Journal of Plastic, Reconstructive & Aesthetic Surgery (2009) 62, 1650–1660

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

An algorithmic approach to abdominal flap breast reconstruction in patients with pre-existing scars — results from a single surgeon's experience☆

Frank Hsieh [a], Devor Kumiponjera [a], Charles M. Malata [a,b,*]

[a] *Department of Plastic and Reconstructive Surgery, Addenbrooke's University Hospital, Cambridge, UK*
[b] *Cambridge Breast Unit, Addenbrooke's University Hospital, Cambridge, UK*

Received 15 May 2008; accepted 10 August 2008

KEYWORDS
Breast reconstruction;
Pre-existing abdominal scars;
Microvascular surgery;
TRAM/DIEP/SIEA flaps;
Pedicled TRAM flap;
Donor-site morbidity

Summary *Background:* Breast reconstruction using the TRAM flap and its variations in patients with pre-existing abdominal scars is controversial. In our practice, abdominal scars are considered not to be a contraindication for such reconstruction. We therefore reviewed our experience and reconstructive strategies adopted in such patients over a 7-year period.
Methods: Patients with previous abdominal scars undergoing abdominal flap breast reconstruction performed by a single surgeon (Jan 2000–Dec 2006) were retrospectively reviewed with respect to scar types, reconstructive approach, flap outcomes and donor-site complications.
Results: Thirty patients (mean age = 52 years) with pre-existing scars (midline, Pfannenstiel, subcostal, appendicectomy, etc.) underwent unilateral ($n = 24$) or bilateral ($n = 6$) breast reconstruction (36 flaps). The flap design strategies employed included splitting the flap (hemi-TRAM), skewing it to avoid abdominal scars, minimal abdominoplasty flap undermining and selective use of DIEP, SIEA, free and pedicled TRAM flaps. There were no free flap failures (0/30), except for one pedicled TRAM flap failure (one out of six). One bilateral DIEP reconstruction patient developed an abdominal bulge requiring mesh repair. No significant wound dehiscence or frank abdominal hernias were recorded.
Conclusion: Pre-existing scars are not an absolute contraindication to abdominal flap breast reconstruction. With careful preoperative planning and adoption of appropriate reconstructive strategies, it is possible to achieve satisfactory results comparable to patients without

☆ Presented in part at the following Academic Meetings: • 41st Congress of the European Society for Surgical Research (ESSR), Rostock, Germany, May 17-20, 2006.
• British Association of Plastic Reconstructive & Aesthetic Surgeons Summer Meeting, Sheffield, UK, July 12-14, 2006.

* Corresponding author. Address: Department of Plastic and Reconstructive Surgery, Addenbrooke's Hospital, Cambridge University Hospitals NHS Trust, Cambridge, CB2 2QQ, UK. Tel.: +44 1223 586672; fax: +44 1223 257177.
E-mail address: cmalata@hotmail.com (C.M. Malata).

1748-6815/$ - see front matter © 2008 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.bjps.2008.08.009

abdominal scars. An algorithmic approach to the selection of the relevant techniques is presented.
© 2008 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights reserved.

The transverse rectus abdominis musculocutaneous (TRAM) flap and its variations remain the most widely used method for autogenous breast reconstruction following mastectomy. First described by Hartrampf et al. in 1982, it has been established as the 'gold standard' for breast reconstruction.[1–3] The use of this versatile flap in patients with pre-existing abdominal scars poses a challenge to the reconstructive surgeon, primarily because of its potential unreliability. Previous abdominal surgery may result in devascularisation of portions of the flap which could compromise its survival. The rate of donor-site complications is also reportedly increased in these patients, especially those with subcostal scars.[4–6] Therefore, the presence of midline or paramedian laparotomy and Pfannenstiel scars may preclude the TRAM flap as the first flap choice in many cases.[5–9] In order to counteract the potential flap unreliability, various operative strategies have been proposed to improve TRAM flap perfusion with variable success. These include surgical delay, TRAM flap modifications and microvascular augmentation of its perfusion.[7,8,10–16] Despite these reports, TRAM flap use in patients with significant abdominal scars is still debatable. It has been suggested by some that the TRAM flap is perfectly safe and effective in these patients,[5,9] whilst others have reported an increased risk of complications.[6] Moreover, there is currently no published literature addressing TRAM flap elevation in patients with multiple scars. In our practice, abdominal scars, single or multiple, are not considered to be contraindications to TRAM flap breast reconstruction. We, therefore, retrospectively reviewed our experience with such patients over a 7-year period with specific objectives of documenting their flap/donor-site outcomes and formulating an algorithm of safe, simple and effective operative strategies for managing these patients.

Patients and methods

Hospital medical records for all patients undergoing abdominal flap breast reconstruction by a single surgeon (CMM) from January 2000 to December 2006 were reviewed retrospectively. Patients with previous abdominal scars were identified. The case notes of each patient were then searched for specific information on previous abdominal surgery, reconstructive approach, flap outcomes and donor-site complications. To control for possible confounding factors that could affect outcomes, additional data were gathered on patient's age, body mass index (BMI), timing of the reconstruction (immediate vs. delayed), flap type (pedicled vs. free vs. total muscle sparing), laterality (unilateral vs. bilateral), use of prosthetic mesh in donor-site closure, smoking history and significant co-morbidities.

The minimum time interval between surgery and review of the case notes was 1 year in order to allow sufficient time for any complications to manifest.

Table 1 Patient Demographics ($n = 30$ patients)

Mean age (years) (range)	52 (37–69)
BMI mean (range)	27.2 (21.6–35.2)
Smokers	5 (16.7%)
Diabetics	1 (3.3%)

Table 2 Reconstructive flap types in patients with abdominal scars ($n = 30$ patients)

Free muscle-sparing TRAM	15
Free DIEP	11
Free hemi-TRAM	3
Free SIEA	1
Pedicled TRAM	6
Total Number of Flaps	36

Table 3 Abdominal scar types in patients undergoing breast reconstruction

Scar type	Patients
Midline laparotomy[a]	5
Pfannenstiel[b]	23
Subcostal (open cholecystectomy)	4
Grid-iron (appendicectomy)[c]	6
Laparoscopy	4
Left open nephrectomy	1

[a] Four patients with midline laparotomy scars had more than one scar.
[b] Eight patients with Pfannenstiel scars had more than one scar.
[c] Five patients with appendicectomy scars had more than one scar.

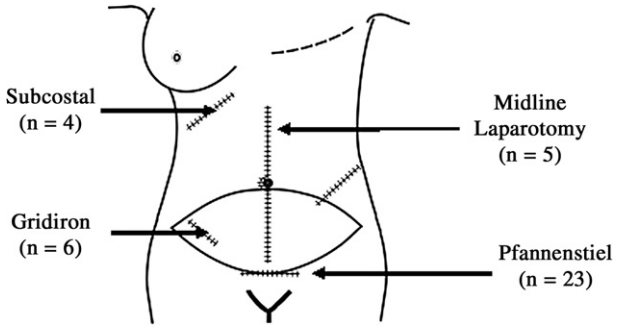

Figure 1 The main abdominal scar types encountered were midline laparotomy, Pfannenstiel, subcostal cholecystectomy and appendicectomy scars.

Table 4 Frequency of anterior abdominal wall scars ($n = 30$ patients)

Scar Group	Number of Patients
Single scar	21
Two scars	5
Three scars	2
Four scars	2

Table 5 Flap-related complications ($n = 30$ patients)

Complete flap failure	1 (pedicled)
Partial flap failure	0
Re-exploration	0
Fat necrosis (minor)	2
Skin necrosis (minor)	1
Delayed wound healing	1
Wound dehiscence	0

Table 6 Donor-site complications ($n = 30$ patients)

Seromas requiring aspiration	7
Hernia/Bulge	1
Wound dehiscence	1
Infection	0
Dog-ears needing revision	1

Results

Over the 7-year period, 110 abdominal flap breast reconstructions were carried out by the senior author (CMM) in 98 patients. Of these, 30 patients (31%) had significant pre-existing abdominal scars. No patient with a sufficient abdominal pannus was turned down for TRAM flap breast reconstruction on account of the existing scars. The abdominal scar patients were almost equally divided between immediate ($n = 14$) and delayed ($n = 16$) reconstruction. Their ages ranged from 37 to 69 years (mean = 52) (Table 1). The reconstruction types included 15 free muscle-sparing TRAM, three free hemi-TRAM, six pedicled TRAM, 11 free deep inferior epigastric perforator (DIEP) and one free superficial inferior epigastric artery (SIEA) flaps (Table 2).

The main abdominal scar types encountered were midline laparotomy, Pfannenstiel, open cholecystectomy (subcostal), appendicectomy and laparoscopic scars (Table 3) (Figure 1). Nine patients (30%) had more than one abdominal scar (Table 4). At surgery, the donor blood vessels were present in all patients, and none were found to have been previously divided. There was one pedicled TRAM flap failure (1/6) 3 days postoperatively in a 50-year-old patient with a previous Caesarian-section scar (Table 5). All the 30 free flaps were successful. None of the flaps developed significant fat necrosis resulting in volume loss. There were no wound dehiscences or frank abdominal hernias, but one bilateral DIEP reconstruction patient developed a generalised lower abdominal bulge requiring onlay mesh repair (Table 6). The healing problems were minor and required no operative intervention.

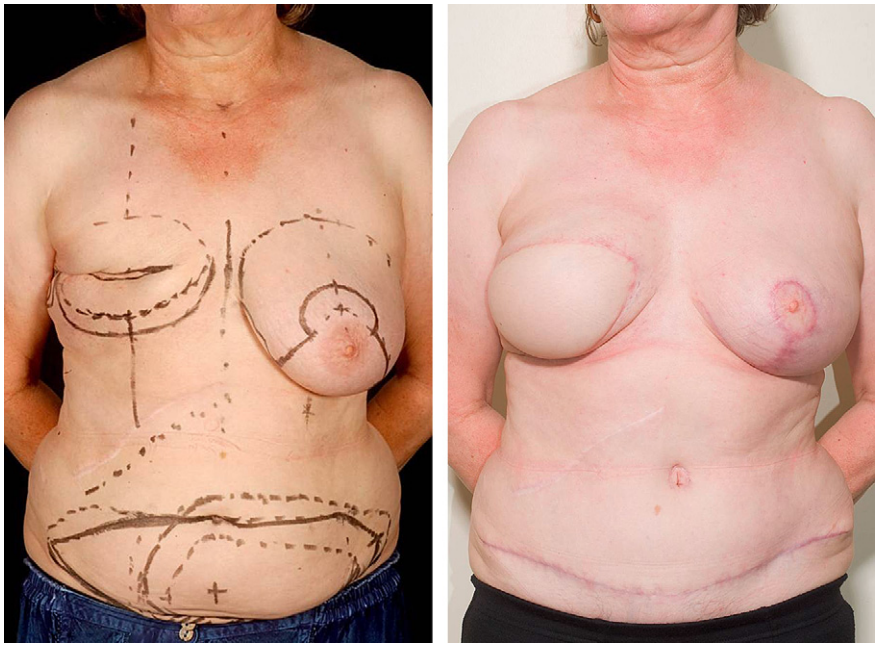

Figure 2 (Left) A 59-year-old patient with an open cholecystectomy scar and a Pfannenstiel sterilisation scar prior to free TRAM flap breast reconstruction. The flap harvest is skewed to the opposite side of the subcostal scar, while the abdominoplasty flap undermining was to stop 3 cm below the upper abdominal scar. (Right) The 6-month postoperative appearances prior to nipple reconstruction show acceptable breast mound symmetry and an abdomen which healed without wound breakdown.

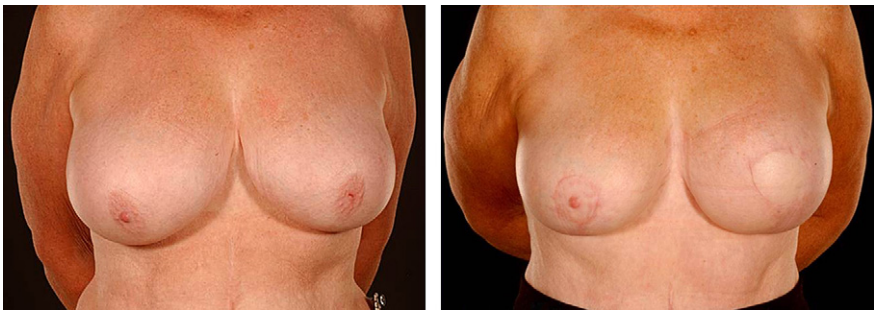

Figure 3 (Left) Preoperative photograph showing a 66-year-old patient with an upper midline open cholecystectomy scar. Postoperative appearance 9 months following immediate left breast reconstruction with a free muscle-sparing TRAM flap and simultaneous contralateral mastopexy (right). Patient declined nipple areolar reconstruction.

Representative cases of the results achieved in patients with various abdominal scars are illustrated below.

Subcostal scars

In the patient who underwent a delayed right breast reconstruction with a free TRAM flap, the strategy employed to reduce abdominal donor-site wound healing problems was to minimise the undermining of the abdominoplasty flap on the side of the subcostal scar (Figure 2).

Upper midline abdominal scars

Upper midline scars make abdominal closure more difficult, especially centrally because of their restricted stretch. In our practice, this tightness was overcome by multiple stab releases (Figure 3) or Z-plasties of the scars.

Lower midline laparotomy scars

In patients with midline laparotomy scars, a simple but effective strategy is to vertically split the infra-umbilical tissue into two, resulting in a hemi-TRAM or hemi-DIEP (Figure 4).

Pfannenstiel scars

Although Pfannenstiel scars can potentially disrupt the deep inferior epigastric vessels (DIEVs), this has not been our experience regardless of whether the indication for the incision was a Caesarian section (Figure 5), hysterectomy or other gynaecological operation.

Multiple abdominal scars

Abdominal flap breast reconstruction in patients with multiple scars is still possible with careful preoperative planning and combined strategies as illustrated in Figure 6 in which an extended free hemi-TRAM was used.

Discussion

Breast reconstruction using autologous tissue yields the most durable and natural-appearing results with the greatest consistency.[2,3] The TRAM flap has the ability to reconstruct a large volume breast without the use of implants and may be associated with fewer long-term complications compared with other reconstructive techniques.[17,18] However, abdominal flap breast reconstruction in patients with pre-existing abdominal scars remains a challenge for the plastic surgeon. In the senior author's practice, no patients were turned down for an abdominal flap breast reconstruction as long as they had an adequate abdominal pannus. To achieve this, different operative strategies were adopted to overcome the limitations posed by abdominal scars with acceptable rates of flap- and donor-site morbidity. These operative strategies are briefly discussed below.

Vertical midline splitting of the abdominal flap: hemi-TRAM (Figures 4 and 6)

The hemi-TRAM flap is an elegant strategy when faced with a midline abdominal scar. It is particularly applicable to patients with lower midline scars. This is a commonly employed technique, with Heller et al. recently using it successfully in 26 out of 43 patients with midline scars.[9] In our study, breast reconstruction with free hemi-TRAMs was successfully performed in three patients (Figures 4 and 6).

One of the limitations of the hemi-TRAM flap is the relative lack of volume. This problem is often overcome by contralateral breast reduction, if needed, to achieve size symmetry. Others have suggested the use of the bipedicled free TRAM flap[19] or implant augmentation of the hemi-TRAM reconstructed breast.[20,21] Other innovative ways of increasing flap volume are the use of pedicled hemi-TRAM flap combined with a contralateral free hemi-TRAM flap[9] or stacked pedicled TRAMs[22] or stacked free hemi-DIEP flaps.[15]

Skewing the flap to avoid the lower abdominal scars (Figure 7a and b)

Although appendicectomy and herniorrhaphy scars are often located in Zone IV of the flap which is routinely discarded, sometimes these scars may lie within the proposed flap boundaries. In this case, the free flap is based on the DIEVs on the opposite side of the abdomen because of the potentially unreliable vascularity of the tissue beyond the scar. The flap is skewed to avoid the scar (Figure 7a), and its volume is increased on the ipsilateral side in a manner

Figure 4 This patient's lower midline abdominal scar resulted from a childhood laparotomy for a perforated appendix. She presented for salvage breast reconstruction on account of severe recurrent peri-implant capsular contracture and painful radiation-induced soft-tissue changes (Preoperative anteroposterior and right oblique views). Her breast was successfully reconstructed with a free hemi-Tram flap, leading to symptomatic relief and elimination of her laparotomy scar (Postoperative anteroposterior and right oblique views).

akin to Kroll's extended free TRAM flap.[23] It is therefore important for a surgeon to be versatile in the use of both ipsilateral and contralateral vascular pedicles in abdominal flap breast reconstruction. Alternatively, the tissue beyond the scar is merely discarded in patients with an ample abdominal pannus which still leaves them with an adequate flap size (Figure 7b).

Minimal abdominoplasty flap undermining (Figures 6 and 8)

Subcostal scars such as those following open cholecystectomies have the potential for necrosis of the abdominoplasty flap inferomedial to the scar because of reduced vascularity. Furthermore, such patients are not suitable for pedicled

Figure 5 (Preoperative anteroposterior and right oblique views) Preoperative photographs showing a 45-year-old patient with a Caesarian section Pfannenstiel scar. The 18-month postoperative results after delayed breast reconstruction with a DIEP flap and simultaneous contralateral superomedial breast reduction (Postoperative anteroposterior and right oblique views). Note the mild breast asymmetry following weight gain and increase in size of the DIEP-flap reconstructed breast.

TRAMs because the superior epigastric vessels have been transected by the subcostal incision. This is, therefore, a well-established indication for free TRAM flap breast reconstruction.[24] The strategy employed to reduce abdominal wound healing problems was to limit the undermining of the abdominoplasty flap to the level of the scar with or without skewing the flap (Figure 8). Others have suggested complete undermining, but preservation of one perforator inferior to the scar[25] is not always easy to achieve.

Superficial inferior epigastric artery (SIEA) free flap (Figure 9)

The use of SIEA free flap virtually eliminates abdominal donor-site morbidity, because the rectus abdominis fascia and muscle are undisturbed during its elevation.[26–29] Despite its obvious advantages, the SIEA is limited by its inconsistent vascular pedicle anatomy, especially the short and small artery.[29] In our practice, in line with the Arnez et al.

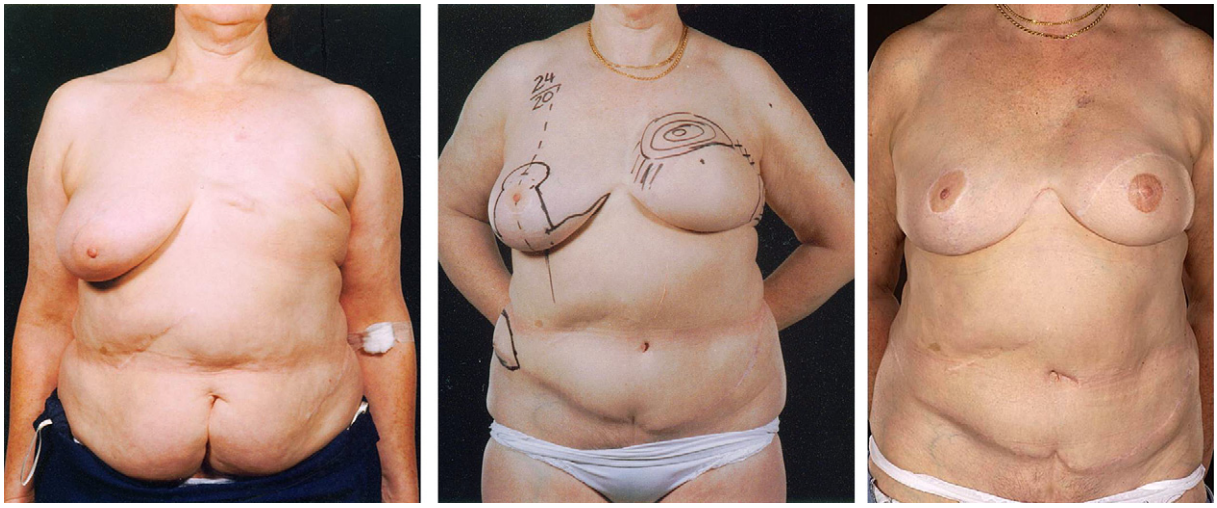

Figure 6 (Left) A 54-year-old patient with Pfannenstiel, lower midline, right subcostal and left nephrectomy scars presented for delayed abdominal flap breast reconstruction which was accomplished with a skewed and extended right hemi-TRAM free flap. Abdominal closure was achieved with minimal abdominoplasty flap undermining, resulting in an eccentric transverse donor-site scar (middle). She subsequently requested flap liposuction and abdominal dog-ear excision at the time of contralateral balancing breast reduction. The final aesthetic outcome 8 months later is presented (right).

recommendation, this flap is preferred to the TRAM or DIEP flap if its vessels are suitable.[27,28] The perfusion of the SIEA flap is only reliable to just beyond the midline[30]; therefore, it is an especially attractive proposition when patients have scars of the contralateral part on the abdomen or indeed an infra-umbilical midline scar, as illustrated in Figure 9.

Reducing the target breast volume by contralateral breast reduction (Figures 5 and 9)

In patients with lower midline abdominal scars, undergoing hemi-TRAM or hemi-DIEP breast reconstruction, the relative lack of flap volume may be a problem in matching the contralateral breast. This similar situation is also often encountered in patients undergoing SIEA flap reconstruction since only a minor part of the flap across the midline can be included.[30] The strategy used in such patients was to reduce the opposite breast to achieve symmetry (Figures 5 and 9).

Free TRAM and its variations

Despite being historically considered the 'gold standard' for breast reconstruction,[1–3] the conventional pedicled TRAM flap is relatively contraindicated in patients with pre-existing abdominal scars because of concerns about the reliability of its blood supply.[6,31] In our practice, this concern accounted for our preferential use of free tissue transfers in patients with scars, as their vascularity is better than pedicled TRAMs.[23,32–37] Our technique is based on the muscle-sparing design popularised by Grotting et al.[32,33] The free muscle-sparing TRAM flap is said to be a reliable operative strategy to reconstruct breasts in patients with pre-existing abdominal scars.[24] Donor-site morbidity including abdominal bulging and herniation is minimised with the preservation of most of the rectus sheath and muscle.

Criticisms of the free TRAM flap have centred mostly on the abdominal-wall donor-site morbidity.[38] This led to the development of the DIEP flap[39–41] which can achieve

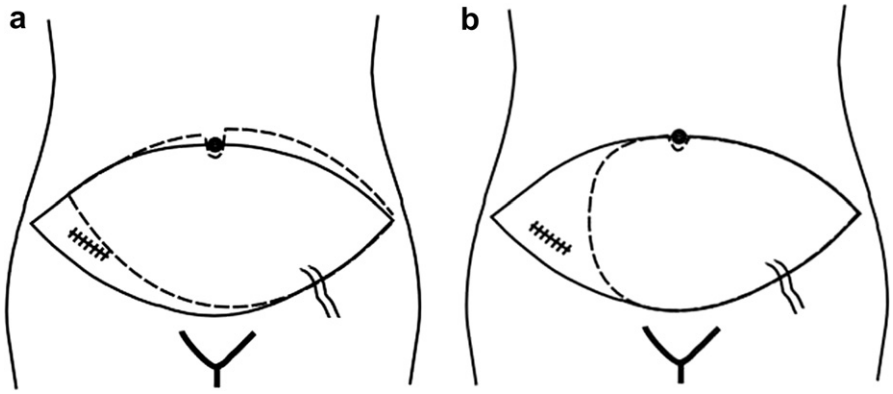

Figure 7 Line diagrams illustrating (a) the skewing of the flap upwards and to the left to avoid the appendicectomy scar; **(b)** Discarding part of the flap (Zone IV) in a patient with large abdominal pannus.

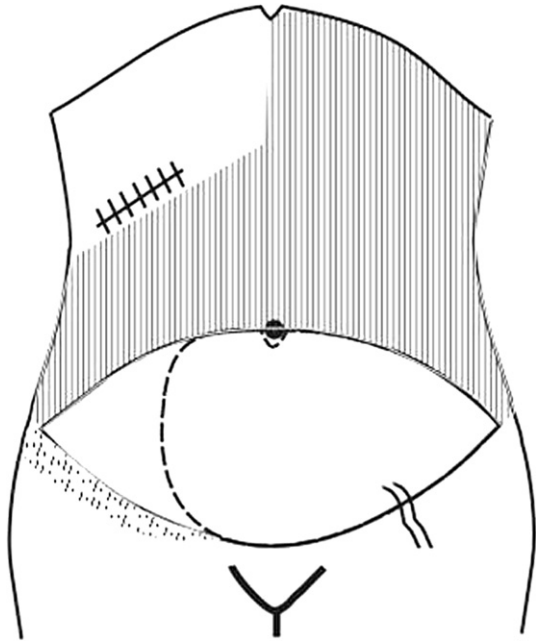

Figure 8 Line diagram to illustrate minimal undermining (line-shaded area) of the subcostal abdominoplasty flap designed to reduce its necrosis and consequent wound-healing problems. Subcutaneous undermining inferiorly beyond the inguinal ligament (shaded area) can aid donor-site closure if required (see also Figure 6).

comparable aesthetic outcomes, but with remarkably reduced donor-site morbidity,[38,41–44] postoperative pain,[45] hospital stay and hospital cost.[46,47] Free DIEP and muscle-sparing TRAM flaps were the two most commonly used abdominal flap designs in our study. Of these two flaps, the DIEP flap was preferentially used for the above reasons, unless the perforators were found unsuitable intra-operatively.[48] Some studies have suggested that there are no significant differences in venous congestion, flap necrosis and fat necrosis rates after DIEP and muscle-sparing free TRAM flap breast reconstruction,[49] but this is by no means universally accepted.[47,48]

Avoidance of pedicled flaps (Figure 5)

Pedicled TRAM flaps should be avoided in patients with pre-existing abdominal scars because of the already precarious blood supply compared to free tissue transfer.[32,36] In our series, only patients with minor scars, such as those resulting from laparoscopic surgery, underwent pedicled TRAM flap breast reconstruction. Its general indications are, however, restricted to patients who are non-smokers, not obese, with no peripheral vascular disease or diabetes mellitus. In practice, it is usually reserved for those with small-to-moderate volume requirements.[3]

Patients who object to the use of breast prostheses and insist on abdominal flap reconstruction despite the presence of multiple scars can be successfully reconstructed by the use of a combination of strategies (Figure 6). It is, however, very important to obtain a detailed and accurate past surgical history which led to the scars. This is because the precise surgery undertaken may adversely affect flap vascular reliability. Although there are recent reports of the successful harvest of TRAM flaps in patients who have previously undergone abdominoplasties[50] or liposuction,[51–53] we considered the flap to be no longer available in the former and the approach to be too unreliable in the latter. Abdominal scars should not be approached lightly in

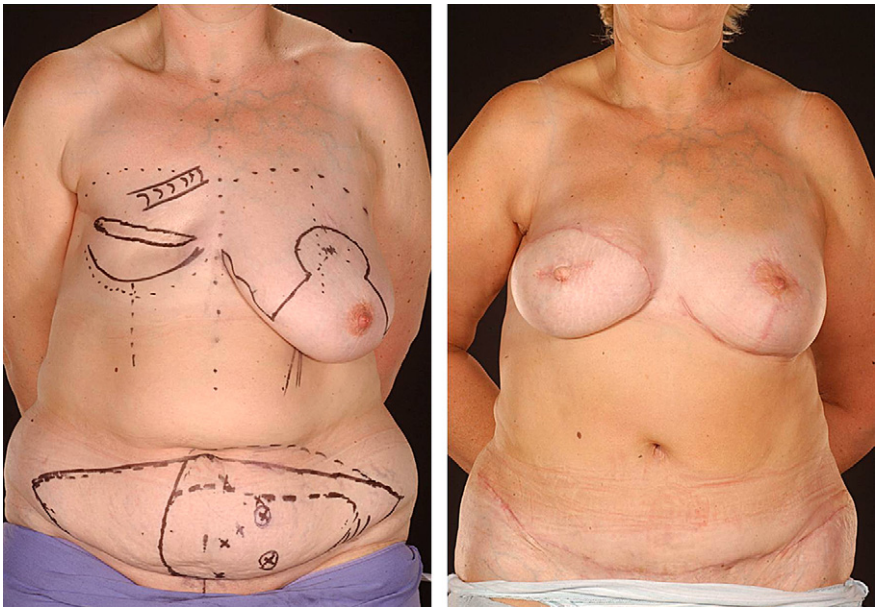

Figure 9 (Left) Following massive weight loss, this 49-year-old patient had delayed right breast reconstruction with an SIEA free flap. The preoperative markings for the SIEA flap and contralateral superomedial reduction mammoplasty[3] are shown. She had had a Pfannenstiel scar from a gynaecological operation 7 years previously. The simultaneous left breast reduction was used to achieve breast symmetry and minimised volume requirements as shown 8 months later (right).

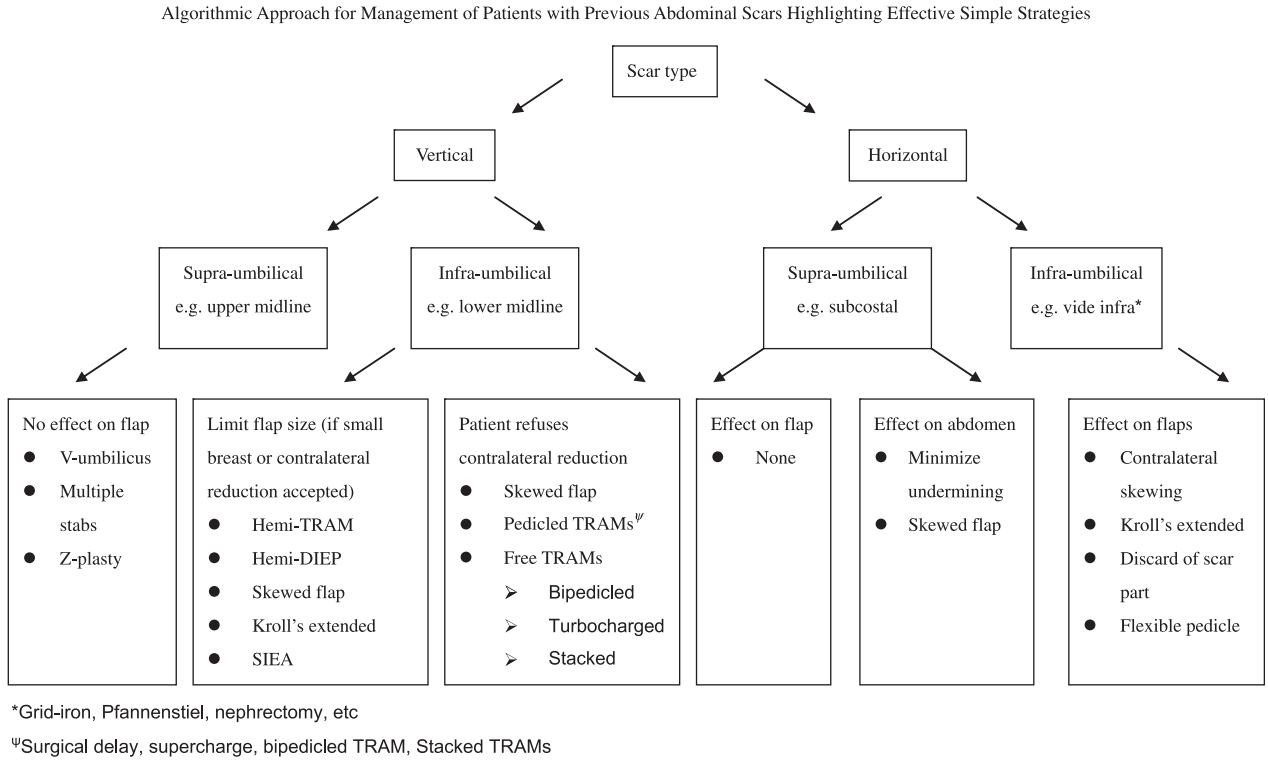

Figure 10 An algorithmic approach for management of patients with previous abdominal scars highlighting effective, simple strategies.

patients seeking abdominal flap breast reconstruction. This single operator series, however, shows that it is possible to safely undertake this reconstruction without the need to use expensive investigations or complex microvascular surgical techniques as proposed by others.[16,25] Some centres have recently adopted preoperative imaging of the DIEVs using CT or MRI.[54,55] In our practice, we found the hand-held Doppler ultrasound to be sufficient in locating suitable perforators for optimal flap design and flap survival. Angiography can be useful in establishing the continuity of the DIEVs in patients with significant transverse lower abdominal scars. Its reliability is, however, dependent on the skill and experience of the interventional radiologists. Our algorithmic approach highlighting simple operative strategies for safe and effective abdominal flap breast reconstruction in patients with pre-existing abdominal scars is presented in Figure 10.

We have found it useful to divide abdominal scars into vertical or horizontal types. Within each of these two major groups, we subdivide the scars depending on their location with respect to the umbilicus. The supra-umbilical location predominantly has an effect on the donor-site morbidity, while the infra-umbilical location has a greater influence on the flap-design choice and reliability.

In conclusion, abdominal scars do not constitute an absolute contraindication to abdominal flap breast reconstruction. With careful preoperative planning and adoption of appropriate reconstructive strategies, it is possible to obtain good aesthetic results comparable to patients without abdominal scars. An algorithmic approach can facilitate the achievement of this objective.

Acknowledgement

The authors thank Dr. Fuan Chan, formerly Senior House Officer in Plastic Surgery, for his assistance in collecting the data and transcribing the early drafts of the manuscript.

Conflict of interest

None.

Funding

None.

References

1. Hartrampf CR, Scheflan M, Black P. Breast reconstruction with a transverse abdominal island flap. *Plast Reconstr Surg* 1982; **69**:216—25.
2. Miller MJ. Immediate breast reconstruction. *Clin Plast Surg* 1998;**25**:145—56.
3. Malata CM, McIntosh S, Purushotham A. Immediate breast reconstruction after mastectomy for cancer. *Br J Surg* 2000;**87**: 1455—72.
4. Mehrara BJ, Santoro TD, Arcilla E, et al. Complications after microvascular breast reconstruction: experience with 1195 flaps. *Plast Reconstr Surg* 2006;**118**:1100—9.
5. Takeishi M, Shaw WW, Ahn CY, et al. TRAM flaps in patients with abdominal scars. *Plast Reconstr Surg* 1997;**99**:713—22.
6. Losken A, Carlson GW, Jones GE, et al. Importance of right subcostal incisions in patients undergoing TRAM flap breast reconstruction. *Ann Plast Surg* 2002;**49**:115—9.

7. Beegle PH. Microvascular augmentation of TRAM flap circulation ("supercharged" TRAM). In: Hartrampf CR, editor. *Breast reconstruction with living tissues*. New York: Raven Press; 1991. p. 175.
8. Pernia L, Miller H, Saltz R, et al. "Supercharging'' the rectus abdominis muscle to provide a single flap for cover of large mediastinal wound defects. *Br J Plast Surg* 1991;**44**:243–6.
9. Heller L, Feledy JA, Chang DW. Strategies and options for free TRAM flap breast reconstruction in patients with midline abdominal scars. *Plast Reconstr Surg* 2005;**116**:753–9 [discussion: 60–61].
10. Wagner DS, Michelow BJ, Hartrampf Jr CR. Double-pedicle TRAM flap for unilateral breast reconstruction. *Plast Reconstr Surg* 1991;**88**:987–97.
11. Pennington DG, Nettle WJ, Lam P. Microvascular augmentation of the blood supply of the contralateral side of the free transverse rectus abdominis musculocutaneous flap. *Ann Plast Surg* 1993;**31**:123–6 [discussion: 26–27].
12. Semple JL. Retrograde microvascular augmentation (turbocharging) of a single-pedicle TRAM flap through a deep inferior epigastric arterial and venous loop. *Plast Reconstr Surg* 1994; **93**:109–17.
13. Marck KW, van der Biezen JJ, Dol JA. Internal mammary artery and vein supercharge in TRAM flap breast reconstruction. *Microsurgery* 1996;**17**:371–4.
14. Berrino P, Casabona F, Adami M, et al. The ''parasite'' TRAM flap for autogenous tissue breast reconstruction in patients with midabdominal scars. *Ann Plast Surg* 1999;**43**: 119–26.
15. Ali RS, Garrido A, Ramakrishnan V. Stacked free hemi-DIEP flaps: a method of autologous breast reconstruction in a patient with midline abdominal scarring. *Br J Plast Surg* 2002; **55**:351–3.
16. Das-Gupta R, Busic V, Begic A. Deep inferior epigastric perforator flap (DIEP) breast reconstruction in the presence of a midline vertical scar. *Br J Plast Surg* 2006;**59**:675–6.
17. Hartrampf Jr CR. The transverse abdominal island flap for breast reconstruction. A 7-year experience. *Clin Plast Surg* 1988;**15**:703–16.
18. Rosen PB, Jabs AD, Kister SJ, et al. Clinical experience with immediate breast reconstruction using tissue expansion or transverse rectus abdominis musculocutaneous flaps. *Ann Plast Surg* 1990;**25**:249–57.
19. Arnez ZM, Scamp T. The bipedicled free TRAM flap. *Br J Plast Surg* 1992;**45**:214–8.
20. Kronowitz SJ, Robb GL, Youssef A, et al. Optimizing autologous breast reconstruction in thin patients. *Plast Reconstr Surg* 2003;**112**:1768–78.
21. Serletti JM, Moran SL. The combined use of the TRAM and expanders/implants in breast reconstruction. *Ann Plast Surg* 1998;**40**:510–4.
22. Spear SL, Travaglino-Parda RL, Stefan MM. The stacked transverse rectus abdominis musculocutaneous flap revisited in breast reconstruction. *Ann Plast Surg* 1994;**32**:565–71.
23. Kroll SS. Bilateral breast reconstruction in very thin patients with extended free TRAM flaps. *Br J Plast Surg* 1998;**51**:535–7.
24. Hartrampf CR, Michelow BJ, Casas LA. Concepts in TRAM flap design and execution. In: Hartrampf CR, editor. *Breast reconstruction with living tissues*. New York: Raven Press; 1990. p. 41.
25. Schoeller T, Huemer GM, Kolehmainen M, et al. Management of subcostal scars during DIEP-flap raising. *Br J Plast Surg* 2004; **57**:511–4.
26. Stern H, Nahai F. The versatile superficial inferior epigastric artery free flap. *Br J Plast Surg* 1992;**95**:270–4.
27. Arnez ZM, Khan U, Pogorelec D, et al. Breast reconstruction using the free superficial inferior epigastric artery (SIEA) flap. *Br J Plast Surg* 1999;**52**:276–9.
28. Arnez ZM, Khan U, Pogorelec D, et al. Rational selection of flaps from the abdomen in breast reconstruction to reduce donor site morbidity. *Br J Plast Surg* 1999;**52**:351–4.
29. Chevray PM. Breast reconstruction with superficial inferior epigastric artery flaps: a prospective comparison with TRAM and DIEP flaps. *Plast Reconstr Surg* 2004;**114**:1077–83 [discussion: 84–85].
30. Cormack GC, Lamberty BGH. Superficial inferior epigastric artery flap. In: Cormack GC, Lamberty BGH, editors. *The arterial anatomy of skin flaps*. Edinburgh: Churchill Livingstone; 1992. p. 437 [Chapter 7].
31. Moon HK, Taylor GI. The vascular anatomy of rectus abdominis musculocutaneous flaps based on the deep superior epigastric system. *Plast Reconstr Surg* 1988;**82**:815–32.
32. Grotting JC, Urist MM, Maddox WA, et al. Conventional TRAM flap versus free microsurgical TRAM flap for immediate breast reconstruction. *Plast Reconstr Surg* 1989;**83**:828–41.
33. Grotting JC, Beckenstein MS, Arkoulakis NS. The art and science of autologous breast reconstruction. *Breast J* 2003;**9**:350–60.
34. Galla TJ, Lukas B, Feller AM. Pedicled versus free TRAM flap for breast reconstruction. *Handchir Mikrochir Plast Chir* 1999;**31**: 126–33.
35. Serletti JM, Moran SL. Free versus the pedicled TRAM flap: a cost comparison and outcome analysis. *Plast Reconstr Surg* 1997;**100**:1418–24.
36. Schusterman MA, Kroll SS, Weldon ME. Immediate breast reconstruction: why the free TRAM over the conventional TRAM flap? *Plast Reconstr Surg* 1992;**90**:255–61.
37. Baldwin BJ, Schusterman MA, Miller MJ, et al. Bilateral breast reconstruction: conventional versus free TRAM. *Plast Reconstr Surg* 1994;**93**:1410–6.
38. Blondeel N, Vanderstraeten GG, Monstrey SJ, et al. The donor site morbidity of free DIEP flaps and free TRAM flaps for breast reconstruction. *Br J Plast Surg* 1997;**50**:322–30.
39. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. *Ann Plast Surg* 1994;**32**:32–8.
40. Blondeel PN, Boeckx WD. Refinements in free flap breast reconstruction: the free bilateral deep inferior epigastric perforator flap anastomosed to the internal mammary artery. *Br J Plast Surg* 1994;**47**:495–501.
41. Hamdi M, Weiler-Mithoff EM, Webster MH. Deep inferior epigastric perforator flap in breast reconstruction: experience with the first 50 flaps. *Plast Reconstr Surg* 1999;**103**:86–95.
42. Nahabedian MY, Manson PN. Contour abnormalities of the abdomen after transverse rectus abdominis muscle flap breast reconstruction: a multifactorial analysis. *Plast Reconstr Surg* 2002;**109**:81–7 [discussion: 88–90].
43. Nahabedian MY, Dooley W, Singh N, et al. Contour abnormalities of the abdomen after breast reconstruction with abdominal flaps: the role of muscle preservation. *Plast Reconstr Surg* 2002;**109**:91–101.
44. Futter CM, Webster MH, Hagen S, et al. A retrospective comparison of abdominal muscle strength following breast reconstruction with a free TRAM or DIEP flap. *Br J Plast Surg* 2000;**53**:578–83.
45. Kroll SS, Sharma S, Koutz C, et al. Postoperative morphine requirements of free TRAM and DIEP flaps. *Plast Reconstr Surg* 2001;**107**:338–41.
46. Kaplan JL, Allen RJ. Cost-based comparison between perforator flaps and TRAM flaps for breast reconstruction. *Plast Reconstr Surg* 2000;**105**:943–8.
47. Kroll SS, Reece GP, Miller MJ, et al. Comparison of cost for DIEP and free TRAM flap breast reconstructions. *Plast Reconstr Surg* 2001;**107**:1413–6 [discussion: 17–8].
48. Weiler-Mithoff E, Hodgson EL, Malata CM. Perforator flap breast reconstruction. *Breast Dis* 2002;**16**:93–106.
49. Nahabedian MY, Tsangaris T, Momen B. Breast reconstruction with the DIEP flap or the muscle-sparing (MS-2) free TRAM flap:

is there a difference? *Plast Reconstr Surg* 2005;**115**:436—44 [discussion: 45—6].
50. Ribuffo D, Marcellino M, Barnett GR, et al. Breast reconstruction with abdominal flaps after abdominoplasties. *Plast Reconstr Surg* 2001;**108**:1604—8.
51. Hess CL, Gartside RL, Ganz JC. TRAM flap breast reconstruction after abdominal liposuction. *Ann Plast Surg* 2004;**53**:166—9.
52. Karanas YL, Santoro TD, Da Lio AL, et al. Free TRAM flap breast reconstruction after abdominal liposuction. *Plast Reconstr Surg* 2003;**112**:1851—4.
53. De Frene B, Van Landuyt K, Hamdi M, et al. Free DIEAP and SGAP flap breast reconstruction after abdominal/gluteal liposuction. *J Plast Reconstr Aesthet Surg* 2006;**59**:1031—6.
54. Masia J, Clavero JA, Larranaga JR, et al. Multidetector-row computed tomography in the planning of abdominal perforator flaps. *J Plast Reconstr Aesthet Surg* 2006;**59**:594—9.
55. Rozen WM, Phillips TJ, Ashton MW, et al. Preoperative imaging for DIEA perforator flaps: a comparative study of computed tomographic angiography and Doppler ultrasound. *Plast Reconstr Surg* 2008;**121**:9—16.