Factors Associated with Anastomotic Failure after Microvascular Reconstruction of the Breast

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The prevalence of anastomotic failure resulting in return to the operating room and flap necrosis after microvascular breast reconstruction ranges from 1 to 5 percent. The purpose of this study was to review a set of factors that may be associated with this occurrence. Microvascular reconstruction of the breast was performed in 198 women from January of 1998 to July of 2002. The mean age for all women was 47.7 years. There were 158 unilateral and 41 bilateral reconstructions, for a total of 240 flaps. The specific flaps included the free transverse rectus abdominis musculocutaneous flap ($n = 176$), the deep inferior epigastric perforator flap ($n = 58$), and the superior gluteal artery perforator flap ($n = 6$). Upon recognition of anastomotic failure, women were immediately returned to the operating room. Factors that were considered relevant to anastomotic failure included the choice of recipient vessel, timing of reconstruction, previous chest wall radiation therapy, previous axillary lymph node dissection, tobacco use, diabetes mellitus, patient age, and hematoma. Patient follow-up ranged from 5 to 59 months. Descriptive statistics, Fisher's exact test, and exact logistic regression were used for analyses and to summarize data. Of the 240 flaps, return to the operating room was necessary for 20 (8.3 percent), total necrosis occurred in nine (3.8 percent), and the rate of flap salvage was 55 percent (11 of 20 flaps). Venous occlusion was responsible for 16 of the 20 returns and eight of the nine failures. Statistical analysis demonstrated that both return to the operating room and flap necrosis were significantly associated with venous occlusion, delayed reconstruction, and hematoma. Previous lymph node dissection and previous radiation therapy had only a weak association with return to the operating room. The results of this study demonstrate that venous occlusion is responsible for return to the operating room and flap necrosis in the majority of cases. Age, tobacco use, choice of recipient vessel, and diabetes mellitus were not associated with anastomotic failure. The significance of delayed reconstruction may be related to its frequent association with previous lymph node dissection and/or radiation therapy resulting in perivascular fibrosis. (*Plast. Reconstr. Surg.* 114: 74, 2004.)

Microvascular reconstructions of the breast using free transverse rectus abdominis musculocutaneous (TRAM), deep inferior epigastric perforator (DIEP), and superior gluteal artery perforator (SGAP) flaps have been performed for nearly 15 years.[1–6] The advantages of these techniques are well described and include fewer abnormalities at the donor sites related to strength and contour, less fat necrosis, and improved symmetry.[7–10] Since inception, however, these techniques have been the topic of much discussion and controversy that has been primarily based on the complexity of these operations, risk of total flap failure, financial considerations, and patient satisfaction.[6,8,11–14] This controversy is heightened by the fact that pedicle flap counterparts, the pedicle TRAM flap and the latissimus dorsi flap, represent simpler methods of reconstruction with a decreased flap failure rate.

The prevalence of anastomotic failure following microvascular breast reconstruction resulting in return to the operating room ranges from 5 to 10 percent and resulting in flap necrosis ranges from 1 to 5 percent.[6,8,15] The etiology of anastomotic failure is multifactorial and can be the result of preoperative, intraoperative, and postoperative factors that have been described previously.[16] Many factors can be optimized to improve anastomotic and flap success. These include patient selection, surgical technique, and postoperative hemodynamic monitoring. Some factors, however, cannot be completely optimized. These include

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the effects of prior mastectomy and axillary lymph node dissection, prior chest wall radiation therapy, medical comorbidities, and advanced patient age. Thus, the purpose of this study was to evaluate a set of candidate factors and quantify those that associate significantly with anastomotic failure. Identification of these factors may improve outcomes following microvascular reconstruction of the breast.

Patients and Methods

Patient Selection

Microvascular reconstruction of the breast was performed in 198 women from January of 1998 to July of 2002. Standard indications included tobacco use, obesity, and averting a delay procedure. The authors' indications also included preservation of abdominal strength, preservation of abdominal contour, minimizing the occurrence of fat necrosis, and the ability to reconstruct a breast of sufficient volume to minimize the need to perform additional operations for symmetry.

During the initial evaluation, all patients were provided with the options of breast reconstruction using autologous tissue or implants. For women interested in autologous tissue, the abdomen was the primary donor site and the buttock was the secondary donor site. An assessment of the soft-tissue volume requirement of the breast was compared with the amount of soft tissue available in the abdominal area. In some situations, the abdomen was not a suitable donor site because of prior abdominal operations, morbid obesity, or inadequate volume. In these cases, the SGAP flap was considered as an alternative donor site.

Operative Technique

The salient features related to the harvest and elevation of the free TRAM, DIEP, and SGAP flaps have been previously described.[1,7,8,17,18] The selection of abdominal flaps, including the free TRAM and DIEP, was based on intraoperative assessment of the perforators.[8] When a large perforator was visualized (1.5 to 3 mm), a DIEP flap was performed and included from 1 to 3 perforators. In the absence of a dominant perforator or when perforator diameter was less than 1.5 mm, a muscle-sparing free TRAM (MS-1 or MS-2) was usually performed. The recipient vessels included the thoracodorsal or internal mammary artery and vein. For the initial 3 years of the study, the thoracodorsal vessels were used exclusively. Currently, the choice of recipient vessel is based on several factors primarily related to the timing of the reconstruction and the type of mastectomy performed. The thoracodorsal vessels are used for all unilateral or bilateral reconstructions following modified radical mastectomy in which the vessels are readily accessible. The internal mammary vessels are used for all delayed reconstructions as well as all unilateral and bilateral immediate reconstructions following sentinel lymph node biopsy or simple mastectomy. The benefit of this is to prevent perivascular and perilymphatic fibrosis in the axillary region and to minimize the incidence of lymphedema.

In preparation for the microvascular anastomosis, 3000 to 5000 IU of heparin was administered intravenously, 5 minutes before division of the vascular pedicle. All anastomoses were performed by hand using 8-0 or 9-0 interrupted nylon sutures. The anastomotic coupler was not used in this series of reconstructions. The anastomotic technique was end to end for all flaps except one in which an end-to-side technique was used for an SGAP reconstruction. All operations for this analysis were performed by the primary author (Nahabedian) to minimize procedural variations.

Postoperative Care and Monitoring

Postoperative monitoring consisted of direct assessment of the flap every 15 minutes while in the recovery room, every hour for the first 24 hours, and every 2 hours for the next 48 hours. Women were usually discharged to home on the third postoperative day. The specific monitoring instruments included a handheld Doppler probe, assessment of surface temperature gradients, flap color, and capillary refill. The Doppler was used to assess arterial and venous flow. A biphasic signal was indicative of a patent artery and vein, whereas a monophasic signal was indicative of arterial or venous thrombosis. The implantable Doppler was not used in these reconstructions. Flaps demonstrating venous insufficiency were observed for signs of progression. Progressive venous insufficiency implies a gradual increase in congestion with a purplish discoloration indicative of venous occlusion. Nonprogressive venous insufficiency implies a mild and stable level of congestion that is indicative of patent but insufficient venous outflow. This form of venous insufficiency was managed with medic-

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inal leeches. The benefit of using leeches for venous congestion has been previously described.[19] The leeches were applied every 2 to 8 hours depending on the degree of venous insufficiency and continued for 2 to 4 days to allow venous collateralization to occur. Progressive venous insufficiency required reexploration. The decision to return to the operating room and explore the anastomosis was based on evidence or suspicion of vascular compromise. Venous occlusion manifested as a congested, tense, and warm flap with brisk and rapid capillary refill. Arterial occlusion manifested as a pale, cool flap with absent capillary refill.

Salvage of the failing flap required prompt return to the operating room, usually within 30 to 60 minutes to minimize ischemic injury. An intravenous bolus of heparin, 3000 to 5000 IU (Wyeth-Ayerst, Philadelphia, Pa.), was administered. The anastomosis was evaluated both visually and with the hand-held Doppler probe. In case of venous thrombosis only, the vessel was divided at the site of the anastomosis. A Fogarty embolectomy catheter was passed proximally and distally to evacuate blood clot. When adequate venous flow was obtained, the vessel edges were débrided and anastomosed. When venous flow could not be achieved, it was assumed to be the result of thrombosis within the microvasculature of the flap. In these circumstances, a bolus of an intraarterial thrombolytic agent such as streptokinase (25,000 IU; AstraZeneca, Westborough, Mass.) or Retavase (10 units; Centocor, Malvern, Pa.) was administered. Absence of flow suggested irreversible thrombosis that required flap removal. Repair of the venous anastomosis with a vein graft or use of alternate recipient vessels was considered when there was insufficient length of the vascular pedicle.

Statistical Analysis

Descriptive statistics was used for data summarization. Statistical analyses were performed using the Fisher's exact test and exact logistic regression.[20] The *FREQ* and *LOGISTIC* procedures of the SAS System with the *EXACT* option were used. The *EXACT* option has been added to the *LOGISTIC* procedure of the SAS System version 8.1 for small and/or skewed data or for cases where the frequency of one or more cells is below 5 (the case in this study). No variable selection method can be used in combination with the *EXACT* option using this procedure, however. Therefore, we used the Fisher's exact test to first identify those explanatory variables which have pairwise significant associations with the response and then check the joint association of such explanatory variable with the response using the exact logistic regression.

RESULTS

The mean age for all women was 47.7 years (range, 25 to 75 years). Mean follow-up was 26 months (range, 5 to 56 months). The reconstruction was unilateral in 158 women and bilateral in 41 women, for a total of 240 flaps. The specific flaps used were the free TRAM ($n = 176$), DIEP ($n = 58$), and SGAP ($n = 6$) flaps. Candidate factors to be associated with anastomotic failure are listed in Table I. The occurrence of each factor is based on the total number of flaps. Of the 240 flaps, return to the operating room was necessary for 20 (8.3 percent), total necrosis occurred in nine (3.8 percent), and the rate of flap salvage was 55 percent (11 of 20 flaps). Return to the operating room was necessary for 13 free TRAM, five DIEP, and two SGAP flaps. Total necrosis occurred in seven free TRAM flaps, one DIEP flap, and one SGAP flap. Circulatory abnormalities within the flap were recognized at a mean of 12 hours following the operation (range, 2 to 36 hours). Medicinal leeches were used on four flaps that demonstrated nonprogressive venous insufficiency. These leeches were used for 2 to 3 days. A blood transfusion was necessary in all women and included an autologous unit and 1 to 2 units of banked blood.

The factors associated with return to the operating room were analyzed and listed in Table II. Venous occlusion was the primary reason for returning to the operating room in 16 of

TABLE I
Candidate Factors to Be Associated with Anastomotic Failure

Factor	No. of Flaps	Percent
Flaps	240	100
Mean age, years	47.7	–
Immediate reconstruction	205	85
Delayed reconstruction	35	15
Thoracodorsal	202	84
Internal mammary	38	16
Previous axillary LND	55	23
Previous chest wall XRT	27	11
Tobacco use	31	13
Diabetes mellitus	4	2

LND, lymph node dissection; XRT, radiation therapy.

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TABLE II
Factors Associated with Return to Operating Room

Factor	No. of Flaps	Total Flaps Returned to OR (%)	Total Flaps for Each Factor (%)
Flaps	20		8.3
Mean age, years	47.4	–	–
Immediate reconstruction	13	65	6
Delayed reconstruction	7	35	20
Thoracodorsal	15	75	7
Internal mammary	5	25	13
Previous axillary LND	8	40	15
Previous chest wall XRT	5	25	19
Tobacco use	1	5	3
Diabetes mellitus	0	0	0
Hematoma	6	30	2.5
Arterial occlusion	4	20	1.6
Venous occlusion	16	80	6.7

OR, operating room; LND, lymph node dissection; XRT, radiation therapy.

TABLE III
Factors Associated with Flap Failure

Factor	No. of Flap Failures	Percent of Failures	Percent of Factor
Flaps	9		3.8
Mean age, years	46.3	–	–
Immediate reconstruction	5	56	2.4
Delayed reconstruction	4	44	11.4
Thoracodorsal	6	67	3
Internal mammary	3	33	8.7
Previous LND	4	44	7.3
Previous XRT	2	22	7.4
Tobacco use	0	0	0
Diabetes mellitus	0	0	0
Hematoma	2	22	33
Arterial occlusion	1	11	25
Venous occlusion	8	89	90

LND, lymph node dissection; XRT, radiation therapy.

the 20 flaps. Although the majority of women that required re-exploration had immediate reconstruction (65 percent versus 35 percent), the percentage, when evaluated for all women following delayed or immediate reconstruction, was higher for delayed reconstruction (20 percent versus 6 percent, respectively). Analysis of recipient vessels demonstrated that the thoracodorsal artery and vein required reexploration in the majority of cases (15 versus five). The percentage was higher, however, for the internal mammary (13 percent versus 7 percent) when the analysis included all women.

Of the 20 women who required return to the operating room, the case of one woman was considered to be preventable and related to a technical factor and 19 were not. The technical factor included a bleeding venous branch resulting in a hematoma, venous thrombosis, and flap necrosis. There was no obvious etiology for the remaining 19 flaps. In these flaps, intraoperative evaluation of the thrombosed vessels demonstrated that all of the anastomoses were intact without evidence of an intimal flap or back-wall suture placement.

Factors associated with flap failure were examined and are listed in Table III.. Of the total number of flap failures, five occurred following immediate and four following delayed reconstruction. When evaluated based on all women who had delayed reconstruction, however, there was a fivefold increase (11.4 percent versus 2.4 percent) in flap failure following delayed reconstruction. Venous occlusion appeared to be responsible for anastomotic failure in eight of the nine flap failures. Descriptive results of the analysis of the women who required re-exploration and who had flap failure are listed in Table IV.

Statistical Analysis

The results of the Fisher's exact test indicating the probability of the significance of the associations between the response and explanatory factors are shown in Table V. The Fisher's exact test indicated that return to the operating room associated significantly with venous occlusion ($p < 0.001$), delayed reconstruction ($p < 0.01$), and hematoma ($p < 0.001$). Flap necrosis associated significantly with venous occlusion ($p < 0.01$), delayed reconstruction ($p = 0.028$), and hematoma ($p = 0.024$). Previous lymph node dissection ($p < 0.06$) and previous radiation therapy ($p < 0.06$) approached significance in their associations with return to the operating room but not with flap necrosis. Age, tobacco use, choice of recipient vessel, and diabetes mellitus were not associated significantly with anastomotic or flap failure. For the majority of cases in this study, venous occlusion appeared to be responsible for returning to the operating room and flap necrosis.

The results of the exact logistic regression including the return to the operating room as the response variable and venous occlusion, delayed reconstruction, hematoma, previous lymph node dissection, and previous radiation therapy as the explanatory variables that had pairwise significant associations with the return to the operating room based on the Fisher's exact test indicated a significant ($p < 0.0001$) joint association. Venous occlusion and hematoma, however, were the only variables with

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TABLE IV

Descriptive Results of Patients Who Had Flap Failure and Required Re-exploration

Patient	Flap	Flap Outcome	Age (yrs)	Tobacco	Diabetes Mellitus	Timing of Reconstruction	Occlusion	Recipient Vessel	Hematoma	Previous ALND	Previous XRT
1	Free TRAM	Failure	58	No	No	Immediate	Vein	Thoracodorsal	No	No	No
2	Free TRAM	Failure	54	No	No	Delayed	Vein	Thoracodorsal	No	Yes	No
3	Free TRAM	Salvage	57	No	No	Delayed	Vein	Thoracodorsal	No	Yes	Yes
4	Free TRAM	Salvage	63	No	No	Immediate	Artery	Thoracodorsal	Yes	No	No
5	Free TRAM	Failure	32	No	No	Delayed	Vein	Thoracodorsal	No	Yes	No
6	Free TRAM	Salvage	37	Yes	No	Immediate	Vein	Thoracodorsal	Yes	No	No
7	Free TRAM	Salvage	53	No	No	Delayed	Artery	Thoracodorsal	No	Yes	Yes
8	Free TRAM	Failure	52	No	No	Immediate	Vein	Thoracodorsal	No	Yes	No
9	DIEP	Salvage	40	No	No	Immediate	Vein	Internal Mammary	No	Yes	Yes
10	Free TRAM	Failure	47	No	No	Delayed	Vein	Internal Mammary	No	Yes	No
11	DIEP	Failure	51	No	No	Immediate	Vein	Thoracodorsal	Yes	No	Yes
12	Free TRAM	Salvage	44	No	No	Immediate	Artery	Thoracodorsal	No	Yes	No
13	DIEP	Salvage	53	No	No	Immediate	Vein	Thoracodorsal	Yes	No	No
14	DIEP	Salvage	39	No	No	Immediate	Vein	Thoracodorsal	No	No	No
15	Free TRAM	Salvage	50	No	No	Immediate	Vein	Thoracodorsal	Yes	No	No
16	SGAP	Salvage	50	No	No	Delayed	Vein	Internal Mammary	No	No	No
17	DIEP	Salvage	35	No	No	Immediate	Vein	Thoracodorsal	No	No	No
18	SGAP	Failure	36	No	No	Immediate	Vein	Internal Mammary	No	No	No
19	Free TRAM	Failure	33	No	No	Immediate	Artery	Thoracodorsal	No	No	No
20	Free TRAM	Failure	54	No	No	Delayed	Vein	Internal Mammary	Yes	No	Yes

TRAM, transverse rectus abdominis musculocutaneous; DIEP, deep inferior epigastric perforator; SGAP, superior gluteal artery perforator; ALND, axillary lymph node dissection; XRT, radiation therapy.

individual significant associations ($p < 0.001$, and $p < 0.03$) with the response in the presence of other variables.

The results of the exact logistic regression model including flap necrosis as the response variable and venous occlusion, delayed reconstruction, and hematoma (the variables that had pairwise significant associations with the flap necrosis based on the Fisher's exact test) indicated that although the joint association of these variables was significant ($p < 0.0001$), only venous occlusion had an individual significant ($p < 0.001$) association with the response in the presence of the other two variables.

Discussion

Flap failure following microvascular reconstruction of the breast is a devastating complication. The literature contains a plethora of information regarding techniques and outcomes after microvascular reconstruction[1–6]; however, there is a paucity of information regarding mechanisms of flap failure.[15,16,18] Although factors that might increase the risk of anastomotic and flap failure have been identified, it remains unclear as to what factors differentiate between success and failure. Those factors that may increase the risk of failure can be divided into two groups: those that are within the control of the surgeon and those that are not. Factors that can be controlled by the surgeon are ultimately related to meticulous technique, knowledge of the relevant anatomy, and attention to detail. In 1994, Khouri stated, "The difference between success and failure in free flap surgery rests upon a multitude of minute details. There is no cookbook or quick-fix recipe; the entire operation must be flawlessly executed with no room for

TABLE V

Probabilities of Significance of Associations between Factors

Factor	Return to Operating Room	Flap Failure
Age	0.99	0.94
Tobacco use	0.49	0.61
Diabetes mellitus	0.99	0.99
Delayed reconstruction	0.01	0.028
Thoracodorsal	0.344	0.175
Internal mammary	0.332	0.156
Previous LND	0.06	0.217
Previous XRT	0.06	0.268
Hematoma	0.001	0.024
Venous occlusion	0.001	0.01

LND, lymph node dissection; XRT, radiation therapy.

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error."[16] There are other factors, however, that cannot be controlled by the surgeon. These factors include patients' age, previous radiation therapy, previous axillary lymph node dissection, delayed reconstruction, scar, postoperative hematoma, and the effects of diabetes mellitus and tobacco use. It was the purpose of this study to evaluate these factors and determine whether there was an association with anastomotic and flap failure.

In selecting the factors associated with anastomotic failure for this study, it became evident that all were ultimately related to the quality of the recipient and donor vessels. Although the authors recognize that there is an association between obesity and flap failure, obesity was not included as a candidate factor in this study because obesity is related to patient selection rather than the quality of recipient vessels. Chang et al.[21] have demonstrated that flap failure is increased in obese and overweight women ($p < 0.05$) when compared with normal weight women (3.2 percent versus 1.9 percent versus 0 percent, respectively). The factors that were selected for this analysis have all been previously analyzed, though usually one at a time. To the best of our knowledge, however, evaluation of all these factors and their impact on a specific endpoint (anastomotic and flap failure) has not been performed previously for microsurgical reconstruction of the breast.

Review of previous studies has generated support and provided the basis for this study. Advanced patient age and its relationship to microvascular success have been evaluated in two recent studies. Lipa et al.[22] have demonstrated a flap failure rate of 1.7 percent (one of 58 women) following free TRAM reconstruction in women over 65 years of age. Girotto et al.[23] have demonstrated 100 percent flap survival following reconstruction in seven women with either a free TRAM or DIEP flap in women over 65 years of age. No additional morbidity was related to advanced patient age in these two studies. Serletti et al.[24] have demonstrated that it is the American Society of Anesthesiologists physical status of the patient and length of the operation that are the significant predictors of postoperative morbidity.

The microangiopathic alterations associated with diabetes mellitus have been extensively studied in both experimental and clinical studies. Experimental studies using rats have demonstrated that the degree of intimal repair and endothelialization is lower in poorly controlled diabetics and can lead to anastomotic failure.[25] When glucose levels are well controlled, however, patency of the anastomosis is less affected.[26] Indeed, clinical studies have demonstrated that patients with diabetes mellitus are not at increased risk for flap failure, abnormal healing of the anastomosis, or intolerance to an ischemic challenge as long as normoglycemia is maintained.[27,28] Khouri et al.,[15] in a prospective study of microvascular procedures that included breast reconstruction, reported no increase in anastomotic or flap failure in patients with diabetes mellitus, advanced age, or with a history of tobacco use.

The vascular manifestations associated with tobacco use are well known.[29–31] Some of the alterations that can occur include decreased endothelial synthesis of nitric oxide that impairs endothelium-dependent vasodilation of arteries, development of atherosclerosis, and increased plasma fibrinogen levels that potentiate vascular thrombosis through platelet activation.[32,33] Clinical studies evaluating the effects of tobacco use on a microvascular anastomosis following free TRAM reconstruction have not demonstrated additional morbidity, however. Chang et al.[34] reported that the incidence of vessel thrombosis and flap loss was comparable to that observed in women who did not use tobacco. Padubidri et al.[35] have demonstrated that the incidence of total flap necrosis did not differ among smokers, exsmokers, and nonsmokers (2.6 percent versus 4.3 percent versus 1 percent, respectively). The authors did not distinguish between the free TRAM and the pedicle TRAM in their study.

The effect of radiation on arteries and veins has been well documented. Perivascular fibrosis, endothelial damage, and microvascular occlusion can impair the quality of recipient vessels.[36–39] Recent studies have elucidated the anatomic and physiological changes on arteries and veins that are associated with radiation. Schultze-Mosgau et al.[39] demonstrated that the histological changes following radiation were dose-dependent. After a dose of 60 to 70 Gy, the histologic changes included intimal dehiscence, hyalinosis, and a decreased ratio of the media to total vessel area. These changes were observed in the artery but not in the vein. When no radiation was administered or when the radiation dose was 40 to 50 Gy, these changes were not observed. Beckman et al.[36] demonstrated that external beam radiation impaired endothelial-dependent vasodilation of

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arteries that might contribute to the development of arterial occlusive disease. The clinical significance of this phenomenon may be related to slow recovery from vasospasm that can lead to arterial thrombosis.

The selection of recipient vessels for microvascular breast reconstruction has been well studied. The vessels that are most commonly used include the internal mammary and thoracodorsal artery and vein. Anatomical studies of the internal mammary vessels at the level of the fourth rib have demonstrated a diameter of 0.99 to 2.55 mm for the artery and 0.64 to 4.45 mm for the vein.[40,41] The diameter of the thoracodorsal vessels ranges from 1.5 to 3.0 mm for the artery and 2.5 to 4.5 mm for the vein.[41,42] Clark et al.[43] reported that the diameter of the internal mammary vein became unsuitable for microvascular anastomosis below the level of the fourth rib. Lorenzetti et al.[44,45] studied the blood flow rate of the inferior epigastric, internal mammary, and thoracodorsal arteries and demonstrated flow rates of 11 ml/minute (range, 5 to 17 ml/minute), 25 ml/minute (range, 15 to 35 ml/minute), and 5 ml/minute (range, 2 to 8 ml/minute), respectively. The conclusions from this study were that either vessel was capable of adequate inflow to the flap and that blood flow in the flap was independent of the flow rate of the recipient artery. Clinical trials comparing the efficacy of the internal mammary and thoracodorsal vessels have been useful. In a recent prospective study of 100 patients, Moran et al.[46] reported that either vessel was suitable for microvascular anastomosis. However, the rate of conversion from the initial recipient vessel to an alternate vessel was 12.5 percent for the internal mammary and 7 percent for the thoracodorsal. Numerous studies have demonstrated that the success rates using the internal mammary or thoracodorsal vessels range from 95 to 99 percent.[8,47,48]

The results of our study demonstrate that venous occlusion was responsible for return to the operating room and flap necrosis in the majority of cases. The two factors that were associated most significantly with both anastomotic and flap failure were delayed reconstruction and postoperative hematoma. A weak association was detected between return to the operating room with previous axillary lymph node dissection and previous radiation therapy. No association was detected between patient age, tobacco use, choice of recipient vessel, and diabetes mellitus. The importance of delayed reconstruction is most likely related to its frequent association with previous axillary lymph node dissection and/or radiation therapy resulting in perivascular fibrosis. This is more commonly observed with the thoracodorsal artery and vein. In fact, the results of this study have demonstrated that anastomotic and flap failure occurred most often in the delayed setting in which the thoracodorsal vessels were used.

The significant associations between hematoma with anastomotic and flap failure were surprising. The most likely explanation may be that a hematoma compresses not only the vascular pedicle but also the flap itself, resulting in thrombosis of the microvasculature. The deleterious effect of a hematoma is exacerbated in the delayed setting because the flap is inset within a relatively confined space. We observed extensive thrombosis both in the vascular pedicle and in the flap itself with hematoma volumes ranging from 100 to 150 cc. Although the exact source of the hematoma was found in only one woman, a logical explanation is available. In the setting of venous thrombosis, the flap becomes hypertensive and the blood vessels that were previously coagulated begin to bleed resulting in a hematoma.

Based on these results, our algorithm for microvascular breast reconstruction has been refined. Although advanced patient age, tobacco use, and diabetes mellitus do not appear to affect anastomotic and flap success, women are advised to stop smoking tobacco for 2 weeks before surgery and to maintain glycemic control. The timing of the reconstruction is an important aspect that can affect the quality of the recipient vessels. Although the selection of vessels did not influence the outcome of microvascular reconstruction in this study, we believe that this factor may affect anastomotic success in some cases. Early in our experience, the thoracodorsal artery and vein were used for all immediate and delayed reconstructions. In the delayed setting, in which a previous axillary lymph node dissection had been performed, perivascular fibrosis was found to occasionally compromise the quality of the recipient vessels. This was further aggravated in the presence of radiation therapy. Of the first three flap failures in this study, two followed delayed reconstruction in which an axillary lymph node dissection had been performed (Table IV). Our current vessel of choice for delayed reconstruc-

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tions is the internal mammary artery and vein because these vessels are of relatively large caliber, have excellent inflow and outflow, and tolerate radiation. In addition, obstruction of flow resulting from pedicle malposition has not been observed.

Our algorithm for salvaging the flap following anastomotic failure has also been modified and refined. The decision to return to the operating room is based on evidence or suspicion of vascular compromise. Women are transported to the operating room usually within 30 minutes from the time of recognition. A heparin bolus is administered to prevent progression of the clot. The anastomosis and the chest wall are thoroughly inspected. When a hematoma is identified, hemostasis is obtained using clips or sutures. In only one of the six patients from this study with a postoperative hematoma was an active bleeding vessel found. Thrombosis of the artery and/or vein is managed by dividing the vessels at the anastomosis and inspecting the vessels for red or white clot representing blood or platelets, respectively. The technique of reestablishing flow is described in the Patients and Methods section. After restoration of flow, two new drains are placed along the axilla and the inferior border of the breast. Women are maintained on dextran 40 at 30 cc per hour. Heparin infusion is not maintained unless there is a problem with thrombosis intraoperatively.

CONCLUSIONS

The success of the anastomosis and survival of the flap seems to depend on two sets of factors. Factors that can be controlled by the surgeon are ultimately related to proper patient selection, knowledge of the relevant anatomy, an understanding of flap physiology, and meticulous technique. Factors that are outside the control of the surgeon include advanced age, comorbidities, prior axillary lymph node dissection, and prior radiation therapy. Recognition of these two variables facilitates understanding of the factors that constitute the difference between flap failure and flap success.

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