A 10-Year Retrospective Review of 758 DIEP Flaps for Breast Reconstruction

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This study examined 758 deep inferior epigastric perforator flaps for breast reconstruction, with respect to risk factors and associated complications. Risk factors that demonstrated significant association with any breast or abdominal complication included smoking ($p = 0.0000$), postreconstruction radiotherapy ($p = 0.0000$), and hypertension ($p = 0.0370$). Ninety-eight flaps (12.9 percent) developed fat necrosis. Associated risk factors were smoking ($p = 0.0226$) and postreconstruction radiotherapy ($p = 0.0000$). Interestingly, as the number of perforators increased, so did the incidence of fat necrosis. There were only 19 cases (2.5 percent) of partial flap loss and four cases (0.5 percent) of total flap loss. Patients with 45 flaps (5.9 percent) were returned to the operating room before the second-stage procedure. Patients with 29 flaps (3.8 percent) were returned to the operating room because of venous congestion. Venous congestion and any complication were observed to be statistically unrelated to the number of venous anastomoses. Overall, postoperative abdominal hernia or bulge occurred after only five reconstructions (0.7 percent). Complication rates in this large series were comparable to those in retrospective reviews of pedicle and free transverse rectus abdominis musculocutaneous flaps. Previous studies of the free transverse rectus abdominis musculocutaneous flap described breast complication rates ranging from 8 to 13 percent and abdominal complication rates ranging from 0 to 82 percent. It was noted that, with experience in microsurgical techniques and perforator selection, the deep inferior epigastric perforator flap offers distinct advantages to patients, in terms of decreased donor-site morbidity and shorter recovery periods. Mastery of this flap provides reconstructive surgeons with more extensive options for the treatment of postmastectomy patients. (*Plast. Reconstr. Surg.* 113: 1153, 2004.)

In the past decade, there has been increasing awareness of alternative management options for the treatment of breast cancer.[1–31] A recent study indicated that only approximately 7.5 percent of postmastectomy patients undergo any form of breast reconstruction.[32] However, that value is increasing because surgical oncologists are collaborating more frequently with reconstructive surgeons to maximize patient satisfaction and minimize psychosocial developments. Current autogenous reconstructive techniques primarily include the transverse rectus abdominis musculocutaneous (TRAM) flap and the deep inferior epigastric perforator (DIEP) flap. To reduce complication rates, the TRAM flap technique has been modified to include the upper TRAM flap, the double-pedicle TRAM flap, the microassisted TRAM flap, whole-muscle versus partial-muscle flaps, a free flap, and selective preliminary vascular delay.[33–36] The purpose of this study was to provide in-depth analysis of an extensive patient population, which would allow strong statistical comparisons with previous retrospective TRAM flap reviews.[1–8]

Predictors of increased flap morbidity were smoking, chemotherapy, prereconstruction radiotherapy, postreconstruction radiotherapy, hypertension, diabetes mellitus, abdominal scarring, obesity, age, flap size, number of venous anastomoses, and number of perforators. The complications studied were fat necrosis, partial flap loss, total flap loss, arterial thrombosis, venous congestion, postoperative hernia, infection, seroma, and hematoma.

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Patients and Methods

Patients

Before the beginning of the study, the Louisiana State University Health Sciences Center-New Orleans institutional review board reviewed and granted approval for this research project (identification no. 5468). The hospital and office records for 609 patients who underwent DIEP flap breast reconstruction at Louisiana State University Health Sciences Center-New Orleans-affiliated hospitals between August of 1992 and August of 2002 were then reviewed by one author. Complications were classified as any complication, breast-specific complication, fat necrosis, partial flap loss, total flap loss, venous congestion, arterial thrombosis, breast infection, breast seroma, breast hematoma, donor-site complication, or postoperative hernia.

Parameters Assessed

Potential risk factors assessed for association with complications included (1) age of more than 60 years; (2) obesity, defined as more than 25 percent over the estimated ideal body weight, based on the criteria described by Watterson et al.[1] (ideal body weight of 100 pounds for 5 feet, with the addition of 5 pounds for each 1 inch over 5 feet); (3) hypertension (any patient treated with medication on the date of reconstruction); (4) diabetes mellitus (any patient diagnosed as having the disease, regardless of type and management); (5) significant abdominal scarring, defined as any scar involved in the flap tissue (midline, paramedian, or Kocher) (low transverse and appendectomy scars were excluded because they were often insignificant in flap elevation); (6) smoking (any patient actively smoking on the date of the operation); (7) chemotherapy, performed either before or after reconstruction; (8) prereconstruction radiotherapy, defined as radiotherapy performed either before mastectomy or after mastectomy but before delayed reconstruction; and (9) postreconstruction radiotherapy, defined as radiotherapy performed after reconstruction. Other independent variables of interest included (1) flap size (flaps of <1000 g versus >1000 g); (2) number of perforators (number of perforators used to perfuse the flap tissue); (3) venous anastomoses (either single or double venous anastomoses were performed, depending on the availability of internal mammary recipient vessels); (4) immediate versus delayed reconstruction (reconstruction performed immediately after mastectomy or delayed after mastectomy); and (5) unilateral versus bilateral reconstruction (reconstruction performed for one breast or both breasts at the same time).

Statistical Analyses

Case-control methods were used for the study design. A case was a flap with one or more complications to be analyzed. A control flap was a flap that did not have the complication. For univariate analyses, crude odds ratios, 95 percent confidence intervals, and p values were calculated for all predictors. Only variables with p values of less than 0.2 were considered for multivariate analyses. Adjusted odds ratios, 95 percent confidence intervals, and p values were calculated by using multiple logistic regression. A p value of less than 0.05 was considered statistically significant.

Results

Overall Results

Of the 758 flap procedures included in this study, 82.1 percent were performed after cancer resection, 5.5 percent after implant failure, and 12.4 percent for prophylaxis. The average patient age at the time of DIEP flap reconstruction was 48.9 years (range, 16 to 74 years). A total of 149 women underwent bilateral breast reconstruction, whereas 460 women underwent unilateral breast reconstruction. Of the 758 breast reconstructions, 454 reconstructions (59.9 percent) were performed immediately and 304 (40.1 percent) were delayed, with no statistically significant difference in complication rates between the reconstruction groups. The data for this analysis are breast-specific, rather than patient-specific. For bilateral reconstructions, each breast was evaluated separately. There was no assumption of independent patient observation for statistical analysis, to allow this breast-specific comparison. The mean follow-up period for patients in this series was 13.2 months (range, 1 week to 88.1 months), and the average hospital stay was 3.86 days (Table I). Many out-of-town patients underwent extended follow-up monitoring with a local board-certified plastic surgeon. A summary of the incidences of complications is presented in Table II.

TABLE I

DIEP Flap Breast Reconstructions (758 Flaps among 609 Women)

Mean age at date of operation (years)	48.9 (range, 15–74)
Mastectomy for cancer	622 (82.1%)
Mastectomy for failed implants	42 (5.5%)
Mastectomy for prophylaxis	93 (12.3%)
Flap technique	
Unilateral	460 (60.7%)
Bilateral	298 (39.3%)
Breast reconstructions	
Immediate	454 (59.9%)
Delayed	304 (40.1%)
Mean follow-up period, months	13.2 (range, 1 wk to 88.1 months)
Venous anastomosis	
Single	585 (77.2%)
Double	173 (22.8%)
No. of perforators	
One	150 (19.8%)
Two	378 (49.9%)
Three	200 (26.4%)
Four	27 (3.6%)
Five	3 (0.4%)
Mean blood loss, ml	304.6
Mean flap weight, g	615.4
Average hospital stay, days	3.86
Mean unilateral operative time, hours	4.6
Mean bilateral operative time, hours	7.3

Any Complications

The overall incidence of any complication, ranging from mild wound dehiscence to total flap loss, for the DIEP breast reconstructions was 30.2 percent. The complications assessed were fat necrosis, partial flap loss, venous congestion, arterial thrombosis, donor-site complication, hematoma, seroma, and infection. Crude analyses demonstrated significantly higher incidences of complication with smoking ($p = 0.0000$), postreconstruction radiotherapy ($p = 0.0000$), and hypertension ($p = 0.0370$) (Table III). Multivariate analyses confirmed statistical significance for postreconstruction radiotherapy ($p = 0.0000$), smoking ($p = 0.0001$), and hypertension ($p = 0.0390$) (Table IV).

TABLE II

Summary of Complication Incidences among 758 Flaps

Complication	Incidence
Overall	229 (30.2%)
Breast	153 (20.2%)
Fat necrosis	98 (12.9%)
Partial flap loss	19 (2.5%)
Total flap loss	4 (0.5%)
Seroma	35 (4.6%)
Hematoma	14 (1.8%)
Infection	21 (2.8%)
Return to operating room	45 (5.9%)
Venous occlusion	29 (3.8%)
Arterial occlusion	4 (0.5%)
Abdominal complication	103 (13.6%)
Postoperative hernia	5 (0.7%)

Breast Complications

The overall breast complication rate was 20.2 percent. Crude analyses demonstrated significantly higher incidences of breast complications with smoking ($p = 0.0043$), postreconstruction radiotherapy ($p = 0.0000$), and hypertension ($p = 0.0409$). An association with diabetes mellitus ($p = 0.0890$) was also observed.

Donor-Site Complications

The overall donor-site complication rate was 13.6 percent. Higher incidences of complications were observed with smoking ($p = 0.0033$) and chemotherapy ($p = 0.0337$). Age, weight, hypertension, radiotherapy, and diabetes mellitus were noted to be statistically irrelevant in this analysis.

Fat Necrosis

Fat necrosis developed for 98 patients (12.9 percent). A control breast was any breast that did not develop fat necrosis, regardless of other complications. Crude analyses revealed higher incidences of fat necrosis with smoking ($p = 0.0226$) and postreconstruction radiotherapy ($p = 0.0000$). Associations of fat necrosis with age ($p = 0.1808$), hypertension ($p = 0.1405$), diabetes mellitus ($p = 0.2784$), single venous anastomosis ($p = 0.3644$), and chemotherapy ($p = 0.3429$) were observed (Table V). Multivariate analyses confirmed statistical sig-

TABLE III

Risk Factors and Their Association with Any Complication

Risk Factor	Odds Ratio	Confidence Interval	*p*
Smoking at date of operation	2.24	1.51–3.31	0.0000
Postreconstruction radiotherapy	5.40	2.93–9.95	0.0000
Hypertension	1.60	1.03–2.48	0.0370
Age of >60 years	1.43	0.89–2.29	0.1410
Chemotherapy	1.24	0.87–1.77	0.2389
Diabetes mellitus	1.47	0.71–3.05	0.3019
Obesity	1.08	0.73–1.61	0.7100
Abdominal scar	0.95	0.65–1.39	0.7738
Prereconstruction radiotherapy	1.04	0.69–1.56	0.8567
Two venous anastomoses	1.01	0.70–1.47	0.9449

TABLE IV
Logistic Regression for Any Complication

Predictor	Odds Ratio	Confidence Interval	*p*
Postreconstruction radiotherapy	5.92	3.08–11.37	0.000
Smoking	1.75	1.26–2.42	0.001
Hypertension	1.65	1.03–2.65	0.039
Age	0.951	0.85–1.07	0.387

nificance for postreconstruction radiotherapy ($p = 0.0000$) but did not demonstrate statistical significance for smoking ($p = 0.1050$) (Table VI).

Partial Flap Loss

The overall incidence of partial flap loss was 2.5 percent. Higher incidences of partial flap loss were associated with chemotherapy ($p = 0.0507$) and postreconstruction radiotherapy ($p = 0.0767$); however, there was no statistical significance. There was also no statistically significant correlation with smoking, diabetes mellitus, abdominal scars, or hypertension in our study.

Venous Occlusion

The overall incidence of venous occlusion was 3.8 percent in this study. Associations of venous occlusion with increased age ($p = 0.2477$) and diabetes mellitus ($p = 0.0806$) were observed. No correlation with the number of perforators used, the number of venous anastomoses, smoking, prereconstruction radiotherapy, postreconstruction radiotherapy, or chemotherapy was noted.

Complications without Significant Risk Factors

The overall incidences of infection and seroma were 2.8 and 4.6 percent, respectively. There was no statistical significance for these. However, higher incidences of seroma were

TABLE V
Risk Factors and Their Association with Fat Necrosis

Risk Factor	Odds Ratio	Confidence Interval	*p*
Postreconstruction radiotherapy	9.10	4.96–16.68	0.0000
Smoking	1.80	1.08–2.97	0.0226
Hypertension	1.54	0.87–2.71	0.1405
Age of >60 years	1.51	0.83–2.75	0.1808
Diabetes mellitus	1.65	0.68–4.04	0.2784
Chemotherapy	0.78	0.46–1.31	0.3429
Two venous anastomoses	1.25	0.77–2.04	0.3644
Prereconstruction radiotherapy	0.83	0.47–1.49	0.5438
Obesity	0.86	0.83–2.75	0.6235
Abdominal scar	1.02	0.61–1.72	0.9261

TABLE VI
Logistic Regression for Fat Necrosis

Predictor	Odds Ratio	Confidence Interval	*p*
Postreconstruction radiotherapy	9.28	4.94–17.4	0.000
Smoking	1.43	0.928–2.20	0.105
Hypertension	1.24	0.64–2.37	0.525
Age	0.957	0.84–1.09	0.509

associated with abdominal scars ($p = 0.2223$) and weight ($p = 0.3393$). The overall hematoma incidence was 1.9 percent, but there were no statistically significant risk factors. There were also no statistically significant risk factors for total flap loss or arterial thrombosis.

Independent Variables

Number of perforators. The overall incidences of any complication and fat necrosis increased as more perforators were recruited (Figs. 1 and 2). Univariate statistical analysis was chosen for comparisons of less than four perforators versus five perforators, the point at which the most significant difference was noted (especially for any complication). For any complication, there was statistical significance for increased complications with five perforators ($p = 0.0193$). Multivariate analysis confirmed this significance for increased complications with five perforators ($p = 0.0320$). In addition, univariate analysis of partial flap loss indicated significance for any complication with the use of five perforators ($p = 0.0471$), but significance was not noted with multivariate analysis. We then performed univariate analysis to determine whether there was a statistically significant increase in the complication rate when more than one perforator was used. We observed this to be

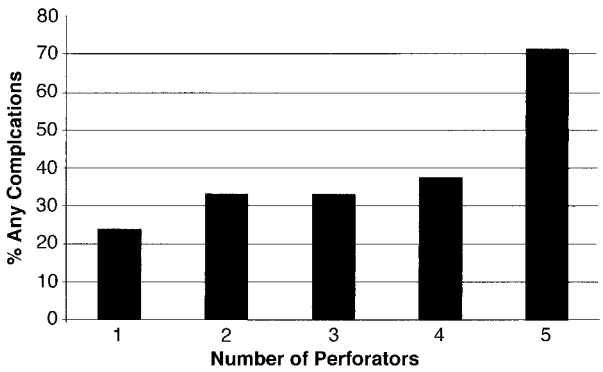

FIG. 1. Incidences of any complications with increasing numbers of perforators. The incidence increased with more perforators and was statistically significant with five perforators ($p = 0.0193$).

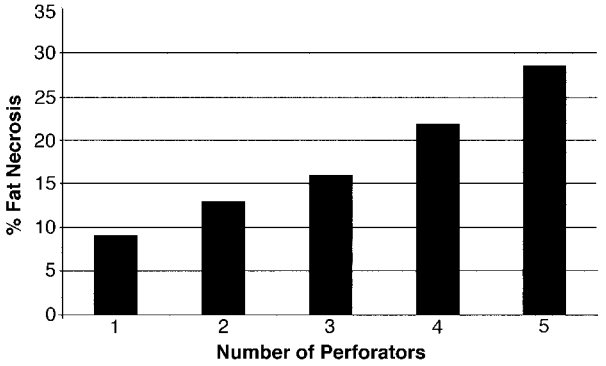

FIG. 2. Incidences of fat necrosis with increasing numbers of perforators. The incidence increased with more perforators but there was no statistical significance overall.

true, with one perforator resulting in significantly fewer complications than two or more perforators ($p = 0.0418$). This finding was confirmed with multivariate analysis ($p = 0.0260$). For fat necrosis, there was no statistical significance for an increasing incidence of complications with five perforators ($p = 0.2346$), but there was a steady trend of increased fat necrosis incidences with more perforators.

Flap weight. Univariate analysis was used to compare any complication, fat necrosis, and partial flap loss for flaps weighing more than 1000 g. There was no statistical significance for any complication ($p = 0.5183$), fat necrosis ($p = 0.5183$), or partial flap loss ($p = 0.1810$).

DISCUSSION

After a decade of experience with the DIEP flap, it has become the preferred choice for breast reconstruction at our institution. Better cosmesis can be achieved with skin and soft tissue, and there is no sacrifice of the abdominal musculature, which has led to a marked decrease in the hernia rate. Our series demonstrated a 0.6 percent hernia rate, involving five patients who underwent repairs with primary closure and Marlex mesh overlays in second-stage procedures. This rate compares well with pedicle TRAM flap studies, which noted hernia rates of 0 to 15 percent.[1] Most of our patients were observed to have suture unraveling where the perforator was dissected through the rectus muscle sheath.

With an average unilateral reconstruction time of 4.66 hours and a bilateral reconstruction time of 7.3 hours, the operative time is not increased, in comparison with the free TRAM flap. Most patients were transferred to the ward, receiving orally administered analgesic agents, by the first postoperative day and patients demonstrated an average hospital stay of 3.86 days, resulting in reduced hospital costs and increased patient satisfaction.[37]

A strong correlation between postoperative radiotherapy and the development of complications was observed. That finding has led our department to delay reconstruction for all patients who might require radiotherapy. In addition, smoking was significantly associated with overall complications. Our institution now requires all actively smoking patients to abstain for at least 4 weeks preoperatively. In contrast to previous TRAM flap studies, our study demonstrated no correlation between obesity or abdominal scarring and increasing incidences of overall complications.[1] We support Blondeel[28] in the thought that, although obese patients require more tedious dissection, the perforators are often larger in caliber and adequately supply the flap. With experience in microsurgical techniques and perforator selection, we think it is possible to work around an abdominal scar and reduce the risks of flap ischemia and necrosis. Our flaps are routinely trimmed so that no questionable areas remain once the centralized blood supply has been chosen.

Interestingly, as the number of perforators increased, so did the incidence of complications. In addition, more perforators were often used for patients with more risk factors. One possible explanation is that, when one or two perforators are used, they have large diameters and can easily provide inflow for the whole flap. In cases in which four or five perforators are required, there is no strong centralized blood supply and flap survival is dependent on small-diameter vessels. Therefore, these data support even one perforator, compared with two or three perforators, as providing a very adequate blood supply for an autogenous breast. Accurate judgment of adequate perforators involves a learning curve. Blondeel[28] thinks that the distance of the dominant perforators from the midline, not the number of perforators, determines zone IV viability. Previous studies of abdominal wall vascular anatomical features by Heitmann et al.[27] noted that one or two perforators per pedicle can be reliably observed to be greater than 1 mm. In addition, all major perforators can usually be found within 8 cm of the umbilicus, reaffirming the reliability of zones I to III for flap reconstruction. Zone IV is disregarded in the

same manner as for pedicle and free TRAM flaps.

The association of hypertension and increased complication rates may be related to underlying atherosclerosis of the vessels themselves or the overall poor health and comorbidities of hypertensive patients. In addition, previous studies quoted 1000 g as the cutoff point for use of a DIEP flap.[13] Our data indicated no correlation between flap weight and the development of complications. Our institution routinely excises zone IV and any other ischemic tissue, so that all remaining tissue has adequate inflow regardless of flap weight.

Many flap surgeons raise concerns regarding increased potential for fat necrosis and partial flap loss with the DIEP flap, despite decreased donor-site morbidity. Our study indicated complication rates comparable to those in retrospective reviews of TRAM flap breast reconstructions[1–8] (Table VII). Our fat necrosis and partial flap necrosis rates were 12.9 and 2.5 percent, respectively. Some retrospective reviews defined a minimum of 10 percent partial flap loss or 2 cm of fat necrosis for classification; however, we based our data strictly on physical examination findings documented in the clinical or hospital notes.[1,25]

In addition, some reconstructive surgeons selectively use the DIEP flap and often intraoperatively choose the use of a DIEP flap or a free TRAM flap. Our institution does not use the free TRAM flap. For patients with inadequate abdominal tissue in preoperative assessments, use of a gluteal artery perforator flap is our procedure of choice. We use the superficial inferior epigastric artery flap in certain cases, if an adequate superficial inferior epigastric artery is present, instead of a DIEP flap. This further reduces donor-site morbidity. Blondeel et al.[7] described preserving the superficial inferior epigastric vein with clips and using it as a salvage vessel in cases with venous outflow problems. In addition, the literature raises questions regarding potential tissue ischemia of zone IV when a large contralateral superficial epigastric vein is found. This has led to concern that a second venous anastomosis would be required. With an overall venous thrombosis rate of 3.8 percent, our data did not demonstrate statistical significance for associations of increased thrombosis or complications with the number of venous anastomoses. In comparison with the free TRAM flap, the DIEP flap provides a significantly longer pedicle, which allows tension-free anastomoses. This permits more freedom of design, which results in a centrally located breast mound, especially with anastomoses to the internal mammary system.[25,27]

We think that in certain situations, such as cases with inadequate abdominal tissue to replace the breast or a very dominant superficial venous system, the DIEP flap may not be acceptable. In such cases, we have had success with the gluteal artery perforator flap as an alternative for inadequate abdominal tissue

TABLE VII
Literature Review

Flap	Reference*	No. of Flaps	Complications (%)	Fat Necrosis (%)	Partial Flap Loss (%)	Venous Congestion (%)	Total Flap Loss (%)	Hernia (%)
Pedicle TRAM	Watterson et al.	729	24	11	5		0	9
DIEP	Blondeel	100		6	7	4	2	1
DIEP	Hamdi et al.	50		6	6	4	2	0
Free TRAM	Kroll	279		12.9	2.2		0.4	
DIEP, unselected	Kroll	8		62.5	37.5		0	
DIEP, selected	Kroll	23		17.4	8.7		0	
DIEP	Keller	148		6.8		2	0.7	1.4
Free TRAM	Nahabedian et al.	143		9.8	0	1.4	3.5	
DIEP	Nahabedian et al.	20		10	0	0	5	0
DIEP	This study	758	30.3	12.9	2.5	3.8	0.5	0.6

* Watterson, P. A., Bostwick, J., III, Hester, R., Jr., et al. TRAM flap anatomy correlated with a 10-year clinical experience with 556 patients. *Plast. Reconstr. Surg.* 95: 1185, 1995.

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Nahabedian, M. Y., Momen, B., Galdino, G., and Manson, P. Breast reconstruction with the free TRAM or DIEP flap: Patient selection, choice of flap, and outcome. *Plast. Reconstr. Surg.* 110: 466, 2002.

and superficial inferior epigastric vein anastomoses for inadequate outflow.

CONCLUSIONS

On the basis of our retrospective review and our 10-year experience with the DIEP flap for breast reconstruction, we have adopted this method as our standard of care for breast reconstruction. We have adopted smoking and postmastectomy radiotherapy as primary risk factors; we now require our patients to refrain from cigarette smoking for 4 weeks and we delay reconstruction for all potential postmastectomy radiotherapy patients. As microsurgical experience increases, we think that the benefits of this flap technique will outweigh its risks. Many alternative options are available for free autologous breast reconstruction. As experience is gained with the superficial inferior epigastric artery flap, it can be adopted as a sister to the DIEP flap and the choice can be made intraoperatively, much in the way many surgeons currently view the choice of the free TRAM flap versus the DIEP flap. In addition, as surgical experience and clinical research allow greater predictability of perforator anatomical features, the time spent learning microsurgical techniques will be rewarded with a multitude of options for breast reconstruction, affording better patient satisfaction, decreased donor-site morbidity, and shorter hospital stays.

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