Abdominal Wall following Free TRAM or DIEP Flap Reconstruction: A Meta-Analysis and Critical Review

Li-Xing Man, M.D., M.Sc.
Jesse C. Selber, M.D., M.P.H.
Joseph M. Serletti, M.D.
Pittsburgh and Philadelphia, Pa.

Background: Numerous studies compare techniques for free flap breast reconstruction techniques, with no consensus regarding differences in complication rates. This study compared the risk of fat necrosis, partial flap loss, total flap loss, abdominal bulge, laxity, or weakness, and abdominal hernia after deep inferior epigastric perforator (DIEP) and free transverse rectus abdominis myocutaneous (TRAM) flap surgery for breast reconstruction.
Methods: A MEDLINE and manual search of English-language articles on DIEP and free TRAM flap surgery published up to April of 2007 yielded 338 citations. Two levels of screening identified 37 relevant studies. The Mantel-Haenszel fixed-effects and DerSimonian and Laird random-effects models were used to perform the meta-analysis.
Results: Six studies reporting both DIEP and free TRAM flap outcomes were used to estimate pooled relative risks of complications and confidence intervals. There was a twofold increase in the risk of fat necrosis (relative risk, 1.94; 95 percent CI, 1.28 to 2.93) and flap loss (relative risk, 2.05; 95 percent CI, 1.16 to 3.61) in DIEP patients compared with free TRAM patients. There was no difference in the risk for fat necrosis when the analysis was limited to studies using muscle-sparing free TRAM flaps (relative risk, 0.91; 95 percent CI, 0.47 to 1.78). DIEP patients had one-half the risk of abdominal bulge or hernia (relative risk, 0.49; 95 percent CI, 0.28 to 0.86). Sixteen studies reporting DIEP outcomes and 23 studies reporting free TRAM outcomes were used to estimate pooled complication rates. Pooled flap-related complication rates were higher in DIEP patients, whereas donor-site morbidity was higher in free TRAM patients.
Conclusion: This analysis suggests that the DIEP flap reduces abdominal morbidity but increases flap-related complications compared with the free TRAM flap in breast reconstruction. (*Plast. Reconstr. Surg.* 124: 752, 2009.)

In autogenous breast reconstruction, traditional thinking suggests a theoretical continuum along which reliability is increased at the expense of donor-site morbidity. The free transverse rectus abdominis myocutaneous (TRAM) flap occupies one end of this continuum, with extremely high reliability but possibly a higher incidence of abdominal hernia and bulge. The deep inferior epigastric perforator (DIEP) flap occupies the middle of this continuum, with seemingly lower reliability but also lower donor-site morbidity. The superficial inferior epigastric artery (SIEA) flap occupies the other extreme.

Recent literature, however, suggests there may not be a significant difference in abdominal wall morbidity between the DIEP and the muscle-sparing free TRAM flaps.[1,2] One possible explanation is that muscle-sparing techniques have evolved in sophistication to leave the vast majority of rectus muscle intact and thus potentially functional. The DIEP flap often requires tedious dissection of in-

From the Department of Otolaryngology, University of Pittsburgh School of Medicine, and Division of Plastic Surgery, University of Pennsylvania School of Medicine.
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tramuscular perforators, inadvertently disrupting some motor nerves and potentially causing functional impairment, particularly when perforators do not line up in the longitudinal axis of the muscle.[3] In fact, recent anatomical studies have revealed that the average perforator traverses the muscle a distance of 1.32 cm, requiring sacrifice of at least that width of muscle to complete the DIEP dissection.[4] This distance is often similar to the width of muscle harvested in a muscle-sparing free TRAM flap. For this reason, a well-executed muscle-sparing free TRAM flap that joins adjacent perforators within a very small cuff of muscle may cause no more harm to the long-term function of the rectus muscle and abdominal wall than a routine DIEP flap.

There are passionate enthusiasts on both sides of this argument, and a robust body of literature has grown out of the debate. Because of this wealth of existing data, meta-analysis becomes an extremely attractive approach to comparing outcomes. It allows us to summarize decades of research by pooling power from many individual studies.

PATIENTS AND METHODS

The objectives of this study were (1) to compare flap and donor-site complication rates between the DIEP and free TRAM flaps; (2) to summarize the rates of complications (i.e., fat necrosis; partial flap loss; total flap loss; abdominal wall bulge, laxity, or weakness; and abdominal wall hernia); and (3) to examine whether outcomes have improved over time.

Data Sources

A broad search of the English-language literature was performed using both computerized and manual components. The computerized search was performed using PubMed to query the MEDLINE database up to April of 2007 (cut-off date, April 25, 2007). The MEDLINE database was searched using the following search terms: "DIEP," "deep inferior epigastric," "free TRAM" or "free transverse rectus abdominis myocutaneous," and "breast" and "flap." Two manual strategies were used to retrieve additional studies. First, recently published articles that may not have been indexed on MEDLINE by the search cutoff date were identified by searching PubMed using the keywords for the prior 6 months with no other limits. Second, hand searching of bibliographies of original research reports and review articles was performed.

Study Selection

All studies were considered potentially eligible if they aimed to investigate complication rates in patients undergoing either DIEP or free TRAM flap surgery for breast reconstruction. Selection criteria were qualitatively predefined and required each included study to clearly describe study design, number of patients enrolled, and number of total flaps performed. Also, the included studies had to report complication rates or raw data that allowed for the calculation of complication rates for at least one of the following five complications: (1) fat necrosis; (2) partial flap loss; (3) total flap loss; (4) abdominal wall bulge, laxity, or weakness; and (5) abdominal wall hernia. Study selection was accomplished through two levels of study screening (Fig. 1). In the first level of screening, abstracts were reviewed for the following exclusion criteria: publication of abstracts only; case reports, letters, comments, and reviews; case series with nonconsecutive recruitment of patients; languages other than English; studies reporting novel or modifications of surgical techniques; animal or cadaveric studies; and physiologic or anatomical studies. Studies with fewer than 10 patients in a treatment group were excluded for the analysis of pooled complication rates, but studies comparing DIEP and TRAM flap treatment outcomes with fewer than 10 patients in a subgroup were eligible for inclusion for the first planned analysis.

Full articles were then retrieved for all studies that passed the first level of selection. Articles were read in full and further selected using the above inclusion and exclusion criteria. When there were multiple publications describing the same or overlapping series of patients, only the study with the most patients or flaps was selected to avoid the double counting of patients. Articles that passed both levels of selection were considered for each of the planned analyses.

Data Extraction

Data extraction was performed following guidelines outlined by the Meta-analysis Of Observational Studies in Epidemiology statement for reporting meta-analyses of observational studies.[5] Information from each included study was recorded using a standardized data extraction form: lead author; publication year; recruitment period; study type; study location; number of patients; number of flaps; number of unilateral flaps; number of bilateral flaps; average patient age or age

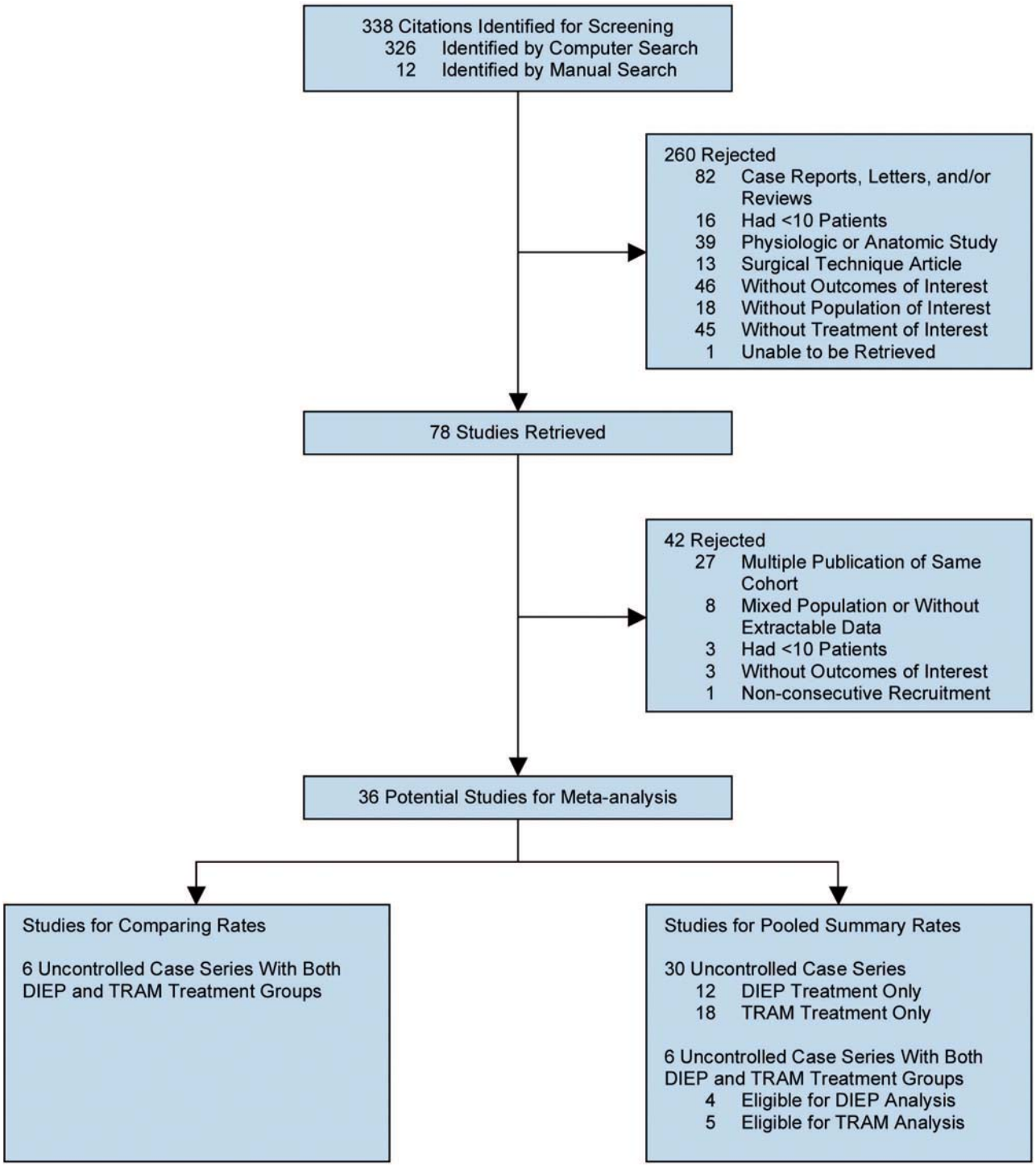

Fig. 1. Study attrition diagram.

range; follow-up time; percentage of immediate reconstructions; percentage of smokers; percentage of obese patients; percentage of patients who had previously received radiation therapy; percentage of patients in the study population with previous abdominal scars; number of flaps with fat necrosis; number of partial flap losses; number of total flap losses; number of patients with abdominal wall bulge, laxity, or weakness; and number of patients with an abdominal wall hernia. Results for subgroups were extracted as independent populations.

Statistical Analysis

Rates for fat necrosis, partial flap loss, and total flap loss were calculated based on the number of flaps performed in each series. Rates for abdominal complications were calculated based on the number of patients in each study. For the first planned analysis, rate ratios were used to estimate relative risks, and 95 percent confidence intervals were created using the original data. In the second planned analysis, standard errors were estimated based on the binomial distribution.[6] When there was no occurrence of an outcome in a specific study, the standard error was estimated by using the mean standard error from the other studies. For each of the planned analysis, the Mantel-Haenszel fixed-effects method was used by default to synthesize pooled estimates from the results of individual studies.[7,8] When a formal test for heterogeneity indicated that the individual studies were not homogeneous for an outcome, however, the DerSimonian and Laird random-effects method was used to incorporate both within-study and between-study variability.[9] Cumulated pooled estimates of complication rates were calculated based on publication year. Funnel plots were generated to assess for publication bias. All calculations were performed using Stata version 8.2 software (Stata Corp., College Station, Texas).

RESULTS

Data Retrieval and Study Characteristics

A total of 338 abstracts were identified in the initial screening, with 12 citations identified through manual searching of articles published between October of 2006 and April of 2007 that had not yet been indexed for MEDLINE and through hand searching of bibliographies. Of these, 260 were rejected after the abstracts were reviewed. Of the remaining 78 articles, 42 did not meet inclusion criteria or were rejected because there were multiple publications using the same or overlapping patient cohorts (Fig. 1). All 36 studies that met criteria for meta-analysis were uncontrolled case series. Six studies presented information on complications for both DIEP and free TRAM flap patients, allowing us to calculate relative risks.[1,2,10–13] These studies consisted of 330 DIEP flap and 841 free TRAM flap procedures (Table 1). A muscle-sparing free TRAM flap technique was used in three of the studies.[1,2,12]

Thirty-five studies were used to develop pooled summary complication rates stratified by treatment. Twelve studies had information only on DIEP flap patients,[14–25] and 18 studies had information only on TRAM flap patients.[26–43] Two studies with information on both DIEP and free TRAM flap complications were ineligible for the DIEP analysis because of multiple publication of the same cohort or failure to meet inclusion criteria.[10,11] One study with information on both treatment groups was ineligible for the TRAM flap analysis because of multiple publication of the same patient cohort.[11] In total, 1614 patients receiving 1920 DIEP flaps and 2645 patients receiving 3185 free TRAM flaps were included in the meta-analysis (Tables 2 and 3).

Table 1. Characteristics of Study Populations Comparing DIEP and TRAM Flap Outcomes

Source	Mean Age (yr)	Mean Follow-Up (mo)	No. of Patients	No. of Flaps	Fat Necrosis	Partial Loss	Total Loss	Abdominal Bulge	Abdominal Hernia
Blondeel et al., 1997[10]									
DIEP	44.0	17.8	18	18	NA	NA	NA	0	0
TRAM	46.8	32.1	20	20	NA	NA	NA	2	1
Kroll, 2000[11]									
DIEP	NA	NA	NA*	31	9	5	0	NA	NA
TRAM	NA	NA	NA*	279	36	3	4	NA	NA
Nahabedian et al., 2005[1]									
DIEP	48.3	23.0	88	110	7	0	3	2	0
TRAM	47.1	23.0	89	113	8	0	2	8	0
Bajaj et al., 2006[2]									
DIEP	50.1	9.8	35	43	5	1	2	4	0
TRAM	50.1	10.2	124	150	14	1	0	15	0
Bonde et al., 2006[12]									
DIEP	51	NA	44	44	0	NA	2	1	NA
TRAM	51	NA	233	233	9	NA	5	13	NA
Scheer et al., 2006[13]									
DIEP	49	NA	68	84	36	1	5	2	6
TRAM	49	NA	40	46	4	3	2	3	6

NA, not available.
*Total of 241 patients.

Table 2. Characteristics of Study Populations Reporting DIEP Flap Outcomes

	Patient Characteristics								Complications				
Source	No. of Patients	Mean Age (yr)	Obese (%)	Smokers (%)	Previous Radiotherapy (%)	Previous Abdominal Scarring (%)	Mean Follow-Up (mo)	No. of Flaps	Fat Necrosis	Partial Loss	Total Loss	Abdominal Bulge	Abdominal Hernia
Blondeel, 1999[14]	87	45.4	24.1	23.0	44.8	27.6	18.3	100	6	7	2	1	0
Hamdi, 1999[15]	42	47	21.4	23.8	45.2	45.2	13	50	3	3	1	2	0
Keller, 2001[16]	109	48	NA	NA	NA	NA	28.9	148	10	0	1	4	2
Gill et al., 2004[17]	609	48.9	NA	NA	NA	NA	13.2	758	98	19	4	NA	5
Munhoz et al., 2005[18]	44	56.1	NA	20.5	NA	38.6	23	48	NA	2	2	1	NA
Nahabedian et al., 2005[1]	88	48.3	NA	8.0	NA	NA	23	110	7	0	3	2	NA
Bajaj et al., 2006[2]	35	50.1	NA	17.1	NA	NA	9.8	43	5	1	2	4	0
Bonde et al., 2006[12]	44	51	NA	NA	NA	NA	NA	44	0	NA	2	1	NA
Busic et al.,[19] 2006	64	50	NA	28.1	34.4	NA	NA	65	8	13	4	NA	NA
Cheng et al., 2006[20]	73	44.2	2.7	2.7	4.1	4.1	12.3	74	10	2	0	NA	NA
Garvey et al., 2006[21]	96	53.6	NA	4.2	17.7	49.0	15.2	96	17	NA	3	9	1
Lundberg et al., 2006[22]	50	48	NA	10	36	NA	NA	50	5	0	0	NA	NA
Scheer et al., 2006[13]	68	49	NA	NA	NA	NA	NA	84	36	1	5	2	6
Lindsey, 2007[23]	91	52	9.9	6.6	NA	NA	27	107	1	1	9	0	0
Tran et al., 2007[24]	74	50	NA	NA	NA	NA	22.5	100	12	NA	1	5	0
Yan et al., 2007[25]	40	38.6	NA	NA	17.5	NA	16	43	2	2	2	NA	0

NA, not available.

Table 3. Characteristics of Study Populations Reporting Free TRAM Flap Outcomes

	Patient Characteristics								Complications				
Source	No. of Patients	Mean Age (yr)	Obese (%)	Smokers (%)	Previous Radiotherapy (%)	Previous Abdominal Scarring (%)	Mean Follow-Up (mo)	No. of Flaps	Fat Necrosis	Partial Loss	Total Loss	Abdominal Bulge	Abdominal Hernia
Grotting et al., 1989[26]	10	47	NA	NA	NA	NA	NA	12	0	0	0	0	0
Arnez et al., 1991[27]	50	42	NA	40.0	16.0	26.0	NA	50	NA	2*	3	NA	2
Pennington and Hassall, 1991[28]	13	44.5	NA	NA	15.4	NA	NA	14	0	NA	0	NA	0
Yamada et al., 1992[29]	34	NA	NA	NA	NA	NA	NA	34	NA	2	0	NA	NA
Elliott et al., 1993[30]	40	47	NA	NA	NA	NA	NA	48	NA	2	1	0	0
Gherardini et al., 1994[31]	11	46	0.0	36.4	NA	27.3	NA	11	NA	1	0	4	NA
Banic et al., 1995[32]	111	48	11.7	24.3	13.5	46.8	19	123	10	8	6	14	8
Blondeel et al., 1997[10]	20	46.8	25.0	50.0	65.0	25.0	32.1	20	NA	NA	NA	2	1
Khouri et al., 1997[33]	120	46.7	20.0	33.3	NA	58.3	37.2	240	0	0	1	NA	14
Nieminen et al., 1999[34]	175	48	NA	NA	NA	NA	45.5	185	NA	NA	2	12	NA
Chang et al., 2000[35]	718	40–49	8.9	12.6	NA	NA	NA	936	55	13	8	21	20
Alderman et al., 2002[36]	67	46.2	NA	NA	NA	NA	24	67	NA	10*	1	NA	8†
DeBono et al., 2002[37]	97	47	NA	22.7	NA	NA	NA	105	16	2	4	3	5
Huang et al., 2004[38]	15	43.9	NA	NA	NA	NA	26.7	15	1	0	1	0	0
Kovacs et al., 2004[39]	34	51.5	4.0	23.5	17.6	41.2	74	68	1	1	3	NA	1
Mustonen et al., 2004[40]	26	NA	NA	NA	NA	NA	NA	26	3	NA	3	NA	2
Nahabedian et al., 2005[1]	89	47.1	NA	15.7	NA	NA	23	113	8	0	2	8	NA
Olsson and Tukiainen, 2005[41]	16	51	NA	31.3	NA	43.8	NA	18	NA	0	0	1	1
Salmi, 2005[42]	102	50	NA	NA	NA	NA	NA	102	NA	NA	2	NA	5†
Bajaj et al., 2006[2]	124	50.1	NA	14.5	NA	NA	10.2	150	14	1	0	15	0
Bonde et al., 2006[12]	233	51	NA	NA	NA	NA	NA	233	9	NA	5	13	NA
Scheer et al., 2006[13]	40	49	NA	NA	NA	NA	NA	46	4	3	2	3	6
Selber et al., 2006[43]	500	50	16.0	11.2	NA	NA	NA	569	19	9	2	NA	11

NA, not available.
*Fat necrosis and partial flap loss combined.
†Abdominal wall bulge and hernia combined.

Meta-Analysis of Studies Comparing DIEP and TRAM Flap Treatment

There was a twofold increase in the risk for fat necrosis (fixed-effects pooled relative risk, 1.94; 95 percent confidence interval, 1.28 to 2.93; $p = 0.07$ for heterogeneity) in patients receiving DIEP flaps compared with those with free TRAM flaps (Fig. 2). There was no difference in the risk for fat necrosis when the analysis was limited to studies using muscle-sparing free TRAM flaps as compared with full muscle free TRAM flaps (fixed-effects pooled relative risk, 0.91; 95 percent confidence interval, 0.47 to 1.78; $p = 0.58$ for heterogeneity). Because flap loss was rare, partial and total flap losses were combined into a single category for any flap loss. There was a twofold increase in the risk for any flap loss (fixed-effects pooled relative risk, 2.05; 95 percent confidence interval, 1.16 to 3.61; $p = 0.04$ for heterogeneity) in patients with DIEP flaps compared with those with TRAM flaps (Fig. 3). When the random-effects model was used to account for between-study heterogeneity, there was a trend toward increased risk for flap loss in DIEP flap patients, but the result was not statistically significant (random-effects pooled relative risk, 2.47; 95 percent confidence interval, 0.85 to 7.14). Results did not change greatly when partial and total flap loss were analyzed separately as different outcomes (Table 4). Because some studies distinguished abdominal wall bulge, weakness, or laxity from abdominal wall hernia and others did not, these categories were combined into a single group. The risk for abdominal bulge or hernia in those with DIEP flaps was approximately one-half that of TRAM flap patients (fixed-effects pooled relative risk, 0.49; 95 percent confidence interval, 0.28 to 0.86; $p = 0.57$ for heterogeneity) (Fig. 4).

Pooled Summary Complication Rates

Because some of the outcomes of interest exhibited between-study heterogeneity, a random-effects model was used to calculate all pooled complication rates (Table 5). Overall, the pooled summary complication rates corroborated the findings from the studies comparing DIEP flap to free TRAM flap patients. The rate of fat necrosis in DIEP flap patients (10.1 percent; 95 percent confidence interval, 6.3 to 14.0 percent) was approximately double the rate in TRAM flap patients (4.9 percent; 95 percent confidence interval, 3.2 to 6.7 percent). The rate of total flap loss in DIEP flap patients (2.0 percent; 95 percent confidence interval, 1.0 to 2.9 percent) was also double the rate in TRAM flap patients (1.0 percent; 95 percent confidence interval, 0.5 to 1.4 percent). Pa-

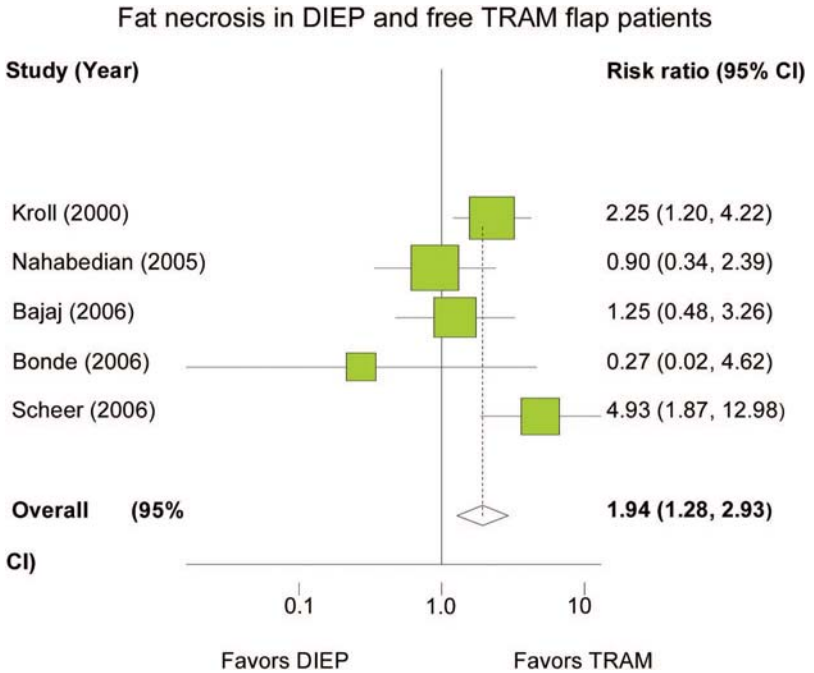

Fig. 2. Fat necrosis in DIEP and free TRAM flap patients. Size of the *solid squares* is inversely proportional to the variance of the study estimate. The *diamond* represents the fixed-effects pooled relative risk and 95 percent confidence interval. The *dashed line* is drawn at the overall pooled estimate.

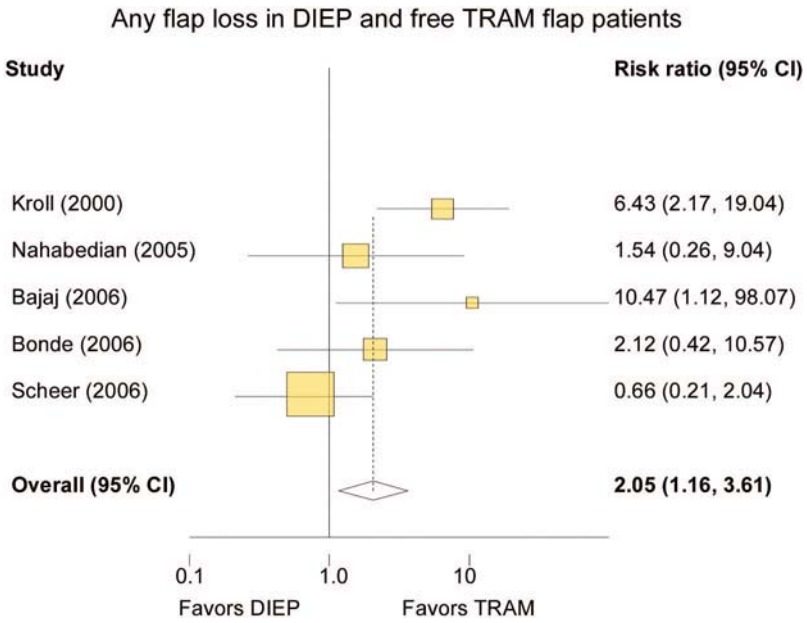

Fig. 3. Any flap loss in DIEP and free TRAM flap patients. Size of the *solid squares* is inversely proportional to the variance of the study estimate. The *diamond* represents the fixed-effects pooled relative risk and 95 percent confidence interval. The *dashed line* is drawn at the overall pooled estimate.

Table 4. Pooled Relative Risks for DIEP versus Free TRAM Flap Patients

	No. of Studies	Pooled Relative Risk	95% CI	Between-Group Heterogeneity, *p* Value
Fat necrosis				
All studies	5	1.94	1.28–2.93	0.07
Muscle-sparing free TRAM flap only	3	0.91	0.47–1.78	0.58
Flap loss				
Any flap loss				
All studies	5	2.05	1.16–3.61	0.04
Muscle-sparing free TRAM flap only	3	2.76	1.03–7.40	0.39
Partial flap loss				
All studies	3	2.29	1.11–4.73	<0.01
Muscle-sparing free TRAM flap only	1	3.49	0.22–54.6	NA
Total flap loss				
All studies	5	2.02	0.89–4.55	0.65
Muscle-sparing free TRAM flap only	3	2.71	0.98–7.53	0.38
Abdominal bulge or hernia				
All studies	5	0.49	0.28–0.86	0.57
DIEP vs. muscle-sparing free TRAM flap	3	0.53	0.25–1.15	0.34

CI, confidence interval; NA, not applicable.

tients receiving DIEP flaps were one-half less likely to report abdominal bulge, laxity, or weakness (3.1 percent; 95 percent confidence interval, 1.6 to 4.6 percent) than those receiving TRAM flaps (5.9 percent; 95 percent confidence interval, 3.6 to 8.1 percent). The rate of abdominal hernia was also much lower in DIEP flap patients (0.8 percent; 95 percent confidence interval, 0.2 to 1.3 percent) than in TRAM flap patients (3.9 percent; 95 percent confidence interval, 2.4 to 5.3 percent).

Complication Rates over Time

The rate of partial flap loss in patients undergoing DIEP flap surgery decreased over time (Fig. 5). The incidence of fat necrosis; total flap loss; abdominal bulge, laxity, or weakness; and abdom-

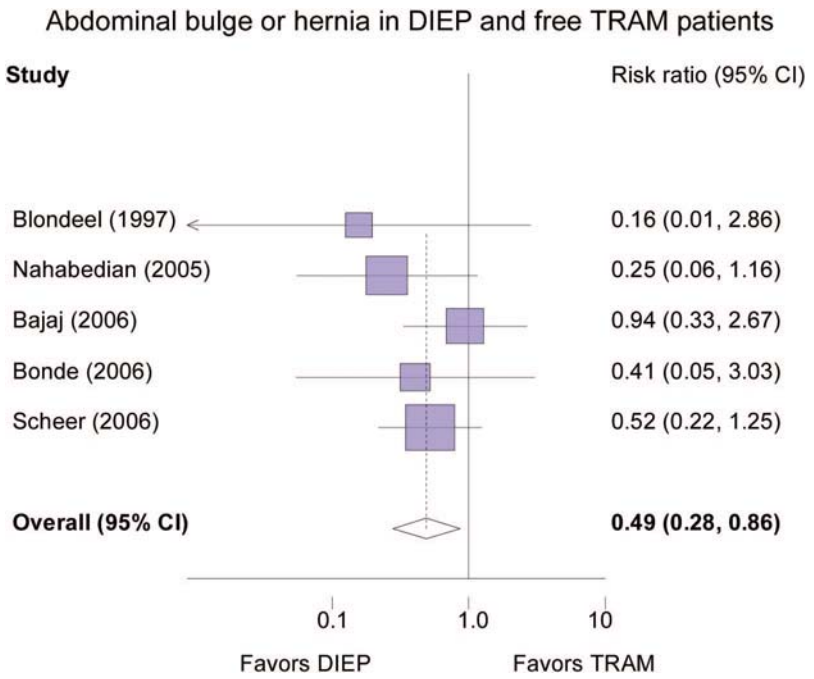

Fig. 4. Abdominal bulge or hernia in DIEP and free TRAM flap patients. Size of the *solid squares* is inversely proportional to the variance of the study estimate. The *arrow* represents an error bar that continues beyond the scale of the graph. The *diamond* represents the fixed-effects pooled relative risk and 95 percent confidence interval. The *dashed line* is drawn at the overall pooled estimate.

Table 5. Pooled Complication Rates for DIEP and TRAM Flap Patients

	No. of Studies	Total No. of Flaps	Pooled Complication Rate (%)	95% CI	Between-Group Heterogeneity, *p* Value
DIEP flap patients					
Fat necrosis	15	1872	10.1	6.3–14.0	<0.01
Partial flap loss	13	1680	2.5	1.1–3.9	0.02
Total flap loss	16	1920	2.0	1.0–2.9	0.03
Abdominal bulge, laxity, or weakness	11	930	3.1	1.6–4.6	0.20
Abdominal hernia	10	1529	0.8	0.2–1.3	0.56
TRAM flap patients					
Fat necrosis	14	2650	4.9	3.2–6.7	<0.01
Partial flap loss	17	2605	1.8	0.9–2.6	0.10
Total flap loss	22	3165	1.0	0.5–1.4	0.22
Abdominal bulge, laxity, or weakness	14	2015	5.9	3.6–8.1	<0.01
Abdominal hernia	18	2609	3.9	2.4–5.3	0.03

CI, confidence interval.

inal hernia in DIEP flap patients did not appear to be related to publication year. The cumulative rate of partial flap loss and total flap loss in patients undergoing free TRAM surgery decreased according to publication year. The rate of fat necrosis and abdominal complications was not related to publication year.

Assessment of Publication Bias

Figure 6 shows a funnel plot for visual assessment of publication bias. The plot is relatively symmetric. There was no evidence of bias using the Egger (weighted regression) or the Begg (rank correlation) method in the studies directly comparing DIEP and free TRAM flap complication rates.[44,45]

DISCUSSION

A guiding principle in all of reconstructive plastic surgery is to provide the best reconstruction possible while limiting the functional and aesthetic defect at the donor site. This principle is no more apparent than in our current approach

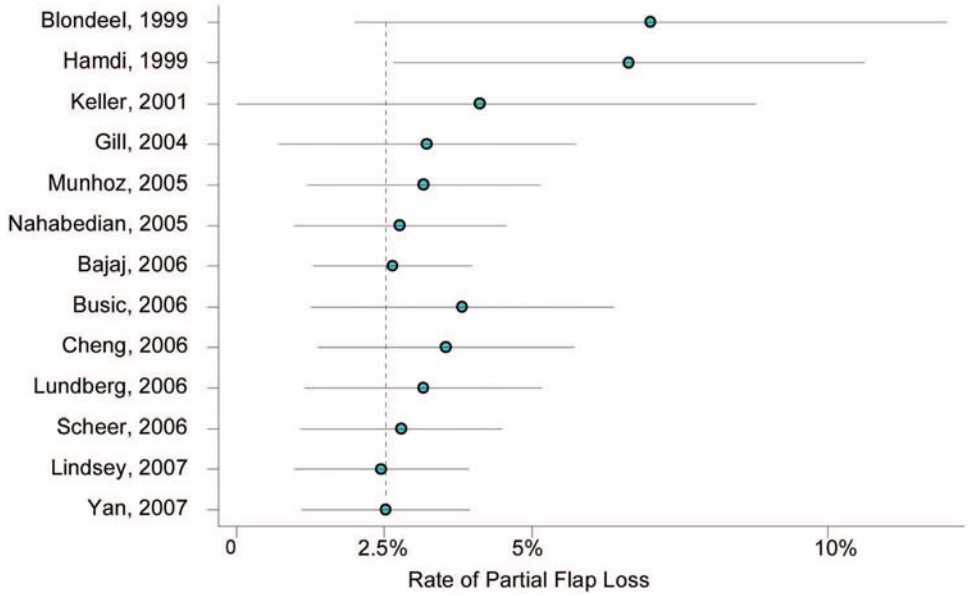

Fig. 5. Cumulative pooled rate of partial flap loss in DIEP flap patients. *Circles* indicate the cumulative pooled rate of partial flap loss over time (by publication year) in individual studies. *Horizontal lines* represent the corresponding 95 percent confidence interval.

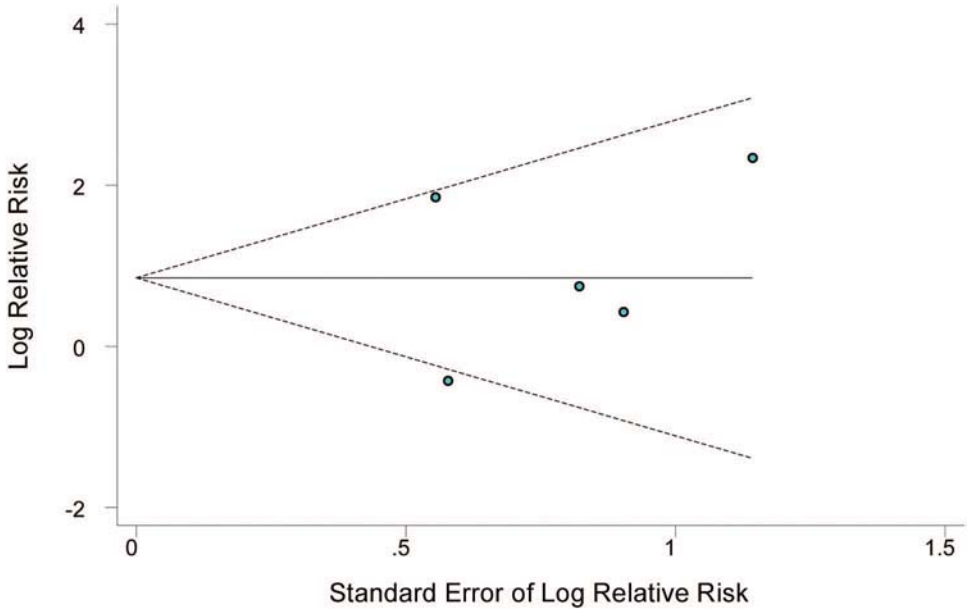

Fig. 6. Funnel plot of log relative risks according to their standard errors for any flap loss. The *horizontal solid line* is drawn at the pooled log relative risk for any flap loss, and *dashed lines* represent the expected 95 percent confidence interval for a given standard error, assuming no between-study heterogeneity.

to autogenous breast reconstruction. For all of us, the objective is to provide an aesthetically pleasing, natural breast reconstruction without significant impact on flap reliability. At the same time, we want to achieve this goal without undue compromise of the abdominal wall. For this discussion, we define flap reliability as the absence of fat necrosis, partial flap loss, or total flap loss. The introduction of the pedicled TRAM flap was a milestone in our ability to provide a natural breast reconstruction. This technique came at the expense of abdominal wall integrity and significant

patient selection criteria. The free TRAM flap was introduced as a means of limiting the abdominal donor defect while providing improved vascularity within the flap, allowing for broader patient selection compared with the pedicled TRAM flap. The free TRAM flap, however, has not completely eliminated abdominal donor-site morbidity. The DIEP flap represents a further advance along a continuum, by preserving abdominal wall anatomy while reducing the vascularity of the flap by using fewer perforating vessels. It would make sense that reducing the vascularity of the flap in an effort to maximize abdominal wall donor-site function would come at some expense to flap reliability.

The results of this meta-analysis quantify much of what we have suspected all along. First, in studies that directly compare the two procedures, DIEP flaps have one-half the risk of abdominal hernia and bulge as the free TRAM flap (relative risk, 0.49) but twice the risk of fat necrosis and partial and total flap loss (relative risk, 1.94 and 2.05, respectively). What is most interesting is that this relationship is mirrored when pooled summaries of studies examining one procedure or the other are compared: DIEP flaps have less than one-half the rate of abdominal hernia or bulge (4 percent versus 10 percent), twice the rate of fat necrosis (4.9 percent versus 10 percent), and approximately two-thirds the rate of partial and total flap loss (2.8 percent versus 4.5 percent). Because of the way in which this investigation was conducted, we have two fairly strong and independent data streams, both of which lead us to the same conclusion and reinforce the theoretical concepts discussed above.

Most of the surgeons who routinely perform free flap breast reconstruction have learned to use the free TRAM, DIEP, and SIEA flap techniques. All of us have experienced a significant learning curve as we have moved away from the traditional full muscle, free TRAM flap. The most important part of that learning curve has not been the technical component of these procedures but rather the development of intraoperative decision making in choosing the appropriate technique in a given patient. The critical element of that decision is predicting high flap reliability based on anatomical findings, simultaneously limiting the potential for abdominal wall complications. Inherent in this decision is the cumulative experience of each surgeon. Based on our clinical experience with all of these techniques, many surgeons have felt that using muscle-preserving procedures without consideration of patient parameters or anatomical findings comes at some expense of flap reliability. A small number of our colleagues are adamant about using only one technique or another in all patients, insisting that this compromise is not present. The evidence provided by this meta-analysis definitively concludes that such a tradeoff exists. This study establishes what has been intuitive for most of us: muscle-preserving techniques do come at the expense of some flap reliability, and abdominal wall morbidity is clearly improved with muscle-preserving procedures.

Because of this dynamic tension among techniques, risks, and benefits, we have developed our own algorithm for flap selection based on patient risk factors and anatomy. For patients who smoke, are obese, require large-volume reconstructions (zones 1, 2, and 3), have planned postoperative radiation therapy, or have a history of abdominal liposuction, we tend to select the muscle-sparing free TRAM flap. The improved vascularity of the free TRAM flap has a greater potential to limit the incidence of fat necrosis and partial or total flap loss in these compromised patients. There is no question that we do suffer a small but present increase in the risk of abdominal wall dysfunction when using this technique; however, the flap reliability outweighs the risk of this correctable donor-site complication. In all other patients (in particular, patients undergoing bilateral reconstruction), we make every effort to perform a muscle-preserving technique. Our personal algorithm in these selected (low-risk) patients is to first look for the superficial inferior epigastric vessels. If the SIEA is greater than 1.5 mm in diameter and there is a sufficient accompanying vein, we will proceed with an SIEA flap dissection. If the superficial inferior epigastric vessels are inadequate, we attempt to identify one or two large perforators (DIEP) in close proximity to one another. We like to see a single vein and a palpable arterial pulse within the selected perforator(s). In using two perforators, we attempt to select the perforators that are close to each other, to limit the degree of intramuscular dissection and consequent muscle injury. If there is no dominant perforator, a group of perforators is selected along with a small amount of anterior rectus fascia and rectus abdominis muscle. Most of these small fascial defects are closed directly and do not require mesh. On occasion, the key perforator placement is such that a larger resection of fascia and muscle is required. In these cases, an inlay polypropylene mesh is used to replace the resected fascia. This algorithm takes into account the balance between flap reliability and the potential for abdominal wall morbidity by paying

attention to proper patient selection when deciding among the various techniques. The results of this study provide support for such an algorithm.

The findings in this meta-analysis constitute the general experience of the study population, which is composed of surgeons sufficiently dedicated to free flap breast reconstruction to publish in the peer-reviewed literature. For this reason, the "mean" in this case represents the experience of the very experienced and therefore should not be discounted as the result of easily surmountable technical errors or a "learning curve." Whatever individual experience may suggest, it is clear from this study that, as a general rule, the DIEP flap is less reliable than the free TRAM flap but that, even when it is muscle-sparing, the free TRAM flap suffers a higher rate of donor-site morbidity.

Joseph M. Serletti, M.D.
Division of Plastic Surgery
University of Pennsylvania School of Medicine
10 Penn Tower
3400 Spruce Street
Philadelphia, Pa. 19104
joseph.serletti@uphs.upenn.edu

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