A SINGLE CENTER COMPARISON OF ONE VERSUS TWO VENOUS ANASTOMOSES IN 564 CONSECUTIVE DIEP FLAPS: INVESTIGATING THE EFFECT ON VENOUS CONGESTION AND FLAP SURVIVAL

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Background: Venous complications have been reported as the more frequently encountered vascular complications seen in the transfer of deep inferior epigastric artery (DIEA) perforator (DIEP) flaps, with a variety of techniques described for augmenting the venous drainage of these flaps to minimize venous congestion. The benefits of such techniques have not been shown to be of clinical benefit on a large scale due to the small number of cases in published series. *Methods:* A retrospective study of 564 consecutive DIEP flaps at a single institution was undertaken, comparing the prospective use of one venous anastomosis (273 cases) to two anastomoses (291 cases). The secondary donor vein comprised a second DIEA venae commitante in 7.9% of cases and a superficial inferior epigastric vein (SIEV) in 92.1%. Clinical outcomes were assessed, in particular rates of venous congestion. *Results:* The use of two venous anastomoses resulted in a significant reduction in the number of cases of venous congestion to zero (0 vs. 7, $P = 0.006$). All other outcomes were similar between groups. Notably, the use of a secondary vein did not result in any significant increase in operative time (385 minutes vs. 383 minutes, $P = 0.57$). *Conclusions:* The use of a secondary vein in the drainage of a DIEP flap can significantly reduce the incidence of venous congestion, with no detriment to complication rates. Consideration of incorporating both the superficial and deep venous systems is an approach that may further improve the venous drainage of the flap. ©2009 Wiley-Liss, Inc. Microsurgery 30:185–191, 2010.

While the deep inferior epigastric artery perforator (DIEP) flap is a reliable choice of flap for breast reconstruction, with low rates of complications reported, venous complications continue to be described. In many large series, these have been the more frequently encountered vascular complications seen, with many authors describing insufficient venous drainage requiring reoperation in upto 5% of flaps and venous congestion in as many as 10% of flaps.[1–3] These studies have postulated that the DIEP flap is drained by an intricate network of deep and superficial veins, and that in select cases, the chosen perforating vein may not adequately drain the flap. While some venous complications are related to microsurgical problems (such as venous thrombosis), venous congestion is often due to the intrinsic anatomy of flap vasculature and flap design. While a functioning venous pedicle needs to be evaluated in such cases to exclude a microvascular complication, some cases are due to a relative inadequacy of venous drainage of some regions of the flap.

In a move to minimize venous complications, the use of secondary alternate pathways in addition to the deep inferior epigastric vein (DIEV) for venous drainage has been described, albeit usually performed after venous congestion has already occurred. These options, described for augmenting or supercharging the venous drainage of congested flaps, have been broad, with the methods used comprising additional venae comitantes of the ipsilateral DIEA,[4,5] venae comitantes of the contralateral DIEA,[6] the ipsilateral superficial inferior epigastric vein (SIEV),[2,3,7] and the contralateral SIEV.[8] These reports have all comprised case reports or series of relatively low numbers, and given the low incidence of venous congestion, this has limited the formal evaluation of contributory factors for venous congestion.

Despite the lack of clinical studies, experimental studies in rats have shown that the use of additional routes of venous drainage can have a statistically significant benefit, with a correlation shown between the number of venous outflow routes and survival in abdominal flaps.[9–12] Inclusion of the SIEV as an alternative venous outflow tract further increased flap survival by almost 20%.[10]

While these animal studies have yielded promising results, there has not been a clinical study to formally evaluate the effects of applying more than one route of venous drainage to DIEP flaps to minimize venous congestion. Anecdotally, many surgeons routinely dissect out secondary veins, in case of the need for their future use.

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However, the choice of vein and the routine use of such veins have not been definitively demonstrated. In addition, these studies vary in their accounts of the dominant venous drainage of the lower abdominal integument, with the SIEV largely thought to be the dominant venous drainage route, and through communications with DIEA perforators, the DIEA can vary in its venous dominance. As such, this study comprised a clinical study to compare the use of one vs. two veins for the drainage of a DIEP flap.

METHODS

A retrospective study was undertaken for patients having undergone DIEP flap breast reconstructions during the period of January 2000 to September 2008. This was a consecutive series, with all operations undertaken by a single reconstructive surgical unit, of four core surgeons. The only exclusion criterion was flaps that were supplied by more than one artery (stacked or bipedicled flaps). All flaps were fasciocutaneous, included no rectus muscle, and were raised on a single DIEA.

Recorded data comprised patient demographics, operation details, complications, implementation of secondary venous outflow routes, and details of the vascular basis for flap supply and drainage. Patients were stratified into two groups according to the number of veins used for venous drainage (one vs. two). Complications were compared, as well as differences in operative time.

Uniform Surgical Technique

Preoperative imaging was performed in all cases, with Doppler ultrasound performed before April 2006, and computed tomographic angiography (CTA) utilized thereafter. Both methods were used to map both arterial and venous anatomy preoperatively. Intraoperatively, the dissection and preservation of a length of the superficial inferior epigastric veins bilaterally was routinely performed. The flap was routinely harvested based on the single largest periumbilical perforator identified on imaging (97% of cases). Where this was not appropriate (3% of cases), two perforators were utilized in supply to the flap. Flap harvest and exposure of recipient vessels were performed simultaneously, and in all cases, the primary recipient vein of choice was the internal mammary vein. Where this was insufficient or inappropriate based on individual surgeon opinion, other sources were selected.

The decision to use an alternative (secondary) source of venous drainage was made based upon individual surgeon preference, with factors influencing this decision including a good match of two donor and recipient veins, the presence of a subjectively enlarged (greater than 1.5 mm) SIEV, a subjectively engorged (tense and dilated) SIEV, or in the presence of frank venous congestion during flap harvest or flap in-setting (where pedicle flow continuity was confirmed to be present). The donor vessel of choice was the SIEV, to achieve venous flow through both deep and superficial venous territories, with a second DIEV (DIEA concomitant vein) as an alternative option. The contralateral SIEV was the preferred choice of vessel (97% of cases), however, where inappropriate (inadequate size or absent vessel, or in bilateral reconstructions), the ipsilateral SIEV was used (3% of cases). Where an SIEV was used, the cephalic vein was used as the recipient vessel of choice, harvested through a small incision in an anterior axillary skin crease with minimal operative time or scarring (Fig. 1). Venous anastomoses were performed with anastomotic devices that achieve fast anastomotic times: either "Anastoclip" Vascular Closure Staples (VCS) microstaple clips (AnastoClip Vessel Closure System, Le Maitre Vascular Inc, Sulzbach, Germany) or a microvascular anastomotic coupling device (Microvascular Anastomotic Coupling System, Synovis Micro Companies Alliance Inc, St Paul, MN).

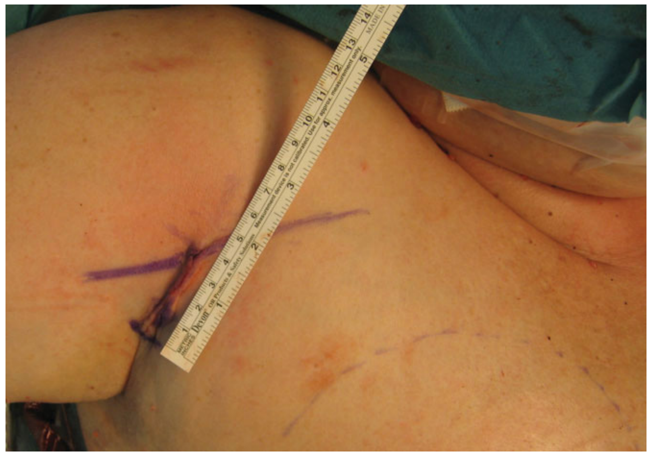

Figure 1. Intraoperative photograph following cephalic vein harvest, demonstrating a short scar in an anterior axillary skin crease. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Flaps were monitored postoperatively with the use of the Cook-Swartz implantable Doppler probe (Cook Medical®, Cook Ireland Ltd, Limerick, Ireland), in which an implantable Doppler probe is wrapped around the venous pedicle following successful venous anastomosis. Venous application of the probe was performed in concordance with both manufacturer and literature specifications, as this will monitor both arterial and venous flow—if arterial flow ceases, venous flow will cease shortly thereafter, providing a monitor for both pedicles. Where there were two venous pedicles, probes were applied to each pedicle. The Cook-Swartz probe was used as the primary monitoring technique, with flaps assessed routinely (half-hourly monitoring for the first postoperative day, hourly for the second day, two-hourly for the third day, and four-hourly thereafter until planned discharge on day 7), and thorough clinical assessment occuring once daily or following any detection of pedicle compromise by the probe. All blood pressures were normalized before surgery and actively managed in the perioperative period.

Flaps were returned to theater for re-exploration if there were clinical or Doppler evidence of pedicle compromise, or if there was venous congestion of uncertain significance. Venous congestion was defined as the presence of signs of venous congestion (i.e., brisk capillary refill or bleeding, or deep blue color of the flap or draining blood). In such cases, re-exploration of the flap and pedicle was undertaken, and if pedicle compromise was identified (thrombosis or kinking) this was managed directly. If there was relative venous congestion in the presence of a patent venous pedicle, augmentation of venous outflow was attempted to be achieved with the inclusion of a secondary venous pedicle. Venous congestion was noted regardless of outcome at re-exploration.

Statistical Analysis

Data was presented as means, and given with standard deviations and ranges. The distribution of data was skewed and did not normalize after sequential root transformations or log transformations. The Mann-Whitney U test was used for the statistical analysis of nonparametric continuous data. Nominal data was analyzed with Fisher's exact test. Significance was set at $P < 0.05$. Analyses were performed using Statistical Package For Social Sciences (SPSS) for Windows version 16.0 (SPSS Inc., Chicago, IL).

RESULTS

A total of 564 DIEP flap breast reconstructions were performed in 501 patients, with 438 unilateral and 63 bilateral reconstructions. Of these, 273 breast reconstructions were performed in which only a single venous outflow route was implemented, and 291 cases had two veins used primarily for venous outflow (for the reasons listed in the Methods section). The patients in each of these groups were similar (Table 1), with similar comorbidites and were of similar age. The two-vein group had more unilateral reconstructions, and less immediate reconstructions, but these were not clinically significant.

The DIEV was the primary source of venous drainage in all cases (Table 2), and for secondary venous drainage, the SIEV was used most commonly (92.1%), followed by a second DIEV (7.9%). In the vast majority of cases where an SIEV was used, the cephalic vein was harvested as the recipient vein for these anastomoses (82.8% overall). There were no differences in outcomes when each of these venous outflow routes were compared for venous congestion (0 cases in either group). Of note, the use of a secondary vein did not result in any increase in operative time (385 minutes vs. 383 minutes, $P = 0.57$).

Of the 273 flaps in which a single vein was used, seven flaps demonstrated venous congestion on clinical examination postoperatively. Of the other 291 flaps, which received an additional vein during initial breast reconstruction, no flaps demonstrated any signs of venous congestion. This decrease in the rate of venous congestion with the use of two veins was statistically significant, $P = 0.006$ (Table 3). Of the seven congested flaps, five were due to venous thrombosis and two were due to relative venous congestion with no pedicle compromise. All cases of venous congestion were taken back to theater for re-exploration, and all cases of pedicle compromise were taken back to theater for re-exploration, with the ultimate cause for compromise identified in theater. Other complications were statistically similar between the groups, including complete flap failures (due to either arterial or venous thrombosis), partial flap losses, arterial or venous complications, and overall take-backs.

Notably, while there were five cases of venous thrombosis in each group, all cases in which venous thrombosis did occur in the one-vein group resulted in global venous congestion identified on examination (5/5 = 100%), however, in the two-vein group, venous thrombosis in a single vein (identified with the implantable Doppler probe) did not result in any clinical suggestion of venous congestion in any cases (0/5 = 0%). There were no cases in which venous thrombosis occurred in both veins in the two-vein group. In the two-vein group, venous thrombosis was identified with the implantable Doppler probe and findings at theater, rather than the clinical manifestations of venous failure. Of the cases of venous thrombosis, one case of venous thrombosis resulted in complete flap failure in the one-vein group (1/5 = 20%), whereas no cases resulted in complete flap failure in the two-vein group (0/5 = 0%). All other cases of complete failure flap were due to arterial thrombosis.

DISCUSSION

This study has demonstrated that by prospectively embarking on a second venous anastomosis, the venous drainage of a free flap can be significantly improved, reducing the incidence of venous congestion. The study has also demonstrated that this can be readily achieved, without any demonstrable increase in operative times if planned effectively. In our series of over 500 DIEP flaps, we have reduced our venous congestion rate to zero if a secondary vein is performed. The use of the cephalic vein as a recipient vessel as described, and the use of anastomotic devices that achieve fast anastomotic times (either "Anastoclip" Vascular Closure Staples (VCS)

Table 1. Demographics and Operative Details for Each of the Two Groups, Comparing the Use of One Venous Anastomosis to Two Venous Anastomoses

	One-vein group	Two-vein group	*P* value
Mean age at breast reconstruction (years)	49.6 (SD = 9.4) Range: 20–72	51.5 (SD = 7.9) Range: 28–73	0.063[a]
Risk factors (*n*)			
Previous stroke or myocardial infarction	2/230	2/271	0.86[b]
Type 2 diabetes mellitus	4/230	2/271	0.30[b]
Hypertension	12/230	28/271	0.038[b]
Corticosteroids	7/230	5/271	0.37[b]
Nature of reconstruction (*n*)			
Immediate reconstruction	51/273	27/291	0.022[b]
Delayed reconstruction	222/273	264/291	0.022[b]
Unilateral reconstruction	188/230	249/271	0.001[b]
Bilateral reconstruction	42/230	22/271	0.001[b]
Operation details (minutes)			
Mean ischemia time	68.3 (SD = 25.2) Range: 31–217	67.6 (SD = 22.7) Range: 31 – 158	0.712[a]
Procedure time: all procedures	383 (SD = 122) range: 165–740	385 (SD = 118) range: 170–730	0.57[a]
Procedure time: unilateral reconstruction	343 (SD = 102) range: 165–670	355 (SD = 110) range: 170–730	0.33[a]
Procedure time: bilateral reconstruction	473 (SD = 118) range: 285–740	487 (SD = 94) range: 305–680	0.24[a]

SD, standard deviation.
[a]*Two tailed Mann-Whitney U test.*
[b]*Fisher's exact test.*

microstaple clips or a microvascular anastomotic coupling device, allowed us to perform a second venous anastomosis with no increase in operative time. Our use of these anastomotic procedures has been described previously,[13] and it should be noted that these occurred more frequently in the latter part of the series, and thus a learning curve is certainly an important consideration in evaluating surgical times.

The need to augment the venous drainage of a free flap is not new, with both the DIEV and SIEV used adjunctively to augment venous drainage of the lower abdominal wall integument (Fig. 2). Previous experimental studies utilized "supercharging" techniques to improve flap survival, with both arterial supercharging[14,15] and venous superdrainage[9,11,16–18] both shown to be of benefit in reducing reoperative rates. Inadequate venous outflow particularly has been shown to incrementally reduce the chance of flap survival when compared with arterial failure.[19,20] The limitation of all of these previous studies is the low incidence of venous complications in DIEP flap surgery, and the resultant difficulty in evaluating these small numbers. Our series of 564 DIEP flaps revealed only seven cases of venous congestion, highlighting this difficulty. Despite this, the statistical significance between groups was clear.

While venous pedicle flow is essential for global venous drainage, relative venous insufficiency can ensue despite a patent venous pedicle. The venous drainage of a DIEP flap depends on the volume of supply by the DIEV and is thus dependant on the intrinsic individual vascular anatomy of the flap and on flap design. In some cases, there is inadequate drainage of some regions of the flap, leading to venous congestion. The physiology of venous failure is also pertinent for discussion. Inadequacy of local venous outflow results in a rise of venous pressure and venous distention. With venous return stimulated by autonomic venous tone, the denervation that occurs is a free flap compounds these changes. Increasing intravascular pressure increases the filtration rates across the vessel wall leading to an almost immediate formation of edema,[21] with the increased interstitial fluid impairing the diffusion of oxygen to cells.[22,23] In addition, the obstruction of venous outflow results in persisting arterial inflow and the accumulation of highly unstable ogygen-derived

Table 2. Vascular Anatomy of the Flaps, Comparing the Use of One Venous Anastomosis to Two Venous Anastomoses

	One-vein group	Two-vein group
Primary recipient artery (*n*/%)		
Internal mammary artery	158/273 (57.9%)	244/291 (83.8%)
Circumflex scapular artery	99/273 (36.3%)	41/291 (14.1%)
Thoracodorsal artery	4/273 (1.5%)	6/291 (2.1%)
Thoracoacromial artery	10/273 (3.7%)	0
Primary recipient vein (*n*/%)		
Internal mammary artery	157/273 (57.5%)	244/291 (83.8%)
Circumflex scapular artery	97/273 (35.5%)	41/291 (14.1%)
Thoracodorsal artery	15/273 (5.5%)	6/291 (2.1%)
Thoracoacromial artery	1/273 (0.4%)	0
Cephalic artery	1/273 (0.4%)	0
Secondary donor vein (*n*/%)		
Deep inferior epigastric vein	–	23/291 (7.9%)
Superficial inferior epigastric vein	–	268/291 (92.1%)
Secondary recipient vein (*n*/%)		
Internal mammary	–	28/291 (9.6%)
Circumflex scapular	–	11/291 (3.8%)
Thoracodorsal	–	11/291 (3.8%)
Cephalic	–	241/291 (82.8%)

Table 3. Operative Complications, Comparing the Use of One Venous Anastomosis to Two Venous Anastomoses

	One-vein group	Two-vein group	*P* value
Overall take-backs/reoperations (*n*/%)	38/273 (14%)	48/291 (16%)	0.44[a]
Venous congestion (*n*/%)			
Overall venous congestion	7/273 (2.6%)	0/291 (0%)	0.006[a]
Venous congestion due to venous thrombosis	5/7 (71%)	–	–
Venous congestion due to relative venous insufficiency	2/7 (29%)	–	–
Vascular complications (*n*/%)			
Arterial thrombosis	10/273 (4%)	8/291 (3%)	0.54[a]
Venous thrombosis	5/273 (2%)	5/291 (2%)	0.92[a]
Flap loss (*n*/%)			
Overall complete flap loss	5/273 (2%)	6/291 (2%)	0.38[a]
Complete flap loss due to venous thrombosis	1/5 (20%)	0/6 (0%)	0.45[a]
Complete flap loss due to arterial thrombosis	4/5 (80%)	6/6 (100%)	0.45[a]
Partial flap loss	2/273 (0.7%)	2/291 (0.7%)	0.98[a]
Other complications (*n*/%)			
Hematoma	23/273 (8%)	21/291 (7%)	0.58[a]
Infection	23/273 (8%)	37/291 (13%)	0.16[a]
Fat necrosis	31/273 (11%)	25/291 (9%)	0.26[a]
Seroma	2/273 (0.7%)	9/291 (3%)	0.08[a]

[a]*Fisher's exact test.*

free radicals.[24–26] These free radicals have detrimental effects on tissue viability.[24,27] When this is profound and prolonged as in the case of venous thrombosis, this can result in complete flap failure, as demonstrated with the 20% of venous thromboses in the one-vein group being unsalvageable. If this is less profound, as occurs in the cases of relative venous congestion, flap failure is less likely to ensue, with no such cases failing in our cohort.

The DIEP flap has been reported to have rates of venous congestion as high as 8%.[2] It is thought that the dependence of venous drainage of the flap on one or several perforators provides a less dependable venous drainage than the TRAM flap.[3] While the use of a second DIEV has been utilized in the past, and indeed we have used it, we prefer the use of the SIEV as a secondary route for venous drainage. While the use of the SIEV as a secondary source of venous drainage has been utilized in previous clinical studies,[2,3,7,8] our study has demonstrated this on a broader scale. Other more novel studies have shown that the superficial venous drainage of a flap can also be used for such techniques as for venesection in a congested flap[28] or for supercharging venous drainage by anastomosis to a DIEV branch.[29]

Several anatomical studies of the venous drainage of the abdominal wall have suggested that it is the SIEV that is the major venous drainage to the lower abdominal wall (i.e., the DIEP flap/TRAM flap skin paddle). In addition to cadaveric studies,[30] studies with advanced imaging techniques such as computed tomographic angiography (CTA) have reiterated this.[31] With the venous territory of the SIEV likely to be different to that of the DIEV, it is logical that a second DIEV may not contribute to the drainage of as much additional tissue as the

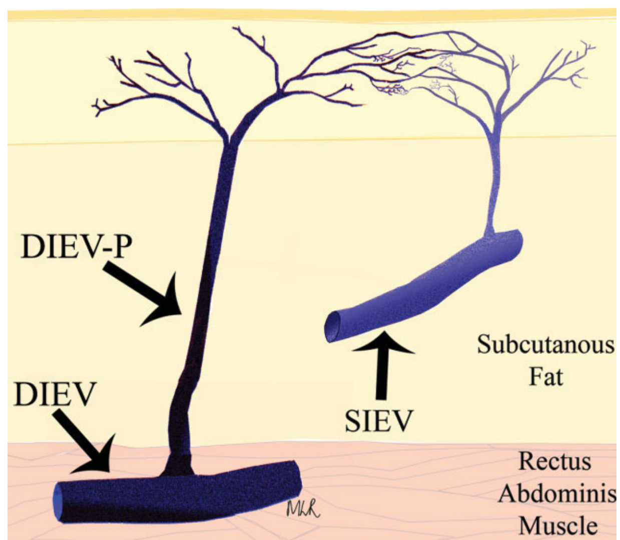

Figure 2. Representation of the venous anatomy of the anterior abdominal wall, with the subcutaneous tissues drained by both superficial and deep venous systems, the superficial inferior epigastric vein (SIEV) and the deep inferior epigastric vein (DIEV), respectively, through DIEV perforators (DIEV-P). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

use of the SIEV. Other studies have also demonstrated the broad drainage basin of the SIEV, with intercommunicating vessels between both SIEVs across the midline, facilitating contralateral drainage,[30,31] and perforating branches of the DIEV penetrating the rectus abdominis muscle to anastomose with the DIEV.[30] However, these anatomical studies have shown that the communicating branches between the DIEV and the SIEV, the DIEV diameter, and the DIEV branching patterns may each vary considerably between different DIEVs. It is thus likely that using a second DIEV is beneficial, a result shown in our study, with no difference when each method was compared. Additionally, the SIEV traverses the inguinal lymphatics, and as such has the potential to cause lymphatic leakage, however, in our series, seroma rates were similar between groups. Larger studies would be useful to evaluate this phenomenon.

In our study, we selected the use of an alternative source of venous drainage based upon individual surgeon preference, with key factors influencing this decision including the ease of matching two donor and recipient vessels, the presence of a subjectively enlarged or engorged SIEV, or the presence of venous congestion during flap harvest or flap in-setting. Although selection based on these specific factors does incorporate some selection bias, a uniform approach to including two sources of venous drainage necessarily would include all such cases, eliminating this bias. While these measures are subjective, SIEV measurement can be performed preoperatively on either Doppler ultrasound or with the use of CTA, which we routinely perform preoperatively.[32,33] The presence of a considerably larger diameter of the SIEV compared with the DIEV has been shown to point to a dominant venous drainage by the SIEV as a drainage route for the abdominal skin paddle.[30] This has been translated to sizes of 1.5–2 mm or greater, with prospective dissection and preservation of the SIEV suggested as a safety net for salvage of congested flaps.[1,7,10] In addition to preoperative and intraoperative techniques for predicting venous congestion, advance postoperative monitoring techniques (such as tissue oximetry and microdialysis) can identify early venous congestion and potentiate early flap salvage. We utilized one such tool in the monitoring of venous complications, namely the Cook-Swartz implantable Doppler probe, which was able to potentiate a high salvage rate of flaps complicated by venous thrombosis. In fact, with most cases of venous thrombosis salvaged, most of the flaps that failed in our cohort were due to arterial failure.

CONCLUSIONS

The use of a secondary vein in the drainage of a DIEP flap can significantly reduce venous congestion, with its resultant interventions, with no detriment to overall complication rates. This is a particularly feasible option where the prospective harvest of a cephalic vein occurs and the use of venous anastomotic devices can aid the use of a second vein without any increase in operative times over the use of a single vein.

Consideration of incorporating both the superficial and deep venous systems is an approach that may further improve the venous drainage of the flap. We suggest that the use of both systems of venous drainage be planned prospectively in DIEP flap transfer as a means to improving operative outcomes.

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