20.2

The deep inferior epigastric artery perforator (DIEAP) flap

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SYNOPSIS

- The deep inferior epigastric artery perforator (DIEAP) flap provides a large volume of soft, malleable tissue that resembles the natural consistency of the breast.
- DIEAP flap dissection is comparable with conventional myocutaneous free flap surgery, once the initial learning curve is overcome.
- The main advantage of the DIEAP flap is preservation of full rectus abdominis muscle function with less donor site morbidity.
- In experienced hands, the DIEAP flap loss rate is less than 1%.
- The DIEAP flap is the perforator flap of choice for autologous breast reconstruction.

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Introduction

Perforator flaps have become increasingly popular in recent years. They are at the top of the reconstructive ladder and are considered an advancement of musculocutaneous and fasciocutaneous flaps. Passive muscle and fascial carriers are no longer required to ensure flap vascularity, and by virtue of their composition, perforator flaps permit excellent "like for like" tissue replacement with minimal aesthetic or functional donor morbidity. Perforator flaps are usually thin, pliable, easily moldable flaps that are well suited to resurfacing work. They are also ideal for reconstructing pliable structures such as the tongue or for molding complex contours in the head and neck region. Perforator flaps with large amounts of subcutaneous fat are ideal for reconstructing the breast.

A perforator flap is defined as a flap of skin and subcutaneous tissue, which is supplied by an isolated perforator vessel. Perforators pass from their source vessel to the skin surface either through or between the deep tissues (mostly muscle). Any vessel that traverses through muscle before perforating the outer layer of the deep fascia to supply the overlying skin is termed a "myocutaneous perforator". A vessel that traverses through septum, i.e., between the muscle bellies, is designated a "septocutaneous perforator".

Evolution of perforator flaps has been intimately related to growing knowledge of the blood supply to the skin and the history of musculocutaneous and fasciocutaneous flap development.

The deep inferior epigastric artery perforator (DIEAP) flap arose as a refinement of the conventional myocutaneous lower abdominal flap. The myocutaneous perforators of the inferior epigastric vessels were described[1] soon after the first transverse rectus abdominis myocutaneous (TRAM) flap was performed for breast reconstruction by Holmström and Robbins.[2,3] In the mid-1980s, following Taylor's landmark work on the vascular territory of the deep inferior epigastric artery, it became apparent that the lower abdominal flap could be perfused solely by a large periumbilical perforating vessel. That assumption was confirmed in 1989, when Koshima and Soeda[4] published two cases of "inferior epigastric skin flaps without rectus abdominis muscle".

Initially the DIEAP flap met with animosity from many in the surgical community, as it challenged conventional teaching and was thought to be unsafe.

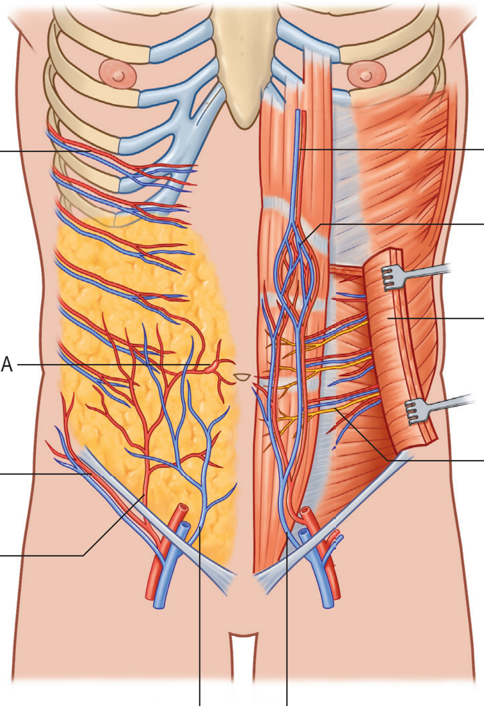

Fig. 20.2.1 The vascular anatomy of the lower abdomen. In the right hemi-abdomen, the skin is removed down to the superficial inferior epigastric vessels. The artery with its common veins, and the superficial inferior epigastric vein can be found medial to the superficial circumflex iliac vessels. Around the umbilicus, the perforators of the deep inferior epigastric system connect with arteries and veins of the superficial system. The anterior branches of the intercostal arteries and veins move anterior and distally from their origin at the midaxillary line. Variable anastomoses between these different vessels make up for a complex and intense random network between the skin and the deep fascia. On the left side of the abdomen, the deep fascia of the rectus abdominis muscle is removed and the fascia of the external and internal oblique have been retracted. The deep inferior epigastric artery and vein pass deep to the lateral board of rectus abdominis as they move more cranially and enter into the rectus abdominis a few centimeters higher. Segmental branches of the deep inferior epigastric system connect with the anterior branch of the intercostal artery and veins (particularly the lateral branch of the deep inferior epigastric artery). The anterior intercostal nerves run together with the segmental branches and branch into sensory branches that run with the perforators into the subcutaneous tissues and motor branches that run medial and distally in the rectus abdominis muscle. More cranially, the deep inferior epigastric vessels anastomose in the diffuse network throughout the muscle with the superior epigastric artery. DIEA, deep inferior epigastric artery; SEA, superior epigastric artery; SCIA, superficial circumflex iliac artery; SIEA, superficial inferior epigastric artery; SIEV, superficial inferior epigastric vein.

However, we are now in an era where DIEAP flaps are routinely performed in plastic surgery units throughout the world.[5]

With an increased emphasis on optimizing the aesthetic result and minimizing donor site morbidity, in the authors' opinion, the DIEAP flap is the current gold standard in breast reconstruction.

Basic science/anatomy

The deep inferior epigastric artery perforator (DIEAP) flap

The deep inferior epigastric artery arises from the external iliac, immediately above the inguinal ligament. It curves forward in the subperitoneal tissue and then ascends obliquely along the medial margin of the abdominal inguinal ring. Continuing its course upward, it pierces the transversalis fascia, passing in front of the linea semicircularis, ascending between the rectus abdominis and the posterior lamella of its sheath.

The deep inferior epigastric artery finally divides into numerous branches, which anastomose, above the umbilicus, with the superior epigastric branch of the internal thoracic artery and with the lower intercostal arteries (Figs. 20.2.1 & 20.2.2).

The anatomy of the deep inferior epigastric artery system is very variable.[15,16] The average pedicle length is 10.3 cm, and the average vessel diameter is 3.6 mm. Normally, the deep inferior epigastric artery divides into two branches, with a dominant lateral branch (54%). However, if the deep inferior epigastric artery does not divide, the vessel has a central course (28%) with multiple small branches to the muscle and centrally located perforators. If the medial branch is dominant (18%),

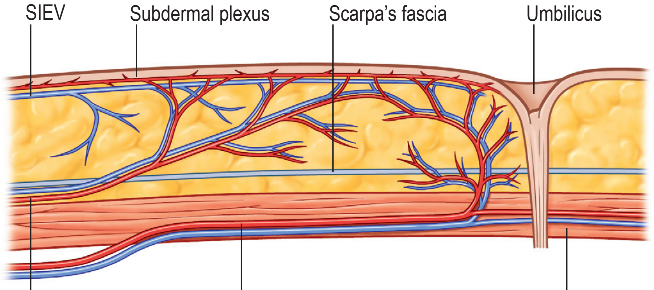

Fig. 20.2.2 The same anatomic structures as explained in Fig. 20.2.1 but seen in a paramedian sagittal view. SIEA - superficial inferior epigastric artery; DIEA - deep inferior epigastric artery; SCIA - superficial circumflex iliac artery; SEA - superior epigastric artery; SIEV - superficial inferior epigastric vein

Historical perspective

In 1989, Koshima and Soeda[4] reported the first clinical application of the inferior epigastric artery perforator flap. They demonstrated that it was possible to harvest the same amount of lower abdominal skin and fat as in the TRAM flap, without sacrificing the rectus abdominis muscle. Koshima *et al*.[6] then reported another 13 cases with free thin paraumbilical perforator based flaps. Later, Pennington *et al*.[7] used an anastomosis between the distal end of the ipsilateral pedicle and the contralateral pedicle to augment the blood supply of a free TRAM flap. Allen and Treece[8] reported 22 successful breast reconstructions with the DIEAP free flap, and finally, Blondeel and colleagues[9,10] improved the understanding of the flap and popularized its use in autologous breast reconstruction.[11–14]

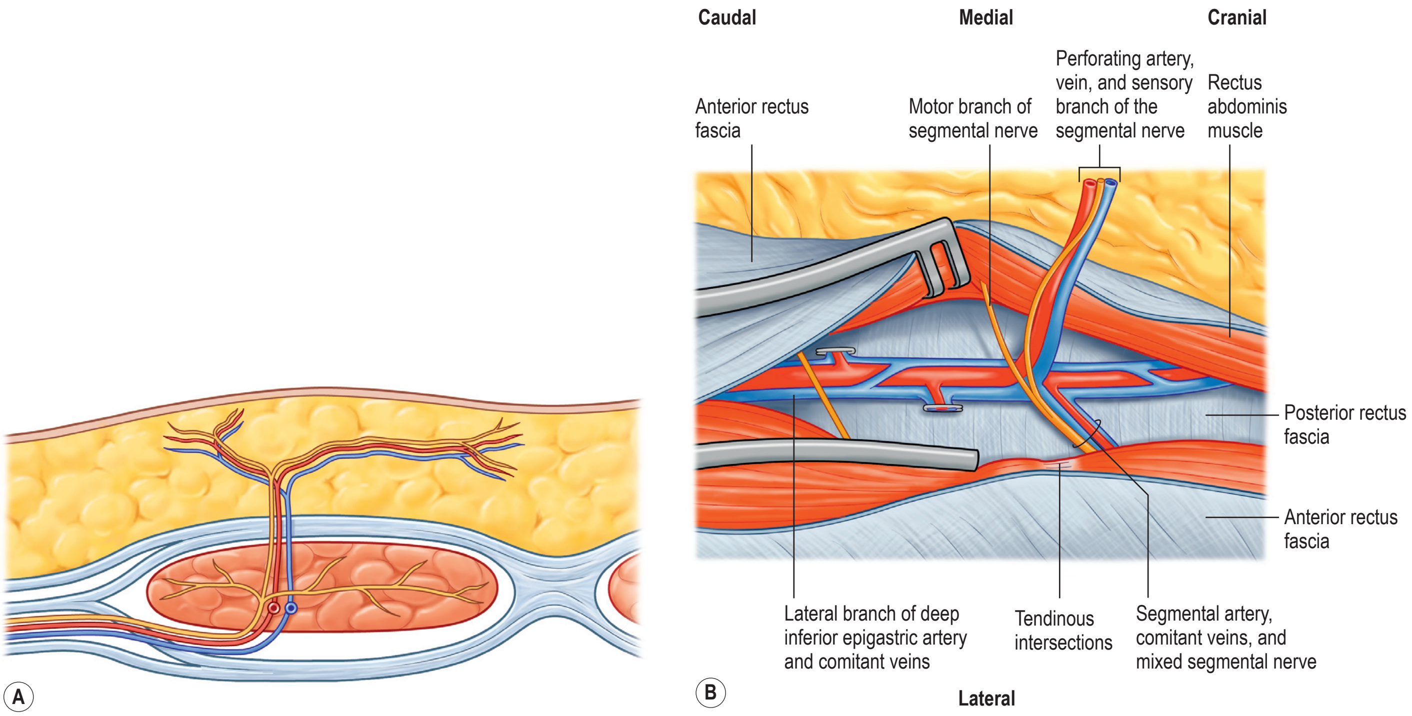

Fig. 20.2.3 (A,B) The anatomy of the intercostal nerves. The mixed intercostal nerves run below the fascia of the internal oblique and predominantly enter the rectus abdominis muscle at its posterior surface at the level of the lateral branch of the deep inferior epigastric artery. They follow the intercostal and segmental vessels and mostly pass over the submuscular or intramuscular part of the lateral branch of the deep inferior epigastric artery. At that point, it splits into two motor branches, one lateral and one medial, and additionally into a pure sensory nerve that accompanies the perforating artery and vein.

flow appears to be significantly lower than in a central system or in patients with a dominant lateral branch.[17]

Blondeel *et al*.[17] found between two and eight large (>0.5 mm) perforators on each side of the midline. The majority of these perforators emerged from the anterior rectus fascia in a paramedian rectangular area 2 cm cranial and 6 cm caudal to the umbilicus and between 1 and 6 cm lateral to the umbilicus. Anatomic symmetry was hardly ever encountered. The closer a perforator is to the midline, the better the blood supply to the least vascularized part of the flap across the midline, as one choke vessel less has to be transgressed. However, the lateral perforators are often dominant and easier to dissect because they run more perpendicularly through the muscle. The sensory nerve that runs with these perforating vessels is also often much larger (Fig. 20.2.3). The medial perforators provide better perfusion of the flap, but they have a longer intramuscular course, requiring more elaborate dissection with extensive longitudinal splitting of the muscle. An alternative is to extend the design of the flap to include more tissue from the flank. If one is uncertain as to whether or not enough volume can be transferred, the perforators can be dissected on both sides (Siamese flap).[6]

Preference is also given to perforators that pass through the rectus abdominis muscle at the level of the tendinous intersections. At this point, the perforators are frequently large and have few muscular side branches. The distance from the subcutaneous fat to the deep inferior epigastric vessels is also shorter, simplifying this most delicate part of the dissection.[18]

As a result, the design of a DIEAP flap is made over the most centrally located, dominant perforator, lateral or medial, as long as sufficient abdominal subcutaneous fat tissue is available and the least vascularized part of the flap across the midline can be discarded (Fig. 20.2.4). At the origin of the perforator, several nerves are encountered (see Fig. 20.2.3). Although there is no constant anatomy, mixed segmental nerves run underneath or through the muscle from laterally and split into a sensate nerve running with the perforator into the flap and a motor nerve crossing on top of the deep inferior epigastric vessels distal to the bifurcation of the perforator, into the medial part of the rectus abdominis muscle.[19] One should always expect and anticipate a variety of anatomic differences.

The superficial inferior epigastric artery (SIEA) originates 2–3 cm below the inguinal ligament directly from the common femoral artery (17%) or from a common origin with the superficial circumflex iliac artery (48%). It then passes superiorly and laterally in the femoral triangle lying deep to Scarpa's fascia and crosses the inguinal ligament at the midpoint between the anterior superior iliac spine and the pubic tubercle. Above the

Fig. 20.2.4 Once the position of the dominant perforator is located on the abdomen, the flap is centered over this perforator. The incision on the abdomen is symmetrical on both sides, but the least vascularized part of the flap will be discarded.

inguinal ligament, the SIEA pierces Scarpa's fascia and lies in the superficial subcutaneous tissue. During its course, the SIEA lies deep to and parallel to the superficial inferior epigastric vein. The vein drains directly into the saphenous bulb.[20]

The SIEA is seen as a direct perforator to the skin while the perforators of the deep system are considered indirect perforators (Fig. 20.2.5). Of all vessels, it is important to choose the largest, most dominant

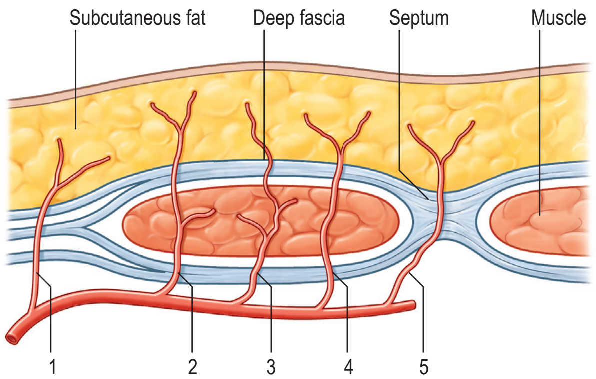

Fig. 20.2.5 The different types of perforators that can be found at the lower abdominal wall. (1) The branches of the superficial inferior epigastric artery are direct perforators that vascularize the subcutaneous fat and skin after perforating the deep and superficial fascia. All other perforators are indirect perforators; (2) perforators that have a predominant vascularization of the subcutaneous fat tissue and skin with few muscular branches; (3) perforators that branch off of side branches that have a predominant goal of nourishing the muscle; (4) perforators that pass through the rectus abdominis muscle without branching; (5) perforators that pass through the septum or around the rectus abdominis muscle with the sole purpose of vascularizing the subcutaneous tissues.

perforator destined to vascularize the fat and skin that has few or no side branches to the muscle.

The superficial inferior epigastric vein is the largest vein draining the skin paddle of the DIEAP flap. It is located below the dermal plexus but above Scarpa's fascia, midway between the anterior superior iliac spine and the pubic symphysis. Harvesting an elliptical skin island transects this vein, redirecting the venous drainage through the smaller perforating veins. Connections between the superficial epigastric vein and the deep inferior epigastric system exist in every patient, but substantial medial branches crossing the midline have been found to be absent in 36% of cases.[21,22] In these flaps, venous connections are only present through the subdermal capillary network. This explains why the portion of a flap farthest from the midline may suffer from venous congestion and why the presence of this problem is so variable and unpredictable.

The lymphatic drainage of the DIEAP flap can be divided into a superficial and a deep system. The superficial collectors are located directly underneath the reticular dermis. Deep cuts performed during de-epithelialization may injure this system. The superficial collectors drain to the superficial lymph nodes in the groin. The deep system drains the deep structures of the abdominal wall, i.e., the muscles and fascia and is located in close proximity to the arteries and veins. Careful dissection of the vascular pedicle avoids iatrogenic damage to this lymphatic system. The deep system drains to the inferior epigastric artery and then to the deep iliac nodes.[23]

Recipient vessels

The internal mammary artery and its accompanying veins are the first choice for DIEAP flap breast reconstruction.[10,12,24] Its central position on the chest wall facilitates microsurgery and offers the most flexibility during breast shaping. The vessels are easy to dissect and are usually protected from radiotherapy damage. In a number of irradiated vessels perivascular fibrosis can be encountered. Chest wall inflammation, following infected implant removal or extreme capsular fibrosis, can sometimes cause severe perivascular scarring.

Although the artery is usually of sufficient caliber, the size of the veins is very variable. In most cases, the veins on the left side of the chest wall are smaller than those on the right side. For this reason, the authors prefer to dissect the vessels at the level of the left third or fourth rib, but at the level of the fourth rib on the right side. A small segment of cartilage can be removed together with some intercostal muscles, both cranially and caudally (Fig. 20.2.6). This provides sufficient exposure of

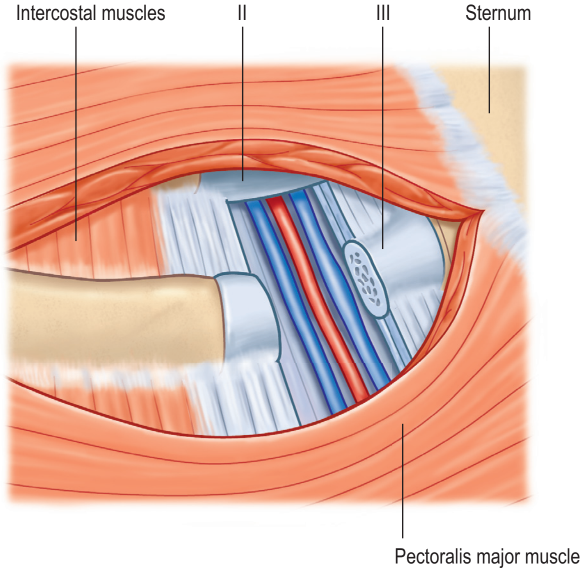

Fig. 20.2.6 The internal mammary artery and two common veins on the right side after removing a small part of the costal cartilage of the third rib.

the vessels and adequate recipient vessel length. One can also limit the dissection and exposure to the removal of only the intercostal muscles. Wider exposure can be obtained by nibbling away the lower border of the superior rib and the upper border of the inferior rib.

At the level of the second and third intercostal space, large perforators sometimes emerge from between the intercostal muscles to perforate the medial part of the pectoralis major muscle. The size of these vessels is variable, and it is estimated that they can only be used as recipient vessels for free flaps in about 5–10% of cases. These vessels can be identified and evaluated above and below the pectoralis during preparation of the recipient site. If no adequate perforators are found, the internal mammary artery and the accompanying veins are then prepared.[25]

Patient presentation

When designing a DIEAP flap, the main factor is the amount of viable tissue that can be harvested on a particular perforator. The most accurate indicator of this is preoperative localization of the dominant source of blood inflow by duplex Doppler or computed tomography (CT) imaging. In addition to defining the "safe" flap territory, these techniques provide a degree of reassurance by avoiding intraoperative surprises, and considerably reduce operative time. A reduction of operative costs significantly decreases the overall expense of the reconstructive procedure.

More recently, magnetic resonance angiography has shown promise in the imaging of perforators. In addition to producing accurate and detailed images, there is no radiation exposure,[26] unlike CT imaging.

Besides this imaging, the conventional preoperative work-up includes blood work, oncologic screening, and additional tests for concomitant diseases if necessary.

Ultrasound evaluation of perforator vessels

This is performed with a color Doppler, which employs a combination of grayscale and color Doppler imaging. This modality has 100% positive predictive value and few false-negatives.[27]

Grayscale imaging shows the anatomic detail of fixed points, axial vessels, and perforating branches. The addition of color Doppler allows identification of blood flow, direction (towards or away from the probe), pattern of flow (i.e., venous or arterial), and finally a measure of blood flow velocity.[28–31]

The disadvantages of color duplex lie in its lack of anatomic detail and operator dependence. It requires a detailed knowledge of 3D vascular anatomy, as well as expertise in the handling of the devise. While it provides dynamic information about blood flow, this may lead to a false sense of security because humeral and nervous stimuli can affect the microcirculation and cause fluctuations in vessel flow. Hence, flow rates do not always correlate with the size of the perforator.

In addition to preoperative imaging, it is possible to use a unidirectional hand-held pencil probe for identification of superficial vessels in the operating theatre. The perforators identified can be marked on the patient's skin to allow accurate flap design and aid intraoperative dissection. This is a simple and inexpensive technique, which provides a useful intraoperative adjunct.[32] There can, however, be false-negative and false-positive signals as a result of interference from axial vessels or perforators that run parallel to the fascia, before entering their suprafascial course.

CT imaging

Multidetector-row helical CT is a recent innovation that permits rapid delineation of an anatomic area of interest, giving excellent resolution and low artifact rating. It takes less than 10 min to perform and is well tolerated by patients. This has become the modality of choice for the identification of abdominal wall perforators.[33–35] The use of magnetic resonance imaging (MRI) to avoid the high X-ray dose is promising but still needs further refinement.[36]

The scanning is performed in conjunction with intravenous contrast medium and allows evaluation of the donor and recipient vessels. Information collected includes the exact location and intramuscular course of

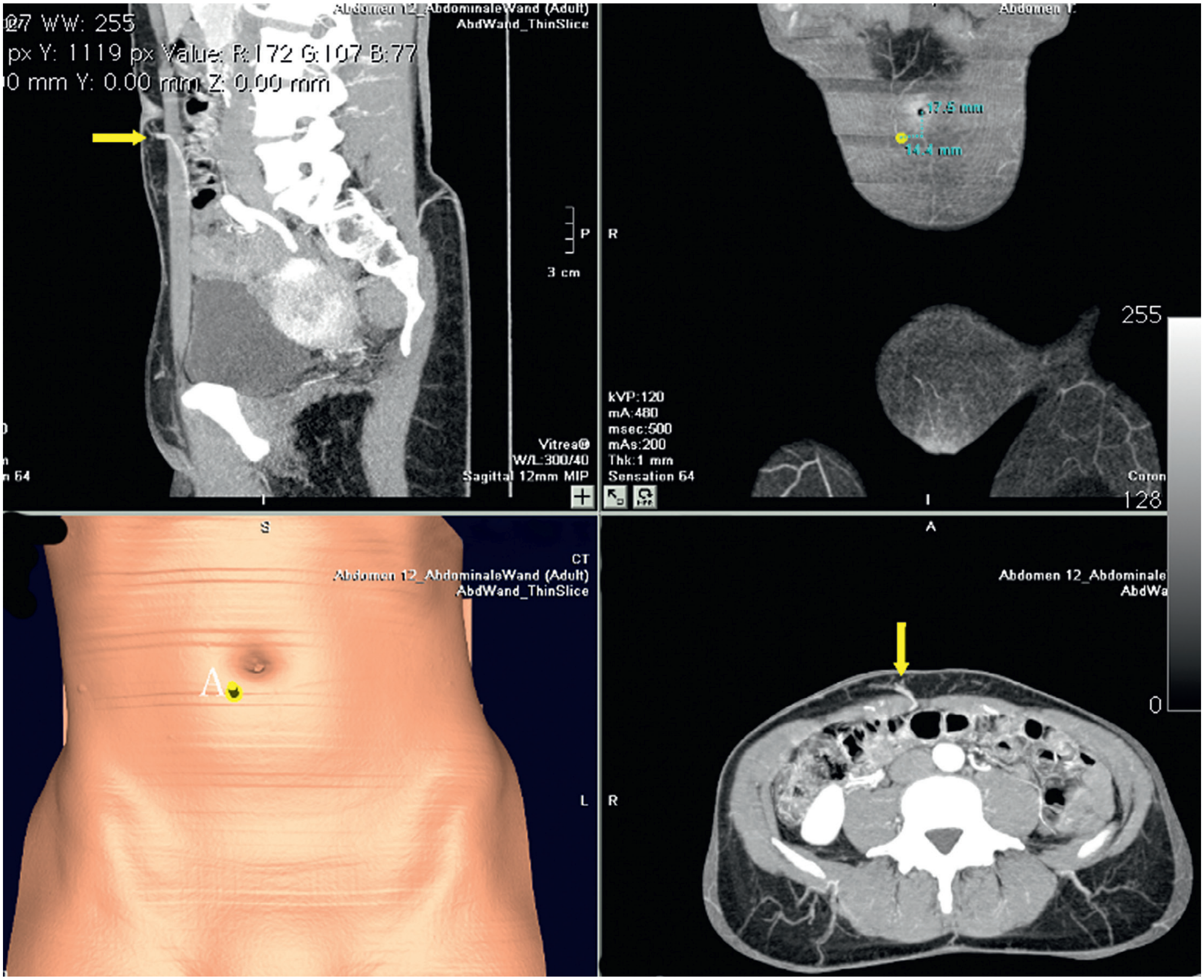

Fig. 20.2.7 Different views and 3D reproductions of a perforator on the right side of the abdominal wall. The sagittal view shows the course of the vessel through the rectus abdominis muscle. The location of the perforator is described in relation to the umbilicus.

vessels from their origin, the caliber of the perforators, and also identifies the dominant vessel. Delineation of the relative dominance of the deep and superficial systems allows the surgeon to consider different options preoperatively. Not only can this modality be used to select suitable patients preoperatively but also operative times are reduced by a mean of 21%, with the obvious associated cost benefits.[37]

The disadvantages of multidetector-row helical CT lie in the X-ray dosage and use of intravenous contrast media, with the resultant risk of anaphylaxis. The X-ray dose, albeit significant, is less than a conventional liver CT scan and can be combined with staging investigations to reduce the overall exposure. Interpretation of the images can be done before and during surgery by the surgeon him/herself and correlated to intraoperative findings (Figs. 20.2.7 & 20.2.8).

Patient selection

Patients eligible for an autologous breast reconstruction with a DIEAP or SIEA flap are mainly those with sufficient lower abdominal subcutaneous fat tissue. In Western society, many women are good candidates, but cultural differences can apply. For example, Asian women are generally slimmer and may prefer other donor sites such as the anterolateral thigh area. The lower abdomen is, however, first preference for autologous breast reconstruction. Only in very slender women, or in cases where scarring of the abdominal wall

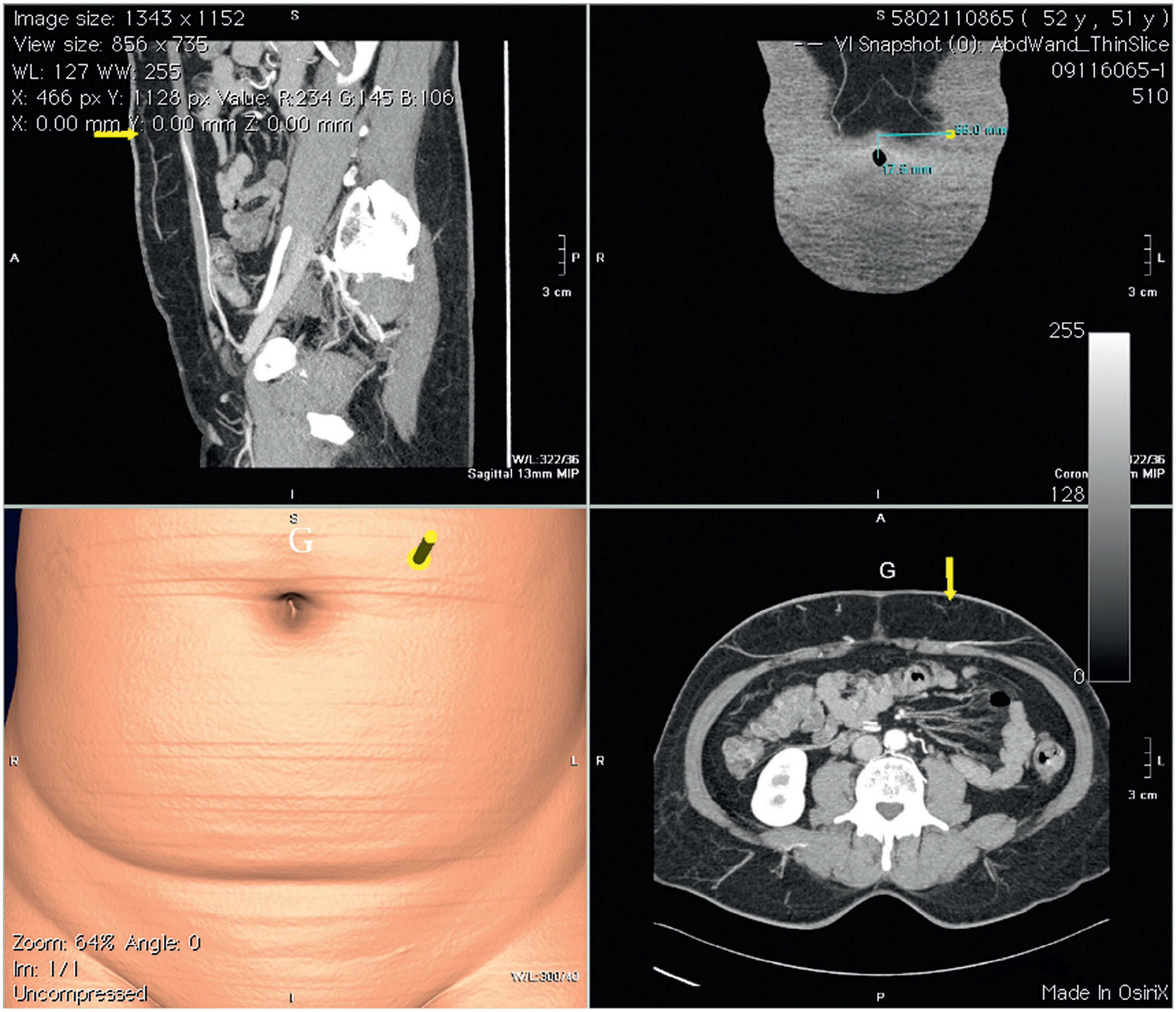

Fig. 20.2.8 CT-angiograms of a supraumbilical lateral perforator on the left side, symmetrical to a similar perforator on the right side, vascularizing only the most lateral parts of the lower abdomen. The sagittal view shows a relatively easy dissection as the vessel penetrates directly in the muscle, but choosing this perforator means that tissue beyond the midline will not be vascularized.

endangers the normal blood circulation of the free flap or the abdominoplasty flap, secondary options, such as gluteal perforator flaps or internal thigh flaps, are considered. Pedicled latissimus dorsi or thoracodorsal artery perforator flaps in combination with an implant are further down the reconstructive ladder and implant basic techniques are avoided if possible.

Severe obesity, uncontrolled diabetes, debilitating cardiovascular disease, and uncontrollable coagulopathies are the most frequent examples of absolute contraindications to DIEP flap reconstruction. Smokers and unmotivated patients are advised to postpone their surgery if oncologically possible. Implant reconstruction is only recommended in patients with a poor prognosis or those with a limited life span because of age or concurrent disease. In addition, patients objecting to donor site scars, those refusing complex surgery, or those unable to accept the possible microsurgical complications are seen as candidates for implant-based surgery.

Surgical technique

Preoperative marking

For this surgical technique,[38] the patient is marked in a standing position. A fusiform skin island is drawn on the abdomen, similar to the one used for breast reconstruction with a free TRAM flap, but the bulk of the flap is centered over the selected perforator. Although the size and shape may vary slightly, the borders of a DIEAP flap are generally located at the level of the suprapubic crease, the umbilicus, and both anterior superior iliac spines, but the flap may be extended laterally to the midaxillary lines.

A DIEAP flap generally measures 12–15 cm in height and 30–45 cm in width. However, the tension of the donor site following closure should be estimated, as this ultimately limits the size of the flap that can be harvested. A horizontal line is drawn just above the umbilicus and another one marked 12–15 cm below this. At a level 2 cm below the umbilicus, the lateral limits of the flap are marked 15–23 cm on either side of the midline. The amount of subcutaneous fat present in the flanks is assessed, as this can be included in the flap if required (Fig. 20.2.9A). All the outer markings are connected by a continuous line placed in natural skin creases.

Operative procedure (see Video 20.2.1 ▶)

The patient is placed in a supine position with the arms positioned beside the trunk. If available, imaging data is drawn on the patient's abdomen using a 1 cm grid system based on the umbilicus. Two intravenous lines, an indwelling urinary catheter, and antithrombotic stockings are applied. A warming blanket is used to keep the patients core body temperature at 37°C. The proposed incision lines are infiltrated with a dilute solution of local anesthetic and adrenaline (40 mL 1% xylocaine with 1/100 000 adrenaline in 40 mL sterile water), except in the region of the superficial epigastric veins. Three separate stab incisions are then placed around the umbilicus and connected with the aid of skin hooks. The umbilicus is incised circumferentially down to the fascia. While making the inferior incision, care is taken to preserve the superficial epigastric veins. If the venous drainage of the flap is insufficient or thrombosis of the perforating vein(s) occurs after the anastomosis, the superficial epigastric veins can be used as an additional venous conduit. Two or three veins may be present, but they commonly unite further down the abdominal wall. The veins are dissected over a length of 2–3 cm and ligated with clips to make them easily retrievable later, if needed. If the caliber of the superficial epigastric artery is noted to be large enough, a similar skin island to the DIEAP flap can be harvested on these two vessels. The incisions are continued down to the fascia. Beveling is avoided unless extra volume is required, as this may later lead to a depressed scar in the lower abdomen. Laterally however, the flap may be beveled to include more fat and reduce residual "dog-ears".

Dissection of the vascular pedicle of a DIEAP flap can be divided into three different technical stages: suprafascial, intramuscular, and submuscular. The most demanding stage is the intramuscular dissection of the vascular pedicle.

Suprafascial dissection

Dissection begins laterally in the flanks and progresses medially with the aid of cutting and coagulating diathermy. The skin and subcutaneous fat are lifted off the external oblique fascia up to the lateral border of the rectus abdominis muscle. At this point, dissection proceeds more cautiously as the perforators are identified. Gentle traction on the flap helps provide good exposure of the vessels. Again, if imaging data is available, the dissection can progress rapidly to the preselected perforator, with ligation of the more laterally placed perforators (Fig. 20.2.9B). If only a unidirectional Doppler probe was used, one can try to visualize as many perforators as possible before selecting the largest one. This method needs some expertise, can be time-consuming, and does not allow evaluation of all the medial perforators.

If the caliber of one vessel is estimated to be insufficient, an adjacent perforator located on the same vertical line can also be dissected. The abdominal wall muscles must be relaxed at all times and the perforating vessels kept moist with normal saline. No antispasmodic agents are routinely used. When dissecting a perforator from the lateral side, it is important to realize that a side branch may be located more medially. Extra care must be taken when dissecting the full circumference of a vessel, but complete dissection helps prevent vessel damage when raising the flap from the contralateral side (Fig. 20.2.9C,D).

The anterior rectus fascia is then incised with a pair of scissors following the direction of the rectus abdominis muscle fibers at the rim of the tiny gap in the fascia through which the perforating vessel passes (Fig. 20.2.9E). If more than one perforator is dissected, the different gaps can be connected with each other. A small cuff of fascia may be left around the perforator if the vessel is small or if the surgeon feels more comfortable doing so.

Lifting the fascia helps mobilize the perforator, which can be freed by blunt dissection, gently pushing away the loose connective tissue. The perforator can be adherent to the deep surface of the anterior rectus fascia for a variable distance before it plunges into the muscle. The division of the fascia is continued superiorly for a distance of 3–4 cm and inferiorly to the lateral border of the rectus abdominis muscle in an oblique line towards the inguinal ligament (Fig. 20.2.9F). At this point, the direction of the division of the fascia is changed into the direction of the fibers of the external oblique muscle. This avoids a continuous area of weakness of the lower abdominal wall, as closure of the fascia is performed on top of the rectus abdominis muscle. Two separate incisions, one around the perforator and one over the deep inferior epigastric vessels at the lower lateral border of the rectus muscle, can also be performed.

It is advisable to fully complete the dissection of the DIEAP flap on one side before progressing to the other.

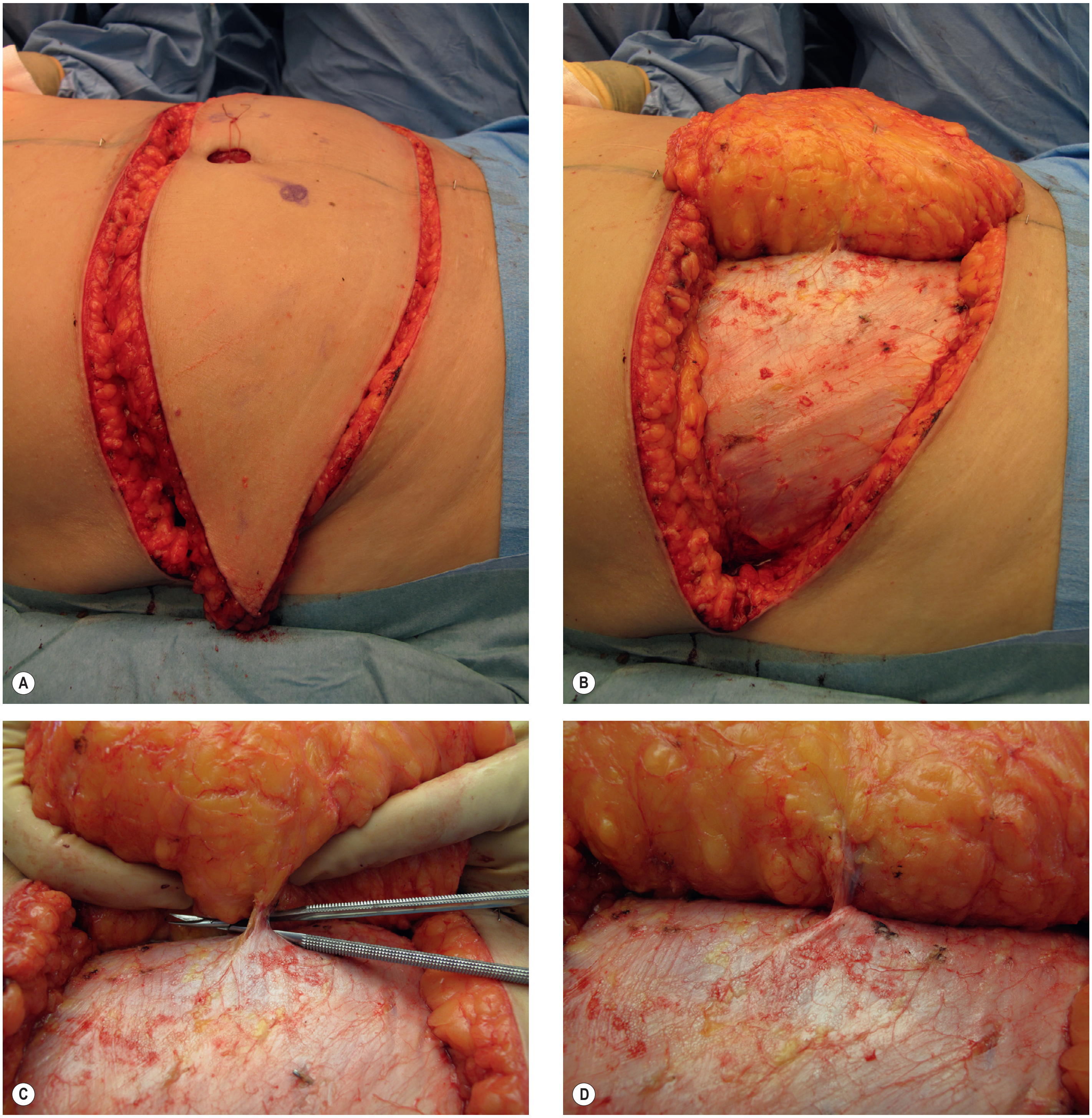

Fig. 20.2.9 (A) Incision of skin and subcutaneous tissue is extended towards the flanks if additional tissue is needed. The dominant perforator on the right side is marked with an 'x' on the flap. **(B)** The flap is elevated from lateral to medial until the area around the preoperatively marked perforator is reached. Undermining is then continued proximal and distal to the perforator. **(C)** Undermining continues around the perforator for a distance of about 2 cm. Lifting up the subcutaneous tissue is easier at this point when the deep fascia is still closed. **(D)** Access to the perivascular loose connective tissue is found by incising the gap in the deep fascia and the tissues surrounding the vessels.

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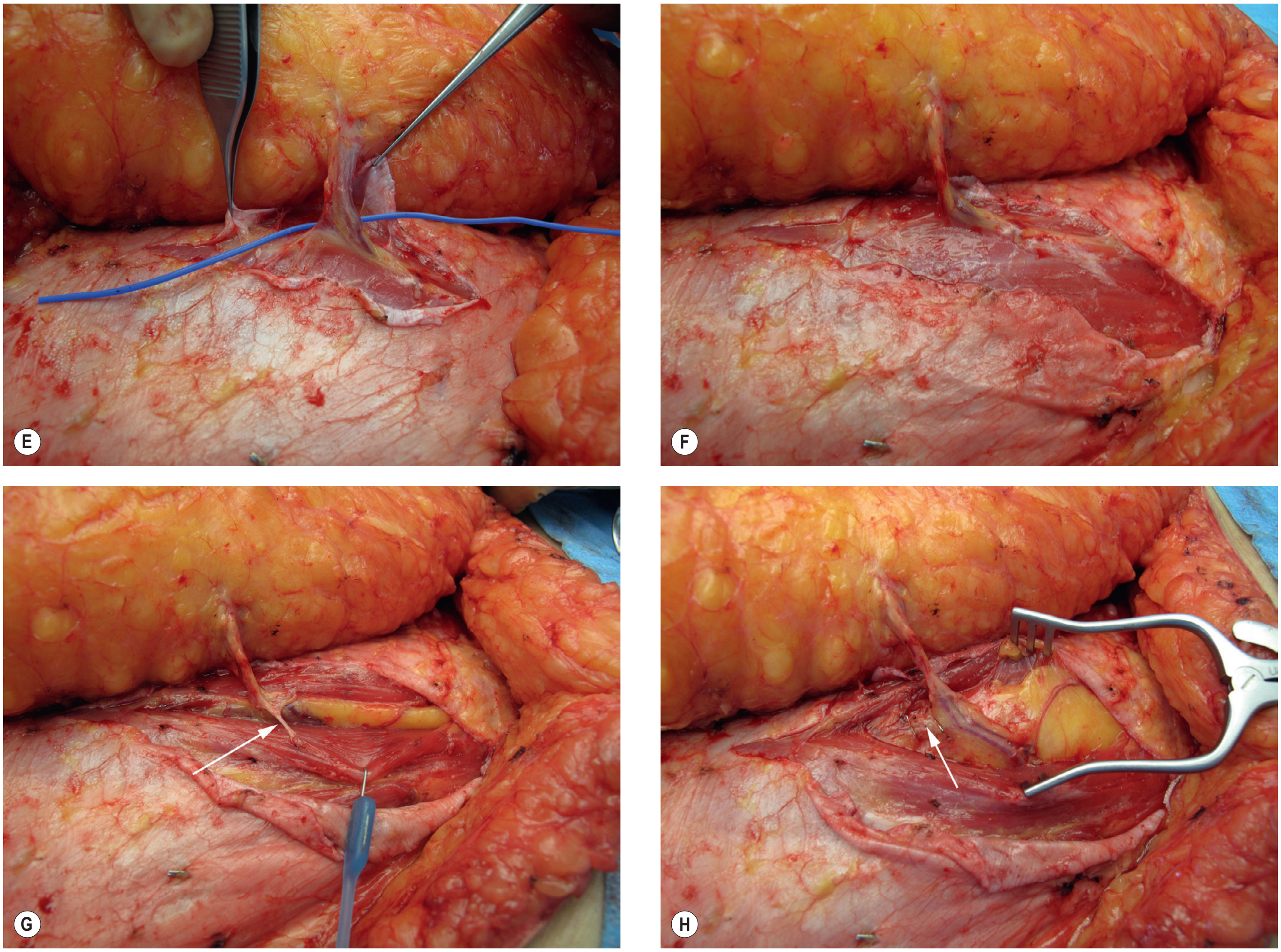

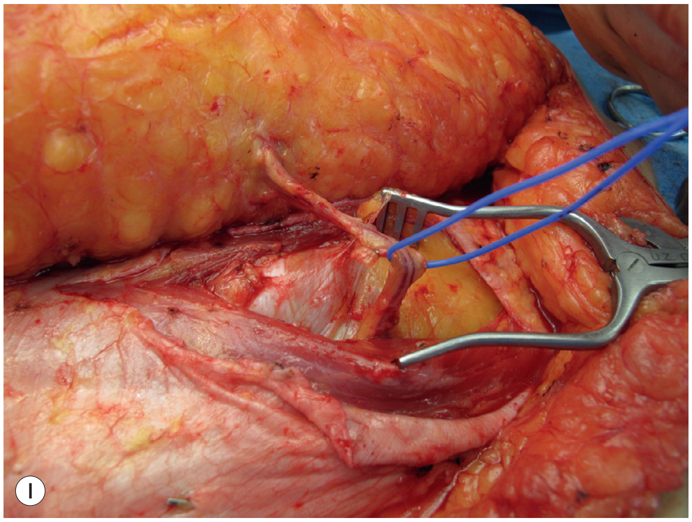

Fig. 20.2.9, cont'd (E) The deep rectus fascia is incised vertically following the fibers of the rectus abdominis muscle both cranially and caudally. The perforator is freed in its supramuscular course. **(F)** The deep fascia is opened all the way down to the infralateral border of the rectus muscle and further distally along its lateral border to create exposure of the deep inferior epigastric artery and vein. **(G)** The rectus abdominis muscle is split following the muscle fibers until the posterior fascia or the peritoneum can be seen. Sensory nerves coming from lateral and following the perforator can be transected. Motor nerves are left intact (white arrow). **(H)** Wide exposure is achieved with a self-retaining retractor. A bloodless field allows perfect control of the dissection. The main branch of the deep inferior epigastric artery and its veins is clipped distal to the perforator (white arrow). **(I)** Once the entire course of the perforator and the main vessel is clear, the posterior part of the perforator and the main vessel is dissected off the surrounding tissues. The distal part of the deep inferior epigastric vessels can be dissected either through the same incision through the rectus muscle or from laterally by pulling the rectus muscle medially.

This allows a "life boat" in the form of a contralateral DIEAP flap or TRAM flap to be performed if the perforator is inadvertently damaged. It is important to emphasize that the vessels must be protected at all stages and complete muscle relaxation is necessary until donor site closure is obtained. As dissection progresses, the DIEAP flap should be secured to the abdominal wall with the aid of staples.

Intramuscular dissection

The rectus abdominis muscle should be split in a longitudinal direction in the perimysial plane through which the perforating vessel traverses. Splitting the muscle fibers makes dissection easier as the vessel becomes larger (Fig. 20.2.9G). The perforator is again liberated by blunt dissection, staying close to the vessel at all times, as it remains covered by a thin layer of loose connective tissue. As a general rule, if resistance to dissection is encountered, a side branch or a nerve will be identified. Different muscular branches must be ligated with care, and hemoclips are placed 1–2 mm away from the main vessel so that if one inadvertently comes off, it can easily be replaced. This technique avoids damage and spasm of the main perforating vessel. Placing a vessel loop around the vascular pedicle allows additional retraction without any unnecessary tension being placed on the vessel. Using bipolar coagulating diathermy and small hemoclips, one continues to ligate all the side branches until the origin of the perforator on the major branch of the deep inferior epigastric vessel is reached at the posterior surface of the rectus abdominis muscle (Fig. 20.2.9H).

If two perforators have been selected, the rectus abdominis muscle must be widely separated. If the perforators run in two adjacent perimysial planes, the fibers may have to be cut. However, transection of large parts of the rectus abdominis muscle or division at the level where a motor nerve crosses from the lateral to the medial side should be avoided.

Submuscular dissection

The lateral border of the rectus abdominis is raised using non-crushing tissue forceps. Special care is taken not to injure the mixed segmental nerves entering the muscle laterally. The sensory nerve branch can be dissected by epineural splitting.[19] In this way, an additional 5–9 cm can be obtained, facilitating neural suturing at the recipient site. If possible, all the motor branches are left intact. However, in cases where a motor branch runs between two perforators, then this nerve has to be cut. Once the flap is harvested, it can be re-sutured.

Between the mixed segmental nerves, the plane posterior to the rectus abdominis muscle is opened, exposing the main deep inferior epigastric vessel. Side branches of the main stem are ligated, and the dissection is continued by retracting the rectus abdominis muscle medially until the proximal part of the pedicle is completely liberated. The length of the pedicle can be tailored to meet the needs of different recipient sites or the demands of the shape of the flap (Fig. 20.2.9I). The more distal the perforator is located in the flap, the further the deep inferior epigastric vessels need to be dissected into the groin. Frequently however, the pedicle can be transected at the lateral border of the rectus abdominis muscle. At this level, there is sufficient pedicle diameter and length to enable a safe microsurgical anastomosis.

If one is certain that the blood flow through the deep inferior epigastric vessel is sufficient (an ultrasonic flow meter can be used), the remainder of the flap can be raised. In cases of midline scars, or when a large flap is needed, the same vascular dissection can be performed on the contralateral side. Otherwise, all the remaining perforators are ligated, the umbilicus is released and the entire skin flap is raised. The pedicle is finally transected when the recipient vessels have been prepared. A hemoclip can be placed on the lateral comitant vein to help orientate the pedicle.

After division of the pedicle, the flap is turned over and the vessels placed carefully onto its undersurface. One has to be meticulous about the position of the pedicle, as it tends to rotate very easily, especially if only one perforator has been harvested. The flap is then weighed, photographed, and transferred. The ischemia time is noted. The flap is placed on moist gauze at the recipient site to prevent desiccation and again stapled to the surrounding skin for security. The flap may be rotated to facilitate microsurgery, provided a note of this is made and the rotation reversed at the end of the procedure.

Hints and tips

Ten golden rules in perforator flap surgery

1. *Map the perforators preoperatively*: identify the most dominant vessels on each side.
2. *Start dissection on one side of the flap*: leave the contralateral side intact until you have finished the entire dissection of the pedicle.
3. *Preserve every perforator until you encounter a larger one*: discard only the smaller ones that you are sure you will not use. Select one or two perforators with the largest diameter that correspond with your preoperative mapping.
4. *Consider the best location of the perforator within the flap*: the more centrally located, the better blood flow to the outer parts of the flap.
5. *Consider the easiest dissection through the muscle*: long intramuscular dissections are more tedious, increase the risk of damaging the vessels, and are more time-consuming.
6. *Dissect close to the vessels*, remaining within the perivascular loose connective tissue, thereby guaranteeing a bloodless field.
7. *Ensure wide exposure* by splitting the rectus muscle along its fibers (avoid digging a small hole).
8. *Carefully ligate every side-branch* at a distance of about 2 mm away from the main pedicle.
9. *Avoid traction on the perforator*: intima rupture is a frequent cause of unexplained clotting of the perforator.
10. *Transect the other perforators after the entire pedicle is dissected*.

Closure of the donor site and fashioning of the umbilicus

As no fascia has been resected, primary tension-free closure of the fascia with a running, non-absorbable 1-0 suture is always possible. The upper skin flap is undermined using cutting diathermy to the level of the xiphoid and costal margin. Two suction drains are placed at the upper and lower margins of the skin flaps and brought out suprapubically on each side of the midline. The lower border of the umbilicus is marked on the anterior abdominal wall at the level of the anterior superior iliac spines and a 2 cm vertical line is drawn above this point. Only a vertical incision is performed. The anterior abdominal wall is extensively thinned at the site of the new umbilicus by trimming of the subcutaneous fat. The umbilicus is then passed through the defect and inset with an interrupted 4-0 absorbable sutures.

The operating table is put in a flexed position to facilitate closure of the anterior abdominal wall. Scarpa's fascia is approximated with interrupted 1-0 absorbable sutures with particular attention being paid to medial advancement of the wound edges to reduce the dog-ears in the flanks. Finally, interrupted 3-0 sutures are placed intradermally to evert the skin edges and a skin adhesive is applied. No further abdominal dressing is used.

Shaping of the DIEAP flap in secondary autologous breast reconstruction

A systematic approach is applied to create easy and reproducible results in shaping of autologous tissue by using the "3-step principle"[11,12] producing a 3D structure from a flat piece of abdominal fat, and skin is broken down into three essential steps: (1) redefining and recreating the basis and borders of the footprint of the breast (the interface of the posterior surface of the breast gland and the thorax) at the right location on the chest wall (Fig. 20.2.10); (2) molding the flap into a tear drop-shaped conus on top of the footprint by means of specific suturing (Fig. 20.2.11); and (3) repositioning the skin envelope (Fig. 20.2.12) over the conus with the correct tension (Fig. 20.2.13).

The breast footprint

Any previous scars or severely damaged tissue that lies over the footprint of the new breast are excised. In modified radical mastectomy cases, the new inframammary fold is incised to a depth of approximately 1 cm to allow easy suturing of the DIEAP flap. While the position of the borders of the new footprint mirror the position of the contralateral footprint, the new inframammary fold position needs to be placed 2–3 cm higher

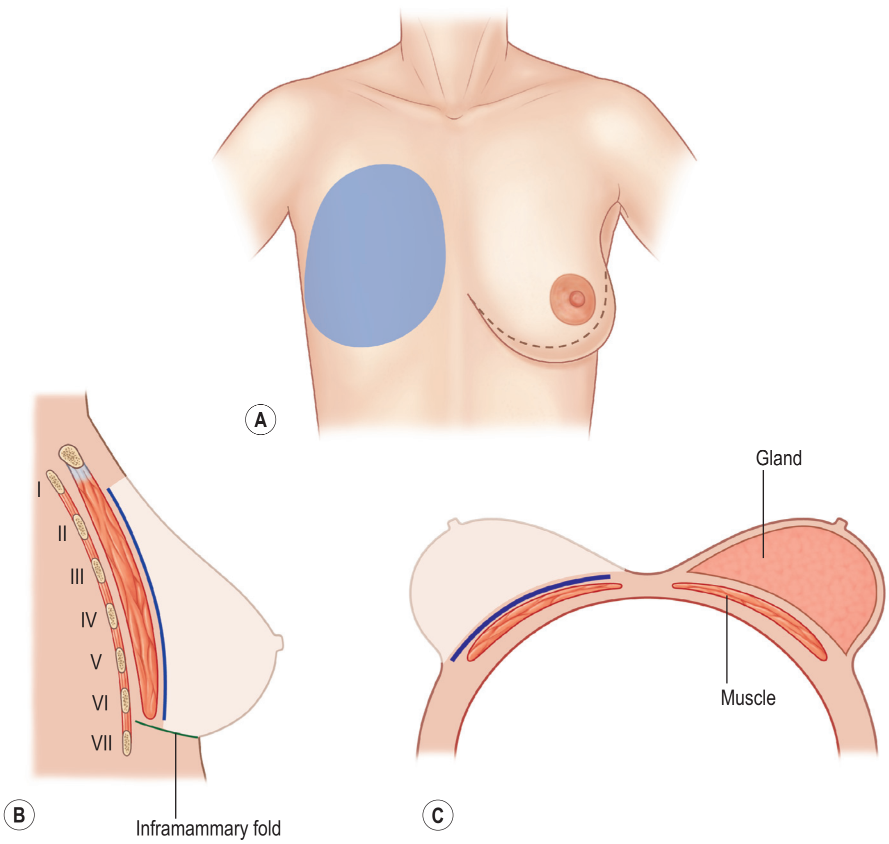

Fig. 20.2.10 **(A)** Coronal; **(B)** sagittal; and **(C)** transverse view of the footprint of the breast.

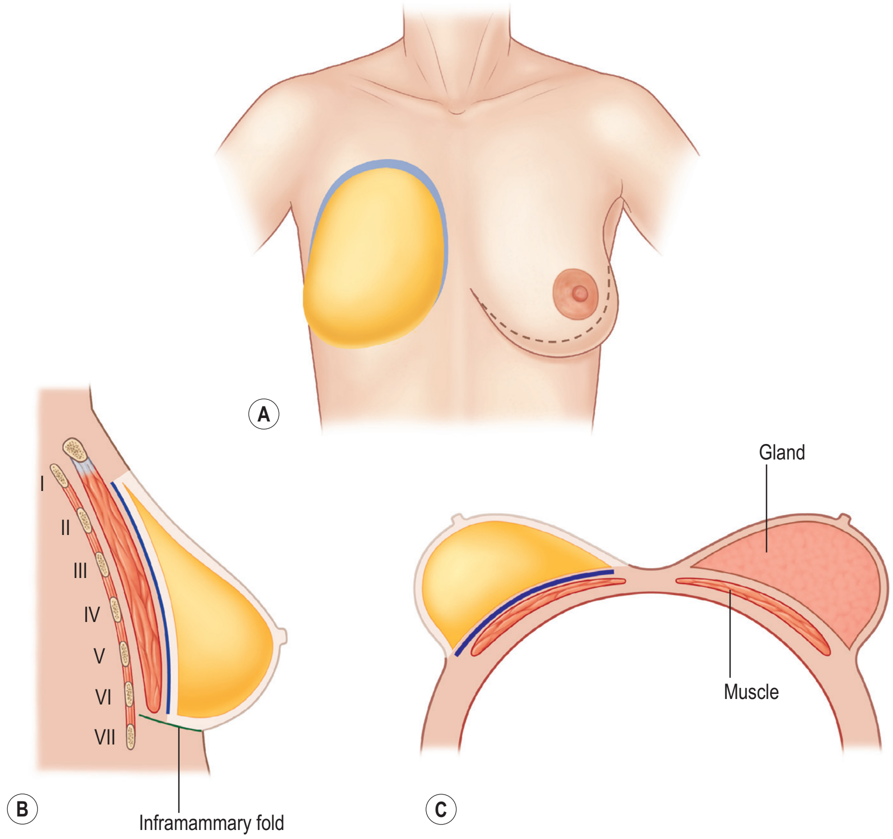

Fig. 20.2.11 **(A)** Coronal; **(B)** sagittal; and **(C)** transverse view of the conus of the breast.

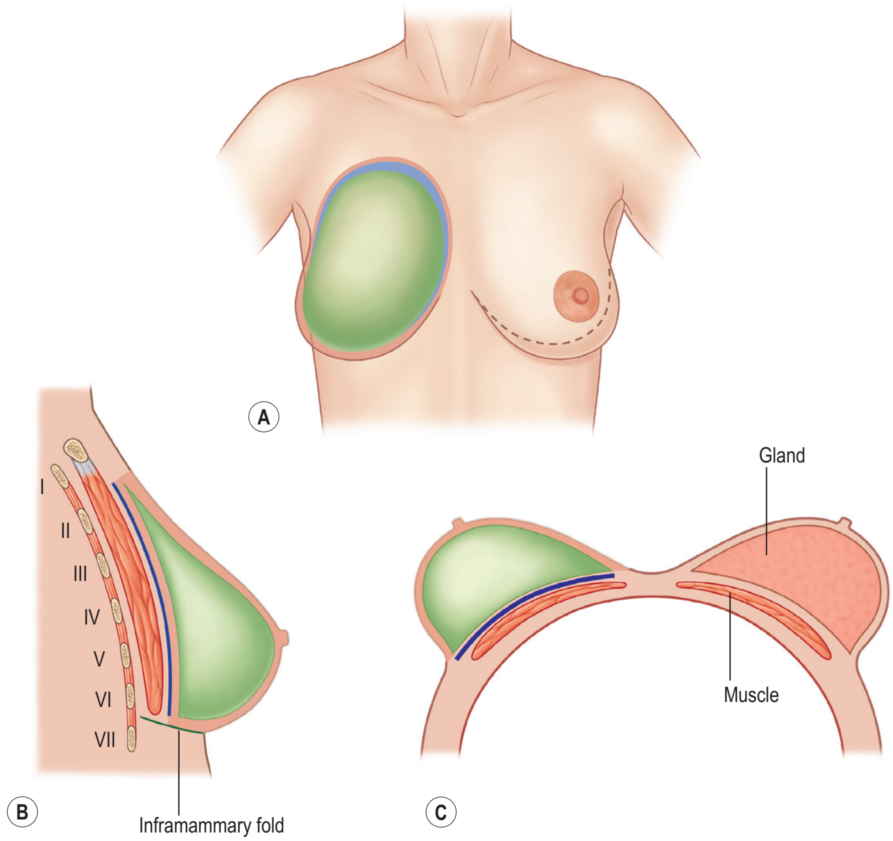

Fig. 20.2.12 **(A)** Coronal; **(B)** sagittal; and **(C)** transverse view of the envelope of the breast.

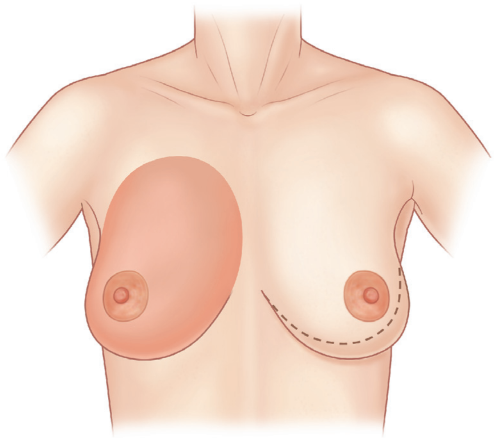

Fig. 20.2.13 The nipple areolar complex is an integral part of the envelope of the breast.

than the contralateral inframammary fold depending on the laxity of the mastectomy flap skin and tension exerted on the abdominoplasty flap closure later in the procedure. The skin in between the mastectomy scar and the inframammary fold is de-epithelialized. In this way, a layer of 1–2 cm of fat in the lower part of the breast is preserved, improving projection. The skin edges of the upper mastectomy flap are thinned down to the dermis for the first 5 mm and then progressively trimmed to obtain a seamless transition into the upper skin edge of the DIEAP flap. The upper mastectomy flap is then undermined on the lateral, cranial, and medial borders of the breast footprint to subsequently accommodate the flap.

In cases of primary breast reconstruction, the edges of the footprint are assumed to be intact. If for oncologic reasons the edges of the footprint need to be undermined or resected, these borders will need to be repaired before transferring the flap.

The breast conus

The authors prefer to use the contralateral DIEAP flap in cases of delayed breast reconstruction. The flap is rotated through 180° prior to transfer, and shaping begins after the anastomosis has been completed (Fig. 20.2.14A).

A wedge of skin is removed around the site of the umbilicus and closed in two layers. This simple maneuver gathers more volume in the lower half of the flap. The more skin that is removed, the more projection that can be achieved, but it does result in compression of the subdermal plexus in this area.

The tendon of the pectoralis major muscle is then identified. The tip of the DIEAP flap is fixed just below the pectoralis tendon by suturing Scarpa's fascia to the pectoralis fascia 2–3 cm medial to the lateral pectoral muscle border. This first key suture recreates the anterior axillary fold (Fig. 20.2.14B).

The lateral edge of the flap is then stapled to the most lateral part of the inframammary fold under slight tension to avoid excessive lateral fullness (see Fig. 20.2.14B). The transition from the lateral pectoral border into the lateral portion of the flap also recreates a natural lazy-S shape along the lateral border of the breast. The exact position of the second key suture is determined by moving the flap along the inframammary fold while assessing the lazy-S contour. It is always better to have minimal fullness in this location at the time of reconstruction, as the flap will shift laterally and distally in the postoperative period.

Medial to the second key suture, in the midclavicular line, the skin of the flap is then bunched up (Fig. 20.2.14C). This, together with the triangular skin resection around the umbilicus, dramatically increases flap projection. It also helps create a sharp angle between the skin of the flap and the abdominal skin below the inframammary fold.

The third key suture is placed at the medial end of the inframammary fold. The flap is not bunched in this location to avoid overfilling of the inferomedial quadrant of the new breast. However, one should be cautious, as if the flap is not placed medially enough, it can be difficult to achieve sufficient cleavage.

Two important components are then assessed: a volume estimation of the DIEAP flap compared with the contralateral breast; and the poorly vascularized tissue in the flap that needs to be resected (previously zone IV, see Fig. 20.2.14C). The latter can be accomplished either by visual inspection of the skin, or by carving into the dermal plexus with a Bistouri in the most distal corner. Tissues that show mixed arterial and venous bleeding can be kept. When a DIEAP flap with an ipsilateral pedicle is used, poorly vascularized tissue is removed before placing the first key suture. The authors recommend making the reconstructed breast 5–10% larger than the contralateral side, anticipating a postoperative reduction in swelling.

The medial part of the flap is then rounded off, providing a smooth transition into the presternal region. Overfilling of the superomedial regions of the breast is also recommended (Fig. 20.2.14D), as gravity will be pulling the flap caudally over the ensuing 6 months. Excessive fat can be removed later, whereas a depression in this area can be very disturbing for the patient.

The breast envelope

Once the final volume of the flap is determined, one can make a rough estimate of how much skin overlying the

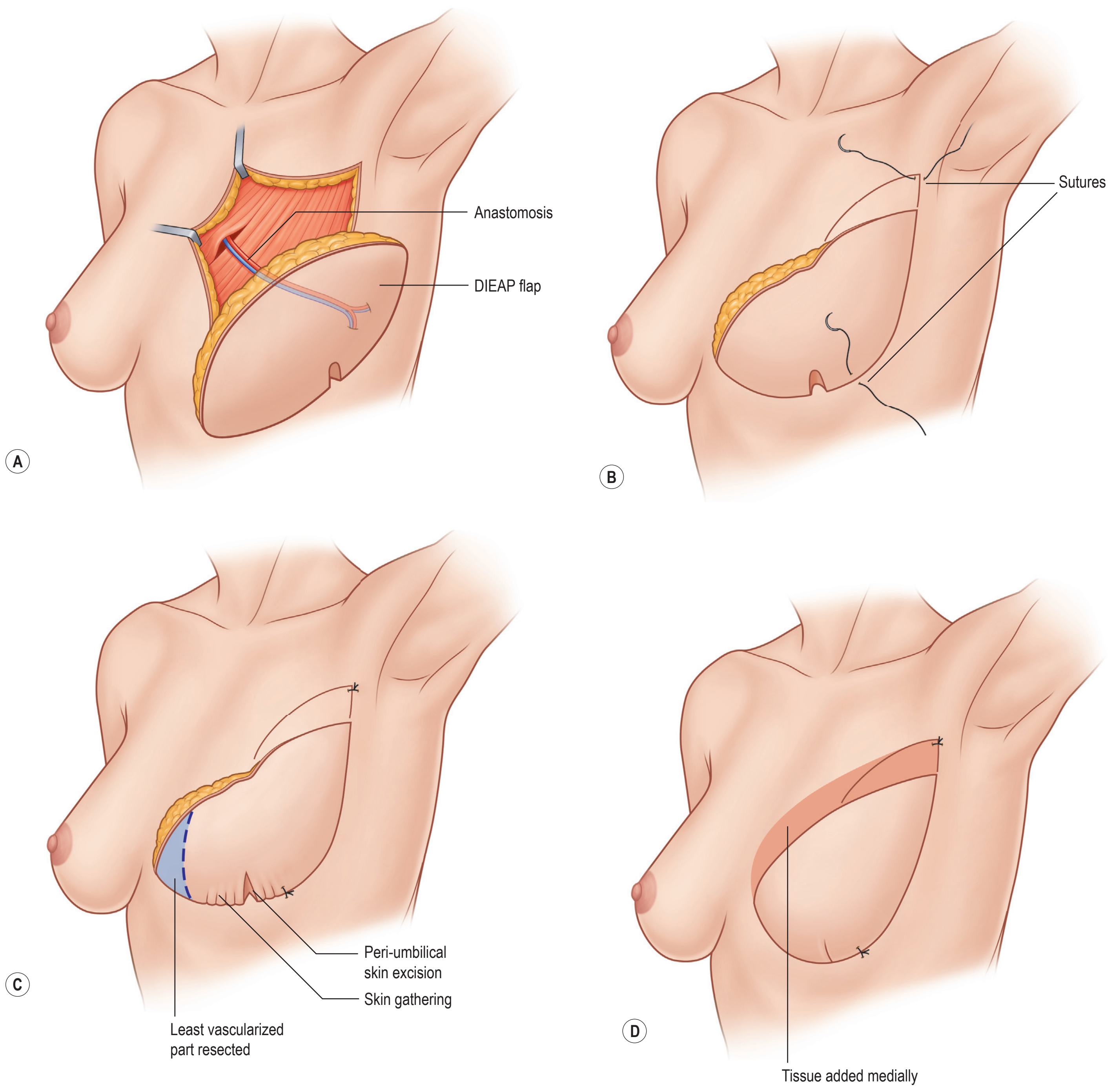

Fig. 20.2.14 (A) The deep inferior epigastric artery perforator (DIEAP) flap is turned 180° after performing the microsurgical anastomosis of the vessels and then **(B)** sutured with two key sutures to the pectoral fascia at the anterior axillary fold and the lateral part of the new inframammary fold making sure to avoid any fullness of the inferolateral quadrant of the new breast. **(C)** A triangular excision of skin around the umbilical area and gathering of the skin at the inframammary fold around the midclavicular line will create projection of the flap and a sharp angle between the lower part of the breast and the abdominal wall. **(D)** The least vascularized part of the flap is then resected making sure to preserve enough tissue to fill the upper medial quadrant of the breast.

DIEAP flap will be required. The flap can be pushed up into the pocket or pulled down, leaving more or less vertical skin height, respectively, on the skin paddle of the flap. The more skin left, the more ptosis can be achieved. Also, the more skin resected in the lateral part of the flap, the more the flap will be pushed medially. Once again, the clinical and aesthetic assessment of the contralateral breast is key in fine-tuning the shape of the DIEAP flap. Finally, the upper part of the skin paddle covered by the mastectomy flap is de-epithelialized.

Postoperative care

The postoperative care is simplified as the function of the rectus muscle is preserved. Preserving the integrity of the muscle also significantly decreases postoperative abdominal wall pain, facilitates rehabilitation, and therefore reduces hospitalization time.

Flap monitoring is mainly clinical. Frequency of evaluation is hourly during the first 24 h, 2-hourly in the second 24 h, and every 4 h during the following 2 days. Adhesive thermometer-strips are stuck to the skin island of the flap and the high sternal region. Differences of more than 2°C are reported to the physician on-call. In addition to temperature, color, consistency of the flap, and capillary refill are registered on a specific microsurgical follow-up sheet. Unidirectional Doppler flowmetry and other more sophisticated devices are not used, as they can produce false-positive signals.[39,40]

Patients are mobilized within 24 h after removing the urinary catheter. Systemic antibiotics are given for 24 h. Except for daily subcutaneous prophylactic doses of low-molecular heparin, no other anticoagulants are given. Besides paracetamol as pain relief and anti-inflammatory, no other drugs are given unless a specific medical condition requires it. Drinking starts 12 h post-operatively. Drains are left for 3–7 days depending on their daily output. Dressing changes are not necessary with the use of skin adhesives. A sterile towel covers the breast(s) and the abdomen to keep the flap warm for the first 5 days. After that, a soft and elastic bra is adjusted. No compressive garments are applied.

Outcomes, prognosis, and complications

The dissection of a DIEAP flap has a steep learning curve, involving a specific technique. Dissection is performed close to the perforating vessels in the plane of loose connective tissue surrounding the pedicle, allowing side branches and crossing nerves to be easily identified and preserved. Dissection through other planes will cause excessive bleeding and slow the surgeon down. Two golden rules apply to any type of perforator flap surgery: a bloodless field and wide exposure of the vessels. A common mistake made is to follow the perforator vessels into a deep hole. Muscle, septum, and other tissues through which the perforators travel should be opened widely to get a clear view and help deal with any bleeding encountered.

A number of technical considerations are important in the planning and execution of the dissection. The wrong choice of perforator can have disastrous complications. With the help of imaging and direct intra-operative visualization, the most dominant perforator can be identified. Unusual courses of perforators such as those rounding the medial or lateral edge of the rectus abdominis muscle must be taken into account. Dominance of the superficial system should be recognized at the beginning of flap harvest, at the time of incision of the lower edge of the flap.

During dissection of the pedicle overstretching of the vessels should be avoided. The use of vessel loops is limited to the actual dissection and should not be left in place as they accidentally can come under traction in a later phase of the operation.

Ligation of side branches should be performed at a distance of 2–3 mm away from the pedicle. When a vascular clip or a ligating suture is placed too close to the main pedicle, it can interrupt the arterial or venous flow. Care should be taken during the motor nerve dissection. Excessive traction or crushing of the nerve can permanently affect its function.

In case of a free flap, torsion of the pedicle can easily occur during transfer of the flap. Exact orientation with the help of vascular clips can avoid this problem. Following anastomosis, kinking of the pedicle can be avoided by placing the pedicle in smooth curves once the shaping has finished. During the shaping of the flap, excessive defatting can lead to areas of partial flap necrosis or fat necrosis.[41] Delayed defatting using liposuction is a safer procedure. Poorly vascularized areas should be resected during the initial procedure to reduce the amount of postoperative complications.

In inexperienced hands, the DIEAP flap dissection will require a longer operating time than a conventional myocutaneous flap. After a number of cases, operating time will fall back and be comparable with myocutaneous flap harvesting, or even shorter if a limited pedicle length is needed.

Abdominal scarring is probably the most important risk factor for raising a DIEAP flap. It can cause major problems during the dissection of the perforators and the epigastric vessels. Intramuscular scarring is not

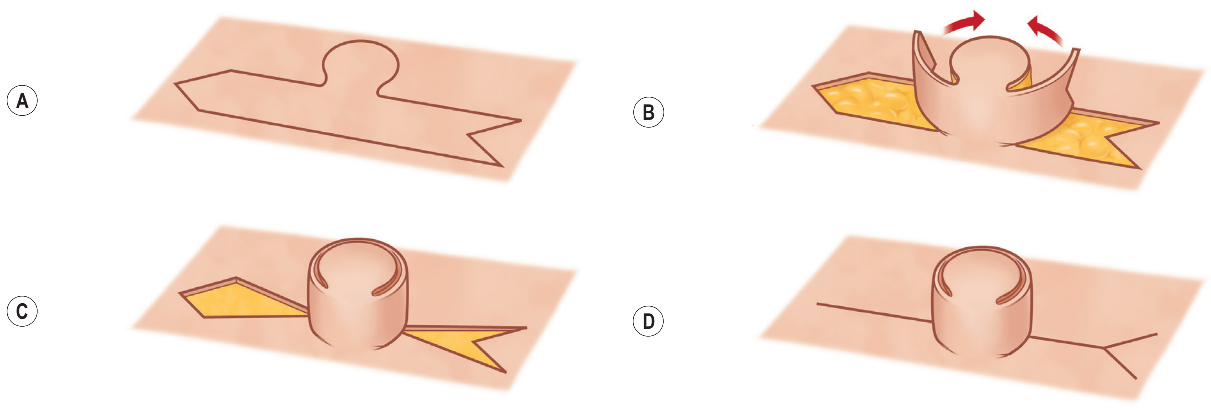

Fig. 20.2.15 **(A–D)** The modified CV-flap technique for nipple reconstruction.

always diagnosed on preoperative ultrasound and can spread out farther than suspected from the place and length of a previous incision.

Smoking is considered a relative contraindication to raising a DIEAP flap. The authors' impression is that the area most distant from the vascular pedicle of smokers is not well perfused, with prolonged vascular spasm. Additionally, wound healing problems and wound infections have been observed more frequently in smokers. Smokers who request elective, delayed reconstructions are asked to stop smoking at least 3 months before becoming a candidate for surgery. This is an additional way to test the motivation of the patient. An unmotivated patient or poor general medical health are the only absolute contraindications to DIEAP flap breast reconstruction.[38,42,43]

Secondary procedures

The free flap transfer and initial shaping is just the first step in achieving a full and natural breast reconstruction. Following the principles of a sculptor, the authors try to create a breast in the first stage that is slightly bigger than the desired volume but resembles the final result as closely as possible. Obtaining a definite result in one procedure is impossible. As removing tissues is so much easier than adding, specific areas of the flap can be aspirated or resected during the second operation 6 months later to achieve symmetry, which is the final goal of this procedure. If more tissue is needed, the flap can be augmented by lipofilling in specific spots to improve the shape or throughout the flap if pure volume augmentation is necessary. Augmentation by implants is possible as well but performed less and less as results of lipofilling become more predictable and successful. Nipple reconstruction is performed using the modified CV flap (Fig. 20.2.15). Scar revisions and adjustments of the borders of the footprint can easily be performed. During the second operation, the contralateral breast can also be corrected in case of unilateral reconstruction. Any preferred technique of breast augmentation, reduction, or mastopexy can be performed as long as symmetry of shape and volume can be achieved.

Finally, bilateral tattooing of the nipple areolar complex is performed under local anesthesia. Even if the contralateral breast has not been operated on, the nipple areolar complex is tattooed to obtain a perfect color match and create an optical effect of camouflaging the reconstruction.

Primary reconstructions will always yield better aesthetic results than secondary or tertiary reconstructions as the natural footprint and skin envelope remain intact, especially if postoperative radiotherapy is avoided. If the conus is properly shaped during the first procedure, secondary procedures can be less complex and less frequent. For that reason, prophylactic mastectomies are performed more routinely today as a risk-reducing operation in hereditary breast cancer for BRCA-1 and -2 mutations (Fig. 20.2.16) or for oncologic reasons (i.e., invasive lobular carcinoma). Prophylactic mastectomy and immediate breast reconstruction without adjuvant radiotherapy should also be considered instead of a wide segmentectomy combined with aggressive radiotherapy, as this can lead to significant deformity of the breast mound.

Secondary (Fig. 20.2.17) and specifically tertiary (implant crippled or failed previous autologous attempts) reconstruction is more complex, as it involves correction and adjustment of all three essential parts of the "3-step" principle. Applying this principle, however, allows the surgeon to not only analyze the problem but also provides an opportunity to develop a clear preoperative strategy. In tertiary reconstructions, the surgeon is often left with no other choice but to remove all previous tissue, implants, and scarring and to start the entire reconstructive process again.

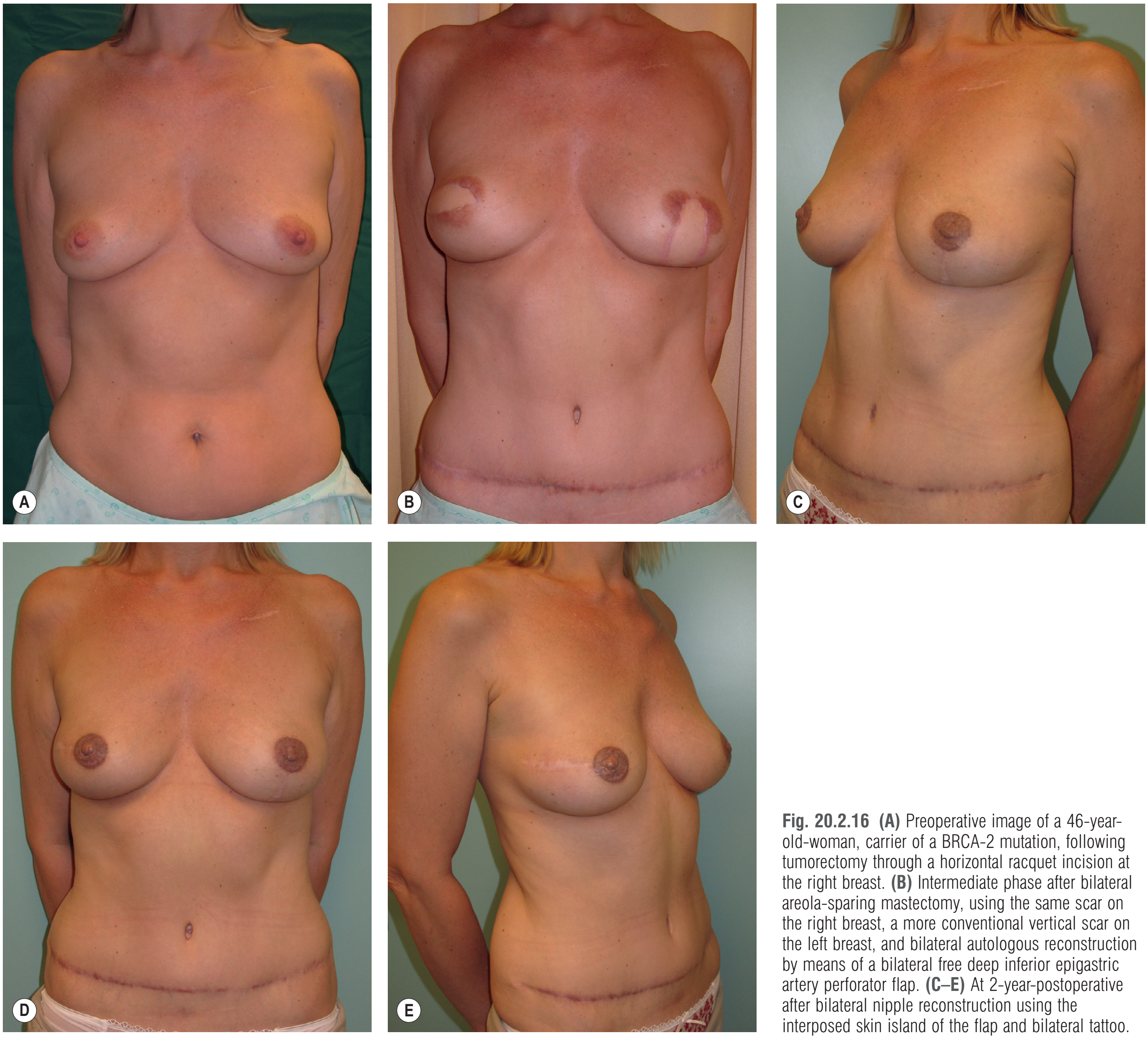

Fig. 20.2.16 **(A)** Preoperative image of a 46-year-old-woman, carrier of a BRCA-2 mutation, following tumorectomy through a horizontal racquet incision at the right breast. **(B)** Intermediate phase after bilateral areola-sparing mastectomy, using the same scar on the right breast, a more conventional vertical scar on the left breast, and bilateral autologous reconstruction by means of a bilateral free deep inferior epigastric artery perforator flap. **(C–E)** At 2-year-postoperative after bilateral nipple reconstruction using the interposed skin island of the flap and bilateral tattoo.

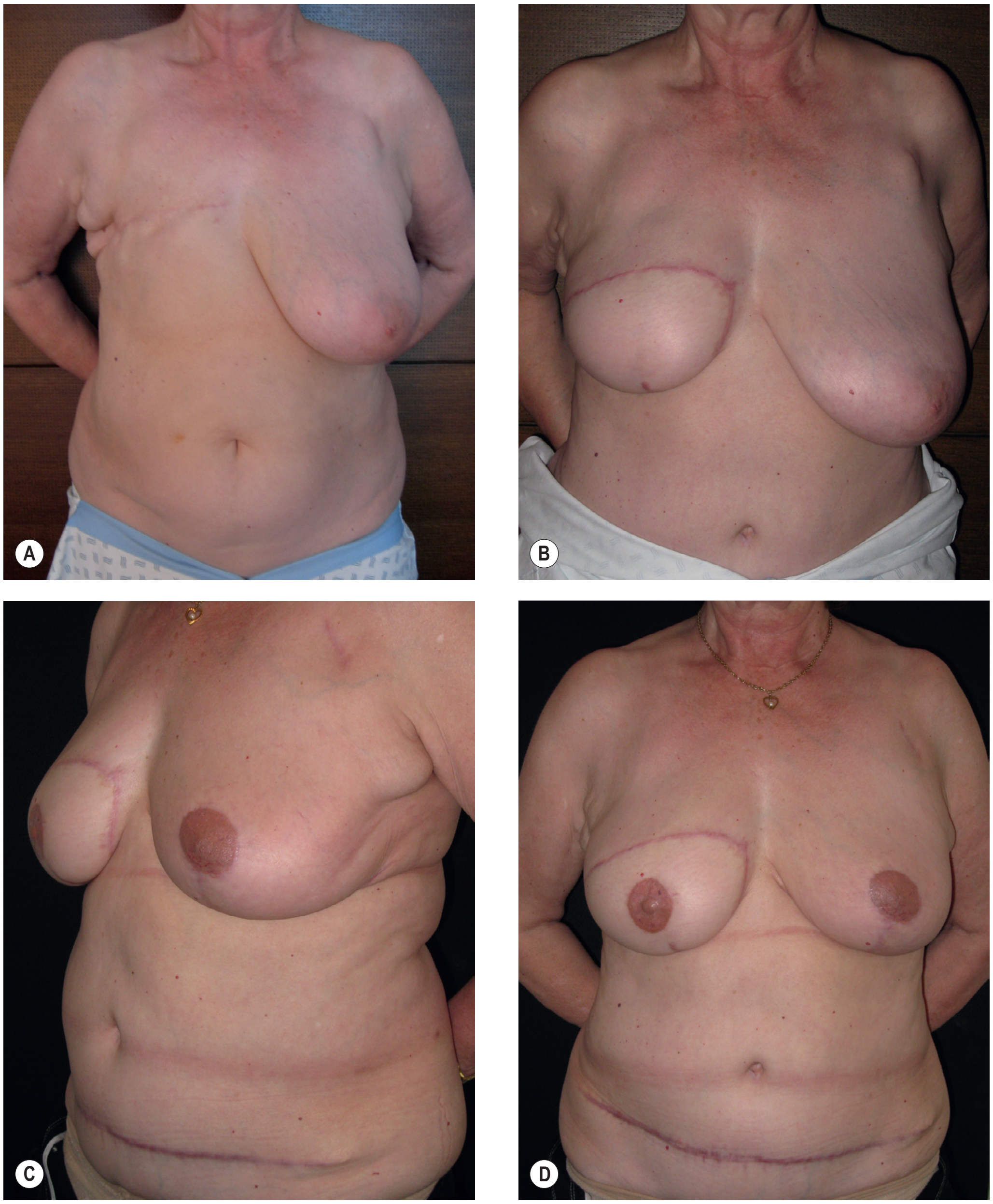

Fig. 20.2.17 **(A)** Preoperative image of a 62-year-old woman following modified radical mastectomy of the right breast with breast hypertrophy/ptosis of the left breast. **(B)** Intermediate phase after secondary autologous breast reconstruction by means of a unilateral free deep inferior epigastric artery perforator flap. **(C–E)** Final result, 1 year postoperatively, after right nipple reconstruction (and later tattoo) and left breast reduction.

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