

# Closer to an Understanding of Fate: The Role of Vascular Complications in Free Flap Breast Reconstruction

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**Background:** Flap loss in autologous breast reconstruction is almost invariably a result of a vascular event; however, not all events portend the same fate. The purpose of this study was to determine whether intraoperative vascular complications predict subsequent postoperative vascular thrombosis and flap loss.

**Methods:** This was a retrospective review of all free flaps performed between 2005 and 2010 in the University of Pennsylvania Health System for breast reconstruction. Details of all vascular thromboses and intraoperative technical difficulties were recorded. Flaps with a routine intraoperative course were compared with those with an intraoperative complication.

**Results:** Overall, 1173 free flaps were performed in 804 patients. In regression analysis, an intraoperative vascular complication was the only independent predictor of a subsequent delayed vascular complication (odds ratio, 3.11; 95 percent confidence interval, 1.25 to 7.73). In subanalysis, intraoperative arterial thrombosis was not associated with a subsequent delayed arterial thrombosis; however, intraoperative technical difficulties were associated with increased delayed arterial thrombosis (1.0 percent versus 4.2 percent,  $p = 0.05$ ) and partial flap loss (0.6 percent versus 4.2 percent,  $p = 0.02$ ). There was a trend toward increased delayed venous thromboses following intraoperative venous thromboses (1.1 percent versus 16.7 percent,  $p = 0.07$ ). In aggregate, there was a higher rate of complete flap loss following any intraoperative vascular complication (0.9 percent versus 3.5 percent,  $p = 0.04$ ).

**Conclusions:** In free flap breast reconstruction, an intraoperative vascular problem leads to increased risk of a subsequent postoperative vascular complication and flap loss. Postoperative vascular complications do not appear to be overtly affected by specific surgical intervention or choice of anticoagulation in the setting of a preceding intraoperative problem. (*Plast. Reconstr. Surg.* 128: 835, 2011.)

**CLINICAL QUESTION/LEVEL OF EVIDENCE:** Risk, III.

**B**reast cancer continues to be a devastating disease worldwide, affecting roughly one in every eight women in their lifetime.<sup>1</sup> Reconstruction of the breast mound with tissue expanders and implants continues to be the most common technique used following mastectomy; however, autologous reconstruction offers an excellent, more natural option that many women find appealing.<sup>2</sup> Although free tissue transfer for breast reconstruction over the past 20 years has

become increasingly popular and techniques have been refined, there remains ample room for improvement. The first step in achieving improved success is a complete understanding of the problem at hand.

Many studies have examined the role of comorbid disease and external contributors to poor outcomes such as vascular complications, wound complication, and flap loss. Although obesity has fairly universally been associated with wound healing problems, few if any studies have been able to identify specific risk factors for postoperative

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thrombosis and flap loss. Overall, complete or partial flap loss rates following free flap breast reconstruction range from 1.5 to 5 percent, with published postoperative vascular complications running on the order of 0.6 to 0.8 percent for arterial thromboses and 1.5 to 2.3 percent for venous thromboses.<sup>3-6</sup> No studies to date have attempted to establish a relationship between intraoperative vascular complications and subsequent postoperative vascular thrombosis and flap loss. The purpose of this study was to further study the fate of the flap that intraoperatively behaves in a different manner compared with the routine one and to determine whether a specific type of corrective measure or anticoagulation plays a role in determining outcomes.

### PATIENTS AND METHODS

This was a retrospective review of all free flaps performed within the University of Pennsylvania Health System between April of 2005 and January of 2010 by the senior authors (J.M.S., L.C.W., and S.J.K.). This study was conducted with prior institutional review board approval. Data were collected by scrutinizing the medical records and operative reports of all patients who had undergone free flap breast reconstruction during that time. Attention was given to patient characteristics that the general medical literature would suggest might predispose to vascular complications such as age, diabetes, obesity (body mass index >30), hypertension, coronary artery disease, peripheral vascular disease, and smoking.<sup>7,8</sup> Information was also gathered about previous irradiation or chemotherapy, and type, timing, and side of reconstruction. As one might expect a higher complication rate in junior surgeons, we also distinguished junior surgeons from the most senior author (J.M.S.). Lastly, details of the operation itself and any untoward intraoperative or postoperative problems were recorded. Intraoperative problems included arterial or venous thromboses and technical difficulties not routinely performed in a standard approach. Technical difficulties were defined as double venous drainage, complete revision of the arterial or venous anastomosis, lack of usability of the initial intended recipient, or additional dissection to reach a healthy recipient target. These technical difficulties were those that could be quantified in a retrospective review. Items such as back-walling, intimal injury, rescue, or replacement stitches were not recorded because these are not typically documented in the operative report. Resident or fellow involvement was not studied as, retrospectively, this is hard to

quantify. Postoperative vascular complications were recorded, including arterial thrombosis, venous thrombosis, and venous congestion.

The primary purpose of this study was to determine the effects of intraoperative complications on the fate of any given flap. To this end, we compared all flaps that had a routine intraoperative course to those with an intraoperative complication. The baseline characteristics of the two study groups were compared to ensure similarity using chi-square analysis. The Fisher's exact test was used in cases where the expected frequency was less than or equal to 5. Statistical significance was considered for a value of  $p \leq 0.05$ . For the purpose of analyzing flap type, transverse upper gracilis and gluteal flaps were lumped together as "other."

After ensuring similarity between the two treatment groups, chi-square and Fisher's exact tests were used to determine which variables were associated with postoperative vascular complications. As vascular complications are rare phenomena, the overall initial analysis was performed by looking at flaps with any intraoperative or any postoperative complication (rather than specific subtype) in an effort to increase overall power. Multiple binary regression analyses were used to control for variables unequally distributed between treatment groups and to determine which, if any, variables were independently associated with the outcome of interest (postoperative vascular complications).

In the subset of flaps that suffered an intraoperative complication, we were interested to know whether a certain type of surgical intervention such as an interposition graft, anastomotic revision, or double venous drainage could be identified as a major contributor to postoperative vascular complications. Similarly, data were collected in this subset on anticoagulant use such as intraoperative heparin bolus, postoperative heparin drip, or aspirin therapy to determine whether any seemed to decrease overall risk. Chi-square and Fisher's exact tests once again were used for analysis.

### RESULTS

#### Baseline Characteristics

The baseline characteristics of the flaps with a routine intraoperative course were compared with those flaps that suffered any intraoperative problem in an effort to ensure similarity of the study groups (Table 1). Age 65 years or older, preoperative radiation therapy, delayed reconstruction, left side for reconstruction, and the use of the

**Table 1. Baseline Characteristics of the Patient Population\***

Characteristics	Routine Intraoperative Course (%)	Intraoperative Complication (%)	<i>p</i>
No. of patients	1060	113	
Risk factor			
Age ≥65 yr	51 (4.8)	11 (9.7)	0.03
Diabetes mellitus	70 (6.6)	6 (5.3)	0.60
Obesity	354 (33.4)	34 (30.1)	0.48
Hypertension	261 (24.6)	35 (31.0)	0.14
Coronary artery disease	13 (1.2)	3 (2.7)	0.19
Peripheral vascular disease	11 (1.0)	0 (0.0)	0.61
Dyslipidemia	176 (16.6)	26 (23.0)	0.09
Current smoking	147 (13.9)	18 (15.9)	0.55
Preoperative radiation therapy	215 (20.3)	38 (33.6)	<0.01
Preoperative chemotherapy	426 (40.2)	50 (44.2)	0.40
Delayed reconstruction	198 (18.7)	32 (28.3)	0.01
Initial target (IMA)	820 (77.4)	100 (88.5)	<0.01
Side (left)	517 (48.8)	66 (58.4)	0.05
Junior surgeon	413 (39.0)	24 (21.2)	<0.01

IMA, internal mammary artery.

\*Percentages were compared between flaps with any intraoperative problem versus those without to ensure similarity between groups.

internal mammary artery as a recipient vessel were all more common in the flaps with an intraoperative vascular complication. Intraoperative complications were less common in the junior surgeon group. Diabetes, hypertension, coronary artery disease, peripheral vascular disease, dyslipidemia, smoking, and chemotherapy were all equally distributed among groups.

Flap type was unequally distributed among groups in that there was a higher percentage of superficial inferior epigastric artery flaps (5.8 percent versus 11.5 percent,  $p = 0.02$ ) performed in the group with intraoperative complications. The use of a transverse rectus abdominis musculocutaneous, deep inferior epigastric perforator, or “other” was equal between groups (Table 2).

### Variable versus Outcome

The primary outcome of interest was a flap with any type of postoperative vascular complica-

tion. Consequently, the variables were next screened to determine which, if any, were associated with a higher rate of having any type of postoperative vascular complication (Table 3). Of all of the variables analyzed, only a preceding intraoperative complication was associated with a subsequent postoperative vascular complication (2.3 percent versus 6.2 percent,  $p = 0.01$ ). Age, diabetes mellitus, obesity, hypertension, coronary artery disease, peripheral vascular disease, smoking, irradiation, chemotherapy, timing, left side of reconstruction, recipient vessel, and junior surgeon were not associated with a higher rate of postoperative vascular complications.

Each flap type was analyzed to determine whether there was an association with a higher rate of postoperative vascular complications. However, no individual flap type was found to be significant (Table 4).

### Regression Analysis

To control for unequally distributed variables (i.e., age, radiation therapy, delayed timing, use of the internal mammary artery, left side of reconstruction, junior surgeon, and superficial inferior epigastric artery flap type), these were run along with intraoperative complications through binary logistic regression analyses to determine whether intraoperative complications would prove to be an independent risk factor for a postoperative complication (Table 5). Intraoperative complications indeed proved to be the only risk factor for a subsequent postoperative vascular complication (odds ratio, 3.11; 95 percent confidence interval, 1.25 to 7.73).

**Table 2. Baseline Flap Type Characteristics of the Patient Population\***

Characteristics	Routine Intraoperative Course (%)	Intraoperative Complication (%)	<i>p</i>
No. of patients	1060	113	
Flap type			
Free TRAM	734 (69.2)	71 (62.8)	0.16
DIEP	238 (22.5)	23 (20.4)	0.61
SIEA	62 (5.8)	13 (11.5)	0.02
Other	26 (2.5)	6 (5.3)	0.12

TRAM, transverse rectus abdominis musculocutaneous; DIEP, deep inferior epigastric perforator; SIEA, superficial inferior epigastric artery.

\*SIEA flaps were more common in the intraoperative complication study group.

**Table 3. Flaps with Any Postoperative Vascular Complication in the Absence or Presence of Each Covariate\***

Covariate	Absent		Present		OR	CI	<i>p</i>
	No. of Flaps	Flaps with Postoperative Complication (%)	No. of Flaps	Flaps with Postoperative Complication (%)			
Age ≥65 yr	1111	30 (2.7)	62	1 (1.6)	0.59	0.08–4.40	1.0
Diabetes mellitus	1097	27 (2.5)	76	4 (5.3)	2.20	0.75–6.46	0.14
Obesity	785	17 (2.2)	388	14 (3.6)	1.69	0.83–3.47	0.15
Hypertension	877	23 (2.6)	296	8 (2.7)	1.03	0.46–2.33	1.0
Coronary artery disease	1157	31 (2.7)	16	0 (0.0)	NA	NA	1.0
Peripheral vascular disease	1162	31 (2.7)	11	0 (0.0)	NA	NA	1.0
Dyslipidemia	971	26 (2.7)	202	5 (2.5)	0.92	0.35–2.43	0.87
Current smoking	1008	25 (2.5)	165	6 (3.6)	1.48	0.60–3.67	0.39
Preoperative chemotherapy	697	15 (2.2)	476	16 (3.4)	1.58	0.77–3.23	0.21
Preoperative XRT	920	21 (2.3)	253	10 (4.0)	1.76	0.82–3.79	0.14
Delayed reconstruction	943	26 (2.8)	230	5 (2.2)	0.78	0.30–2.06	0.62
Initial target (IMA)	253	9 (3.6)	920	22 (2.4)	0.67	0.30–1.46	0.31
Intraoperative vascular complication	1060	24 (2.3)	113	7 (6.2)	2.85	1.20–6.77	0.01
Side (left)	590	12 (2.0)	583	19 (3.3)	1.62	0.78–3.37	0.19
Junior surgeon	736	19 (2.6)	437	12 (2.7)	1.06	0.51–2.22	0.87

OR, odds ratio; CI, confidence interval; XRT, radiation therapy; IMA, internal mammary artery; NA, not applicable.  
 \*These data were used to calculate the odds ratio of a flap having a postoperative vascular complication in the setting of the presence of each covariate.

**Table 4. Flaps with Any Postoperative Vascular Complication per Type of Reconstruction\***

Flap	No		Yes		OR	95% CI	<i>p</i>
	No. of Flaps	Flaps with a Postoperative Complication (%)	No. of Flaps	Flaps with a Postoperative Complication (%)			
Free TRAM	368	13 (3.5)	805	18 (2.2)	0.62	0.30–1.29	0.20
DIEP	912	22 (2.4)	261	9 (3.4)	1.44	0.66–3.18	0.36
SIEA	1098	29 (2.6)	75	2 (2.7)	1.01	0.24–4.32	1.00
Other	1141	29 (2.5)	32	2 (6.3)	2.56	0.58–11.21	0.21

OR, odds ratio; CI, confidence interval; TRAM, transverse rectus abdominis musculocutaneous; DIEP, deep inferior epigastric perforator; SIEA, superficial inferior epigastric artery.  
 \*These data were used to calculate the odds ratio of a specified type of flap having a postoperative vascular complication.

**Table 5. Final Logistic Regression Model\***

	OR	95% CI	<i>p</i>
Age ≥65 yr	0.42	0.06–3.17	0.40
Preoperative XRT	2.22	0.94–5.25	0.07
Delayed reconstruction	0.64	0.22–1.91	0.43
Initial target (IMA)	0.48	0.20–1.18	0.11
SIEA	0.80	0.18–3.53	0.77
Intraoperative vascular complication	3.11	1.25–7.73	0.01
Side (left)	1.55	0.74–3.24	0.25
Junior surgeon	1.48	0.65–3.39	0.35

OR, odds ratio; CI, confidence interval; XRT, radiation therapy; IMA, internal mammary artery; SIEA, superficial inferior epigastric artery.  
 \*Items included were those covariables either unequally distributed among study groups, or those associated with the outcome (flaps with a postoperative vascular complication).

**Postoperative Arterial Thrombosis**

Once intraoperative vascular complications were identified as an independent risk factor for postoperative complications, further analyses were performed on each individual vascular prob-

lem, starting with postoperative arterial thrombosis (Table 6). Intraoperative arterial thrombosis was not associated with a subsequent postoperative arterial thrombosis. There was a trend toward increased risk of a postoperative arterial thrombosis in the setting of a preceding intraoperative venous thrombosis (1.1 percent versus 16.7 percent, *p* = 0.07). Intraoperative venous thrombosis is very rare, which limits the significance of this data point. Interestingly, technical difficulties in the operating room are associated with a higher rate of postoperative arterial thrombosis (1.0 percent versus 4.2 percent, *p* = 0.05). Considered together, flaps with any intraoperative vascular problem were associated with a higher rate of postoperative arterial thrombosis (0.8 percent versus 4.4 percent, *p* < 0.01).

**Postoperative Venous Thrombosis**

Neither intraoperative arterial thrombosis nor technical difficulty was associated with a subse-

**Table 6. Flaps with a Postoperative Arterial Thrombosis as a Function of the Absence or Presence of Each Type of Intraoperative Problem**

	Routine Intraoperative Course		Intraoperative Problem		<i>p</i>
	No. of Flaps	Flaps with Postoperative Arterial Thrombosis (%)	No. of Flaps	Flaps with Postoperative Arterial Thrombosis (%)	
Intraoperative arterial thrombosis	1135	13 (1.1)	38	1 (2.6)	0.37
Intraoperative venous thrombosis	1167	13 (1.1)	6	1 (16.7)	0.07
Intraoperative technical difficulty	1102	11 (1.0)	71	3 (4.2)	0.05
Any intraoperative problem	1060	9 (0.8)	113	5 (4.4)	<0.01

quent postoperative venous thrombosis (Table 7). There is a trend toward increased postoperative venous thrombosis following an intraoperative venous thrombosis (1.1 percent versus 16.7 percent, *p* = 0.07); however, these data again are difficult to interpret given the small number of cases. Considered together, flaps with any intraoperative vascular problem were associated with a higher rate of postoperative venous thrombosis (0.9 percent versus 3.5 percent, *p* = 0.04).

**Technical Difficulties**

As technical difficulties (aside from frank thrombosis) were associated with a subsequent postoperative arterial thrombosis, a closer evaluation of the specific causes was undertaken. Overall, there were three postoperative arterial thromboses in cases where a technical difficulty occurred in the operating room. One followed a revision of the venous anastomosis and two occurred in cases where the initial recipient target had to be aborted and changed to the thoracodorsal because of inadequacy of the internal mammary vessels. As a result, there was no clear association with the type of technical problem and subsequent postoperative arterial thrombosis.

**Flap Loss**

Neither intraoperative arterial nor venous thrombosis was independently associated with partial (Table 8) or complete flap loss (Table 9). Interestingly, intraoperative technical difficulties

were associated with a higher partial flap loss rate (0.6 percent versus 4.2 percent, *p* = 0.02). As a whole, a flap with any intraoperative problem was associated with a higher complete flap loss rate (0.9 percent versus 3.5 percent, *p* = 0.04) and trended toward significance for partial flap loss (0.7 percent versus 2.7 percent, *p* = 0.06). Overall, delayed venous thrombosis was salvaged from complete loss 50 percent of the time but was all or none—never did it result in partial flap loss. Delayed arterial thrombosis was salvaged from complete loss in 64.3 percent of cases; however, the flap was partially lost in an additional 21.4 percent, leading to an overall rate of complete salvage of 42.9 percent.

**Intervention Specific to Intraoperative Vascular Complications**

Of the 113 flaps with any type of intraoperative complication, 100 had available detailed inpatient medical records for review to gain further information from the anesthesia and medication documentation. Surgical intervention following any intraoperative complication, from most common to least common, included arterial revision, venous revision, change of recipient vessel, additional venous drainage, and interposition graft placement (Fig. 1). The use of anticoagulation varied both intraoperatively and postoperatively. Modalities included subcutaneous heparin, aspirin, intraoperative heparin bolus, postoperative heparin drip, and very rarely a thrombolytic

**Table 7. Flaps with a Postoperative Venous Thrombosis as a Function of the Absence or Presence of Each Type of Intraoperative Problem**

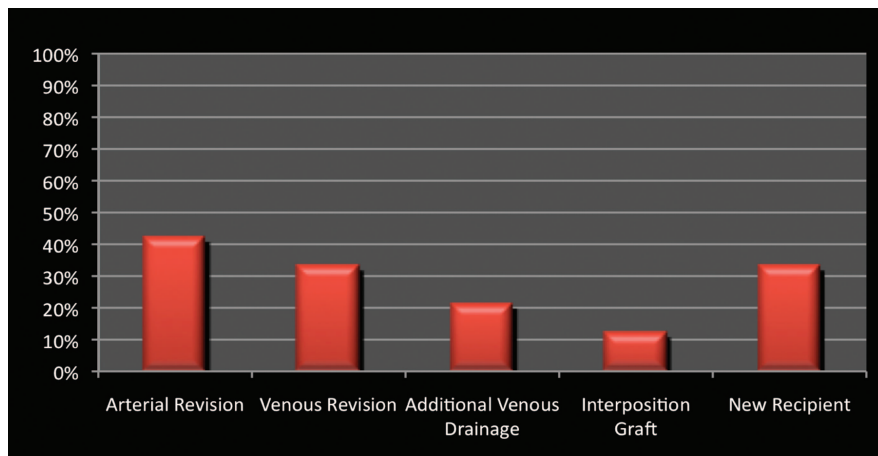
	Routine Intraoperative Course		Intraoperative Problem		<i>p</i>
	No. of Flaps	Flaps with Postoperative Venous Thrombosis (%)	No. of Flaps	Flaps with Postoperative Venous Thrombosis (%)	
Intraoperative arterial thrombosis	1135	13 (1.1)	38	1 (2.6)	0.37
Intraoperative venous thrombosis	1167	13 (1.1)	6	1 (16.7)	0.07
Intraoperative technical difficulty	1102	12 (1.1)	71	2 (2.8)	0.21
Any intraoperative problem	1060	10 (0.9)	113	4 (3.5)	0.04

**Table 8. Partial Flap Loss in the Setting of the Absence or Presence of Each Type of Vascular Problem**

	No Vascular Problem		Vascular Problem		<i>p</i>
	No. of Flaps	Partial Flap Loss (%)	No. of Flaps	Partial Flap Loss (%)	
Intraoperative arterial thrombosis	1135	9 (0.8)	38	1 (2.6)	0.28
Intraoperative venous thrombosis	1167	10 (0.9)	6	0 (0.0)	1.0
Intraoperative technical difficulty	1102	7 (0.6)	71	3 (4.2)	0.02
Any intraoperative problem	1060	7 (0.7)	113	3 (2.7)	0.06
Postoperative arterial thrombosis	1159	7 (0.6)	14	3 (21.4)	<0.01
Postoperative venous thrombosis	1159	10 (0.9)	14	0 (0.0)	1.0
Any postoperative vascular problem	1142	7 (0.6)	31	3 (9.7)	<0.01

**Table 9. Total Flap Loss in the Setting of the Absence or Presence of Each Type of Vascular Problem**

	No Vascular Problem		Vascular Problem		<i>p</i>
	No. of Flaps	Total Flap Loss (%)	No. of Flaps	Total Flap Loss (%)	
Intraoperative arterial thrombosis	1135	13 (1.1)	38	1 (2.6)	0.37
Intraoperative venous thrombosis	1167	13 (1.1)	6	1 (16.7)	0.07
Intraoperative technical difficulty	1102	12 (1.1)	71	2 (2.8)	0.21
Any intraoperative problem	1060	10 (0.9)	113	4 (3.5)	0.04
Postoperative arterial thrombosis	1159	9 (0.8)	14	5 (35.7)	<0.01
Postoperative venous thrombosis	1159	7 (0.6)	14	7 (50.0)	<0.01
Any postoperative vascular problem	1142	3 (0.3)	31	11 (35.5)	<0.01



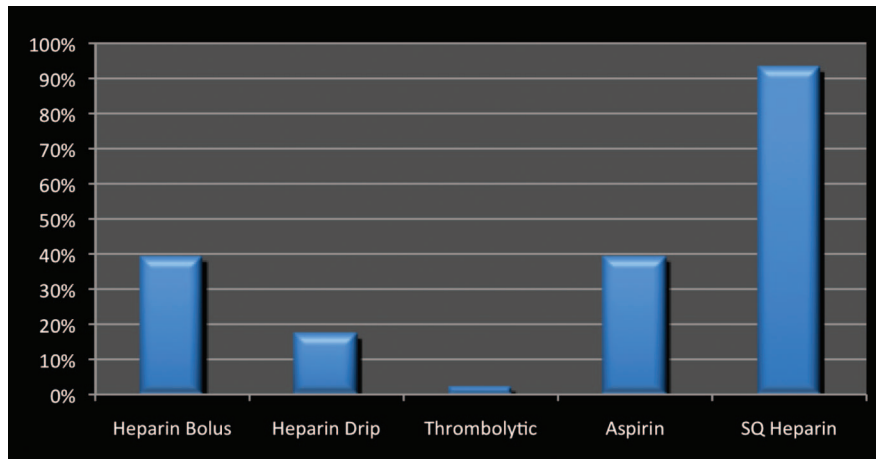
**Fig. 1.** Surgical maneuvers used at the time of initial reconstruction in flaps suffering an intraoperative vascular complication. Overall, multiple modalities are commonly used.

(Fig. 2). None of the specific surgical interventions or anticoagulation types was associated with a significantly different rate of postoperative vascular complications (Table 10).

### DISCUSSION

Vascular complications, given their rarity, are unfortunately difficult to study because of the lack of power. To begin our analysis, we looked at flaps with any postoperative vascular complication as a function of any intraoperative complication. We did this to maximize the power to detect a differ-

ence. For this analysis, any one flap either had a complication or did not; that is to say, we did not simply count the total number of complications. This was done to equally weigh each flap rather than give more weight to one flap with several complications. Through this analysis, we were able to show that a preceding intraoperative vascular complication is the only independent risk factor for a subsequent postoperative vascular problem of those variables studied. Overall, there is a roughly threefold increased risk. This follows intuition in that problems in the operating room are often in-



**Fig. 2.** The use of anticoagulation varies in patients suffering from an intraoperative vascular complication. Although subcutaneous heparin is nearly universal, an intraoperative heparin bolus and aspirin postoperatively are used fairly frequently.

**Table 10. Postoperative Complications as a Function of Type of Surgical Intervention Used or Anticoagulation Used in the Setting of an Intraoperative Complication (n = 100)**

Covariate	Absent		Present		OR	CI	p
	No. of Flaps	Flaps with a Postoperative Complication (%)	No. of Flaps	Flaps with a Postoperative Complication (%)			
Arterial revision	58	5 (8.6)	42	2 (4.2)	0.53	0.01–2.87	0.70
Venous revision	67	4 (6.0)	33	3 (9.1)	1.58	0.33–7.49	0.68
Additional venous drainage	79	4 (5.1)	21	3 (14.3)	3.13	0.64–15.22	0.16
Interposition graft	88	5 (5.7)	12	2 (16.7)	3.32	0.57–19.42	0.20
New recipient	67	5 (7.5)	33	2 (6.1)	0.80	0.15–4.36	1.0
Heparin bolus	61	3 (4.9)	39	4 (10.3)	2.21	0.47–10.46	0.43
Heparin drip	83	5 (6.0)	17	2 (11.8)	2.08	0.37–11.74	0.34
Thrombolytic	98	7 (7.1)	2	0 (0.0)	NA	NA	1.0
Aspirin	61	3 (4.9)	39	4 (10.3)	2.21	0.47–10.46	0.43
Subcutaneous heparin	6	0 (0.0)	94	7 (7.4)	NA	NA	1.0

OR, odds ratio; CI, confidence interval; NA, not applicable.

dicative of unusual circumstances or inherent problems with a given flap and recipient site. Unfortunately, the clinical significance of this finding is that although a surgeon may “successfully” overcome an intraoperative problem, the risk to this flap does not remain in the operating room while the patient is wheeled to the recovery room.

Although age, radiation therapy, delayed timing, use of the internal mammary artery, left side of reconstruction, and superficial inferior epigastric artery flap type were all more common in the group with an intraoperative vascular complication, these factors should not be considered independent risk factors for intraoperative complications, as the statistical approach was not designed to answer this question. When these variables are controlled for by regression analysis, they do not appear to contribute to the overall increased risk of postoperative vascular complications.

Intraoperative complications were less common in the junior surgeon group. This is an interesting finding that may be explained by one of two possibilities. First, there may be a difference in the detail in operative dictations between surgeons. Second, the more senior surgeon generally allows for more resident/fellow participation in the difficult portions of the procedure, knowing that any difficulties will be corrected by him personally. Either way, controlling for all variables in regression analysis and looking at finite documented postoperative vascular complications, we see no difference in postoperative vascular complications between surgeon groups.

In looking at specific types of intraoperative and postoperative vascular complications, the data become a little less clear, although there are several interesting pieces of information worth considering. Most importantly, an intraoperative ar-

terial thrombosis does not lead to increased risk of a postoperative arterial or venous thrombosis. When the arterial thrombosis is corrected, one can rest assured that the flap should behave similar to a routine free flap. As for intraoperative venous thromboses, there appears to be a trend in these data toward increased risk of postoperative arterial and venous thromboses. Although the absolute values greatly differ, the *p* value remains insignificant (0.07), a finding likely resultant from lack of power. Intraoperative venous thromboses are incredibly rare, occurring only 0.5 percent of the time, yet our results suggest that an intraoperative venous thrombosis increases the risk of a subsequent postoperative arterial or venous problem.

Our sample size did not lend enough power to determine what specific type of technical difficulties lead to increased rates of delayed arterial thrombosis and partial flap loss. Although this limits our ability to draw definitive conclusions, one explanation is that the risk is not simply caused by one particular problem. In all likelihood, risk is shared among inherent problems with the recipient vessel and the flap, and technical imperfections leading to the need for revision of an anastomosis. Clinically, some of these variables may be avoidable using impeccable technique, but other patient factors such as scar, intimal friability, and hypercoagulable state are likely not. In this series, three postoperative thromboses and one intraoperative thrombosis occurred in patients with a history of another pathologic clotting problem such as a deep venous thrombosis or pulmonary embolism, or documented clotting disorder. Although an undocumented hypercoagulable state may be more common, overall a documented problem made up a small percentage.

Overall flap loss remains rare; however, its occurrence is catastrophic to surgeon and patient alike. In this series, postoperative venous thrombosis was able to be completely salvaged 50 percent of the time with take-back to the operating room for treatment. Delayed arterial thrombosis was salvaged 42.9 percent of the time by take-back to the operating room; however, an additional 21.4 percent resulted in partial flap loss requiring surgical débridement. Thus, delayed venous thrombosis appears to be an all-or-nothing salvage attempt, whereas delayed arterial thrombosis results in a wider spectrum of salvageability.

We attempted to determine whether any specific surgical intervention following an intraoperative complication was statistically associated with a subsequent delayed vascular problem. For this

analysis, the treatment strategies used in any given flap were studied regardless of whether the complication was an arterial thrombosis, venous thrombosis, or technical difficulty. This was done to increase the number of cases of each surgical maneuver (i.e., arterial revision) to determine whether the technique itself was associated with a delayed problem. There were no statistical associations of each maneuver with a postoperative vascular complication relative to one another. There are two possible explanations for this finding. First, the number of cases is simply not large enough to generate sufficient power to answer the question. Alternatively, the overall increased risk of a subsequent delayed vascular problem is distributed among the different types of intraoperative problems and the subsequent surgical intervention for correction. As we do believe the overall finding that an intraoperative problem does increase the risk of a subsequent postoperative problem, we find the second explanation to be more likely—no single event type or surgical treatment holds a greater portion of the blame.

The use of anticoagulation following free flap reconstruction remains an incredibly controversial topic, with many unanswered questions. The literature suggests that the use of heparin and aspirin in the postoperative period is not universal and lacks a standardized protocol, regardless of area of reconstruction.<sup>9</sup> Most recent literature suggests neither increased complications nor decreased thrombosis with the use of postoperative anticoagulation.<sup>10,11</sup> Chen et al. found a significantly increased risk of bleeding or hematoma with the use of intraoperative heparin, but also showed no significant benefit.<sup>12</sup> Even within our own institution, choice of anticoagulation appears to be dependent on surgeon preference, training, and experience. Although differing opinion certainly clouds our ability to answer the question, perhaps most importantly, our hands are tied scientifically and logistically by the rarity of delayed vascular complications and flap loss. We attempted to provide more data to the dilemma in this study, yet our conclusions admittedly leave us yearning for more answers. We studied the use of anticoagulation only in the subset of flaps where an intraoperative complication was encountered because, at our institution, this is the population in which we sometimes use intraoperative bolus heparin, a postoperative heparin drip, or aspirin therapy. These modalities are not generally used on a routine basis with uncomplicated flaps. The question we wanted to answer was: Do intraoperative complications that are treated more aggres-



sively with anticoagulation behave better postoperatively? The best we can answer with the small number of cases is that there is no overt complete protective effect. That is not to say there is no benefit at all, because in all likelihood the flaps treated with heparin or aspirin were more problematic to begin with. In fact, the postoperative vascular complication rate is higher in the groups treated with heparin or aspirin, though not statistically significantly so. Perhaps if those flaps had not been treated with anticoagulation they would have performed worse. In this subgroup of flaps with an intraoperative problem, there were only two hematomas, neither of which could be attributed to the use of anticoagulation. On a clinical level, we find no evidence to avoid the use of anticoagulation. Until such time as a multicenter prospective study attempts to address this controversy, the use of anticoagulation will likely remain divergent.

Clinically, what can we learn from these data? First, vascular problems encountered in the operating room unfortunately do not always end there despite the surgeon's best efforts. With proper identification and correction of an intraoperative problem, results remain excellent. Can we minimize the intraoperative complications to decrease the overall risk of a postoperative complication? One would hope that performing an anastomosis correctly the first time would decrease the risk; however, additional dissection and changing recipient vessel are likely not modifiable. Thus, the next clinical question becomes, When an intraoperative complication is encountered, can we decrease the risk? These data should lend confidence to the use of multiple corrective measures to accomplish a goal, as no one intervention was identified as problematic. Special attention should be given to flaps in the postoperative period if an intraoperative problem was encountered. Anticoagulation remains a controversial topic and, although it is not without risk, its use in certain circumstances such as thrombosis may be indicated.

### CONCLUSIONS

Although many questions remain on how to improve outcomes in free flap breast reconstruction, the foundation of knowledge has become stronger. The single risk factor identified for postoperative vascular complications is a vascular com-

plication in the operating room at the time of initial reconstruction. Although anticoagulation does not seem to be a silver bullet, recognizing this risk factor offers an initial step toward improving overall outcomes.

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