Autologous Breast Reconstruction Following Mastectomy

Autologe Brustrekonstruktion nach Mastektomie

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Key words
- breast reconstruction
- DIEP flap
- free TRAM flap
- SGAP flap
- IGAP flap
- SIEA flap

Schlüsselwörter
- Brustrekonstruktion
- DIEP-Lappenplastik
- freie TRAM-Lappenplastik
- SGAP-Lappenplastik
- IGAP-Lappenplastik
- SIEA-Lappenplastik

Abstract

The options for breast reconstruction following mastectomy have greatly expanded. Current techniques include pedicle flaps and free tissue transfers. With the advent of perforator flaps, additional options have become available that have the advantage of reduced donor site morbidity. The purpose of this manuscript is to review the most common methods of breast reconstruction using autologous tissues.

Zusammenfassung

Die Möglichkeiten der Brustrekonstruktion mit körpereigenem Gewebe wurden in den letzten Jahren deutlich erweitert. Aktuell stehen verschiedene gestielte und freie, mikrovaskulär reanastomosierte Lappenplastiken zur Verfügung. Durch die Entwicklung der Perforans-Lappenplastiken kamen zusätzliche Lappenplastiken hinzu, die vor allem den Vorteil eines geringeren Hebedefekts aufweisen. Ziel der vorliegenden Arbeit ist es, eine Übersicht über die am häufigsten angewandten Lappenplastiken in der Brustrekonstruktion mit körpereigenem Gewebe zu geben.

Introduction

The use of autologous tissue for breast reconstruction following mastectomy is considered by many plastic surgeons to represent the gold standard. Since the mid 1970s, a variety of methods have been described to reconstruct a breast using tissues from different parts of the body. The principle donor sites have included the abdomen (TRAM, DIEP, SIEA flaps), posterior thorax (latissimus dorsi musculocutaneous, TAP flaps), and the gluteal region (inferior and superior flaps). Other donor sites such as the flank (Rubens flap) and extremities (medial thigh, ALT) have been described but are less commonly used. Traditional methods of breast reconstruction using autologous tissues have incorporated skin, fat, and muscle from the donor site that is usually transferred on a vascularized pedicle. The principle component of the pedicle was the donor site muscle in which the artery and vein traversed. Thus, the purpose of the muscle was primarily to provide the blood supply to the adipocutaneous portion of the flap and secondary to compliment flap volume. Donor site morbidity such as weakness, hernia, and bulge prompted the development of alternative methods. With the evolution of free tissue transfer for breast reconstruction, it was realized that perfusion could be enhanced, so minimizing flap related morbidity, and as a secondary benefit, removal of less muscle which further minimized donor site morbidity such as weakness or hernia.

The most recent innovation using autologous tissue has been in the area of perforator flaps. With this technique, donor site muscle is totally preserved and morbidity is further minimized. Perforator flaps can essentially be harvested from anywhere on the body but are harvested most often from the abdomen, buttock, and posterior thorax. These operations can be more complex and challenging and are associated with a relatively steep learning curve. However, once mastered, perforator flap breast reconstruction can result in excellent outcomes and high patient satisfaction.

The purpose of this manuscript is to review some of the current concepts associated with breast reconstruction using autologous tissue. The review will focus primarily on microvascular breast re-

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construction methods. Emphasis will be placed on patient selection, flap selection, and tips and traps related to operative techniques.

Patient Selection

It is becoming increasingly appreciated that proper patient selection and good outcomes are intimately related. Although most women interested in breast reconstruction may be candidates for autologous reconstruction, not all will be. Candidacy may be precluded for reasons such as medical co-morbidities, extremes of body habitus, lack of interest, or a desire for a quick and simple procedure. That said, approximately 75% of my practice consists of women who have breast reconstruction using autologous tissues. This is in contrast to other individuals or institutions where as much as 90% of the reconstructive procedures are performed using prosthetic devices. This statistic can be partially explained based on the phenomenon of "surgeon selection" that is becoming more prevalent as reconstructive surgeons super-specialize in a particular operation. Some surgeons are recognized for their expertise in perforator flaps and others are recognized for their expertise using prosthetic devices. Both methods have the potential for excellent outcomes.

When evaluating women for autologous breast reconstruction, several factors should be considered that are related to specific characteristics of the patient and breast. These include breast volume and contour, body habitus, donor site considerations, medical co-morbidities, tumor characteristics, patient preference, and the potential for adjuvant therapies. The abdomen has been the donor site of choice for most women. In general, the most important physical finding is a sufficient quantity of skin and fat in order to reconstruct the desired breast volume. Although a woman may be slender with a paucity of abdominal fat, she may still be a candidate for an abdominal flap if the breast volume requirements are low. In women who are overweight or obese, an abdominal flap can still be performed; however, the flap should be tailored to sustain its perfusion requirement and to minimize the incidence of fat necrosis [6,8,18]. The abdomen is usually not considered when there are abdominal scars that will preclude incorporating zones of tissue that would be needed for the reconstruction or when morbidly obese.

In the event that the abdomen is not a suitable donor site and the patient is not a candidate for nor is interested in prosthetic reconstruction, the gluteal region is considered. The SGAP (superior artery gluteal perforator) flap is ideal for women who desire autologous reconstruction, are not candidates for an abdominal flap, and refuse prosthetic reconstruction [9]. The IGAP (inferior gluteal artery perforator) flap can also be used in these situations [2]. Most women will have sufficient donor fat in these areas and will be candidates. An important caveat about the SGAP and IGAP flaps is the potential appearance of the donor site. Although most women will maintain their donor site aesthetic unit, it has been observed that some will have significant scalloping of the buttock and/or gluteal asymmetry. In addition, delayed healing or seroma formation can pose additional problems. This has been a significant area of dissatisfaction in some women. In general, I have found that petite women of shorter stature are more prone to these aesthetic issues; whereas, taller and slender women are less prone. When disfigurement of the upper buttock is a potential concern, the IGAP flap is considered [2].

Table 1 The incidence of various outcomes following free TRAM and DIEP flap breast reconstruction are tabulated

Factor	DIEP	Free TRAM
Fat necrosis	7.30%	7.10%
Venous congestion	4.50%	2.70%
Flap failure	2.70%	1.80%
Abdominal bulge		
▸ unilateral	4.50%	5%
▸ bilateral	6.50%	21%
Sit-ups		
▸ unilateral	100%	97%
▸ bilateral	95%	83%

The posterior thorax can also be used as a donor site in the form of a latissimus dorsi musculocutaneous flap or a thoracodorsal artery perforator flap [11]. Although frequently performed by some, these options are personally used more often following a primary reconstructive failure or for a partial breast reconstruction [10]. The volume and quantity of tissue obtained is generally insufficient for total breast reconstruction unless a prosthetic device is used in conjunction. That said, excellent aesthetic results can still be obtained using these techniques.

The topic of complications is discussed and reviewed with all women. Following autologous reconstruction, it is mentioned that my personal success rate ranges from 97 to 98% for the free tissue transfer using abdominal flaps and 90 to 92% using gluteal flaps. These statistics are acceptable for most women. The reasons for reduced success following gluteal flaps are explained. There are factors such as thin caliber vessels and short pedicle length that are outside the control of the surgeon and may predispose to a poor outcome. For some women the risk is worth taking and for others it is not. The risk of an abdominal bulge following a DIEP flap is 4% following an unilateral and 6% following a bilateral reconstruction [13,15 – 17]. These risks are slightly increased following a muscle-sparing free TRAM flap. The use of a synthetic mesh for abdominal reinforcement is rarely used at the initial operation but may be used for the correction of an abdominal bulge. Another important fact is that when considering the abdomen as the primary donor site, the DIEP flap is used in 90% and a muscle-sparing free TRAM is used in 10% of cases [18, 19]. This is based on an intraoperative assessment of the perforators to ensure that the location and caliber are sufficient to safely perfuse the required flap volume. In the event that the perforators are deemed inadequate, a muscle-sparing free TRAM is performed. It is explained that outcome studies have demonstrated no clinically relevant functional difference between the two (**Table 1**).

Flap Selection

As previously mentioned, the abdomen is the preferred donor site for the majority of breast reconstruction procedures. The abdomen is the source for the pedicle TRAM, free TRAM, DIEP, and SIEA flaps. It can be reasonably stated that the complexity of a given abdominal flap is directly related to the degree in which the abdomen musculature and anterior sheath are preserved. Inherent to understanding these flaps is an appreciation for the

various types of muscle preservation techniques. Classification of muscle sparing is based on the amount of rectus abdominis preserved [15,18] (**Table 2**). Most muscle-sparing operations will require free tissue transfer. Although the microvascular techniques are increasing in popularity, many plastic surgeons (at least in the Unites States) remain reluctant to incorporate them into their practices for various reasons. Given that the pedicle TRAM flap is no longer performed in my practice, emphasis will focus on the microvascular methods.

Perhaps the most challenging decision the microvascular breast surgeon must consider is which flap to select. In my practice, the DIEP flap is performed in approximately 90% of cases followed by the muscle-sparing (MS-2) free TRAM and the SIEA flaps. The normal blood supply to the intact anterior abdominal wall is derived from the deep inferior epigastric system as well as the superficial inferior epigastric system. The deep system is usually more dominant and is therefore preferred and used in the majority of cases. The superficial system is less predictable, often not present, and less commonly used. In fact, performance of an SIEA flap is only possible in approximately 30% of women and is best reserved for women of moderate body habitus and requiring only a hemi-flap for the reconstruction [7]. In approximately 5% of cases in which an abdominal flap is used, the dominant blood supply to the adipocutaneous compartment is derived from the superficial system. This fact may explain the problem of venous congestion that is observed in some DIEP flaps despite a patent venous anastomosis [5].

The decision regarding whether to perform an MS-2 free TRAM or DIEP flap is ultimately based on the presence and quality of the abdominal wall perforatoring vessels. Knowledge of these perforators can be assessed either pre- or intraoperatively. Preoperative assessment is best achieved using CT angiography [3, 21]. With this technique the location and caliber of the perforating vessel or vessels can be adequately determined. This technique has proven to be effective for many surgeons. The advantage of preoperative CT angiography is that the "guesswork" as to whether a perforator is present or suitable is essentially eliminated and the harvesting of a DIEP flap can be more reliably executed. In addition, the CT angiogram can alert the surgeon as to the subfascial course of the perforator. Although not routinely performed in my practice, the benefits of preoperative imaging to facilitate perforator selection are appreciated.

Intraoperative assessment is equally effective in identifying the abdominal wall perforating vessels. Reliance on intraoperative assessment requires more experience because of the variability associated with perforator location, caliber, and number. The "Gent" consensus described the five most common perforator types, some of which are not suitable to adequately perfuse a flap [4]. In general, for a perforator flap to be successfully harvested and transferred, a single perforating artery and vein of at least 1.5 mm in diameter are recommended. These vessels are usually located in the periumbilical region. If a dominant perforator arising from the deep system is not identified, it may be because the superficial inferior epigastric system is the more dominant. In this situation, one can consider performing an SIEA flap or a muscle-sparing free TRAM. The MS-2 muscle-sparing free TRAM is the author's preferred flap. With this flap, a small central segment of the rectus abdominis muscle and anterior rectus sheath (2 – 4 cm) is harvested incorporating several small (< 1.5 mm) vessels (see **Fig. 4**) The author's modified algorithm for the selection of a DIEP or muscle sparing free TRAM is depicted in **Table 3**.

Table 2 Classification of muscle sparing (MS)

Muscle-sparing technique	Definition (rectus abdominis)
MS-0	full width, partial length
MS-1	preservation of lateral segment
MS-2	preservation of lateral and medial segment
MS-3 (DIEP)	preservation of entire muscle

Table 3 Current algorithm for the DIEP and muscle-sparing free TRAM flaps based on volume of flap, degree of abdominal lipodystrophy, number and caliber of perforators, and unilateral vs. bilateral reconstruction

Factor	Free TRAM	DIEP
Breast volume requirements		
▸ < 1 000 grams	+	++
▸ > 1 000 grams	++	+
Abdominal fat		
▸ mild to moderate	+	++
▸ severe	++	+
Perforators > 1.5 mm		
▸ 0	+	no
▸ > 1	+	++
▸ bilateral	+	++

The SIEA flap is an alternative option that is suitable in some women. The superficial inferior epigastric vessels have been demonstrated to be "useable" in 30% of cases [7]. A limitation of the SIEA flap is that the angiosome is confined to the ipsilateral flap; therefore, inclusion of zone 3 will more likely than not result in fat necrosis [12]. Thus, the SIEA flap is ideal for women having unilateral or bilateral breast reconstruction in which only a hemi-flap is used.

The gluteal flaps are arguably the most complex flaps in the armamentarium of the microsurgeon [1,2,9]. In general, these flaps are considered when the abdomen is not a suitable donor site and the patient is not interested in prosthetic reconstruction. Gluteal flaps can be raised with or without the gluteus maximus muscle. There are two perforator flaps that are derived from this region that include the superior (SGAP) and inferior (IGAP) gluteal artery perforator flaps. The specific locations for each flap include the upper buttock (above the piriformis muscle) for the SGAP and the gluteal crease region (below the piriformis muscle) for the IGAP. The gluteal flaps are ideally suited for women who are thin to moderate in body habitus. They are not recommended for heavy to obese women.

Operative Technique: Tips and Traps

When embarking on dissecting perforator flaps, there are several tips and traps that have proven to be quite useful. Given that the SIEA flap can be safely performed in 30% of women, it is recommended to first visualize these vessels. They are usually located between the anterior superior iliac spine and the pubic tubercle along the course of the inferior incision. Should the SIEA/V have a palpable pulse and be deemed useable, then it can be considered for use and dissected to its origin. Should the SIEA/V be deemed not useable, then it can be preserved in the event that a secondary anastomosis is needed to augment vascular flow.

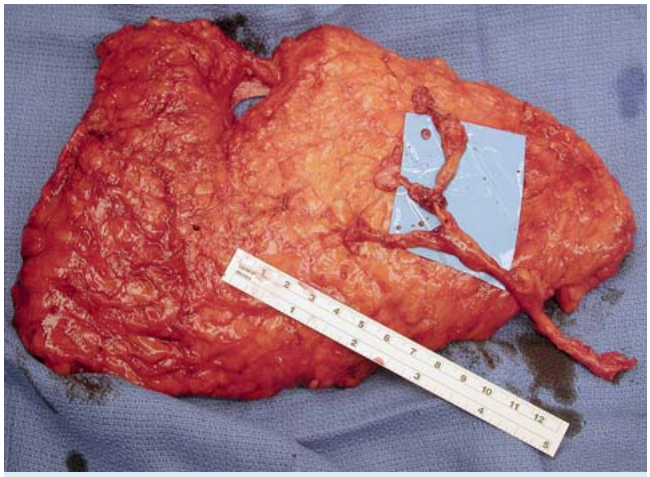

Fig. 1 A type 3 perforator DIEP flap is demonstrated. The perforators are aligned in series requiring only a single myotomy in the rectus abdominis.

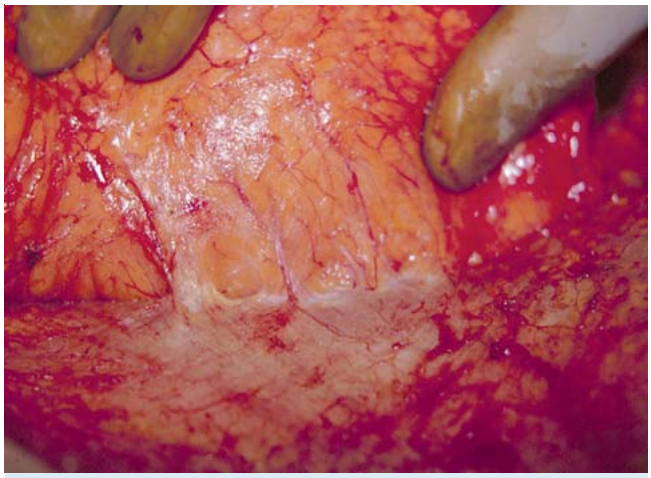

Fig. 2 Several small perforators are demonstrated in the lateral row. These are analogous to the type 3 perforator described by Blondeel. They do not have a palpable pulse, are less than 1.5 mm in diameter, and are not recommended for a single perforator DIEP flap. They are collectively suitable for a muscle sparing free TRAM flap.

The learning curve associated with perforator flaps is one that is long and arduous. It is my personal opinion that approximately 100 flaps are necessary in order to feel comfortable with these operations and perform them in a predictable and reproducible manner. Once that level of confidence is achieved and the technique is mastered, the dissection for a DIEP flap is often easier and faster than that of a muscle-sparing free TRAM flap. However, for this statement to be realized, there are several tips and traps that should be appreciated.

DIEP flap

Dissection of a DIEP flap requires few surgical instruments in my practice and includes a fine tip mosquito clamp, Wietlaner retractors, fine scissors, tissue forceps, and a low set electrocautery device. The selected perforator should be ideally located near the center of the flap in order to obtain equidistant perfusion. A minimal perforator diameter of 1.5 mm is recommended. When several perforators are available, sequential occlusion can be performed to assist with the selection process. Multiple perforators can be considered when they are aligned in series or in close proximity. An example of a type 3 perforator DIEP flap is demonstrated in **Fig. 1**. Medial row perforators are preferred when the flap will include tissue on the contralateral side. Another observation has been the absence of a perforator with a diameter of greater than 1.5 mm in thin women. If concerned, an MS-2 free TRAM is performed incorporating a small central segment of muscle. An example of these small caliber perforators with a diameter < 1.5 mm is demonstrated in **Fig. 2**.

When initiating the dissection, including a small cuff of the anterior rectus sheath (1 – 2 mm) around the perforator is recommended, especially if the perforator is piercing the anterior rectus sheath at a tendinous inscription (**Fig. 3**). During the dissection it is imperative to preserve the lateral intercostal nerves as they pierce the rectus abdominis muscle at the junction of the lateral and central longitudinal segments. Failure to do so will more likely than not result in abdominal weakness or bulge. Motor nerve branches that cross the perforator or the source vessel can be sharply divided. Whether or not to coapt the severed nerve is controversial. Some advocate using a microsuture for coaptation; however, it is these authors' preference to allow the transected end to neurotize into the adjacent muscle. The intramuscular dissection proceeds to the point that the perforator

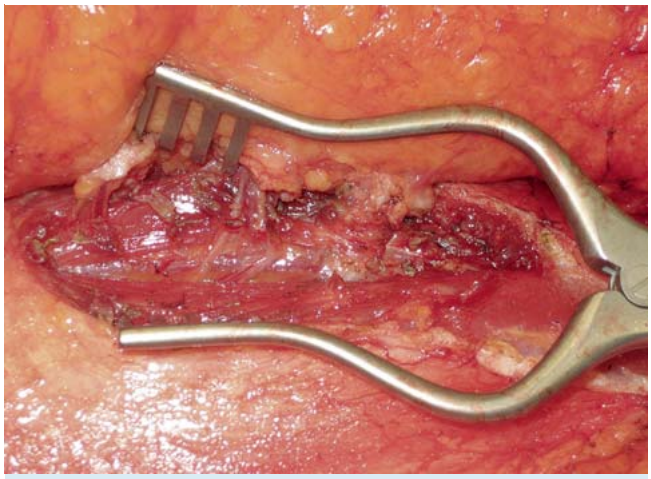

Fig. 3 A close-up view of a typical perforator dissection. The Wietlaner retractors serve to separate the muscle fibers. A small cuff of anterior rectus sheath is included around the type 3 perforator. Small transverse motor nerve branches are demonstrated crossing over the inferior epigastric vessels.

or inferior epigastric vessel becomes submuscular. At that point the dissection progresses from the lateral edge of the muscle towards the iliac vessels. It is recommended to continue the dissection until the vessel diameter approaches 2.5 – 3 mm.

Throughout the dissection of a DIEP flap, it is recommended to assess the perfusion from the peripheral edges of the flap. One can also use a hand-held Doppler probe to listen for the arterial and venous signals. When a unilateral reconstruction is planned, it is wise to preserve the contralateral perforators in the event that a "lifeboat" is necessary. When a bilateral reconstruction is planned, it is advised to proceed cautiously when isolating and dissecting the perforators because a contralateral lifeboat will not be available. When in doubt about the quality of the perforators, a muscle-sparing free TRAM flap is considered. An example of a patient following bilateral DIEP flap is demonstrated in **Fig. 4**.

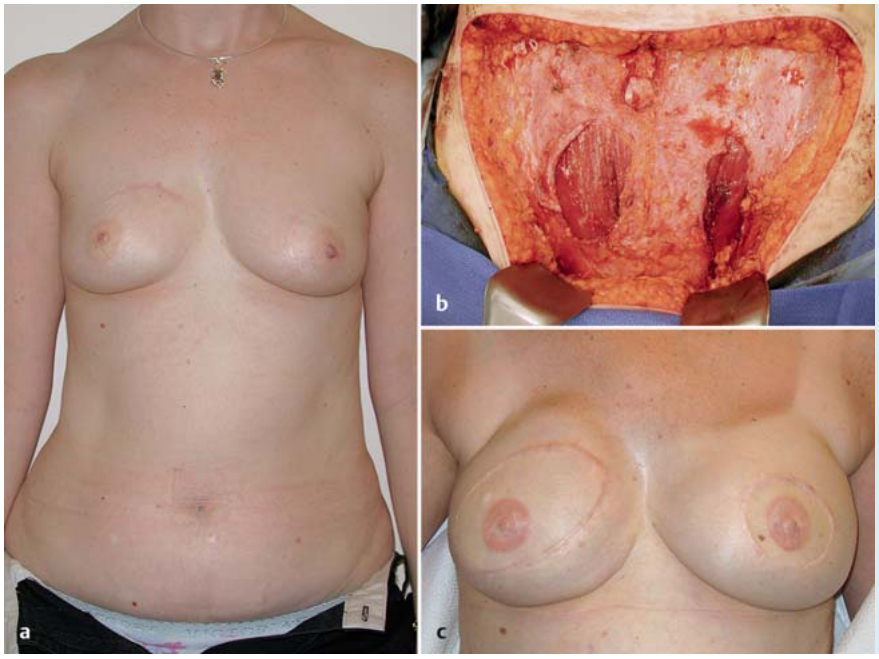

Fig. 4 a to **c** **a** Preoperative photograph of a woman with right breast cancer prior to bilateral mastectomy and DIEP flap breast reconstruction. **b** Typical appearance of the abdominal wall following bilateral DIEP flap harvest. **c** Three-year postoperative image following bilateral DIEP flap reconstruction. The mastectomy was not skinsparing on the right and a skin-sparing prophylactic on the left.

The recipient vessels of choice for the DIEP and all free flaps used for breast reconstruction are the internal mammary artery and vein [14]. These are used for all delayed reconstructions and most immediate reconstruction. The vessels are exposed at either the 3rd or 4th interspace. The cartilaginous segment of the rib is excised. At this level the diameter of the internal mammary vein is 3 – 3.5 mm and that of the internal mammary artery is 2.5 – 3 mm. Given the prevalence of sentinel lymph node dissection and the rarity of axillary dissection, the thoracodorsal artery and vein are rarely used. These vessels are only used in the setting of a modified radical mastectomy where the vessels have been exposed.

Free TRAM

A free TRAM flap is considered when the quality of perforators is poor (< 1.5 mm in diameter) or in the event that the flap volume requirements exceed 1000 grams. A muscle-sparing free TRAM (MS-1 or MS-2) is performed when needed. The advantage of this operation is that multiple perforators can be included in the flap that may minimize the incidence of fat necrosis or vascular compromise. Once a network of perforators is visualized, an anterior sheath outline is delineated and incised. In contrast to the DIEP flap dissection, the anterior rectus sheath is elevated off the rectus abdominis muscle medially and laterally. The muscle is then undermined and the location of the inferior epigastric artery is visualized and palpated. This maneuver will facilitate the dissection of the free TRAM and minimize the chance of injury to the perforators or pedicle. The rectus abdominis muscle is divided using a fine tip mosquito clamp and a low setting electrocautery device. When the perforators are located in the central segment of the rectus abdominis muscle, an MS-2 free TRAM is harvested (**Fig. 5**). When the perforators are predominately over the medial or lateral aspect of the muscle, then an MS-1 free TRAM is harvested. It is important to preserve as much lateral intercostal motor innervation as possible to maintain function of the rectus abdominis muscle. An example of a woman following a bilateral MS-2 free TRAM flap is demonstrated in **Fig. 6**.

Fig. 5 The typical appearance of an MS-2 free TRAM flap incorporating a network of small perforators.

SIEA flaps

The SIEA flap is technically easier to harvest than either the DIEP or muscle-sparing free TRAM flap. It is essentially an adipocutaneous flap that is perfused by a direct perforator, i.e., the perforator does not course through a muscle. Following visualization of the superficial inferior epigastric artery and vein and the decision to proceed with this flap, it is wise to still dissect out the deep system perforators. Following their isolation, the perforators should be sequentially occluded to ensure that the perfusion from the SIEA/V is adequate. If it is, then the SIEA flap can be safely performed. Despite the gains in abdominal wall function and the fact that some surgeons are enthusiastic about this flap, I remain somewhat skeptical about its benefit. Concerns include the smaller caliber vessels, the limited angiosomal territories, the increased incidence of fat necrosis, and the higher rate of redo arterial and venous anastomoses [22]. My personal philosophy is that the key to successful "microvascular" surgery is to make it as "macrovascular" as possible. Small caliber vessels

Fig. 6 a to **c** **a** Preoperative photograph of a woman with left breast cancer. **b** Typical appearance of the abdominal wall following an MS-2 free TRAM flap harvest. **c** Three-year postoperative image demonstrating natural contour and volume following an MS-2 free TRAM flap.

associated with a significant vascular mismatch can predispose to anastomotic failure [20].

SGAP/IGAP flaps

The gluteal flaps are considered by many to be amongst the more difficult flaps to harvest. An appreciation of the anatomic landmarks is essential in raising these flaps. These include the greater trochanter laterally, the posterior superior iliac crest superiorly, and the coccyx inferiorly. The location of the perforators is best determined using a hand-held Doppler probe with the patient in the prone position on the operating table. There may be several Doppler signals that are appreciated. It is my personal preference to select a perforator that is based on the lateral aspect of the flap and toward the periphery of the flap. The reasons for this are that the laterally based perforators will usually provide a pedicle length of 6 – 8 cm; whereas, the medially based perforators are usually 4 – 6 cm in length. In contrast to the DIEP flap when a centrally based perforator is preferred, with the SGAP a peripheral perforator is preferred. This is in order to facilitate the technical aspects of performing a microvascular anastomosis. With a central perforator, some of the useable length is under of flap rather than outside the flap edge. With the peripheral perforator, the added length can be used to facilitate the positioning of the flap during the anastomosis.

Once the perforator is isolated the dissection commences in the subfascial plane. In contrast to a DIEP flap in with the length of the myotomy is minimized, with the SGAP, the length of the myotomy is maximized. This is because the perforator dissection progresses perpendicularly to the cutaneous surface whereas, with the DIEP flap the dissection is parallel with the cutaneous surface. It is important to recognize that the dissection continues deep to the gluteus maximus and medius muscles before penetrating the deep fibrous fascia. Once beyond this point, there are multiple venous branches that must be carefully dissected and divided before choosing the end-point of the perforator.

The IGAP flap is raised with the same landmarks in mind. The skin territory for this flap can be positioned to be “in the crease” as described by Allen [2]. In general the adipocutaneous component of this flap is slightly less than that of the SGAP [1]. Other considerations are that the sciatic nerve is often exposed during this dissection and may result in postoperative discomfort. Because the incision is located in the ischial region, sitting may be restricted for several days following the operation and dehiscence of the incision may be observed more often.

Conclusions

As microvascular surgeons continue to expand upon the armamentarium of autologous tissue options for breast reconstruction, our outcomes will continue to improve. The goal with reconstructive breast surgery is no longer to create just a breast mound but to create a breast with natural shape, volume, contour, and symmetry. Patient expectations following mastectomy and reconstruction have increased and we as reconstructive plastic surgeons should continue to strive for excellence.

Conflict of Interest: None

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Born on September 30, 1959, in Los Angeles, California. Graduated 1987 at the College of Medicine at the University of California in Irvine. Postdoctoral training from 1987 to 1995 in General Surgery, Plastic Surgery and Craniofacial-Maxillofacial Surgery at the University of California, Irvine, at the University of Maryland, Johns Hopkins, as well as at the Shock Trauma Hospital Baltimore, Maryland. From 1995 to 1997 part time Assistant Professor of Plastic Surgery and from 1997 to 2000 fulltime at the Johns Hopkins University in Baltimore. Since 2000 Associate Professor of Plastic Surgery at the Johns Hopkins University in Baltimore (firstly fulltime, since 2005 part time). Furthermore, since 2005 Associate Professor of Plastic Surgery at the Georgetown University in Washington DC (full time). He is member of several societies and associations and has authored over 90 publications.

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