Angiographic Delay: A Viable Alternative to Surgical Delay

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Background: Selective embolization of the inferior epigastric arteries can serve as a method for transverse rectus abdominis musculocutaneous (TRAM) flap delay. The purpose of this study was to determine whether delay by selective arterial embolization is comparable to traditionally surgically delayed TRAM flaps as reported in the literature, in terms of skin and fat necrosis, and to examine whether certain risk factors play a role in TRAM flap fat necrosis despite angiographic delay.

Methods: Retrospective chart review was performed for 88 consecutive patients who underwent unilateral TRAM flap breast reconstruction after selective embolization of bilateral inferior epigastric arteries.

Results: Between 1997 and 2009, 88 pedicled TRAM flaps were performed for breast reconstruction in women with a mean age of 49.7 years. No patients had flap skin necrosis or total flap loss. In all, 13.6% patients had TRAM flap fat necrosis. Two patients in the TRAM fat necrosis group (16.7%) had a positive history of smoking, which was a statistically significant risk factor for necrosis ($P = 0.048$).

Conclusions: Outcomes of pedicled TRAM flaps delayed by selective arterial embolization are comparable to historical controls of those delayed by traditional surgical means (ligation of artery and vein) and better than nondelayed flaps. Smoking remains a significant risk factor for TRAM flap fat necrosis despite the benefit of delay.

Key Words: breast reconstruction, TRAM flap, angiographic delay

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Since its description by Hartrampf et al in 1982,[1] the transverse rectus abdominis musculocutaneous (TRAM) flap has been the most frequently used autologous flap procedure for breast reconstruction. To improve the vascularity of the pedicled TRAM flap, a preoperative delay procedure can be performed. Both surgical delay (ligation of both artery and vein)[2] and delay by selective embolization of the inferior epigastric arteries[3,4] have been described. Scheufler et al first introduced the concept of delay by selective embolization in 2000.[3]

We reviewed a series of 88 consecutive endovascularly delayed unipedicled TRAM flap breast reconstructions by the senior author (N.B.). The purpose of this study was twofold: (1) to determine whether delay by selective arterial embolization is comparable to surgically delayed pedicled TRAM flaps as reported in the literature, in terms of skin and fat necrosis, and (2) to examine whether certain risk factors play a role in TRAM flap fat necrosis despite arterial angiographic delay.

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PATIENTS AND METHODS

Patients

A retrospective chart review was performed of all patients who underwent unilateral breast reconstruction with a contralateral, unipedicled TRAM flap after bilateral selective embolization of the inferior epigastric arteries. All patients with known risk factors were delayed. Few patients with no known risk factors were delayed to maximally improve results and reduce risk of complications. Patient risk factors such as body mass index (BMI), history of diabetes, smoking history, previous abdominal surgery/scars, and preoperative radiation were documented. Immediate versus delayed reconstruction was evaluated. Postoperative complications, such as skin and fat necrosis were recorded.

Selective Embolization

All patients underwent bilateral deep inferior epigastric artery (IEA) embolization. The superficial inferior epigastric arteries are neither entered nor embolized. The same interventional radiologist performed all embolizations. Initially, bilateral groin access was obtained for the first 8 patients. Subsequently, only the right groin was prepped and draped. A 5F vascular sheath was inserted after obtaining access to the right common femoral artery with a micropuncture vascular access set (Cook, US). Initially (first 10–12 patients), selective catheterization of both internal mammary arteries was performed to exclude proximal disease and to establish anatomic continuity with the superior epigastric arteries. All internal mammary arteries were found to be normal despite a history of smoking or advanced age, and in view of the potential risks, this portion of the procedure was discontinued. A 4F Pigtail or Contra catheter was placed through the 5F sheath in the lower aorta and a 40-cm field of view pelvic angiogram was performed. Subsequently, using this catheter to reform a tapered 5F Roberts uterine catheter (RUC) (Cook, US) selective catheterization of the left external iliac artery was carried out and an left anterior oblique angiogram demonstrating the origin of the left IEA, just above the inguinal ligament, was performed. Using digital road-mapping guidance, the IEA was entered with a Turbo Tracker microcatheter (Boston Scientific, US), and the tip of the microcatheter was advanced either to a major branch point or for a minimum of 5 cm beyond the IEA origin. After an angiogram of the IEA to identify the size and course of this vessel, at least 3 either complex helical or vortex fibered 3 mm diameter platinum microcoils (Boston Scientific, US), or more recently, a single 14-cm long 3-mm diameter platinum fibered Nester coil (Cook, US) were deposited (Figs. 1A, B). Using the RUC special catheter a second puncture was not necessary, rather the RUC was used to engage the ipsilateral external iliac artery and after an angiogram of this vessel and the common femoral artery in the right anterior oblique projection, to best visualize the origin of the IEA, road-mapping guidance to the right IEA was used to introduce the microcatheter, and embolization was carried out as mentioned earlier. Initially in our study, hemostasis was obtained by manual compression after completion of the procedure. However, for the last several years, hemostasis has been achieved by application of a 6-French Angio-Seal (St. Jude Medical, US) vascular closure device, minimizing the risk of groin hematoma, and allowing for early ambulation and discharge.

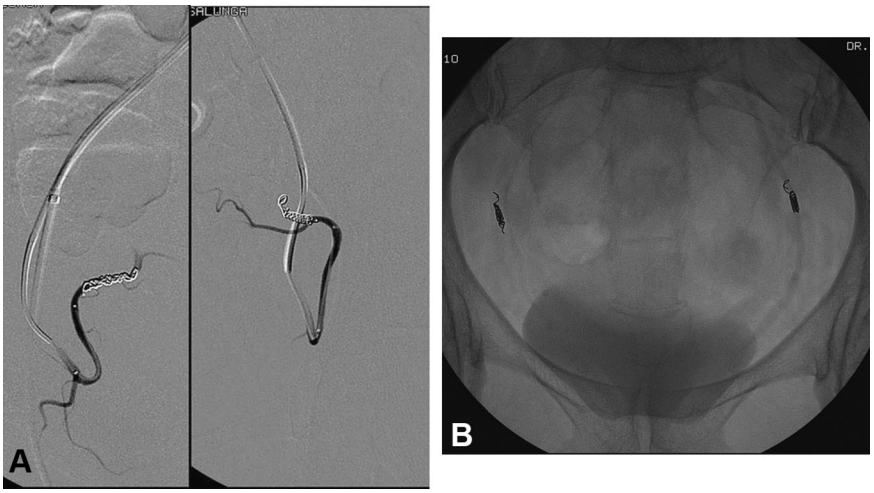

FIGURE 1. A, Placement of Nester platinum fibered microcoils to interrupt the flow in the left and right inferior epigastric arteries. B, Coils in place bilaterally after procedure.

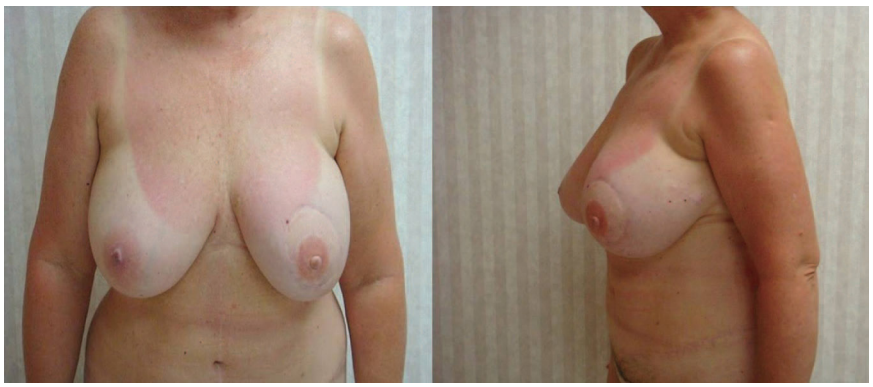

FIGURE 2. Left breast reconstruction with TRAM. Angiographic delay is ideal for creating a large ptotic breast.

Surgical Technique

Elevation of the pedicled TRAM flap was performed according to the original technique described by Hartrampf et al. The senior author (N.B.) performed all TRAM flaps. All patients underwent unilateral breast reconstruction with a contralateral unipedicled TRAM flap. The entire width of the rectus abdominis muscle was harvested and divided at the arcuate line. Typically, zones I, II, and III are used while zone IV is discarded. In most cases, the abdominal fascial defect was closed primarily and reinforced using prolene soft mesh (Ethicon, US) in an onlay fashion.

Data Collection and Statistical Analysis

The authors as well as an independent reviewer performed a retrospective chart review of all patients. Chart review data were entered into a computerized database. Statistical tests included Fisher exact test for categorical variables and *t* test for comparisons of continuous variables. Results were considered statistically significant if $P < 0.05$. The SAS statistical software was used for all statistical analyses.

RESULTS

Demographics

From 1997 until 2009, 88 patients underwent unilateral breast reconstruction using a contralateral unipedicled TRAM flap after selective embolization of bilateral IEA. The average patient age was 49.7 years (range, 33–68 years). All patients underwent breast reconstruction after mastectomy for breast cancer. In all, 49 patients (55.7%) had immediate reconstruction versus 39 (44.3%) who had delayed reconstruction. The average follow-up was 28.1 months. Typical patient results are presented in Figures 2–8.

Risk Factors

In regard to patient risk factors, 73% of women in the study had at least 1 risk factor (Table 1). Although the average BMI was 27 (range, 18.2–35.3), 25% of the women were obese (BMI >30). One patient (1.1%) had a history of diabetes, and 3 patients were smokers (3.4%), which is a small sample size. All patients were advised to stop tobacco products 2 to 3 weeks preoperatively and not to resume until cleared by her surgeon; however, 3 patients were unable to stop smoking in the immediate postoperative period. In all, 33% of patients (n = 29) had previous abdominal scars; and 42% of patients (n = 37) had preoperative radiation.

Selective Embolization

In 88 patients, a total of 175 IEA were successfully and completely catheterized and embolized (1 patient was found to have a congenitally absent IEA). All patients were discharged within 6 hours after procedure. There were no significant groin complications and no angiographic or clinical evidence of errant embolization. Two patients complained of vague lower abdominal pain/discomfort, which was self-limiting and responded to non-steroidal anti-inflammatory drugs (NSAIDS). The average time from embolization to TRAM flap surgery was 4 weeks (range, 1–21.1 weeks).

TRAM Flap Outcome

TRAM flap skin necrosis did not occur in any patient. There was no incidence of total flap loss. Twelve patients (13.6%) had fat

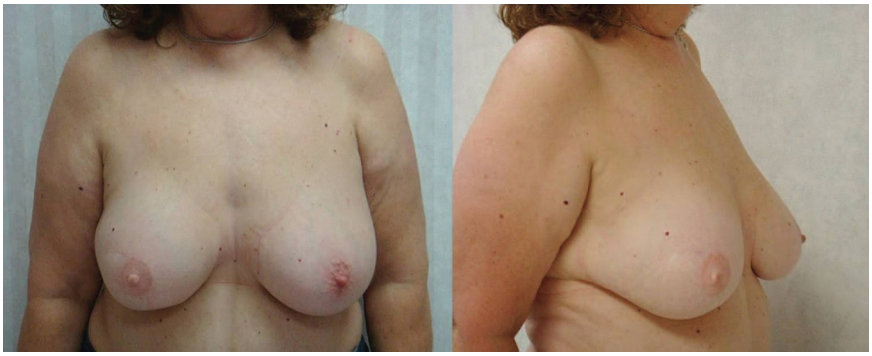

FIGURE 3. Right breast reconstruction with TRAM.

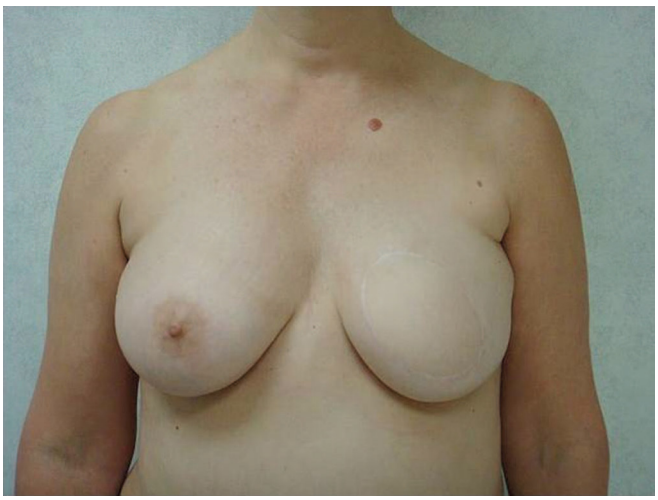

FIGURE 4. Left breast reconstruction with TRAM.

FIGURE 5. Right breast reconstruction with TRAM in an irradiated bed.

FIGURE 6. Left breast reconstruction with TRAM. Note the umbilical scar and additional skin at superior aspect of left TRAM included for symmetry.

FIGURE 7. Right breast reconstruction with TRAM in an irradiated bed.

necrosis of the TRAM flap. The fat necrosis was located either superiorly or laterally on the flap. Those in the superior area correlated with the de-epithelialized skin above the navel during flap elevation. The majority of the patients had fat necrosis in this area (n = 8, 66.7%) compared with those with necrosis laterally (n = 4, 33.3%). Half of the patients underwent excision and closure of the fat necrosis, 1 patient had debridement and healing by secondary intention, and the others resolved without treatment.

Fat Necrosis Subgroup Analysis

To fully understand whether certain risk factors contribute to fat necrosis despite angiographic delay, a subgroup analysis was performed

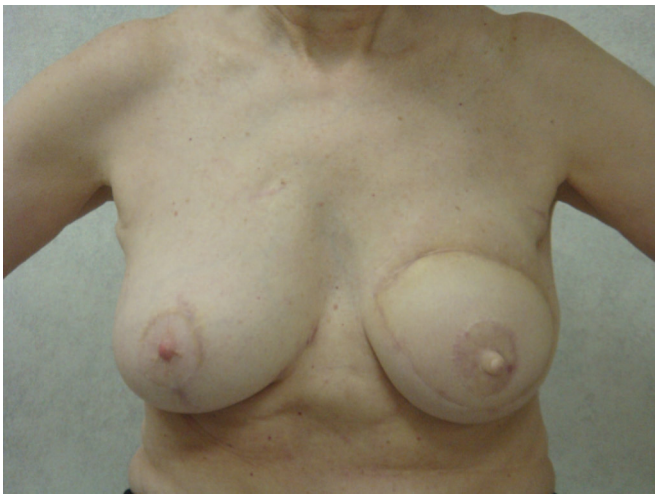

FIGURE 8. Left breast reconstruction with TRAM. Angiographic delay is ideal for creating a large ptotic breast.

(Table 2). Of the 12 women in the fat necrosis group, 8 of them (66.7%) had 1 risk factor and 3 of them (25%) had 2 risk factors. Only one patient had no risk factors. Two patients in the TRAM fat necrosis group (16.7%) had a positive history of smoking compared with 1 patient (1.3%) in the uncomplicated TRAM group, which was a statistically significant risk factor for necrosis ($P = 0.048$). No other risk factors were found to have a statistically significant impact on TRAM fat necrosis.

DISCUSSION

Several options for breast reconstruction after mastectomy exist at present. Although microvascular breast reconstruction is an elegant technique that is widely held to minimize abdominal wall morbidity compared with a pedicled TRAM flap, the standard pedicled TRAM is not destined to become an obsolete procedure. Many community hospitals are not equipped for microvascular flap surgery and many surgeons are either not trained or unwilling, in a community setting, to commit to both labor-intensive reconstruction and complex postoperative monitoring. Most of breast reconstructions are not performed in an academic center. A pedicled TRAM can be performed by many or most board-certified plastic surgeons in a few hours without the need for an intensive care unit stay. If pedicled TRAMs are still to be performed, then it is paramount to minimize morbidity and optimize results. It was for this reason that an angiographic delay procedure has been pursued since 1995. Initially, delay was only used for high-risk patients. However, as comfort grew with the minimal morbidity of angiographic delay and after some unexpected skin and fat necrosis on a low-risk pedicled TRAM flap, delay was performed for all pedicled TRAM flaps. Therefore, the senior surgeon currently recommends delay in all pedicled TRAM flaps.

TABLE 1. Study Population With Risk Factors (Total Patients, n = 88)

No. Risk Factors	Number	%
0 risk factors	24	27.3
1 risk factor	41	46.6
2 risk factors	19	21.6
3 risk factors	3	3.4
4 risk factors	1	1.1

TABLE 2. Subgroup Analysis of Patients With Pedicled TRAM Fat Necrosis After Delay by Selective Embolization

Risk Factor	TRAM Fat Necrosis Group (n = 12)	Uncomplicated TRAM Group (n = 76)	*P*
Age (yr)	48.7	49.9	0.594
Time between embolization and surgery (wk)	3	4.4	0.196
Immediate reconstruction	5 (41.7%)	44 (57.9%)	0.356
BMI	27.6	27	0.641
Diabetes history	0 (0%)	1 (1.3%)	1.000
Smoking history	2 (16.7%)	1 (1.3%)	0.048*
Previous abdominal scars	3 (25%)	26 (34.2%)	0.744
Preoperative radiation	41.7%	42.1%	1.000

$P < 0.05$ was considered statistically significant. Asterisk denotes statistical significance.

TRAM indicates transverse rectus abdominis musculocutaneous; BMI, body mass index.

When the first delay by embolization was performed in 1995, several angiographic factors were taken into account in an attempt to recreate the arterial and venous ligation of surgical delay. Venous embolization of normal veins has not been documented in the angiographic literature to date. At that time, the coils available for embolization were stainless steel with a tendency to damage veins. Furthermore, the venous anatomy can be varied with unusual drainage patterns making accurate, efficient embolization difficult. These factors led to the pursuit of selective arterial embolization alone as a flap delay procedure.

The advantages of selective arterial embolization over surgical delay include quicker recovery, less pain, no need for general anesthesia, and lower cost. Additional benefits of angiographic delay compared with surgical delay are the avoidance of potential abdominal complications, such as cellulitis, wound infection, and abdominal seroma.[5,6] Postoperative induration from surgical delay can make shaping the mound more difficult. Furthermore, delay by selective embolization may be more efficient for a busy plastic surgery practice. No complications occurred from the angiographic delay procedure in our series of 88 patients.

We feel the ideal patient for a pedicled TRAM is modestly overweight but not obese, a nonsmoker, and has a pannus or abdominal contour that would be improved by the removal of a significant amount of skin. The patient should not be inclined to be athletic, as the loss of a rectus muscle is more likely to be missed in such a patient. She may be opposed to contralateral surgery for symmetry, be that a reduction or mastopexy. A pedicled TRAM flap is ideal for creating a large ptotic breast, which is hard to create with a prosthetic reconstruction. A pedicled TRAM flap is also ideal for salvaging a failed prosthetic reconstruction or for a reconstruction in a previously irradiated bed. Bilateral reconstructions and athletic patients are encouraged to seek microvascular reconstruction or prosthetic reconstruction. All patients are made aware of the microvascular technique.

TRAM Flap Fat Necrosis

In all, 5% to 33% of nondelayed pedicled TRAM flaps for breast reconstruction are complicated by partial flap loss or fat necrosis.[5–10] Many authors do not distinguish between fat necrosis and skin necrosis. We feel this is unfortunate because skin necrosis is usually a more devastating complication for both patient and surgeon. Efforts to decrease complications include preparation of the pedicled TRAM flap by performing vascular delay. Surgically delayed pedicled

TABLE 3. Rates of Partial Flap Loss and/or Fat Necrosis

	Pedicled TRAM Without Delay	Pedicled TRAM With Surgical Delay	Pedicled TRAM With Angiographic Delay
Partial flap loss or fat necrosis rates	5%–33%[5–9,12]	4.3%–13%[5–7,10–12]	7.5%[3]

TRAM indicates transverse rectus abdominis musculocutaneous.

TRAM flaps have improved rates of partial flap or fat necrosis of 4.3% to 13% (Table 3).[5–7,10–12] Our rate of 13.6% flap fat necrosis after angiographic delay is similar to surgically delayed pedicled TRAM flaps and better than nondelayed TRAM flaps, especially in high risk populations.

In our series, the majority of patients with TRAM flap fat necrosis had involvement of the superior area. On closer inspection, this superior area corresponded to the deepithelialized skin bridge adjacent (and superior) to the umbilical incision (between zones I and II). At present, we believe that this isthmus of skin cannot withstand ischemic insult easily. Therefore, our recommendations would be to discard this area whenever possible. This would decrease the percentage of patients having TRAM fat necrosis to only 4.5%, which is comparable to other delay methods. The lateral area of necrosis correlates to a less robust blood supply.

All patients with at least one risk factor were delayed, which comprised 73% of our patient population. All patients without known risk factors (only 27.3%) were delayed to maximally improve vascularity of the pedicled TRAM flap and avoid complications. Wallace et al's report of 2 patients with partial TRAM flap loss despite no known risk factors is consistent with the authors' experience and demonstrates that delay should be considered for every patient.[13] Erdmann et al reported delaying 76 consecutive unipedicled TRAM flaps, which resulted in a 6.6% partial fat necrosis rate, and they concluded delay should be considered in both high-risk patients as well as those without risk factors.[11] Later, Wang et al expanded this series and reported 107 consecutive patients who underwent a delayed TRAM procedure to determine the effect of delay on obese and morbidly obese patients.[12] Ribuffo et al and Atisha et al also support the delay of every patient to reduce unexpected complications.[7,10] The benefits of this practice is demonstrated in the 0% total flap loss and 0% flap skin loss in our series.

Patients with a smoking history were at risk for developing TRAM fat necrosis. Multiple previous studies have demonstrated the detrimental effects that smoking has on TRAM flap breast reconstruction.[6,8] Even with delay, smoking has been identified as a critical risk factor for complications.[5,11] It is unsurprising that only one patient, a smoker, had issues with abdominal incision healing.

In this series, age, BMI, history of diabetes, history of radiation, history of previous surgery/scar, time between delay and surgery, and immediate versus delayed reconstruction did not significantly have an impact on TRAM fat necrosis. In regard to time between delay and surgery, the goal was to schedule surgery at least 2 to 3 weeks after the delay procedure; however, scheduling within this time frame was not always possible. We acknowledge that reporting the size of the flaps would have been useful in discussing fat necrosis. However, because of the pedicled nature of the flap, there is no way to accurately quantify the size of the flap. Mastectomy weights are inaccurate because axillary contents are often included.

Delay by Selective Embolization

Scheufler et al were the first to report clinical results of 40 patients who underwent TRAM flap delay by selective embolization of the deep inferior epigastric arteries. The partial flap loss rate decreased from 13.5% without delay to 7.5% with delay and a fat necrosis rate of 2.5%.[3] We agree with Scheufler et al that delay by selective embolization provides better results than nondelayed TRAM procedures. We believe that delay by selective embolization of the deep IEA achieves the necessary dilation of "choke vessels" seen in patients with surgical delay.[14] Ligation of both superficial and deep inferior epigastric arteries is not necessary as Sano et al identified that only the ipsilateral deep IEA or the contralateral superficial IEA need to be ligated to produce the delay effect.[15] Sano et al also reported that ligation of deep inferior epigastric veins is unnecessary to obtain an adequate delay phenomenon in the rat TRAM model.[16] The concern was raised after Scheufler et al's report that venous congestion was more important than arterial delay. Perhaps, it is not as important as postulated before, since the combined results of Scheufler et al and our series, a total of 128 patients, have results that are better than nondelayed flaps and not worse than flaps with delay of both artery and vein.

The obvious weakness of this study is that the controls are historical. Our hope is that an academic center can further explore the merits of this technique with a prospective, randomized study where delay by traditional surgical ligation of both arteries and veins is compared with arterial embolization alone and, perhaps, to arterial and venous embolization.

CONCLUSIONS

Arterial angiographic delay of pedicled TRAM flaps produces similar outcomes when compared with surgically delayed pedicled TRAM flaps (arterial and venous ligation) and better outcomes when compared with nondelayed flaps. Furthermore, angiographic delay has several advantages over surgical delay, such as quicker recovery time, less pain, potentially fewer abdominal complications, no need for general anesthesia, ease of scheduling for the reconstructive surgeon, and less cost. Smoking continues to be a significant risk factor for TRAM flap fat necrosis despite the benefits of a delay procedure. We conclude that the most optimal TRAM flap results may occur with arterial angiographic delay and strict smoking cessation education.

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