large.

Particularly influential on the intraoperative course is the choice of recipient vessels. A variety of configurations have been reported for anastomosis of multiple flaps in a single breast, but no consensus exists as to which recipient vessels are the superior secondary source. The antegrade internal mammary system has become the accepted primary source of recipient vessels for single-flap reconstruction and, as such, discussion of it as a secondary option is not relevant. Other commonly described options include the ipsilateral thoracodorsal or serratus systems, the subscapular system, internal mammary perforators, and branching vessels from the primary flap pedicle.^{2,5,6,9,11} These approaches have all been used successfully in both single-flap and stacked flap breast reconstruction, although each vessel source presents its own disadvantages.

The thoracodorsal vessels are anatomically inconvenient—and necessitate the need for two fields of dissection. This can significantly increase surgical time and complicate inset because of the required pedicle length, restricting optimal flap orientation.^{6,9} In addition, the thoracodorsal system is at risk during the preceding ablative procedure, and the availability of viable recipient vessels cannot always be guaranteed. Internal mammary perforating vessels have unpredictable anatomy, can deprive the mastectomy flaps of needed perfusion when harvested, and may also be damaged

during the ablative procedure.¹¹ A number of reports describe stacked flap anastomoses using branching vessels off of the primary flap pedicle. Although this presents a more consistent option, it can be more technically demanding, relies on single-vessel inflow to perfuse both flaps, and more importantly, does not provide additional venous outflow, as both flaps are dependent on a single vein.^{5,6}

There are a number of available reports of stacked flap breast reconstruction where the retrograde internal mammary system was used as a recipient site for the secondary anastomosis.^{2,4,7,9,13} These studies most frequently use a stacked bipedicle DIEP construct, with two reports describing the use of the retrograde internal mammary vessels with some consistency in up to 27 patients.^{7,8,13} There are very few instances described, however, in which a separate flap was perfused and drained using the retrograde vessels alone, and certainly not as the standard operative strategy in these cases.³ Indeed, most available studies restrict their discussion to the use of the retrograde vein only as a means of obtaining additional outflow.^{4,12,14–18}

Commonly voiced concerns regarding the retrograde internal mammary system include the suggestion of diminished retrograde internal mammary venous outflow because of small-caliber veins and the presence of valves. Indeed, there are published reports that have identified the presence of valves in this system, and some clinical data question the postoperative patency and flow rate of this venous system.^{12,16,17,19} However, cadaveric studies have shown the average diameter of

the retrograde vein at the level of the third intercostal space to be between 2 and 3 mm, which is generally adequate for venous drainage for most flaps.^{12,20} In addition, the reported differences in flow between the antegrade internal mammary veins and the retrograde internal mammary vein have not proved to be clinically apparent, and in some animal studies venous flow normalizes to equivalent values by 48 hours postoperatively.^{8,18,21} Likewise, the results observed in our study, and a host of others, indicate that the valves simply may not be clinically relevant, whether as a result of the presence of robust collateral drainage from the intercostal veins, sternal veins, musculophrenic vein, and internal mammary perforating veins, or as a result of physiologic incompetence under the increased venous outflow pressure.^{8,12–14,16,18,22}

There is also little reason to believe that the retrograde internal mammary arterial perfusion pressure is not physiologically adequate to power a flap. The robust collateral anatomy of this system is well described, and includes contributions from multiple intercostal vessels, the musculophrenic artery, and the superior epigastrics distally.¹³ Our in situ pressure readings demonstrate a consistent retrograde internal mammary artery mean arterial pressure that averaged 69.2 mmHg, or 76.6 percent of the systemic mean arterial pressure, findings that are comparable to other studies in which the retrograde internal mammary artery pressure was 74 to 78 percent that of the antegrade internal mammary artery.¹³ Not only is that likely an adequate perfusion pressure in and of itself, but in vivo data have also shown that the postanastomotic flow and/or pressure of flap arterial pedicles adjusts to the physiologic demands of the flap, with flow actually increasing over time.⁸ Interestingly, there are even case reports describing the successful use of the retrograde internal mammary artery for cardiac bypass procedures, demonstrating the ability of these vessels to adequately perfuse contractile muscle tissue that would theoretically have greater metabolic requirements than the standard adipocutaneous flaps used in breast reconstruction.^{23–26}

In addition, an observation made in one study showed that the internal mammary artery demonstrates flow rates double those of the deep inferior epigastric artery before flap transfer, but after reanastomosis the flow decreases to a level similar to that of the pretransfer deep inferior epigastric artery. At the same time, the thoracodorsal artery, often used as the site of secondary anastomosis, demonstrated a flow rate less than half that of the deep inferior epigastric artery before transfer,

whereas the postanastomotic flow increased to levels similar to the pretransfer deep inferior epigastric artery.²⁷ Yet another study demonstrated similar blood flow in the retrograde and antegrade internal mammary arteries at 5 years postoperatively through color duplex scanning.¹³ None of this should be entirely surprising of course, as it is consistent with the known physiologic alteration of blood flow caused by local regulatory mechanisms that control the microcirculatory environment through direct action on vessel dilation and constriction. These observations provide significant support to the theoretical foundation for using the retrograde internal mammary vessels. Our clinical results bear this out—of the 53 patients included in this study, there were 19 bipedicle stacked DIEP constructs (or 60 flaps), of which half were at least partially dependent on the retrograde anastomosis with a 96.7 percent success rate, and 41 flaps that were independent of any collateral flow, and survived solely on arterial perfusion and venous outflow from the retrograde internal mammary system with a 97.5 percent success rate.

Although the physiologic and clinical data clearly argue in favor of the use of the retrograde system in this manner, it is the logistical implications and clinical outcomes that make this technique so useful. A single field of dissection saves considerable time intraoperatively, and the anatomical consistency of this vessel system is well known. These vessels are not exposed to injury during mastectomy, and their location allows for optimum inset of both flaps in a stacked flap reconstruction, with no restrictions caused by pedicle length or orientation. Another concern that has been expressed is the notion that multiple ribs must be removed to obtain adequate length to use both the antegrade and retrograde vessels.¹¹ However, this has not borne out to be prohibitive to success in our experience. When half of each of the third and fourth ribs is removed during dissection of the intervening intercostal space, we have found there to be more than adequate length for our purposes, with no subsequent functional or aesthetic morbidity.

The techniques presented here are, however, not without limitations. These are technically demanding procedures that require multiple experienced microsurgeons to obtain consistent results, and although this study demonstrates a degree of technical success (comparable to reported flap survival rates upward of 97 percent), these are the results of a highly specialized practice.^{5,7,8} In addition, it should be noted that

all patients in this series have undergone secondary procedures to optimize aesthetic results. It would be beneficial in future studies to compare these outcomes to a relevant control group for a more thorough evaluation of the data, or potentially perform volumetric comparisons with other techniques such as fat grafting, which has become increasingly popular for secondary procedures, although it has at times been plagued by inconsistent results. Additional in situ studies that directly compare the antegrade internal mammary and retrograde internal mammary pressures would also be useful in the future; however, direct measure of the antegrade internal mammary was avoided in this study to avoid risking the integrity of the vessels that were intended for primary microvascular anastomosis through unnecessary manipulation.

CONCLUSIONS

This study reports on the standard use of the retrograde internal mammary system for recipient vessel anastomosis with stacked flap breast reconstruction in a large series of consecutive patients. The results presented demonstrate that the retrograde internal mammary system is capable of independently supporting free tissue transfer for this purpose. In addition, we believe that these vessels provide for an anatomically convenient dissection, are physiologically adequate for the task at hand, and permit improved overall efficiency of these cases with successful postsurgical outcomes.

PATIENT CONSENT

The patient provided written consent for the use of her images.

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