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Reconstructive

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BREAST RECONSTRUCTION

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HISTORY

The radical mastectomy operation was first performed by Halsted in 1882 and first described in the literature in 1889.[1] The operation resulted in dramatic improvement in survival rates associated with breast cancer. Halsted taught against reconstruction of the post-mastectomy breast for fear of compromising local control of the disease, relying instead on skin grafts or healing by secondary intention to close the resulting defect. "As to the closure of the wound," Halsted wrote, "I should not care to say, 'Beware of the man with the plastic operation.' The surgeon should familiarize himself with the principle of the one or two particular plastic operations which make the best use in the simplest manner of any redundant or easily glideable skin, as of the axillary flap, that he may be prepared in any case to utilize in combination with skin grafting such features as seem applicable. But to attempt to close the breast wound more or less regularly by any plastic method is hazardous, and, in my opinion, to be vigorously discountenanced."[1]

Czerny[2] is credited with performing the first breast reconstruction in 1895. He presented a report of the reconstruction of a breast treated for benign pathological abnormality using a lipoma from the lumber region. In 1905, Ombredanne[3] performed breast reconstruction using a pedicled pectoral flap.

Reconstruction of the mastectomy defect using the latissimus dorsi musculocutaneous flap (LDMF) was first described by Tansini[4] in 1906, and the radical mastectomy with LDMF for reconstruction became popular in Europe during the next decade.[5,6] However, as acceptance of Halsted's procedure[1] grew, Tansini's method[4] was largely abandoned and, by 1920, had practically disappeared from the literature.[5]

Throughout the 20th century, attempts at breast reconstruction with free tissue grafts and foreign bodies, including paraffin, vegetable oils, lanolin, beeswax, glass balls, and sponges, were common.[7] The aesthetic results were unsatisfactory, and multiple complications ensued from foreign body reactions to these implantations.[7] In 1942, Gillies and Millard[8] used a tubed abdominal flap for breast reconstruction, and in 1950, Yannilos[9] described the use of a tubed pedicle flap from the opposite breast. These breast-sharing techniques using tubed flaps became a popular method of breast reconstruction by mid-century.[10] Later, reconstruction techniques using local thoracoabdominal flaps were developed.[11]

The modern era of breast reconstruction began in 1963 with the introduction of the silicone gel-filled prosthesis by Cronin and Gerow.[12] This method delayed the reconstruction until months or years had passed after the mastectomy. In 1971, Snyderman and Guthrie[13] reported a successful case of breast reconstruction performed immediately after mastectomy with placement of a subcutaneous silicone prosthesis. Immediate breast reconstruction with a silicone prosthesis then became the standard throughout the decade,[14] although new methods of autologous reconstruction were also being described.[15]

In 1973, Orticochea[16] transferred a contralateral gluteal flap in five stages using the forearm for transport. In 1976, Arnold et al.[17] reported a one-stage procedure in which he used the greater omentum to cover a prosthesis that was then covered with a skin graft. In the mid-1970s, Fujino et al.[18,19] reported the first application of microsurgical techniques to breast reconstruction with his use of a free gluteal tissue transfer. Le-Quang[20] described the inferior gluteal artery musculocutaneous free flap for breast reconstruction in 1978.

In 1977, Schneider et al.[21] and Muhlbauer and Olbrisch[22] introduced the LDMF for breast reconstruction. The technique was further refined the same year by McCraw et al.[23] and was then popularized by Bostwick et al.[24] in 1978. That same year, Serafin and Georgiade[25] described the use of a free groin flap for breast reconstruction. In 1979, Holmström[26] described the transfer of a free abdominoplasty flap to reconstruct the post-mastectomy defect, and in 1982, Hartrampf et al.[27] transferred a transverse abdominal island flap for breast reconstruction. The flap consisted of a portion of the vertical rectus abdominis muscle with a horizontal skin paddle over the lower abdomen for better donor-site closure and more skin and subcutaneous fill. This transverse rectus abdominis myocutaneous (TRAM) flap method was well liked by patients and surgeons and paved the way for a revolution in autologous breast reconstruction. Subsequent modifications aimed to improve the somewhat tenuous blood supply of the flap with bipedicled and delayed TRAM flap transfers.[28–35]

In 1982, Radovan[36] introduced tissue expansion for breast reconstruction to enable gradual expansion of the remaining skin to replace the skin lost during the mastectomy. In 1984, Becker[37] reported using a breast prosthesis consisting of a silicone outer lumen and an inflatable saline inner lumen to perform simultaneous implantation and tissue expansion in a single procedure.

During the past 3 decades, we have witnessed remarkable advances in the field of breast reconstruction.[15] The TRAM flap has made autologous breast reconstruction a routine matter. Microsurgical techniques are now frequently applied to enhance the blood supply of the TRAM flap, decreasing the rates of fat necrosis and reducing donor-site morbidity. Microsurgical techniques have also facilitated transfer of autologous tissues from sources other than the abdomen aided by the concept of perforator flaps, which means tissue for breast reconstruction can be harvested with minimal morbidity. The deep inferior epigastric artery perforator (DIEP) flap is currently the most popular perforator flap technique for breast reconstruction and was first described for breast reconstruction by Allen and Treece[38] in 1994. The DIEP flap requires considerable technical expertise but preserves the underlying rectus abdominis musculature; it therefore incorporates the advantages of the free TRAM flap without the risk of ventral hernia or muscle weakness. The gluteal artery perforator flaps, introduced by Allen and Tucker[39] in 1995, offer similar advantages but have yet to gain widespread appeal. The superficial inferior epigastric artery (SIEA) flap was first used for breast reconstruction by Grotting[40] in 1991 and is associated with virtually negligible donor-site morbidity, although disadvantages include a variable anatomy and limited applicability. The newest flap options incorporate thigh tissue using a transverse upper gracilis (TUG) flap or profunda artery perforator (PAP) flap and can be useful in thin patients with limited donor sites or smaller volume breast reconstruction.

In 2012, members of the American Society of Plastic Surgeons self-reported a total of 91,655 breast reconstructions (compared with 29,607 procedures in 1992, 80,908 in 2000, 62,930 in 2004, and 57,778 in 2005). Of these, 7,437 (8.1%) were by implant alone, 64,575 (70.5%) by tissue expander and implant, 6,007 (6.6%) by TRAM flap, and 6,526 (7.1%) by DIEP flap (compared with 20.1%, 60%, 16.6%, and 3.3%, respectively, in 2005).

THE SKIN-SPARING MASTECTOMY (SSM)

Background

Probably the single greatest influence on the improved quality of breast reconstruction has been the evolution of the mastectomy technique. SSM and breast-conservation therapy are now accepted as oncologically safe procedures that can yield optimal cosmetic outcomes.

The SSM improves the aesthetic result of breast reconstruction because it retains the native skin flap, which does the following:

- Maintains contour of native breast
- Preserves inframammary fold (important landmark for breast reconstruction)
- Avoids differences in skin color and texture from native breast skin
- Results in breast symmetry without contralateral procedures
- Limits incisions to periareolar skin
- Requires less tissue for autologous reconstruction

SSM can be performed with immediate or delayed-immediate breast reconstruction. The overall complication rates from SSM and non-SSM reconstruction are similar.[41] SSM can be used safely in the treatment of invasive cancer without compromising local control, and because the chest-wall skin is a frequent site of local recurrence after SSM, surveillance and early detection are facilitated. Optimal tumor control and aesthetic results are achieved by the oncological and reconstructive surgeons working in concert.

The concept of SSM originated with Freeman[42] in 1962, who suggested a modification of the traditional mastectomy before an implant-based breast reconstruction for benign disease. The term *skin-sparing mastectomy* was first used by Toth and Lappert,[43] who described preoperative planning of mastectomy incisions to maximize skin preservation and to facilitate breast reconstruction. Skin excision is limited to the nipple-areola complex (NAC), with a lateral extension to include the biopsy site for exposure and removal of the tumor. The inframammary fold is preserved. The results are a greater amount of good quality anterior chest-wall skin for the reconstruction and fewer scars on the breast. In women with large, ptotic breasts, a Wise-pattern resection is typically used to diminish the size of the skin envelope.[41,43,44]

Hidalgo[45] reviewed his results of 28 SSM with immediate autologous tissue reconstruction. Prerequisites for this protocol included a favorable biopsy scar location (either periareolar or sufficiently distant from the NAC to avoid a narrow intervening skin bridge); a favorable areolar diameter (to provide adequate exposure for dissection); and a suitable tissue donor site (primarily the abdomen and secondarily the gluteal area). The most common factors detracting from the quality of the results were insufficient tissue volume and asymmetry of either breast shape or areolar position. SSM combined with sentinel node biopsy and/or axillary node clearance can be safely performed through the periareolar incision, although some prefer to perform the axillary procedure through a separate small incision in the axilla.

Although radiotherapy does not represent a contraindication to SSM, the mastectomy should be used with caution if postoperative radiotherapy is likely, because it detracts from the final cosmetic outcome.[46–49] To avoid this situation, intraoperative frozen section or imprint cytology of the sentinel lymph node (SLN) can be performed, with axillary node clearance recommended if the sentinel node biopsy is positive. An alternative approach is to biopsy the SLN before the mastectomy so that nodal status is known at the time of the operation.

The use of SSM does not delay the start of adjuvant therapies.[49] Delayed-immediate breast reconstruction is sometimes an option for patients requiring radiotherapy.[48] With this protocol, a temporary saline expander is used to fill the SSM breast envelope while permanent histology is pending and/or during adjuvant radiotherapy if required before definitive reconstruction. Disa et al.[50] reported survival of all flaps in 11 patients who underwent whole breast radiation and then SSM and immediate breast reconstruction, although partial skin flap loss developed in one patient and capsular contractures developed in two. This report indicates that radiation of SSM skin flaps is well tolerated.

SSM without temporary expander insertion often results in a contracted breast envelope. Delayed breast reconstruction in this setting can be very difficult.[51]

Technique

The common incisions for an SSM include the periareolar, tennis racquet, elliptical, and the Wise-pattern reduction incisions (Fig. 1).[41] It is not necessary to excise the skin overlying the lesion, even when the skin is tethered but not infiltrated by tumor.[52,53]

Type I

Only the NAC is removed. Type I SSM is generally indicated for prophylactic purposes and for patients whose cancer is diagnosed by needle biopsy. Lateral extension of the incision might be necessary to improve exposure to the axillary tail, although a periareolar incision can allow good access to the axillary lymph nodes[54] and to the thoracodorsal trunk without a separate axillary incision in up to 94% of patients.[53]

Type II

The skin overlying the superficial tumors and the previous biopsy incision are removed in continuity with NAC. Type II SSM is used when the superficial tumor or previous biopsy is in proximity to the areola.

Type III

The NAC, the skin overlying the superficial tumors, and the previous biopsy incision are removed without intervening skin. Type III is indicated when the superficial tumor or previous incision is remote from the areola.

Type IV

The NAC is removed with an inverted or reduction-pattern skin incision. The incision is used in large, ptotic breasts when a reduction is planned on the opposite breast. The length of the skin flaps is limited to control the shape of the breast envelope.

Complications

Along with careful dissection above the enveloping fascia of the breast to ensure complete removal of breast tissue, SSM requires a meticulous surgical technique and gentle handling of tissues to prevent skin flap ischemia. The incidence of flap necrosis is similar in SSM and non-SSM, with skin flap necrosis associated with cigarette smoking, radiotherapy, and Wise-pattern reduction skin incisions.[41,43,53] In a series of 633 SSM reported by Carlson,[55] type I incision was used in 232 (36.7%) patients, type II in 293 (46.2%), type III in 40 (6.3%), and type IV in 68 (10.8%). Skin flap necrosis occurred in 22 (9.5%) patients with type I incision, 28 (13%) with type II, 10 (25%) with type III, and 18 (26.5%) with type IV. Among the 79 (12.5%) patients who were smokers, skin flap necrosis developed in 16 (20.3%). Of 21 (3.3%) patients who received radiotherapy, five (23.8%) incurred skin flap necrosis. Overall, 88 patients (13.9%) developed skin flap necrosis.

The Wise-pattern incision and long, random-pattern flaps for large-breasted patients are associated with increased risk of flap necrosis.[55] In such cases, non-Wise-pattern reduction incisions or mastopexy incisions are indicated. Flaps with a relatively acute angle at the tip should be avoided, and special care must be taken not to damage the chest-wall skin during mastectomy.[56] In patients with notable risk

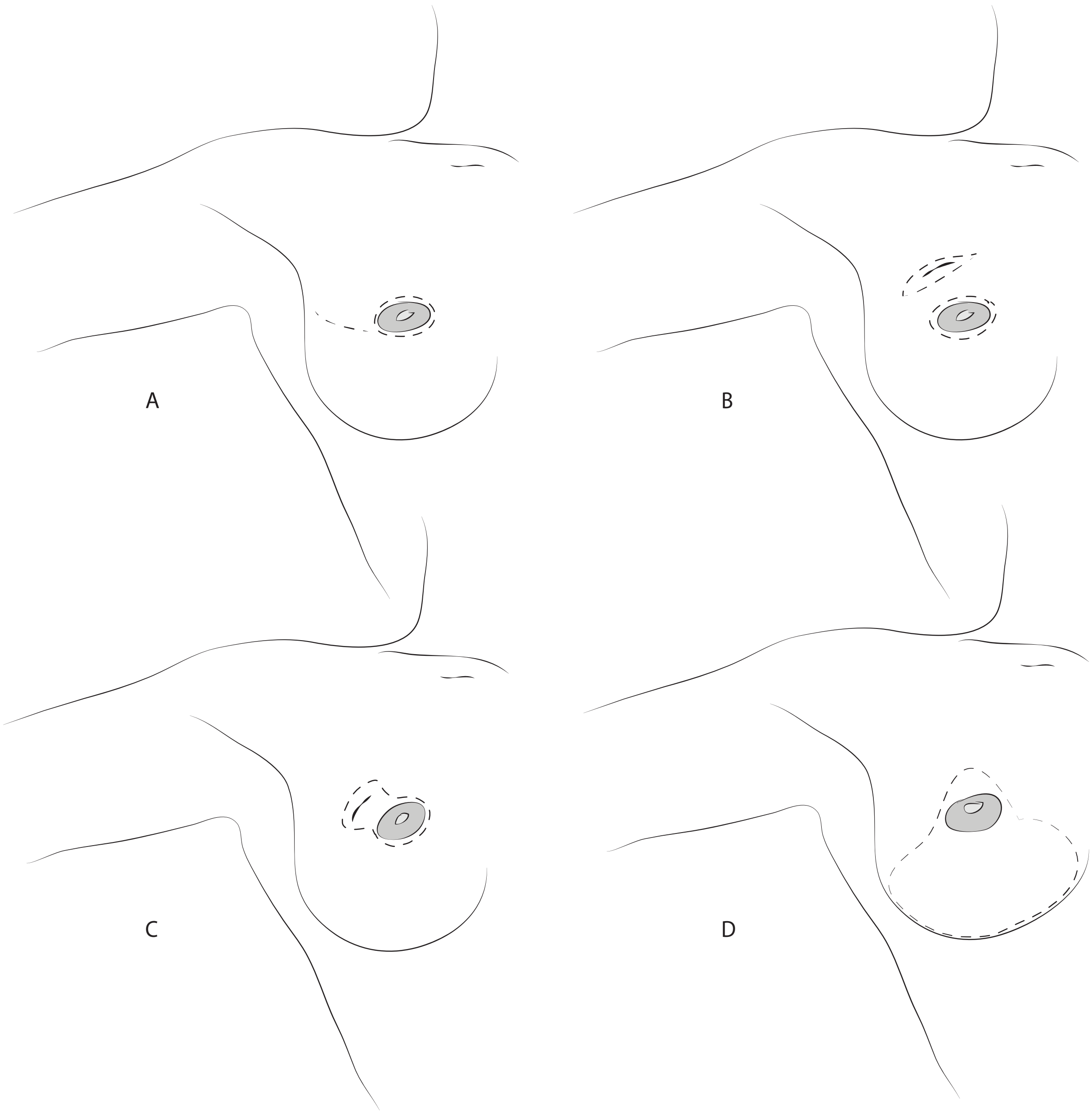

Figure 1. Incisions used in skin-sparing mastectomy. *A*, Tennis racquet. *B*. Elliptical. *C*, Periareolar. *D*, Wise pattern. (*Modified from Carlson et al.*[41])

factors for skin flap necrosis, non-SSM remains the procedure of choice.[51]

Skin flap necrosis can be avoided by intraoperative fluorescein evaluation and resection of areas of native skin that are marginally perfused.[55] Small areas of flap necrosis can be managed conservatively, but larger areas should be managed aggressively with excision, particularly for implant-based reconstruction. Large ischemic areas might dictate transfer of a latissimus flap to salvage the tissue expander. Recently, the SPY Elite System (LifeCell, Bridgewater, NJ) has been introduced as a method of evaluation for mastectomy skin flaps. The near-infrared camera detects the fluorescence of intravascularly injected indocyanine green dye, which binds plasma proteins and provides real-time assessment of tissue perfusion. Newman and Samson[57] and Newman et al.[58] reported their experience in developing this technology and applications in breast reconstruction initially to evaluate perfusion of mastectomy flaps. Komorowska-Timek and Gurtner[59] described 24 breast reconstructions with expanders and tissue flaps, débridement of mastectomy skin and autologous flap tissue, and SPY imaging results. The authors reported an overall complication rate that was reduced from 15.1% to 4%. Subsequently, other authors have reported expanded applications, including identification of perforators, evaluation of primary and secondary perforasomes, flap designs, evaluation of microvascular anastomoses, postoperative flap monitoring, and documentation of flap perfusion.[60–62]

The use of tissue expansion demands careful patient selection.[2] Woerdeman et al.[63] reviewed 400 cases of SSM with immediate implant reconstruction and reported an 18% loss of implants and an overall complication rate of 33% at a mean follow-up duration of 28.6 months. Loss of implants was related to smoking, increased body mass index, and increased surgical specimen weight. Carlson et al.[64] noted a higher failure rate with tissue expander reconstruction than with autologous reconstruction immediately after SSM.

Oncological Safety

SSM can be used safely without compromising local control.[41] All forms of mastectomy leave residual breast tissue, and the only difference is in the amount of microscopic breast tissue left behind in the skin and the inframammary fold. Barton et al.[65] compared the residual glandular tissue after total glandular mastectomy with that after a modified radical mastectomy by multiple biopsies of the anterior chest wall. The authors found residual breast tissue in 22% of the patients who underwent total glandular mastectomy and in 21% of the patients who underwent modified radical mastectomy. Carlson et al.[66] used computer image analysis to examine the inframammary fold tissue retained in SSM. Breast tissue was identified in 13 of 24 specimens but comprised only 0.02% of the total area examined. Beer et al.[67] found that the distance from the superficial layer of the superficial fascia to the overlying skin is so small in the majority of patients that a dissection superficial to the superficial layer will render the skin flaps nonviable in SSM.

Histological examination of local recurrences rarely shows identifiable breast tissue, and the locoregional recurrence rate after total mastectomy for breast cancer has remained relatively constant over the years. The stage of the tumor at the time of excision, including size and nodal involvement, is a stronger predictor of locoregional recurrence than the mastectomy technique used.[68–72] The median time to the appearance of clinically overt local disease is 2 to 4 years and varies with tumor stage. Most locoregional recurrences develop in the skin or subcutaneous tissue of the chest wall.

Disseminated disease almost invariably follows locoregional recurrence after total mastectomy. Gilliland et al.[73] reviewed 60 patients with isolated local recurrence of breast cancer and noted that all eventually died of metastatic breast cancer. This suggests that local recurrence is rarely an isolated event that can be ascribed to inadequate surgical excision but instead represents a component of widespread relapse. To address this further, Carlson et al.[74] evaluated long-term locoregional recurrence after SSM in 539 patients (565 tumors) with breast cancer. Of the 565 tumors, 175 (31%) had stage 0 disease, 135 (23.9%) stage I, 173 (30.6%) stage II, 54 (9.6%) stage III, and eight (1.4%) stage IV. Recurrent disease accounted for the remaining 20 (3.5%) tumors. The mean follow-up duration was 65.4 months (range, 23.7–86.3 months). Locoregional recurrence developed in 31 of the 539 patients, for an overall rate of 5.8%. Recurrence developed in one patient with stage 0 disease, five with stage I, 17 with stage II, six with stage III, and two with recurrent disease. Systemic relapse occurred in 24 (77.4%) of the 31 patients, and seven (22.6%) remained free from recurrence at a mean follow-up of 78.1 months: one patient with stage 0 disease, four with stage I, and two with stage II. The authors concluded that locoregional recurrence after SSM is not always associated with systemic relapse and that surgical conservatism might play a role in locoregional recurrence in patients with early-stage disease.

Kroll et al.[75] reviewed the records of 114 patients with T1 and T2 breast cancers who underwent SSM and 40 patients with T1 and T2 breast cancers who did not undergo SSM. After more than 6 years of follow-up, the authors found that locoregional recurrence was similar in both groups: 7% versus 7.5%, respectively.

Carlson et al.[72] found that the mean time to the appearance of clinically overt local disease was 10.8 to 25.9 months, depending on the tumor stage. Locoregional recurrences developed in the skin and subcutaneous tissue and were detected during clinical examination.

Slavin et al.[70] reviewed 51 patients who had undergone SSM and immediate reconstruction. At a mean follow-up of 45 months, the authors found one (2.0%) locoregional recurrence in a patient with stage I disease.

Toth et al.[76] reviewed their experience with SSM and immediate reconstruction in 50 consecutive patients who underwent surgery between 1985 and 1991. No local recurrences developed during a mean follow-up of 57 months.

Newman et al.[77] found locoregional recurrences in 23 (6.2%) of 372 patients with T1 and T2 tumors treated by SSM and immediate reconstruction. Of the 23 patients, 22 (96%) had recurrences that presented as palpable masses on the skin flap, and the median time to recurrence was 25 months. Fourteen (61%) of the 23 patients were still alive without evidence of disease at a median follow-up of 26 months.

The safety of SSM and immediate breast reconstruction has also been shown for patients with ductal carcinoma in situ (DCIS). Rubio et al.[78] reported that 93 (98%) of 95 patients who underwent SSM and immediate breast reconstruction for DCIS were alive and disease-free after 3.7 years. Further excision was performed in 35 patients with margins positive for tumor, and none of them went on to develop locoregional recurrence. Locoregional recurrence developed in three (3%) patients overall.

A series by Carlson et al.[74] included 175 cases of DCIS, among which there was only one (0.6%) local recurrence after a mean follow-up of 78 months. Slavin et al.[70] presented a series of 51 patients treated for breast cancer. None of the 26 patients with DCIS developed locoregional recurrence at 45 months of follow-up. Spiegel and Butler[79] reported no local or distant recurrences during a mean follow-up period of 9.8 years in 44 patients who underwent SSM and immediate breast reconstruction for DCIS.

SSM is also used in patients with locally advanced disease who are to have immediate breast reconstruction and has not resulted in higher rates of local recurrence or distant metastasis.[80] Some authors[41,80] use SSM with neoadjuvant chemotherapy to downstage locally advanced disease. Further research is required to confirm oncological safety in T3 tumors, however. Extending the SSM indications to stage III disease might compromise the aesthetic result because of postoperative radiotherapy. A prospective study is needed to determine the indications for SSM in stage III cases.[51]

PRESERVING THE NAC

Several studies have shown the oncological safety of preserving the NAC during mastectomy.[81–83] Nipple involvement correlates with tumor size, tumor–areola or tumor–nipple distance, positive lymph nodes, and clinical suspicion. The best candidate for NAC-sparing mastectomy is the patient with a small tumor (T1) at a large distance (>4 cm) from the nipple who has negative axillary lymph nodes.[82] In such patients, breast conservation therapy (BCT) yields excellent results with low complication and recurrence rates. Considering the incidence of nipple involvement in larger tumors (T2, average 33%; T3, >50%) an NAC-sparing mastectomy can be associated with an unacceptably high risk of local relapse and is not recommended.[84]

Some authors use intraoperative frozen section of the retroareolar tissue to determine whether the NAC can be preserved.[81,84] Of concern is the false-negative rate of intraoperative frozen section.[85] Vlajcic et al.[82] compared definitive histology of the retroareolar tissue versus intraoperative frozen section results in 108 patients with invasive disease. The permanent sections revealed that the NAC base was positive in 23.1%, of whom 4.6% had false-negative results shown by frozen section.

Laronga et al.[85] found occult tumor involvement of the NAC in 5.6% of 286 mastectomy specimens. Gerber et al.[86] analyzed NAC conservation in 112 patients who had undergone SSM and 134 patients who had not undergone SSM whose tumor margins were >2 cm from the nipple. On the basis of intraoperative frozen sections of the retroareolar tissue, the NAC was preserved in 54.5% of the patients who had undergone SSM. The aesthetic results after SSM were significantly better after preservation of the NAC ($P = 0.001$). The recurrence rate after a mean follow-up of 59 months was 5.4% in the SSM group and 8.2% in the non-SSM group.

In a series of 217 patients, Simmons et al.[87] reported a rate of nipple involvement of 9.75% for those whose tumors were <1 cm in diameter, 11.9% for tumors 1 to 2 cm, 4.5% for tumors 2 to 4 cm, and 18.2% for tumors >4 cm. The only variable that reliably predicted nipple involvement was the location of the tumor.

The National Surgical Adjuvant Breast and Bowel Project Protocol B-06 is arguably the reigning study on the treatment of stage I and II breast cancer and provides the most powerful data available to address the question of nipple preservation in the setting of invasive cancer. In this study, women with negative or positive axillary lymph nodes and tumors >4 cm in diameter were randomly assigned to one of three treatment protocols: mastectomy, lumpectomy alone, or lumpectomy with radiation therapy.[88] After 12 years of follow-up, no survival advantage was shown for any of the treatment groups. In the lumpectomy cohorts, microscopically clear margins were obtained and the NAC were preserved, whereas the nipple was included in the resection for all patients in the mastectomy group. Although recurrences occurred at the nipple in both the lumpectomy alone and lumpectomy with radiation groups, this did not translate into a change in survival for either group. The authors concluded that if at least 1 cm of breast tissue beneath the NAC is tumor-free, removing the NAC offers no survival advantage when surgical margins are clear.[81]

Sufi et al.[89] proposed the envelope mastectomy with immediate reconstruction. With this procedure, the NAC is preserved and no incisions are made over the breast. Reconstruction is through a single, inconspicuous, mid-axillary line incision. In a series of 71 cases treated with this protocol, three local recurrences occurred after a follow-up of 48 months and only one involved the NAC. A good aesthetic outcome is seen with this technique.[90]

NAC RECONSTRUCTION

Background

The breast reconstruction is not complete until the NAC has also been reconstructed. The aims of NAC reconstruction are to achieve symmetry with the contralateral NAC in size, color, texture, position, and projection. The result must be long lasting and associated with minimal risk of complications.

The ideal NAC reconstruction technique has not yet been discovered, as evidenced by the myriad techniques that have been described. All reconstructions can be categorized into two groups: free grafts and local flaps. Ultimately, the choice of technique depends on the size, color, and projection of the contralateral NAC and the surgeon's experience with a particular procedure.

It is prudent to delay NAC reconstruction until the reconstructed breast reaches its final shape. When planning the procedure, the patient sits upright and uses a mirror to determine where she would like the new NAC. In unilateral reconstruction, the contralateral NAC serves as a template but if the NAC is markedly large, it might be prudent to reduce the NAC and consider nipple sharing techniques for symmetry. Sometimes the final position is adjusted to accommodate residual breast asymmetries. In bilateral reconstruction, the NAC location is planned according to relative anatomic landmarks and aesthetic preferences of the patient. Some patients experience a return of sensation to the NAC postoperatively.

Nipple Reconstruction

Nipple banking is now rarely practiced. The best match in terms of color and texture is the contralateral nipple. Nipple-sharing is ideal for women with large, ptotic nipples. The nipple is harvested as a free graft and sutured to the desired de-epithelialized area. The disadvantages of nipple-sharing from the contralateral breast are the inevitable morbidity to the normal nipple and poor long-term projection of the transplanted nipple. The most commonly used techniques involve local flaps, such as the star flap presented by Anton et al.,[91] the bell flap presented by Eng,[92] the skate flap presented by Little et al.,[93] the double-opposing tab presented by Kroll and Hamilton,[94] and the cervical visor (C-V) flap presented by Losken et al.,[95] among others (Figs. 2–8).[96] Overcorrection is recommended to allow for atrophy and loss of projection with time.

Losken et al.[95] evaluated long-term outcomes of the C-V flap for nipple reconstruction. Eleven patients (14 nipple reconstructions) were asked to rate their level of satisfaction with various characteristics after an average of 5.3 years, and the results were as follows: nipple projection, 42%; pigmentation, 62%; sensation, 26%. Overall patient satisfaction with the procedure was 81%. The average nipple projection of the reconstructed nipple was not statistically different from that of the opposite nipple ($P = 0.08$).

Barton[97] used dermal-epidermal advancement flaps from the latissimus dorsi skin island to perform nipple reconstruction in 10 patients. No tissue loss occurred, and the nipples were still prominent 16 months postoperatively. Barton reported that the technique avoids further donor-site distortion and offers the benefits of available tissues with uninterrupted circulation.

Shestak et al.[98] compared nipple projection after reconstruction with the skate, star, and bell flaps and found that the best long-term nipple projection was achieved and maintained by the skate and star techniques ($P < 0.005$). A substantial decrease in projection of the reconstructed nipple occurred during the first 3 months with all procedures, but after 6 months, the projection was stable, with the skate and star flaps averaging between 30% and 33% projection loss. The loss of both nipple and areola projection after bell flap reconstruction was so remarkable that the authors discouraged the use of this procedure in virtually all patients.

Kroll et al.[99] examined nipple projection of 153 breasts measured at least 6 months after double-opposing tab (n = 106) or star flap (n = 47) nipple reconstruction. The mean follow-up was 2.27 years. Although both methods effectively maintained projection, nipples reconstructed with the modified double-opposing tab flap had slightly more projection than those reconstructed by a star flap.

The use of cartilage grafts, particularly from a rib, has proved promising for long-term preservation of projection. Heitland et al.[100] reported using banked rib cartilage for nipple reconstruction in 17 patients. The cartilage was inserted under an “arrow flap” that was contoured in a “mushroom” shape. After 1 year, the average nipple height decreased approximately 25% from the intraoperative measurement. Thirteen of 17 patients judged the aesthetic outcome to be very good. Graft exposure, which is a limitation of all autologous grafts, occurred in one case.[100]

Nahabedian and Tsangaris[101] described the use of dermal matrix with C-V flap in eight patients undergoing secondary nipple reconstruction. The authors reported loss of projection of 38% to 50% at 6 months to 1 year. One nipple flattened and required tertiary reconstruction with AlloDerm that eventually resulted in good projection.[102]

Areola Reconstruction

As with nipple reconstruction, the best match for areola tissue is the contralateral breast. Skin grafts

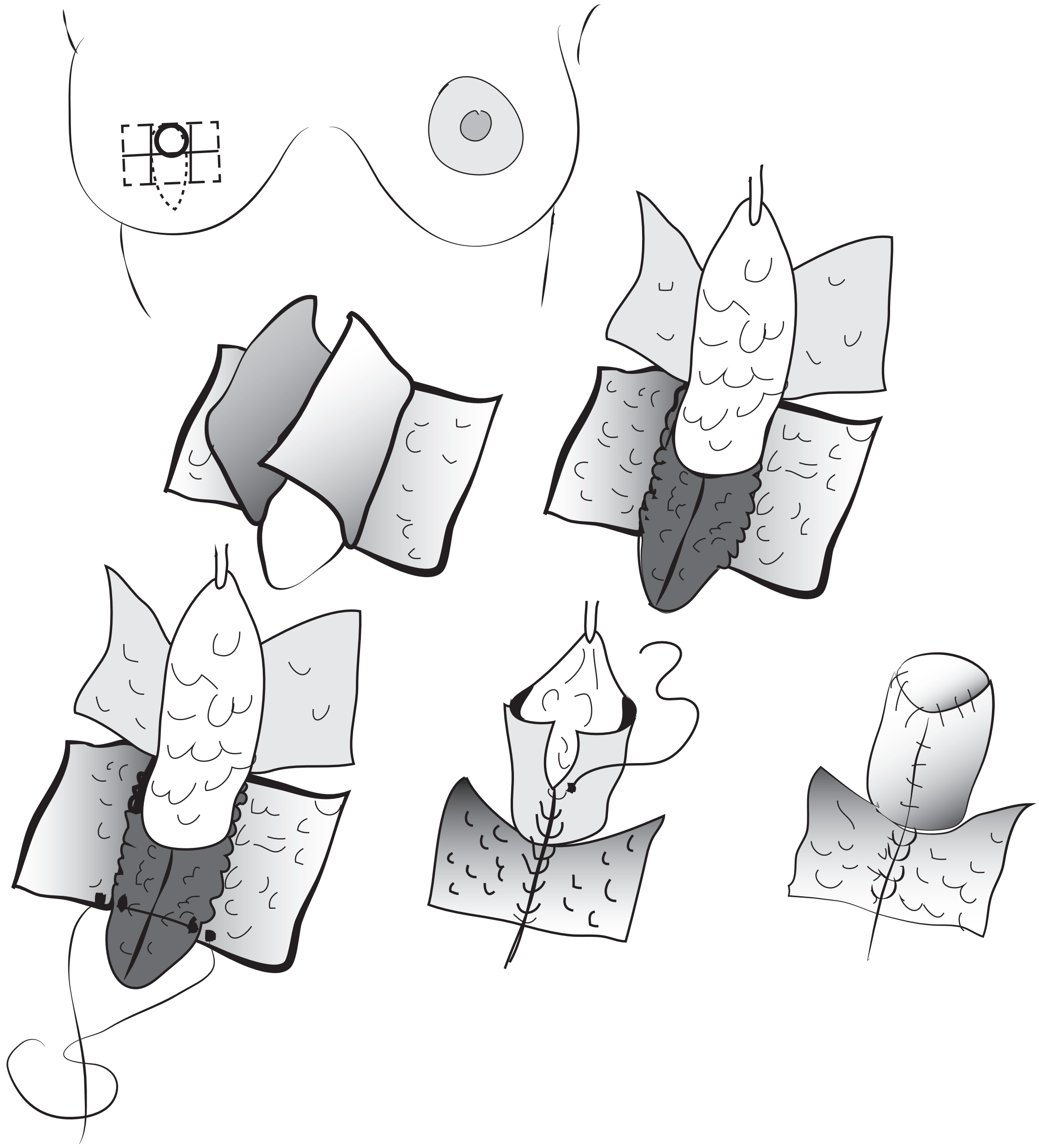

Figure 2. Nipple reconstruction with a modified skate flap. (*Modified from Spear.*[96])

from many donor areas have been reported in the literature, but it is difficult to match the pigmentation and texture of the contralateral areola with a graft. Intradermal tattooing, first introduced by Becker,[103] is a safe and effective method for achieving color match and has largely replaced skin grafting alone. It does, however, require the operator to be trained and experienced to achieve optimal results. Tattooing is performed once the nipple reconstruction has healed, and although pigmentation fading can be expected with time, excellent long-term results and patient satisfaction have been reported.

Spear and Arias[104] analyzed their 6-year experience with nipple tattooing in 151 patients. Of the 103 patients who responded to a questionnaire, 49 (57%) of 86 said their tattoos looked similar to the normal areola. Among women who graded their tattoo color, 50 (68%) of 74 said it was a close match

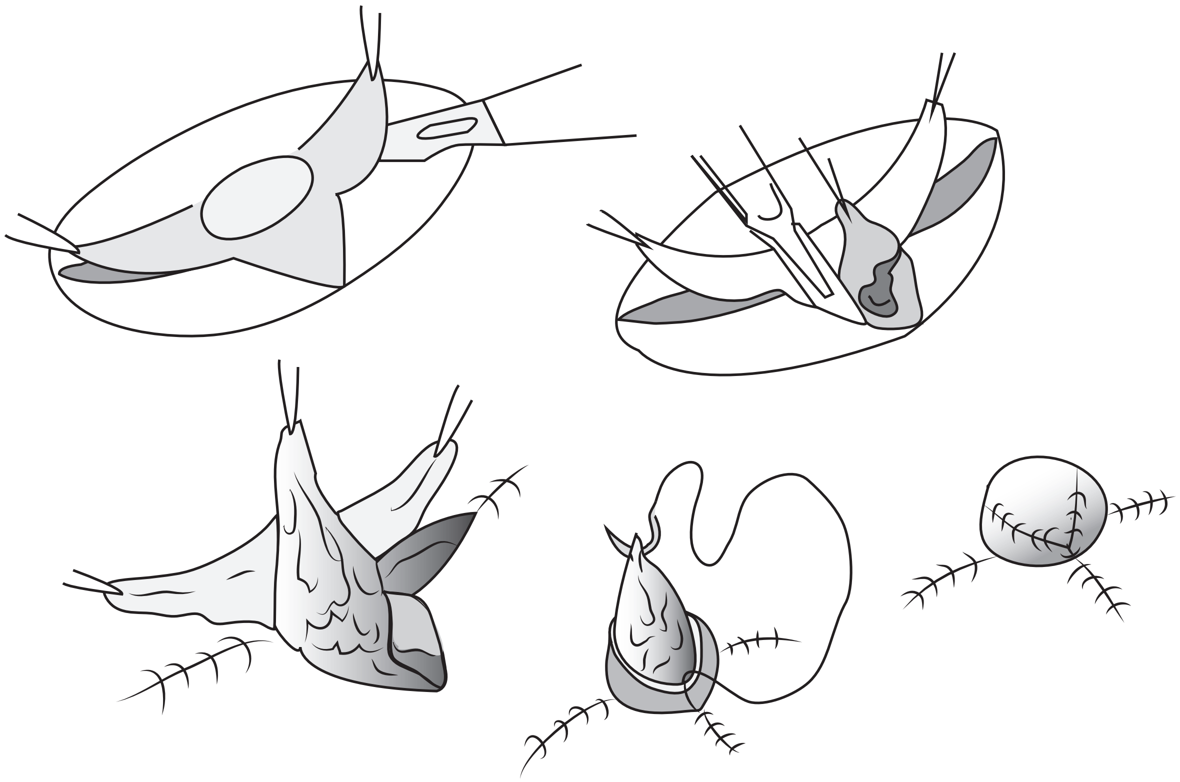

Figure 3. Nipple reconstruction with a modified star flap. (*Modified from Spear.*[96])

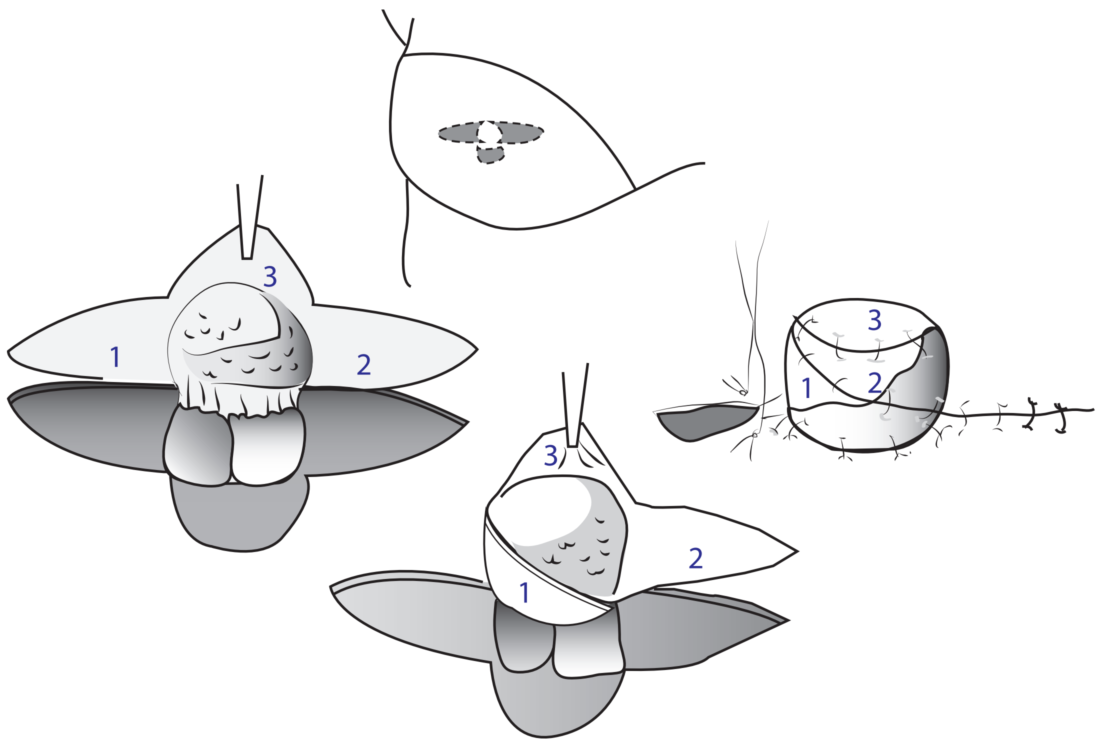

Figure 4. Nipple reconstruction with a C-V flap. (*Modified from Spear.*[96])

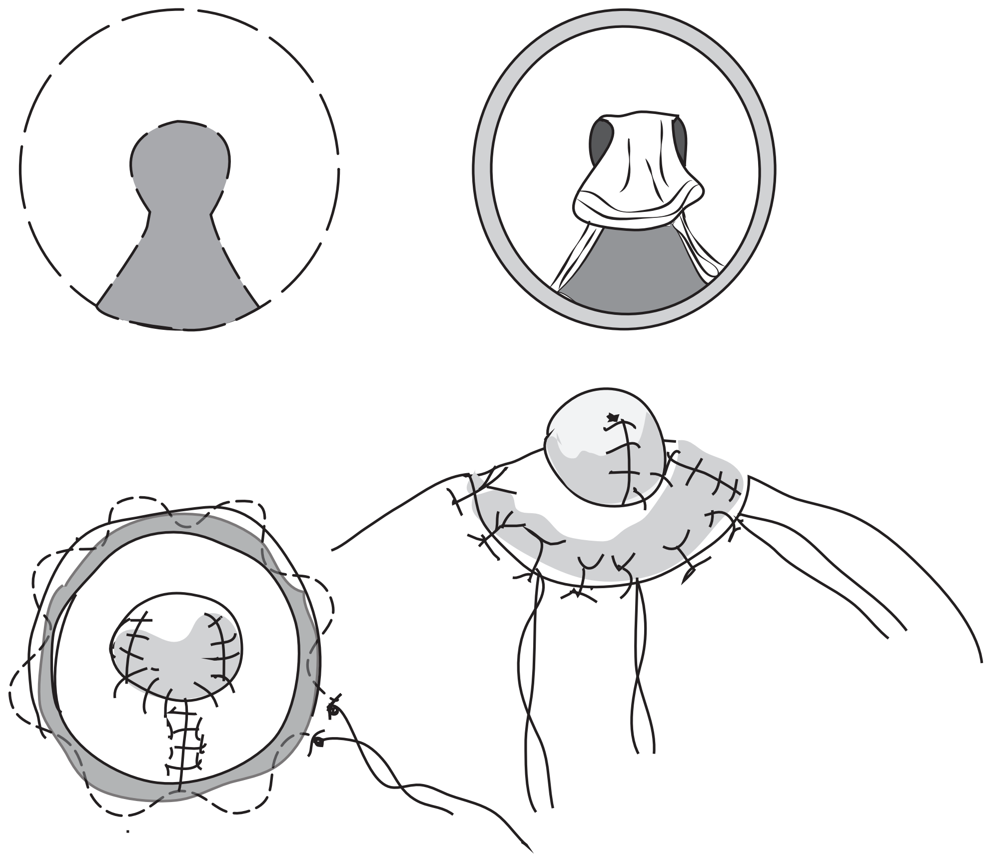

Figure 5. Nipple reconstruction with a bell flap. (*Modified from Spear.*[96])

to or only slightly different from the normal. Pigment fading was the most common complaint, reported by 60% of respondents. Touch-ups were performed in 10% of patients. The average follow-up was 25.2 months. Overall, 84% of respondents rated their results as satisfactory and 86% said they would repeat the procedure if presented with the same choice again. A 3% rate of superficial infection in the series has led to prescription of antibiotics for 48 hours at the time of the procedure.

El-Ali et al.[105] reported the results of 40 consecutive patients who had NAC tattooing performed by the same surgeon. Assessments were made both subjectively by questionnaire and objectively by a computer software program that analyzed the color of the NAC. After a mean follow-up duration of 14 months, 37 (93%) of the 40 patients reported some color fading, which ranged between 5% and 80% (mean, 32%). Based on these findings, the authors now perform the initial tattoo one-third darker than the normal side. A grade of good or very good was assigned by 33 patients (83%) for color match, 36 (90%) for overall satisfaction, and 34 (85%) for enhancement in body image. Digital photographs were taken for 34 (85%) of the 40 patients, and software revealed that the color similarity between normal and tattooed NACs in these pictures ranged between 78% and 97%, with a mean of 91%. One (3%) patient developed a superficial infection.

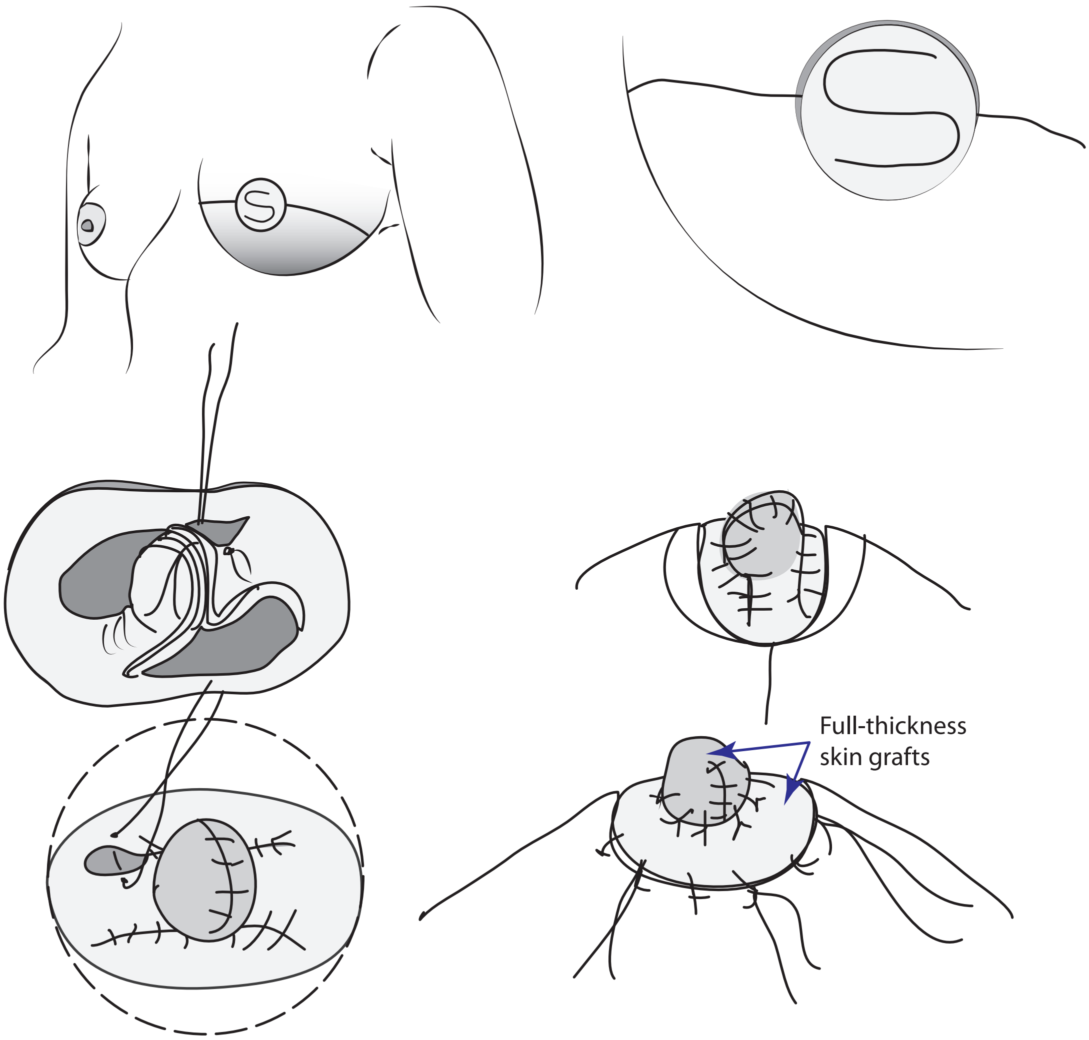

Figure 6. Nipple reconstruction with an S flap. (*Modified from Spear.*[96])

BCT

Background

During the last 4 decades, the surgical treatment of breast cancer has shifted away from the radical Halstedian approach to less aggressive surgical alternatives while maintaining oncological principles. The term *breast conservation therapy* refers to lumpectomy and radiotherapy and was first described by Adair[106] in 1943. Adair's patients achieved 72% 5-year survival after local tumor excision and immediate radiotherapy. This protocol is oncologically safe and has become the preferred treatment for women with stage I and II breast cancer because it is associated with low morbidity[107] and preserves breast sensation.

In 1990, a National Institutes of Health Consensus Development Conference recommended BCT and radiation therapy for the majority of women with stage I or II breast carcinoma.[52] Most centers have incorporated BCT in the treatment algorithms used for the treatment of DCIS and early-stage invasive carcinoma.[108]

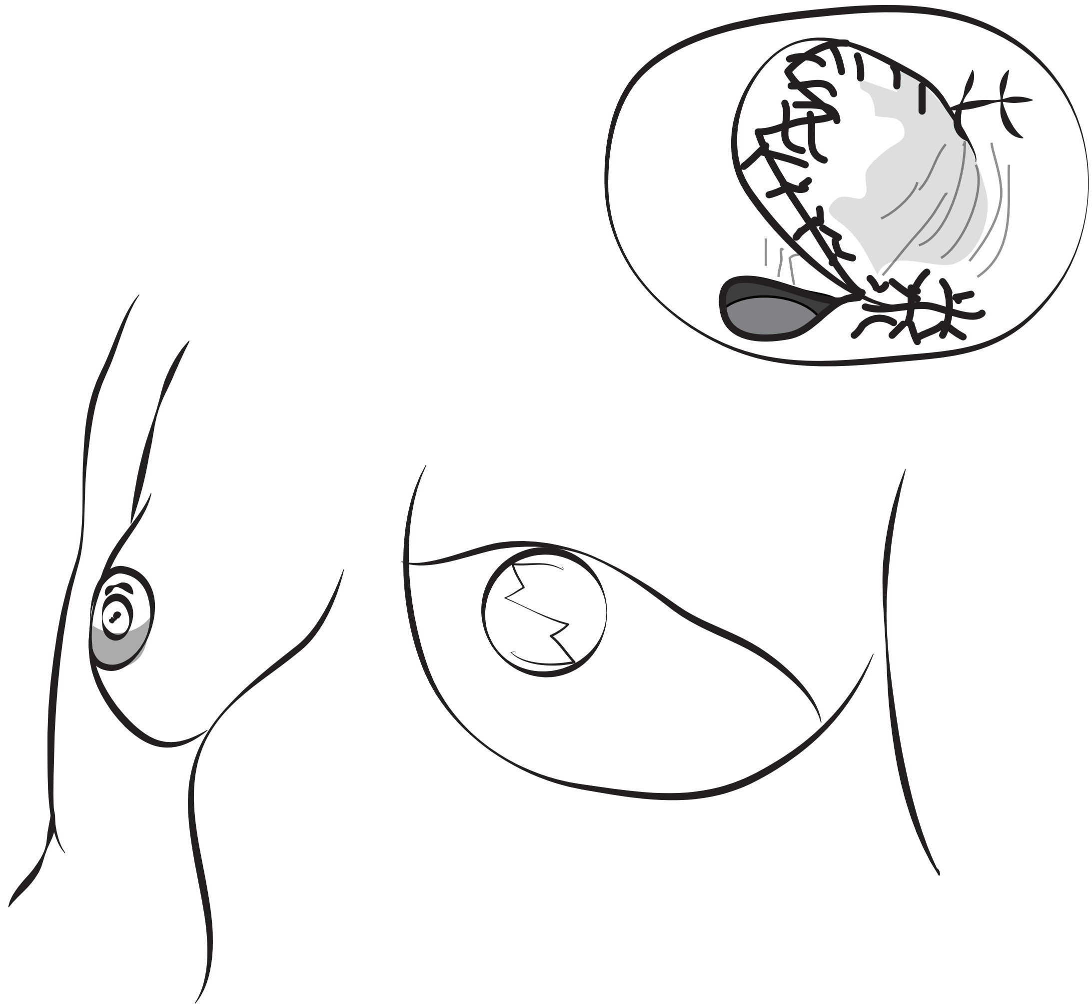

Figure 7. Nipple reconstruction with a double-opposing flap. (*Modified from Spear.*[96])

Oncological Safety

Studies with 20 years of follow-up have shown equivalent survival of patients treated with BCT and those treated with mastectomy.[88,109–113] Veronesi et al.[109] randomized 701 women with T1 breast cancer to receive either classic Halsted mastectomy (n = 349) or quadrantectomy, axillary dissection, and radiotherapy (n = 352). After 20 years, 7.9% in the BCT group and 2.3% in the radical mastectomy group developed local recurrences. Although this difference was statistically significant ($P < 0.05$), it had no effect on survival.

Fisher et al.[88] reviewed 20-year follow-up data on 1851 patients with stage I or II disease randomly assigned to total mastectomy, lumpectomy, or lumpectomy and breast radiation. The axillary nodes were removed in all cases. Among women who underwent radiation after lumpectomy, the recurrence rate 20 years after surgery was 14.3%, with 39.7% of the recurrences detected within the first 5 years, 29.5% at 5 to 10 years, and 30.8% after 10 years. No significant differences were observed in disease-free survival between treatment groups ($P > 0.05$). Incidence of breast cancer did not increase in the contralateral breasts because of postoperative breast radiation.[88,114] A more satisfactory aesthetic

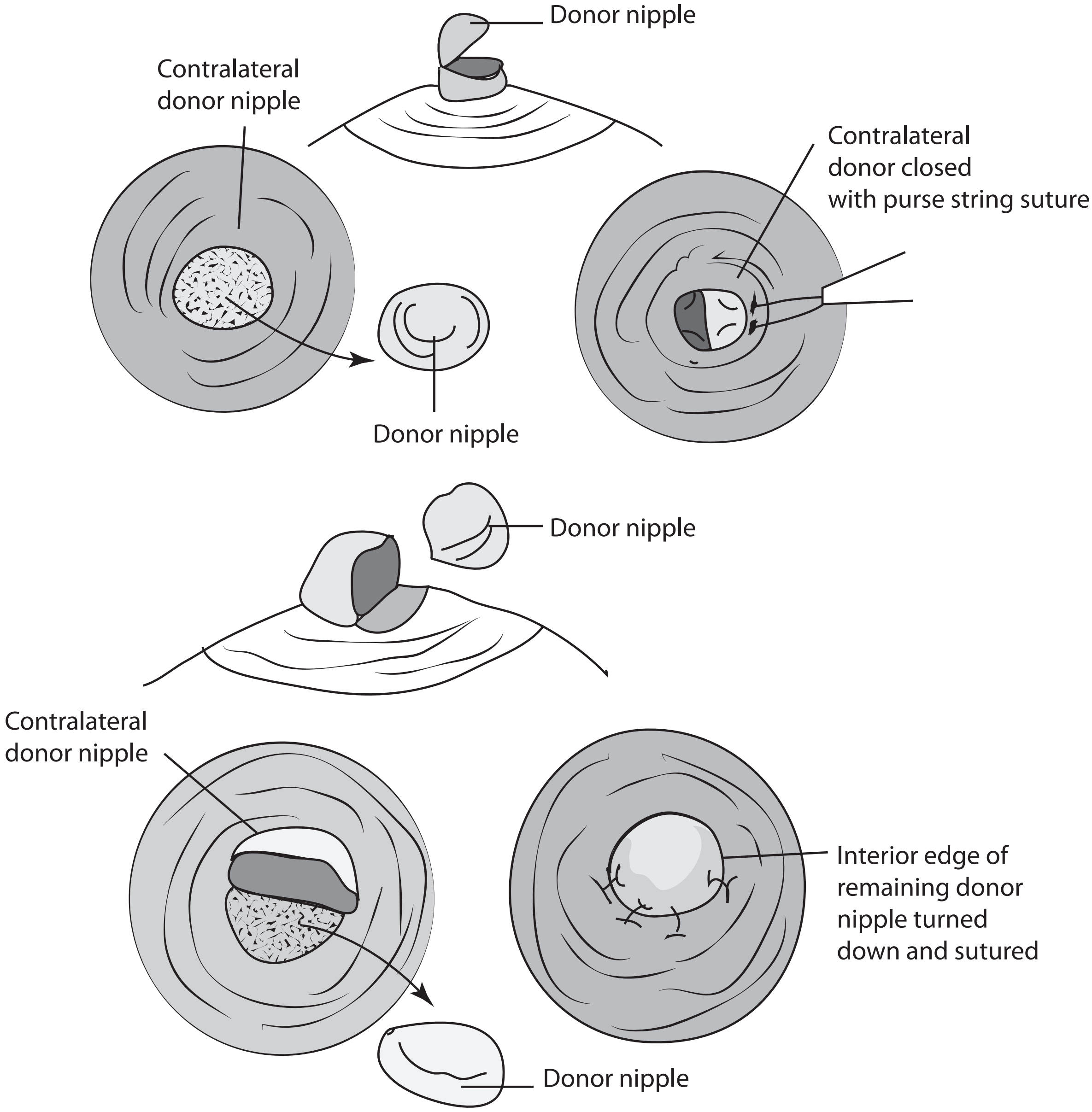

Figure 8. Nipple reconstruction with a composite graft from the contralateral nipple. (*Modified from Spear.*[96])

outcome can be achieved with lumpectomy than with quadrantectomy.

Woerdeman et al.[115] histologically examined 728 mastectomy scars and found no sign of metastasis or new tumor. This histological study offers further evidence of the oncological safety of the lower mastectomy flap.

Therapeutic Mammaplasty

Excision of small tumors within large breasts generally produces satisfactory long-term aesthetic results, particularly when the skin excision is limited and the defect does not extend to the chest wall, in which case the cavity can be left to fill with serous fluid and scar tissue.[116] The management of large tumors relative to breast size, however, requires tissue rearrangement to fill the defect, which can be accompanied by a standard breast reduction technique to avoid mastectomy. BCT is indicated in cases in which clear surgical margins are expected, although patients should be warned that in a small number of cases, conversion to mastectomy might be necessary depending on the result of the permanent sections. The defect usually is corrected at the time of lumpectomy to avert delayed wound healing or necrosis of radiated skin flaps and the risk of a second operation. An exception is made in the event the excisional margins are questionable for tumor.

The breast often is reshaped with well-established breast reduction techniques and contralateral procedures to achieve symmetry. The versatile pedicle of the reduction mammaplasty allows for tumor resection in virtually any part of the breast. Volume-replacement techniques facilitate a wider excision to obtain clear margins, and larger tumors that would otherwise require mastectomy can be resected in expectation of a good aesthetic result. Several techniques have been described to fill excision defects of the breast, all of which generally rely on rotation or advancement of breast parenchyma.

Therapeutic mammaplasty is also indicated in women with small tumors relative to their breast size in whom bilateral reduction mammaplasty is contemplated for symptomatic relief of mammary hyperplasia. Reduction mammaplasty is especially indicated in cases in which the tumor lies within the excision pattern of a popular breast reduction technique and in which contralateral breast reduction is viewed as a positive outcome.[117] The aim is to remove the tumor from areas normally excised during the reduction procedure.

For excisions that lie outside the commonly used reduction techniques, the operation can be modified to create a secondary pedicle or to extend the parenchymal pillar. Tumors lying in the inferior half of the breast can be excised by superior or superomedial pedicle mammaplasty, with the pedicle orientation dictated by the tumor location. The skin incision pattern is chosen on the basis of amount of breast skin, tumor site, location of previous scars, whether the skin overlying the tumor needs to be excised, and need to access the axilla (Figs. 9–16).[96] Tumors in the superior half of the breast require modification of existing mammaplasty techniques. The lateral part of the breast is a common location for breast tumors, which are managed by extending the nipple pedicle or creating a secondary pedicle—whichever option has better vascularity. Tumors in the upper part of the breast are managed by extending an inferior pedicle.

The most difficult tumors to excise and reconstruct aesthetically are those located in the upper inner quadrant of the breast. Fortunately, they are also the least common. The contralateral breast can be treated with a standard pedicle without affecting symmetry.

Central breast tumors can be managed by either wedge excision or an advancement flap, based on the inferior pedicle and a Wise-pattern incision. In smaller breasts without excessive ptosis, a vertical pattern with an inferior pedicle or a medial or horizontal bipedicle can be used and then nipple reconstruction performed. In a series of 50 therapeutic mammaplasties with these techniques, McCulley and Macmillan[118] reported infection occurring in three patients (6%), fat necrosis in four (8%), and delayed wound healing in one (2%). Adjuvant treatment was not delayed in any case. Four patients (8%) had extensive DCIS and underwent mastectomy. The mean follow-up was 13 months, and the cosmetic outcome was judged to be good to excellent in 63% and satisfactory in 33%. No recurrences occurred during the follow-up period.

Losken et al.[119] reported a series of 20 patients with partial mastectomy defects who underwent reduction mammaplasty. The superomedial and inferior pedicles were most versatile in conjunction with a Wise pattern or vertical skin incision pattern. DCIS was present at the excision margin in four (20%) of the 20 patients. Of the four patients, three underwent re-excision and one underwent mastectomy. Adjuvant therapy was not delayed despite complications. No locoregional recurrences had developed at a mean follow-up of 23 months.

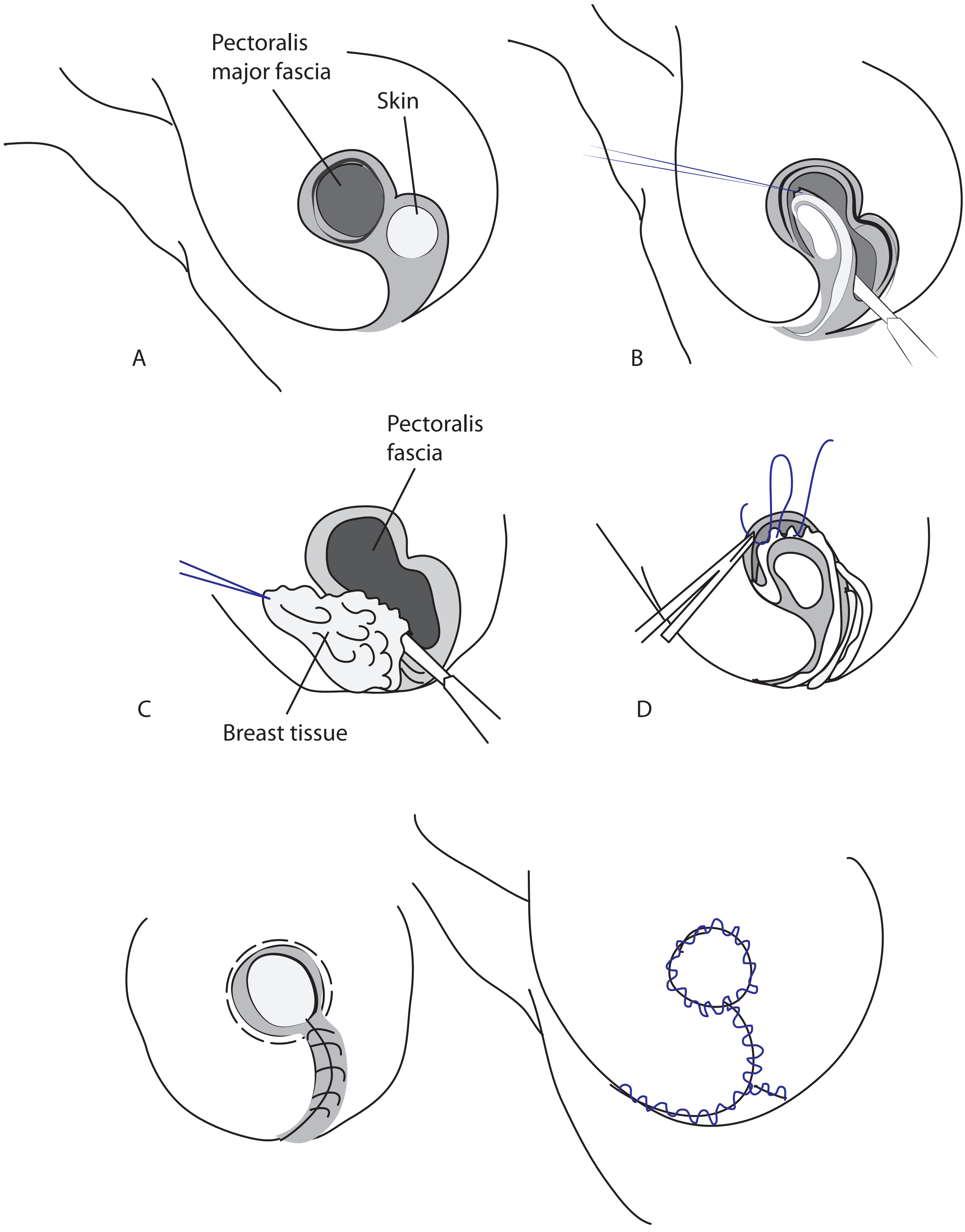

Figure 9. Breast reconstruction after resection of centrally located tumors. The areola and a cylinder of glandular tissue are excised down to pectoralis fascia, and the breast is reshaped by rotating and advancing a skin-parenchymal flap from the inferolateral pole. (*Modified from Spear.*[96])

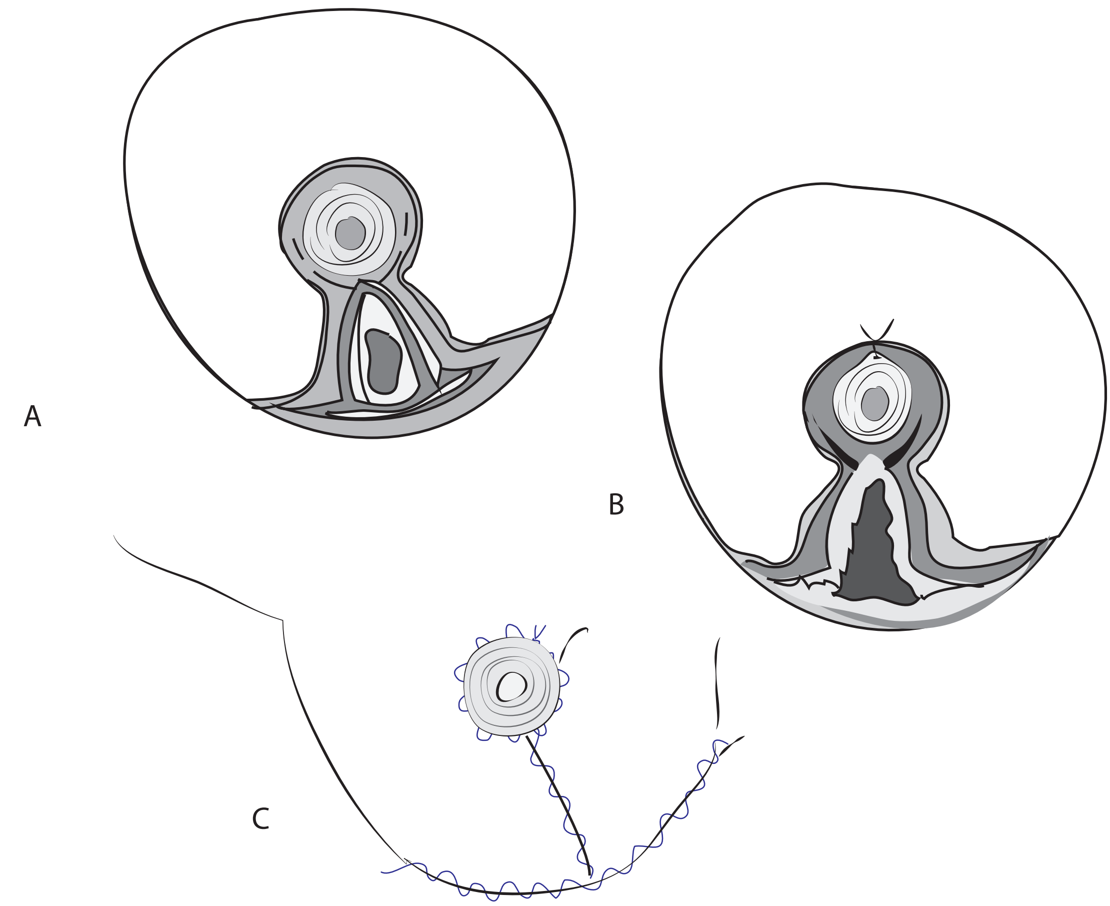

Figure 10. Breast reconstruction after resection of central lower pole tumors by inferior quadrantectomy.

(*Modified from Spear.*[96])

Clough et al.[120] described the findings of a prospective study of 101 patients who had undergone breast reconstruction because of partial mastectomy defects. Among the 101 patients, 17 received neoadjuvant chemotherapy to downsize the tumor. Most cases (80%) were managed with a superior pedicle technique and a Wise-pattern incision. Eleven patients had tumor cells in the excisional margins: six subsequently underwent mastectomy, and five received radiotherapy boost to the tumor bed. Delayed wound healing forced postponement of radiotherapy for four patients and postponement of chemotherapy for one. Local recurrence developed in 11 patients and metastases in 13 at a mean follow-up of 46 months. The aesthetic outcomes, as perceived by the surgeon and two lay people, were considered to be fair to excellent in 88% at 2 years and in 82% at 5 years. The outcomes were significantly worse in women who had received preoperative radiotherapy: poor outcome in 43% of those who had received preoperative radiotherapy versus 13% of those who did not receive preoperative radiotherapy ($P < 0.002$).

Papp et al.[121] traced the course of 40 patients treated with excision to macroscopically disease-free margins of 2 cm. Reduction mammaplasty was performed in 24 of the 40 patients, and the aesthetic outcome was substantially better for the immediate group (87% good) compared with the delayed group (68% good). Masetti et al.[122] noted no local recurrence in 56 patients managed with

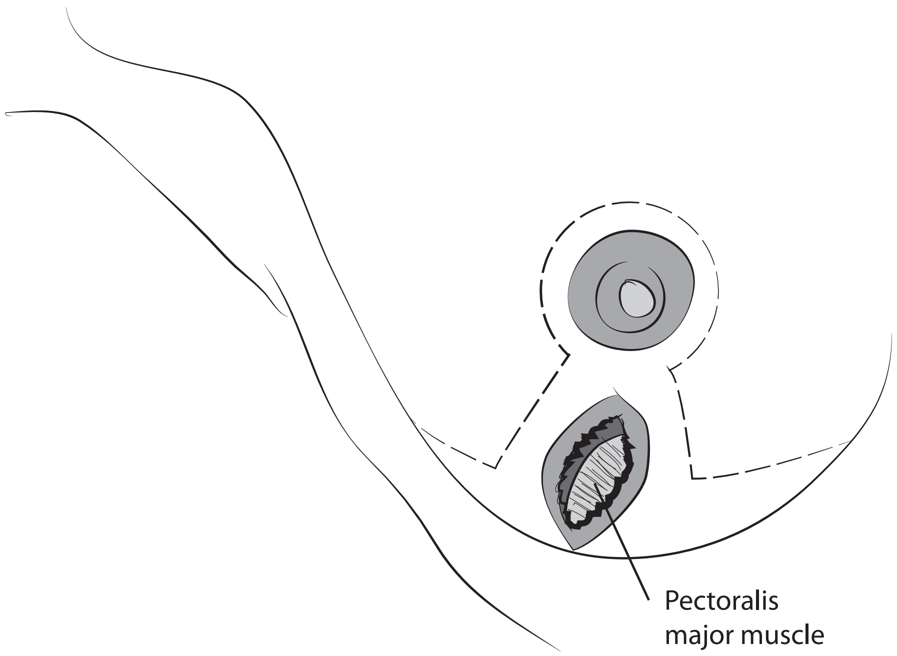

Figure 11. Breast reconstruction after resection of tumors in the lower lateral quadrant. The keyhole pattern can be rotated to fit the excision site. (*Modified from Spear.*[96])

breast-reshaping techniques after a median follow-up duration of 23 months. The aesthetic outcome in that series was considered to be very satisfactory in 91%.

The effects of radiation on the overall cosmetic result depends on breast size and radiation technique used, among other factors.[107] Because morbidity climbs with postoperative radiotherapy of larger breasts, a benefit of the reduction mammaplasty is that the radiation dose can be homogenized.[123–126] In cases in which breast reduction techniques are indicated, excellent aesthetic results and symmetry typically are seen postoperatively.

Another benefit of therapeutic mammaplasty is that the contralateral breast can be examined for occult neoplasia.[107] Reduction mammaplasty might therefore reduce the risk of subsequent breast cancer in a “normal” breast.[127] In a study presented by Clough et al.,[120] one occult carcinoma was present among 101 specimens. Petit et al.[128] identified contralateral carcinomas in five (5%) of 111 specimens.

Local and Distant Flaps

When tumor excision creates a volume deficit that cannot be successfully corrected with a breast-reshaping procedure, a local flap or latissimus dorsi flap is necessary. Local flaps can be harvested from the lateral chest below the axilla, where the resultant hollow is less conspicuous than on the breast.[129] The latissimus dorsi miniflap is capable of replacing large soft-tissue volumes, although this scenario is rare. In a series presented by Dixon et al.,[130] the miniflap was needed in approximately 2.5% of patients during a 2-year period. Follow-up examinations revealed the flap to be radiolucent with minimal scarring, so this procedure does not affect mammographic screening. The latissimus dorsi miniflap transfer is accomplished in one or two operative stages (Fig. 17).[96]

Dixon et al.[130] evaluated the cosmetic outcomes of patients who underwent wide local excision with miniflap reconstruction against age-matched patients who underwent mastectomy and immediate breast reconstruction. The cosmetic outcomes achieved with

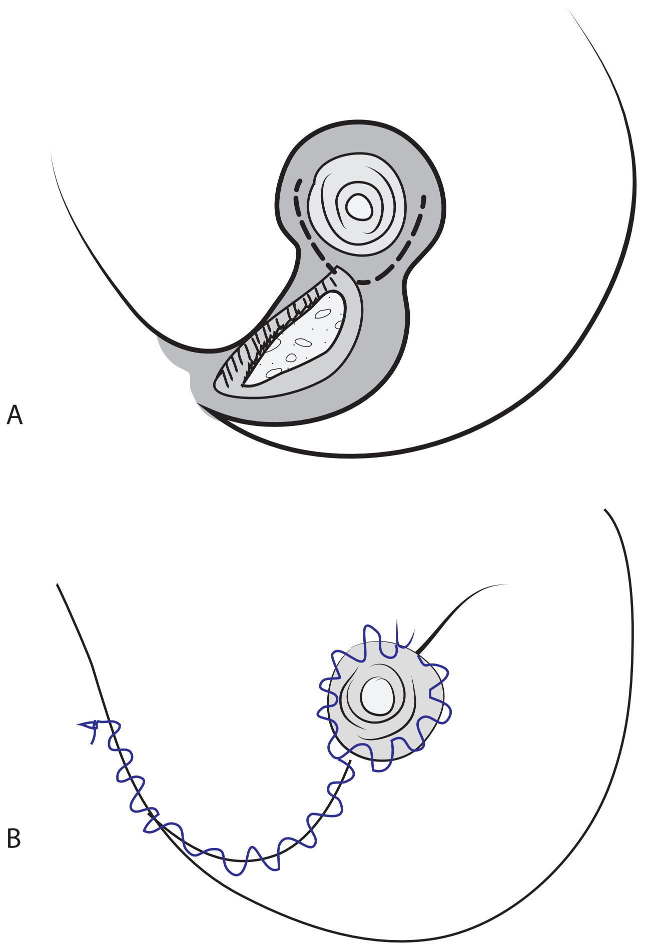

Figure 12. Alternative method of breast reconstruction with a B-type mastoplasty after resection of tumors in the lower lateral quadrant. (*Modified from Spear.*[96])

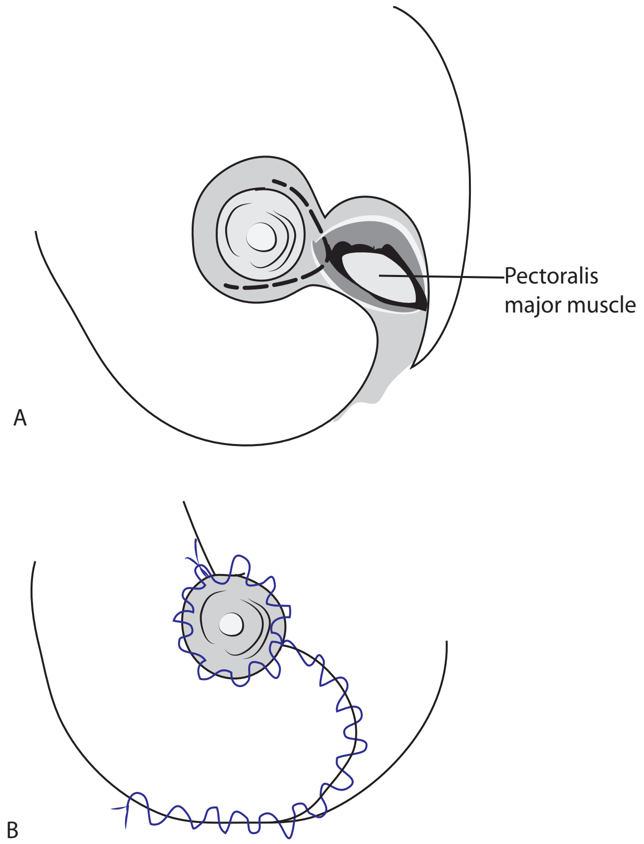

Figure 13. Breast reconstruction after resection of tumors in the lower medial quadrant. (*Modified from Spear.*[96])

wide local excision and miniflap reconstruction were assessed to be good and to be better than cosmetic outcomes achieved with mastectomy and immediate breast reconstruction.

Gendy et al.[131] compared outcomes of 57 patients who underwent SSM and immediate musculocutaneous flap reconstruction with those of 49 patients who underwent partial mastectomy and latissimus dorsi miniflap reconstruction. Despite having a longer median follow-up period (53 months) than that of the SSM group, the miniflap group was considered to be aesthetically superior by panel assessment.

IMMEDIATE VERSUS DELAYED BREAST RECONSTRUCTION

Background

The Surveillance Epidemiology and End Results (SEER) database,[132] which was created by the National Cancer Institute, is the most comprehensive source of national cancer incidence and outcome data

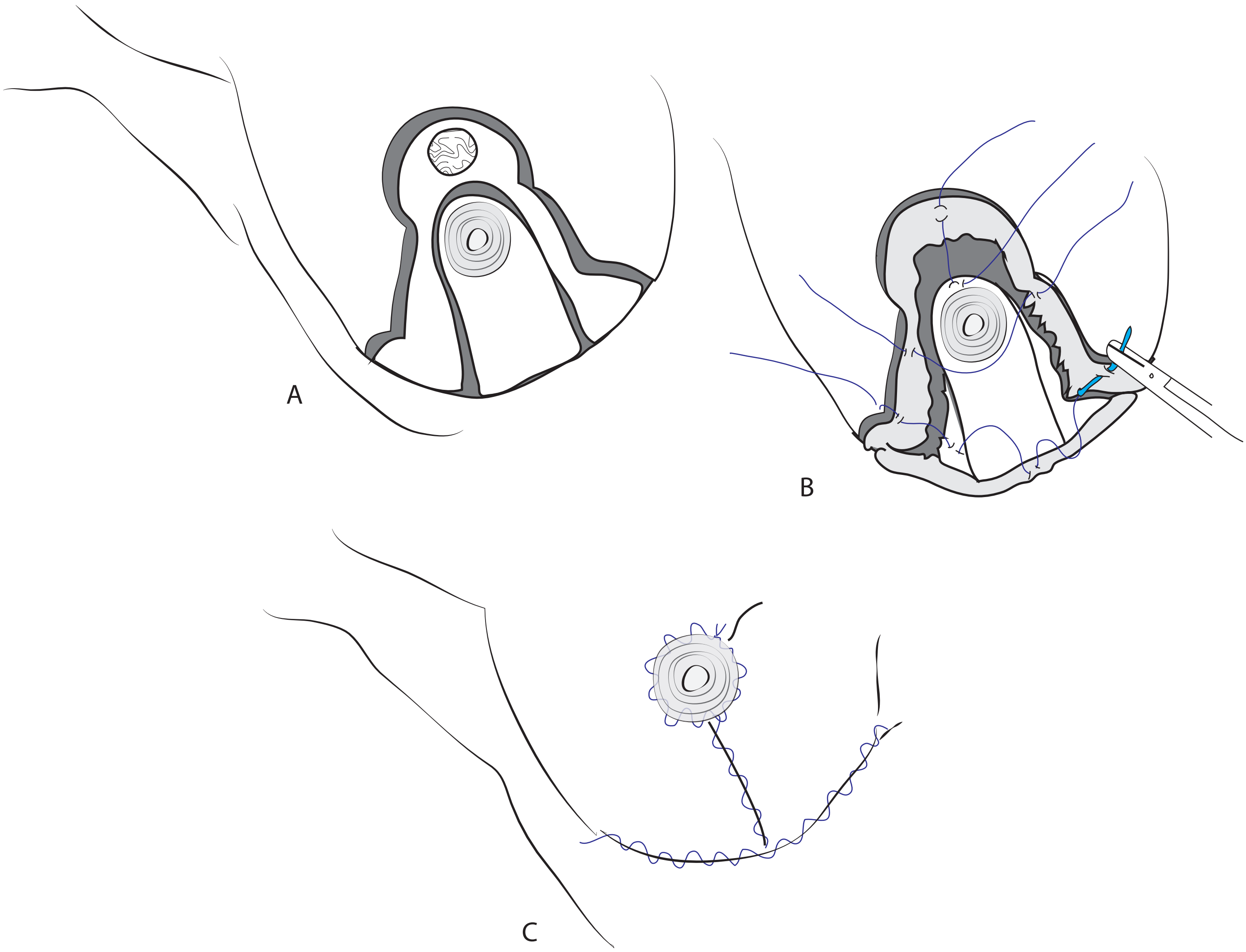

Figure 14. Breast reconstruction after resection of tumors located above the areola. The keyhole pattern can be canted sideways to accommodate the excision. (*Modified from Spear.*[96])

in the United States. According to SEER data for the year 2008, 37.8% of patients undergoing mastectomy also underwent immediate or early delayed (within 4 months of mastectomy) breast reconstruction. Not included in this statistic are delayed reconstructions (>4 months from mastectomy).[133]

The current indications for post-mastectomy radiotherapy have led many patients to receive radiotherapy as part of their breast reconstruction algorithm. All trials comparing systemic therapy to systemic therapy with post-mastectomy radiotherapy in node-positive patients treated with modified radical mastectomy have shown a substantially reduced risk of locoregional recurrence with the addition of radiotherapy.[134,135] A meta-analysis of 18 trials involving 6367 patients also noted significantly reduced overall mortality when radiation was used (odds ratio, 0.83; 95% confidence interval, 0.74–0.94; $P = 0.004$).[136] The American Society of Clinical Oncology guidelines recommend post-mastectomy radiotherapy for patients with T3 tumors and positive axillary nodes, for patients with operable

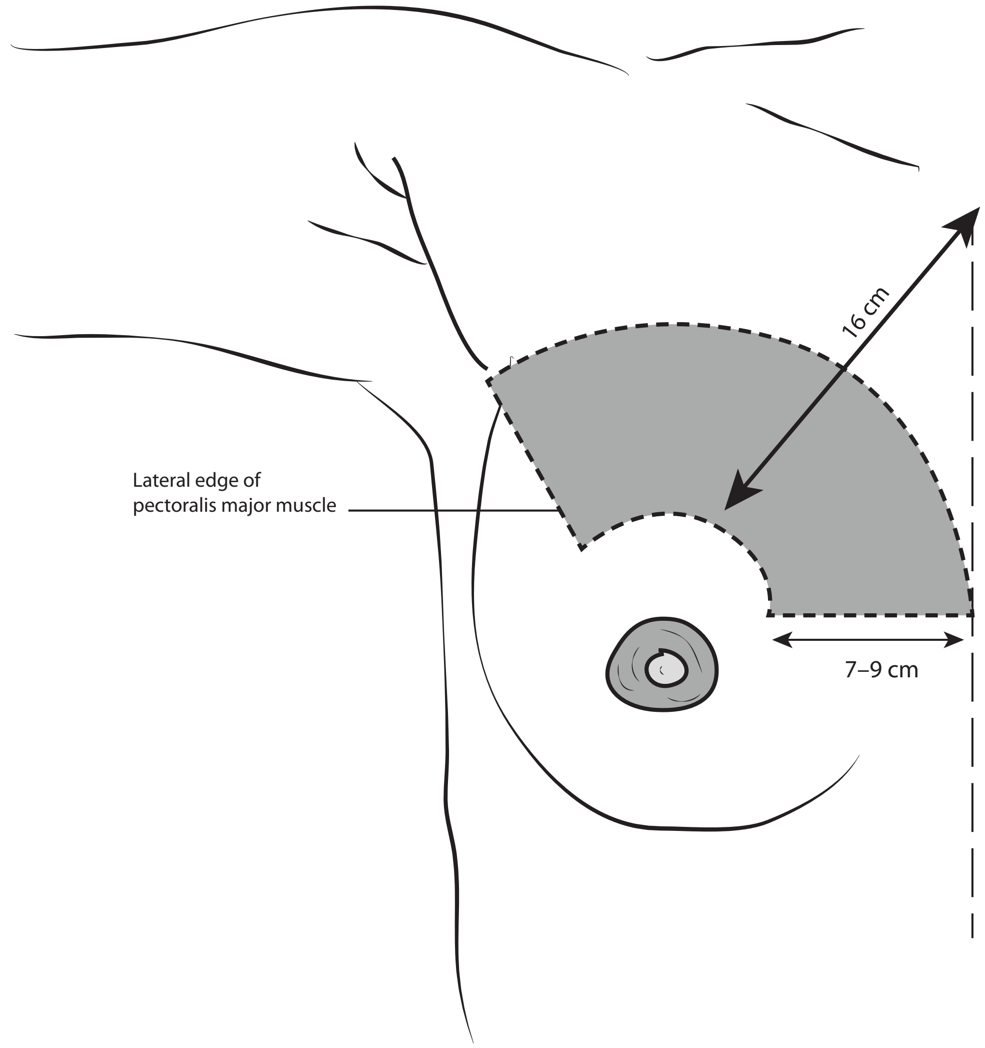

Figure 15. No incisional scars should cross the space indicated by the shaded area. (*Modified from Spear.*[96])

stage III tumors, and for patients with four or more positive axillary lymph nodes.[137] The evidence did not support the routine use of radiotherapy in patients with T1 or T2 tumors who had more than four positive nodes.[137] The Radiation Therapy Oncology Group is currently focusing their research on this cohort.[138]

Immediate Breast Reconstruction

The possibility of radiotherapy should be anticipated before proceeding with immediate breast reconstruction. Traditionally, delayed reconstruction is considered when postoperative radiotherapy is likely because of dangers to the flaps posed by the radiation. In cases in which immediate reconstruction + postoperative radiotherapy is desired, autologous reconstruction is recommended over implant-based procedures. Delayed-immediate reconstruction is also an option in these circumstances.

The cosmetic benefits of immediate breast reconstruction are as follows:[139]

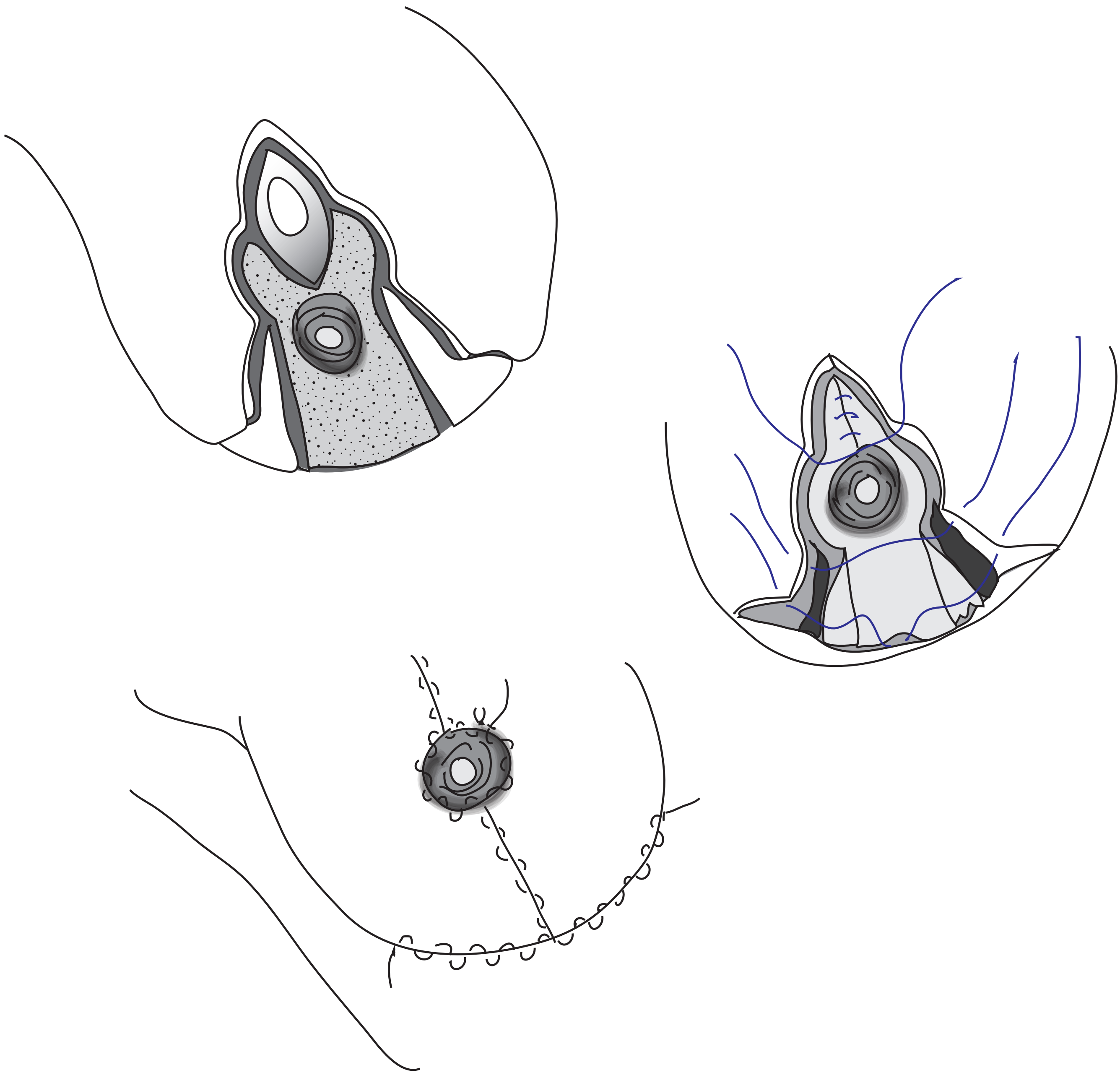

Figure 16. Alternative method of breast reconstruction for tumors that occur within the shaded area shown in Figure 15. (*Modified from Spear.*[96])

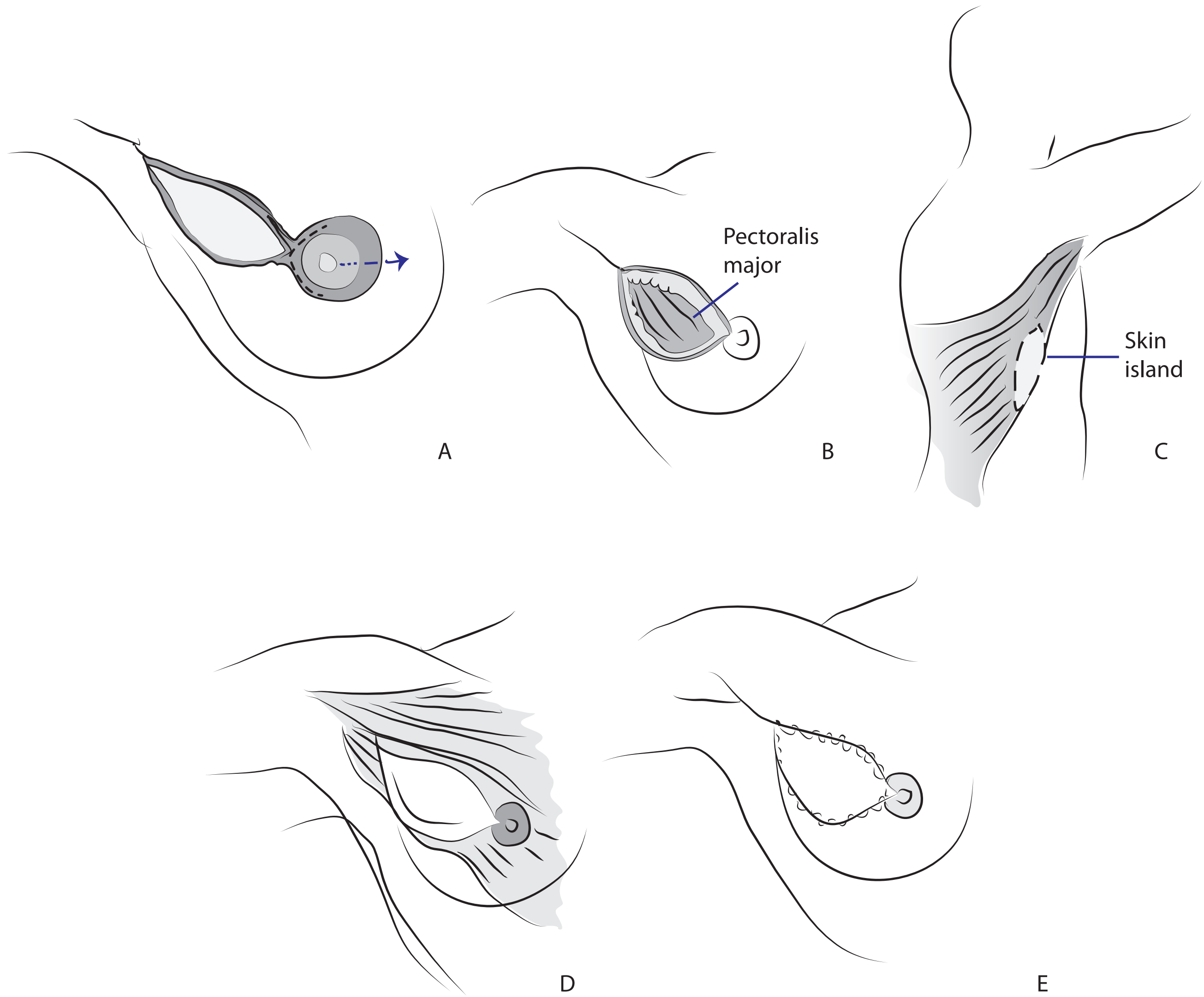

Figure 17. Breast reconstruction with latissimus dorsi miniflap after resection of tumors in the superior outer quadrant (*Modified from Spear.*[96])

- The native tissues are unaffected by soft-tissue contracture and scar.
- The inframammary fold is preserved.
- The breast envelope assumes a natural shape and symmetry when the breast volume is restored.

Other benefits ensue. The superior aesthetic result, especially symmetry with the opposite breast, lessens the need for contralateral reduction surgery, which means that in many cases, the reconstruction can be completed during a single episode of general anesthesia. This translates into decreased anesthetic risk and substantial cost savings.[56,140,141] One study reports that the cost of delayed reconstruction was 62% higher than for immediate breast reconstruction.[140]

Immediate breast reconstruction is an oncologically safe procedure.[142,143] Langstein et al.[144] reported a 2.3% incidence of locoregional recurrences, most of which (72%) were located in the skin or subcutaneous tissue. The authors followed 1694 patients for 10 years after immediate breast reconstruction. They concluded that immediate reconstruction did not delay the detection of local recurrence.

Delayed Breast Reconstruction

Delayed breast reconstruction has several advantages, as follows:

- It avoids the risk of complications associated with radiotherapy to an implant-based reconstruction.
- Permanent sections can be studied before the reconstruction is planned.
- If necessary, the mastectomy flaps can be allowed to heal before reconstruction.
- Any skin damaged by radiotherapy can be resected and replaced during the reconstruction procedure.

The disadvantages of delayed breast reconstruction include the following:

- The need for a skin paddle as part of an autologous reconstruction
- A second operation, which entails double the anesthetic risk and higher overall costs
- The psychological morbidity of living with the mastectomy defect

Delayed-Immediate Breast Reconstruction

Delayed-immediate breast reconstruction was devised for two scenarios: 1) if the surgeon is unable to accurately determine, based on frozen section, the nodal status of the patient at the time of mastectomy; and 2) if the lymphatic spread by the tumor is uncertain and the decision for postoperative adjuvant radiotherapy cannot be made with any degree of reliability.[145–148] A prudent protocol, such as that in place at MD Anderson Cancer Center, consists of the following:[149,150]

1. SSM includes subpectoral insertion of a tissue expander.
2. After permanent sections are reviewed, patients who do not require radiotherapy proceed to immediate breast reconstruction.
3. Patients who do require radiotherapy have their expander fully deflated before receiving radiotherapy (for access to the internal mammary lymph nodes).
4. At the completion of radiotherapy, the deflated expander is serially re-expanded to prevent retraction of the skin envelope and loss of breast shape while awaiting reconstruction.
5. The median interval between stages is 13 days.

This protocol averts the aesthetic and radiation-delivery problems attendant to immediate breast reconstruction. Should the indications for post-mastectomy radiotherapy be expanded in the future to include T1 and T2 tumors with one to three positive nodes, the protocol can easily accommodate these cases.

Pre-mastectomy SLN Biopsy

For the treatment of breast tumors, Brady et al.[151] described SLN biopsy and then mastectomy and reconstruction. The risk of a positive SLN can be estimated on the basis of the following risk factors:[152]

- T2 tumor
- Age ≤50 years
- Lymphovascular invasion on the initial breast biopsy

Pre-mastectomy SLN biopsy might not be indicated in all patients with clinically negative nodes but only in those with the above risk factors. Although the risk of SLN involvement in a clinically node-negative patient is only 35%, it rises to 67% in patients with all three risk factors. These patients can be specifically targeted for invasive and/or additional procedures.

When the SLN biopsy is positive for tumor in one to three nodes, the entire axillary chain is resected and examined histologically. The results of permanent sections help determine the clinical stage of the disease and whether post-mastectomy radiotherapy should be prescribed.

Complications

DeBono et al.[56] compared complications in immediate versus delayed free TRAM flap breast reconstruction and found no difference in postoperative morbidity between the groups except for partial necrosis of the chest-wall flap, which occurred in 16% of patients in the immediate group and 0% in the delayed group. The mastectomy technique has since been modified to prevent this complication. Pinsolle et al.[153] conducted a retrospective study of 266 immediate breast reconstructions with a median follow-up of 7 years. An LDMF with implant was used in 61% of cases, an LDMF alone in 15%, and a subpectoral prosthesis implant in 24%. Smoking, obesity, and radiotherapy were risk factors for complications. The authors recommend delaying the reconstruction in obese patients, smokers, and patients for whom postoperative radiotherapy is planned.

In contrast, the 2-year results of the Michigan Breast Reconstruction Outcome Study of 326 patients found that immediate reconstruction was associated with more and more severe complications than delayed reconstruction.[154] A high body mass index was also associated with high complication rates.

Psychological Benefit

Breast reconstruction after mastectomy, whether immediate or delayed, offers a substantial psychosocial benefit to women.[155–158] Elder et al.[159] reported that most women are satisfied with immediate reconstruction and that the major determinant of aesthetic satisfaction is completion of the procedure. One year after breast cancer surgery and immediate reconstruction, patients' self-image scores were equivalent to those of the normal population.

The choice of reconstructive procedure seems to have no effect on psychosocial status, but it does influence the rate of recovery, vitality, and body image of women who undergo delayed reconstruction.[160] Patients with delayed expander and implant reconstructions report greater improvements in vitality and social well-being but lower gains in body image relative to women who undergo delayed TRAM procedures.[160]

EXPANDER AND IMPLANT BREAST RECONSTRUCTION

Background

A 2005 survey of members of the American Society of Plastic Surgeons revealed that of 57,778 breast reconstruction procedures performed, 46,291 (80%) were implant based.[161] Among them, 11,631 (25%) were implant alone procedures and the remainder were expander and implant procedures.

The silicone gel-filled prosthesis was introduced by Cronin and Gerow[12] in 1963 for delayed breast reconstruction. The prosthesis was implanted subcutaneously and was plagued by an unfortunate tendency to develop a hard capsule around it. With the advent of the LDMF in 1977,[23] the implant could be covered with thick muscle[24] and the cosmetic outcomes were much improved. Tissue expansion was introduced by Radovan[36] and enabled expansion of the chest-wall skin after the wounds had healed satisfactorily. Subsequently, the Becker expander implant made possible tissue expansion and implant placement in a single procedure.[37]

Breast reconstruction by tissue expansion currently involves the gradual expansion of chest-wall tissue by repeated injections of saline into an inflatable silicone balloon. This can be followed by replacement with a definitive implant. The use of a permanent expandable breast implant eliminates the need for a second operative stage. Silicone gel-filled prostheses have been available for post-mastectomy reconstruction during the United States Food and Drug Administration's moratorium on silicone gel-filled implants. Cohesive silicone gel implants are said to be leak-proof and less likely to crease or ripple.

Contraindications

Implant-based reconstruction is contraindicated in patients who have insufficient skin, subcutaneous tissue, and muscle to cover the prosthesis. In certain cases, however, tissue expansion can be used to stretch the skin envelope in women who otherwise have enough muscle for cover. A relative contraindication is in cases in which bilateral breast symmetry might be better achieved with autologous reconstruction, such as in cases of marked ptosis. Implant-based immediate reconstruction, therefore, often is limited to smaller breasts with minimal or no ptosis. The best aesthetic result in terms of symmetry is achieved when bilateral implant-based reconstruction is performed.

Technique

The inframammary fold is an important landmark that must be preserved during mastectomy. If the inframammary fold has been violated, it should be restored with sutures. Viability of the SSM flaps must be confirmed and the nonviable areas excised. If skin flap viability is questionable, rather than delay the reconstruction, an option is to close the area of concern over an intact skin paddle, wait a couple of days for the line of necrosis to become evident, and then complete the reconstruction.

The size of the expander should take into account the base width and height of the normal, intact breast. Overexpansion is planned to allow for some degree of ptosis postoperatively and therefore a more natural-looking breast. After an interval for healing, expansion is started and proceeds as tolerated by the overlying tissue and patient comfort. Once expansion is completed, the expander is left in place for 1 to 3 months until a capsule forms around it and the skin envelope is able to maintain its stretch permanently. The expander is then removed, a capsulectomy or capsulotomy is performed, and a definitive implant is inserted. In cases in which an expander implant is used, only the injection port is removed.

Textured silicone expanders promote development of a capsule before exchange with a permanent implant. Several reports attest to a low rate of capsular contracture and improved contour of the inferior pole with the use of textured implants.[162,163]

Immediate implant reconstruction is limited by concerns regarding unsatisfactory breast shape and capsular contracture. Complete coverage of the implant can reduce the incidence of capsular contracture and visible implant rippling. A dermal matrix sling supports the lower pole of the pectoralis major muscle and creates a pocket that completely encloses the breast implant. This technique shortens the time for expansion or eliminates it altogether and is an attractive option for single-stage breast reconstruction with implants.

The skin-reducing mastectomy has recently been described by Nava et al.[164] A large area in the lower half of the breast is de-epithelialized according to the conventional Wise pattern to form an inferior dermal flap, the superior border of which is sutured to inferomedial fibers of the pectoralis major muscle. The pouch is covered laterally by the serratus fascia, and the skin flaps are closed down to the inframammary fold. The authors report skin flap necrosis in six cases (20%), four of which resulted in implant removal. Both this and the dermal matrix sling technique expand the indications for immediate implant-based reconstruction in women with large ptotic breasts.

The one-stage biodimensional expander implant consists of a fixed silicone component and an inflatable variable-volume saline bladder connected by a remote port. Total submuscular coverage of the implant is possible without releasing the pectoralis major muscle from the chest wall (Figs. 18–20).[96] Lateral coverage is by means of serratus muscle fascia. One-stage breast reconstruction with few complications and a high level of satisfaction has been reported with this biodimensional prosthesis.

Complications

Complications include infection, implant malposition and/or rotation, visible implant rippling, implant extrusion, implant rupture and/or deflation, and capsular contracture with abnormal breast appearance (Baker's III and IV).

The incidence of complications associated with implant-based breast reconstruction ranges widely. Handel et al.[165] reported the results of a prospective series that included data on 3495 implants in 1529 women who underwent surgery during a 25-year period. The cumulative risk (CR) of developing contracture was related to duration since surgery (5.37 CR of capsular contractures per 1000 patient-months after breast reconstruction). Capsular contracture was the most common reason for reoperation. The contracture rate was significantly higher in patients with hematoma (7.17 CR) than in those without (3.27 CR) (Kaplan-Meier long rank test, $P = 0.007$). Smooth and textured implants had similar contracture rates (3.85 versus 3.23 CR of capsular contractures per 1000 patient-months), and polyurethane-covered implants had the lowest risk of contracture (2.19 CR) persisting for at least 10 years after implantation. Textured saline implants had a higher rate of deflation than did smooth saline implants. Despite a considerable number of local complications and reoperations, overall patient satisfaction was high.

Cordeiro and McCarthy[166] reviewed a 12-year, single-surgeon experience with 1522 expander and implant reconstructions in 1221 patients. The incidence of complications after tissue expander insertion was 8.5%, notably higher than after the exchange procedure, 2.7 % ($P < 0.001$). Complications increased with history of preoperative chest-wall radiation. Chemotherapy during expansion apparently made no difference in frequency of complications. Long-term outcomes in a cohort of 315 patients (410 reconstructions) with a mean follow-up of 36.7 months revealed 88% had good to excellent aesthetic results. This rate was higher in bilateral reconstructions and worsened as a result of radiotherapy. Overall, 95% of patients were satisfied with their reconstructions. Baker's III or IV capsular contracture developed in 10.4% of patients, and 4% of permanent implants required exchange.

Radiotherapy

Approximately 90% of two-stage expander saline implant reconstructions in radiated breasts can be successfully completed with the implant in place. Nevertheless, the use of immediate implant-based breast reconstruction and then radiotherapy is associated with a high risk of complications.[167–170] Radiation has complex effects on tissues (leading to localized ischemia, enhanced scar tissue, and capsular formation at the implant-tissue interface) and impaired wound healing.[138]

In a series presented by Spear and Onyewu,[48] 48% (19 of 40 breasts) of reconstructed radiated breasts required the use of flaps in addition to saline implants to complete the reconstruction, compared with 10% (four of 40 breasts) of non-radiated breasts. Prosthetic breast reconstructions in radiated breasts were also associated with substantially more complications than controls, particularly capsular contracture.

Cigarette Smoking

Goodwin et al.[171] examined the effects of smoking on 515 patients who had undergone expander implant reconstruction. The rates of overall complications, reconstructive failure, mastectomy flap necrosis, and infections were significantly higher in the 132 smokers ($P = 0.002$). Complications were also higher in ex-smokers (defined as patients who had stopped smoking more than 4 weeks before surgery) than in nonsmokers.

In a series of 400 patients who had undergone SSM with immediate implant-based reconstruction, Woerdeman et al.[63] showed a significantly higher

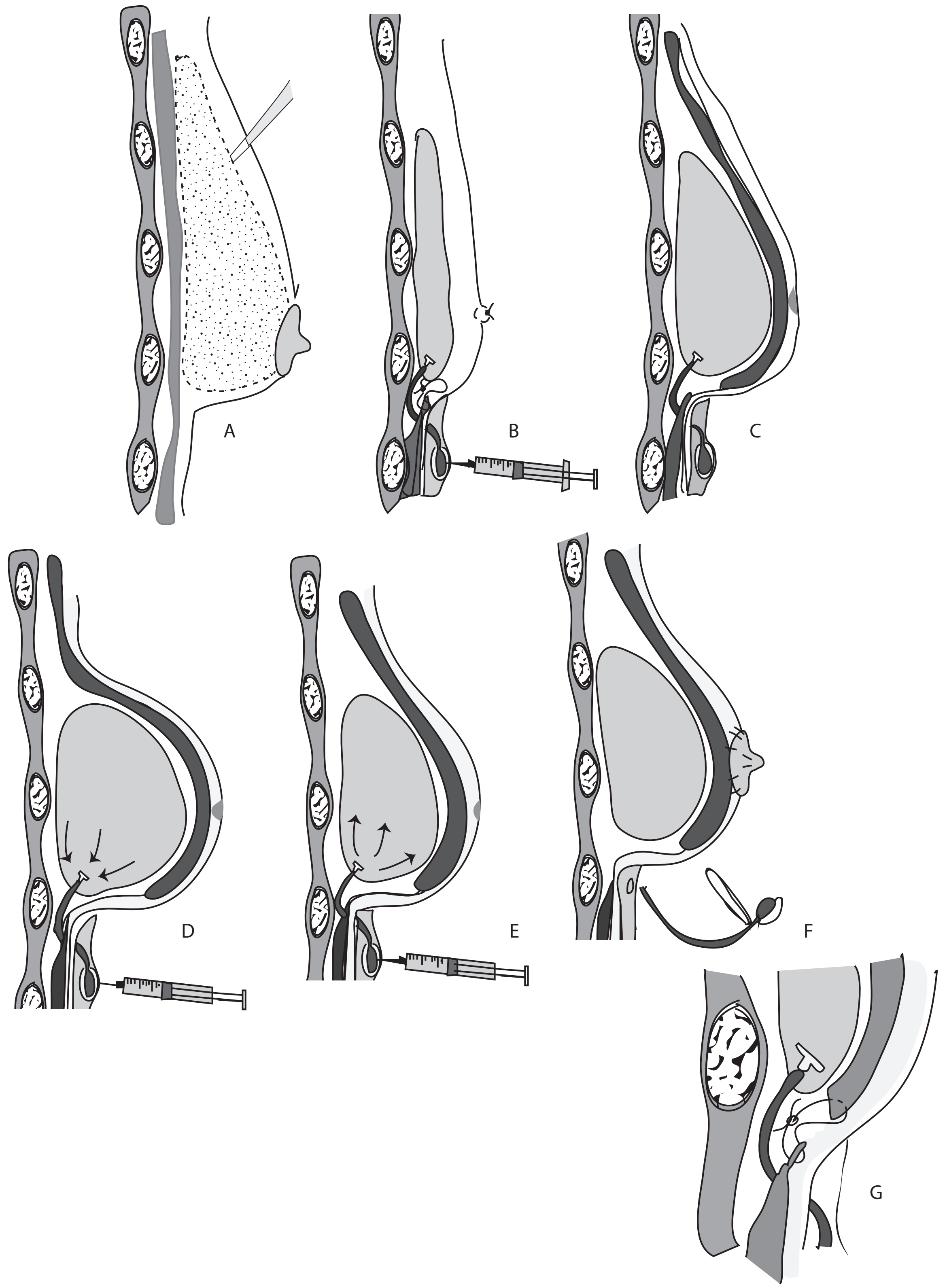

Figure 18. Breast reconstruction by adjustable expander implants. (*Modified from Spear.*[96])

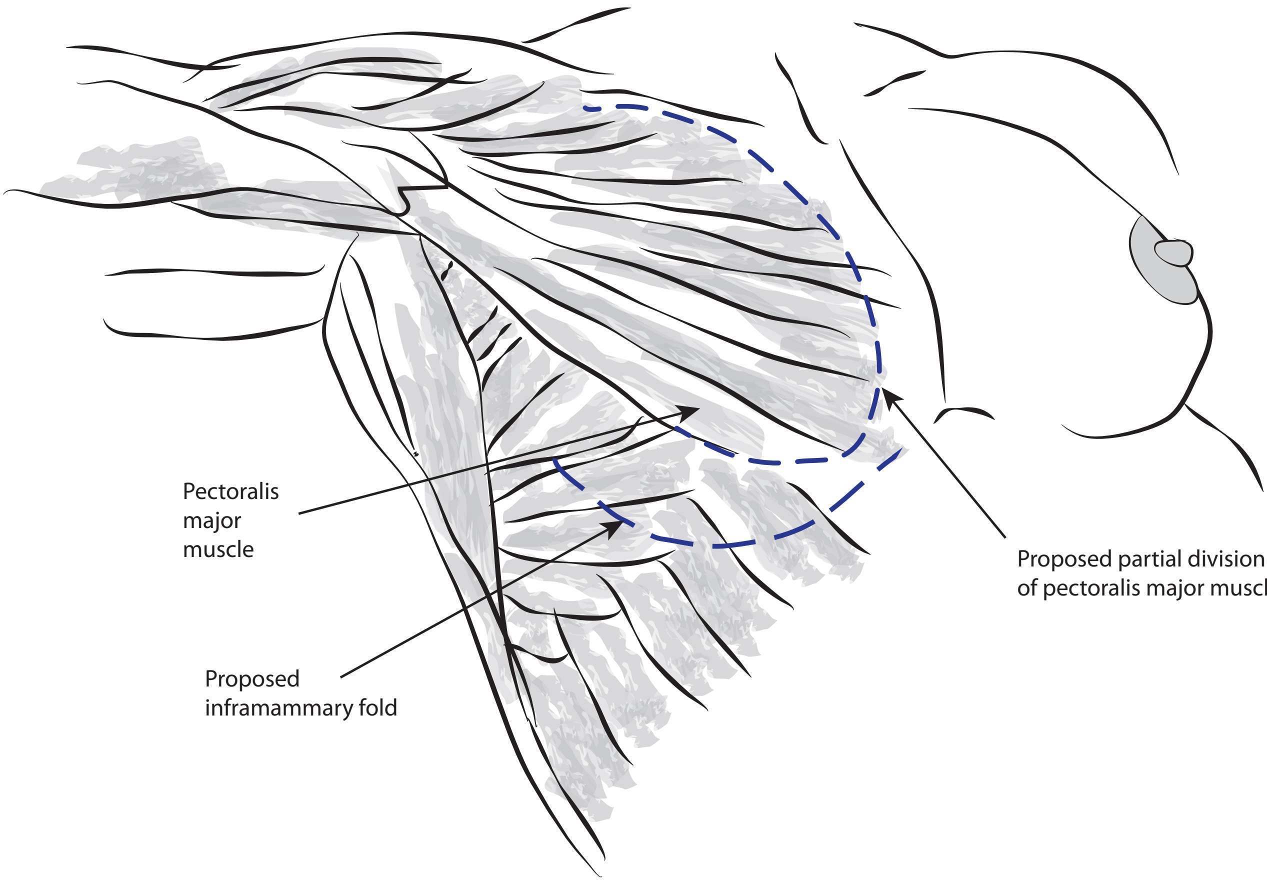

Figure 19. Breast reconstruction by the one-stage biodimensional expander implant technique. The medial fibers of the pectoralis major muscle are partially divided. (*Modified from Spear.*[96])

risk of implant loss among patients who were obese ($P = 0.003$) or who smoked ($P < 0.001$) and in breasts that were larger than average ($P = 0.003$). The mean follow-up was 28.6 months.

AUTOLOGOUS BREAST RECONSTRUCTION

Background

Breast reconstruction with autologous tissue provides well-vascularized muscle and skin to create a breast with more natural texture and appearance than after implant-based reconstruction. Morbidity at the donor site is minimal.

The shift in focus to the recipient site has followed the evolution of the perforator flap concept. Although the LDMF and TRAM flap remain popular options for breast reconstruction, the changing face of reconstruction is evident in the increased popularity of the DIEP, superior gluteal artery perforator (SGAP) and inferior gluteal artery perforator (IGAP) flaps. De Frene et al.[172] showed that perforator flaps can still be raised safely despite a history of liposuction to the flap donor areas, provided that presurgical imaging clears the way for surgery.

Attempts to minimize flap donor-site morbidity continue. In 1989, Koshima and Soeda[173] reported the use of abdominal fat and skin based on the DIEP vessels. Their flap did not include muscle or fascia. Sixteen years later, a survey by the American Society of Plastic Surgeons of breast reconstructions performed in the United States disclosed 9578 (16.6%) TRAM flap and 1909 (3.3%) DIEP flap operations.[161] Among the abdominal flaps, the SIEA

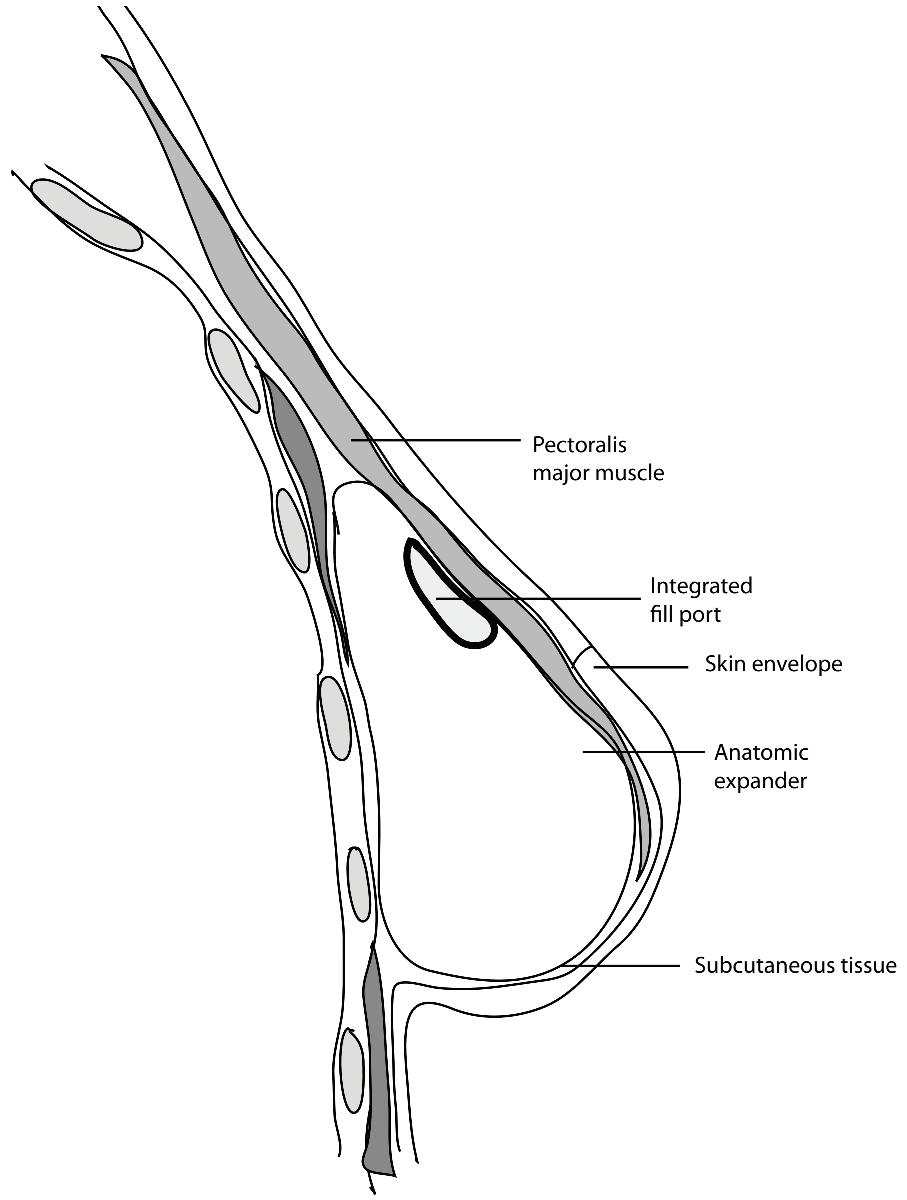

Figure 20. Breast reconstruction by the one-stage biodimensional expander implant technique. A pocket is dissected in the subcutaneous plane extending exactly to the level of the desired inframammary fold. (*Modified from Spear.*[96])

flap is possibly associated with the lowest morbidity but is limited by inconsistent vascular anatomy. Recent alternatives include SGAP, IGAP, and thigh-based perforator flaps (transverse musculocutaneous gracilis [TMG], TUG, and PAP).

The aesthetic result of autologous breast reconstruction tends to improve with time. Autologous reconstruction is particularly indicated when radiotherapy is to be administered, when the chest wall has been previously radiated, in patients with large ptotic breasts or very small breasts, and in cases in which previous implant reconstruction has failed. Ideally, the patient desires autologous reconstruction and abdominoplasty. Successful reconstruction requires intraoperative flexibility. It might be necessary to perform additional abdominal liposuction, to tailor the breast skin laterally, and to perform a contralateral reduction or mastopexy for symmetry. When symmetry is the goal, it is easier to reduce the contralateral breast than to augment it.

Aesthetic Breast Subunits

The aesthetic outcome of nasal reconstruction can be optimized by observing the subunit principle, which is also the true for the breast. Spear and Davison[174] proposed breast reconstructive subunits assessed to provide superior aesthetic results (Fig. 21). In a 10-year review of autologous tissue reconstructions in 264 patients, including 233 TRAM flaps and 31 latissimus dorsi flaps, the authors found the most favorable subunits to be the nipple, areola, and expanded areola. For larger skin defects, the best subunits were the inferolateral, lower half, and total breast. Every effort should be made to preserve the inframammary fold, which is key to a natural-looking result.

Another strategy for maximizing the cosmetic outcome of autologous breast reconstruction was described by Pulzl et al.[175] With their technique, the lower flap is de-epithelialized to the inframammary fold and the entire lower pole subunit is replaced with skin from the autologous flap transferred for the reconstruction (Fig. 22). The authors reported good cosmetic outcomes in 12 reconstructed breasts, including free TRAM, DIEP, and SIEA flaps.

LDMF

The LDMF often is used to cover an implant (Fig. 23), although in selected cases, a sufficient breast mound can be created with the flap alone.[176] Combined with an implant, the LDMF limits capsular contracture and visible rippling of the prosthesis, contributing to a natural texture and appearance of the breast. Tissue expansion is not needed, and secondary revision procedures are easier than by implant-alone methods.

Even when the thoracodorsal pedicle has been previously ligated during axillary dissection, the muscle can be safely perfused on retrograde flow through the serratus branch. The arc of rotation can be extended by detaching the humeral insertion of the muscle or by ligating the serratus branch once patency of the thoracodorsal pedicle is confirmed.

A muscle-sparing latissimus dorsi flap can be harvested to include only the descending branch of the thoracodorsal artery, which increases the reach of the skin paddle while minimizing donor-site morbidity and seroma formation. A muscle-sparing latissimus dorsi miniflap is ideal for reconstructions that need only skin and subcutaneous tissues.

After skin incision, the subcutaneous tissues are beveled to increase the number of perforators in the skin paddle and to carry maximum bulk to the breast. A tunnel high in the axilla connects the anterior and posterior wounds. The tunnel must be no larger than required so as to prevent lateral displacement of the implant. The latissimus and serratus muscles can be sutured back to the chest wall to restore the natural slope of the lateral breast (Figs. 24–26).[96,177]

An extended LDMF can be harvested with larger amounts of subcutaneous tissue and fascia or a fleur-de-lis skin pattern to allow primary closure of a large skin defect or eliminate the need for an implant. In selected cases in which skin is not required, a latissimus dorsi miniflap can be used to fill the defect. Sensation can be restored by coapting the lateral cutaneous branch of the seventh thoracic nerve to the lateral cutaneous branch of the fourth intercostal nerve.

In addition to the complications typically associated with implants, transfer of an LDMF carries a risk of seroma. The use of quilting sutures lessens this risk.

LOWER ABDOMINAL FLAPS

Arterial and Neural Anatomy

The arterial supply to the rectus abdominis muscle was originally delineated by Milloy et al.[178] in 1960. Many authors have since investigated the circulatory

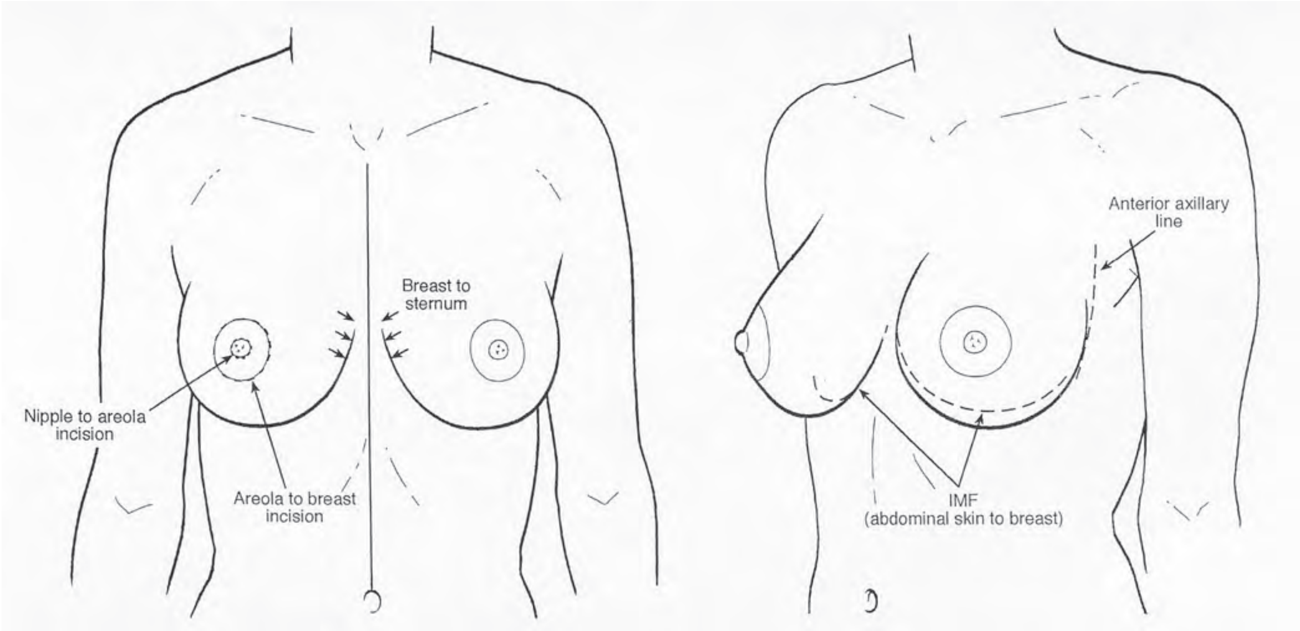

Figure 21. Limited transition lines around the breast include the nipple, areola, inframammary fold (*IMF*), and anterior axillary line, which can camouflage breast reconstruction. (*Reprinted with permission from Spear and Davison.*[174])

anatomy of the abdominal wall.[179–188]

The respective contributions of the deep superior epigastric and deep inferior epigastric vessels to the blood supply of the abdominal skin have been detailed by Boyd et al.[179] Only microscopic communications exist between the superior and inferior epigastric systems in 60% of flaps.[183,186]

Moon and Taylor[188] studied the anatomy of the deep superior epigastric artery (DSEA) and noted three patterns of anastomosis with the deep inferior epigastric artery (DIEA). The most common type was a double-branched system of each vessel (57%); next most common was a single DSEA and DIEA (29%); third was a system of three or more major branches (14%) (Fig. 27).[188] Only 2% of the specimens showed bilaterally symmetrical circulation. In all cases, the two systems were united by choke vessels in the segment of muscle above the umbilicus.

Moon and Taylor[188] assessed the relative vascularity of the upper, middle, and lower transverse abdominal flaps. The superior island receives its primary blood supply from the DSEA with only slight contribution from below. Vessels cross the midline to fill the cutaneous branches from the contralateral DSEA. Contrast material was visualized throughout the skin paddle as far as the lateral border of the opposite rectus abdominis muscle. The middle island is centered at the umbilicus. Its main blood supply is by perforators from the distal DIEA. The perforators fill from the DSEA through "choke" connections within the muscle. Numerous small vessels cross the midline at the subdermal and fascial levels. The periumbilical musculocutaneous perforators often course over the entire flap almost to the contralateral anterior axillary line. The lower island is perfused by the deep inferior epigastric system and contains fewer perforating vessels than do the other two designs. No vascular filling was noted in the deep subcutaneous fat below the subdermal plexus on the other side of the midline. The skin paddle appeared to be vascularized to the lateral edge of the contralateral rectus (Fig. 28).[188] The authors concluded, "Anatomically, [the TRAM] is the most vulnerable design both from an arterial and a venous standpoint."[188]

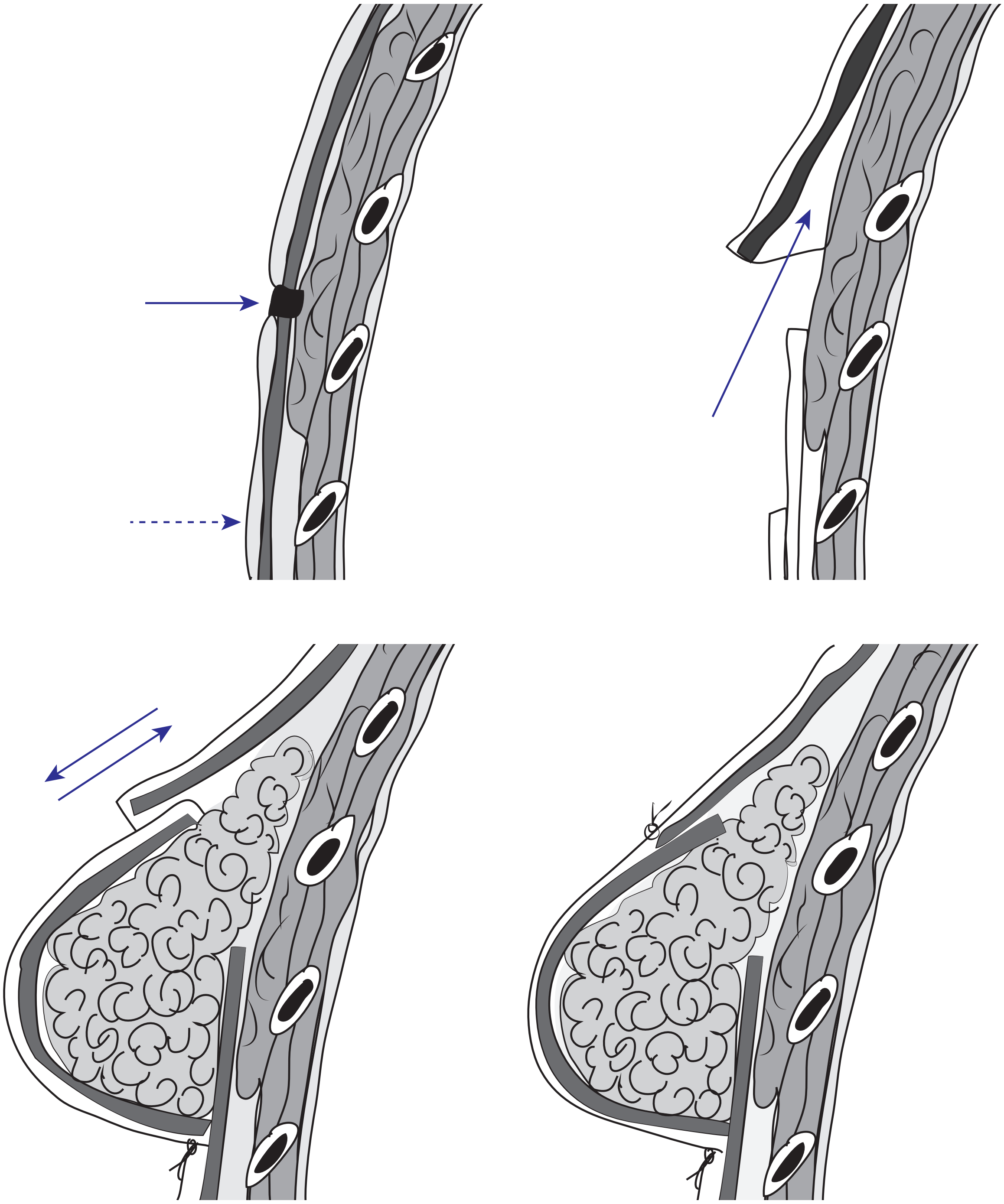

Figure 22. Restoring the inframammary fold without dermal flaps. *Upper left*, Area between mastectomy scar and inframammary fold is deepithelialized. *Upper right*, Superior skin margin is undermined to form pocket for abdominal flap. *Lower left*, Inferior skin margin of the flap is sutured to the lower line of the deepithelialized area, adjusting for the desired degree of lower pole ptosis. *Lower right*, Excess skin is deepithelialized and flap is sutured to superior skin margin. (*Reprinted with permission from Pulzl et al.*[175])

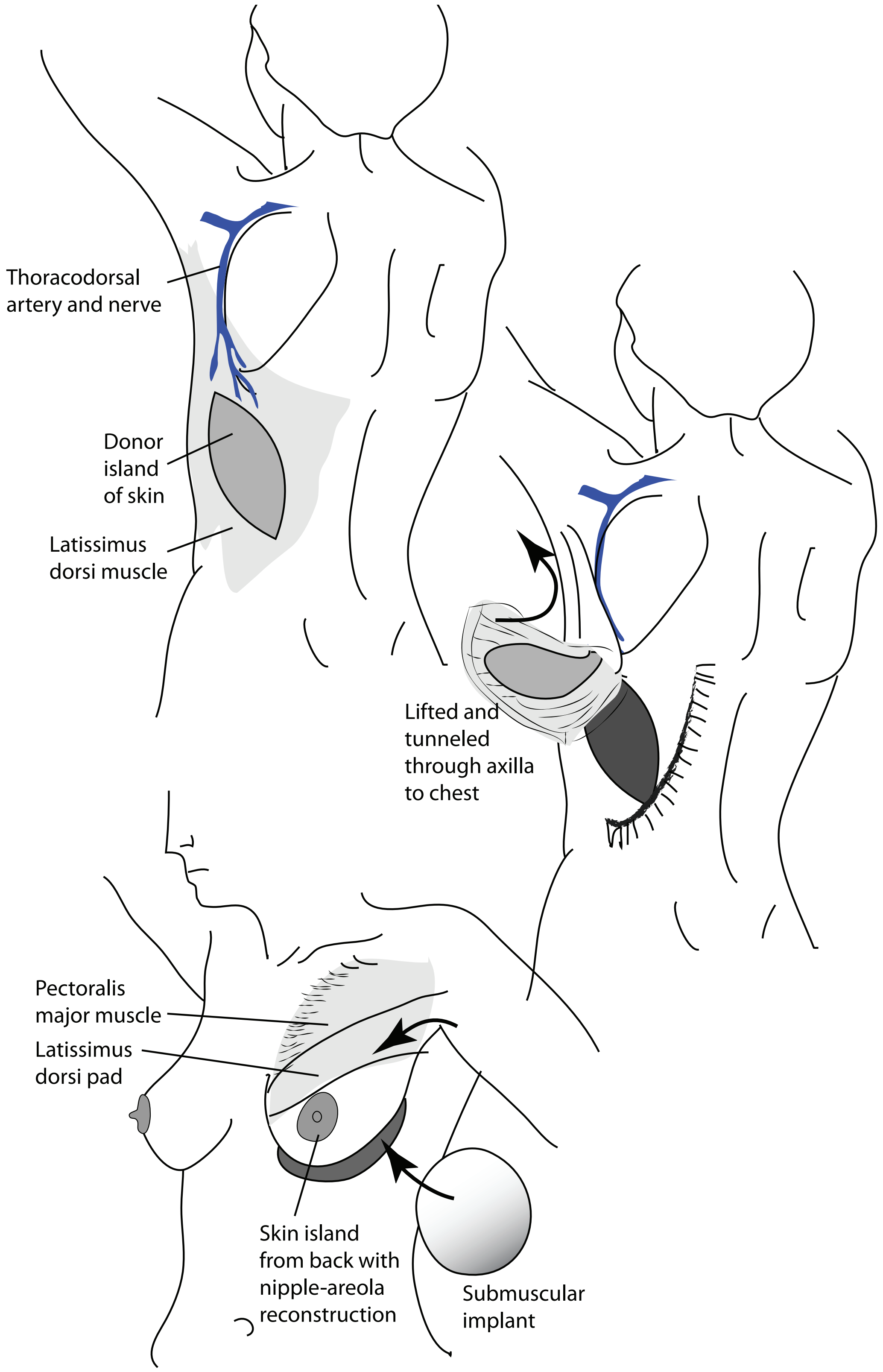

Figure 23. Technique of breast reconstruction with latissimus dorsi musculocutaneous flap over an implant.

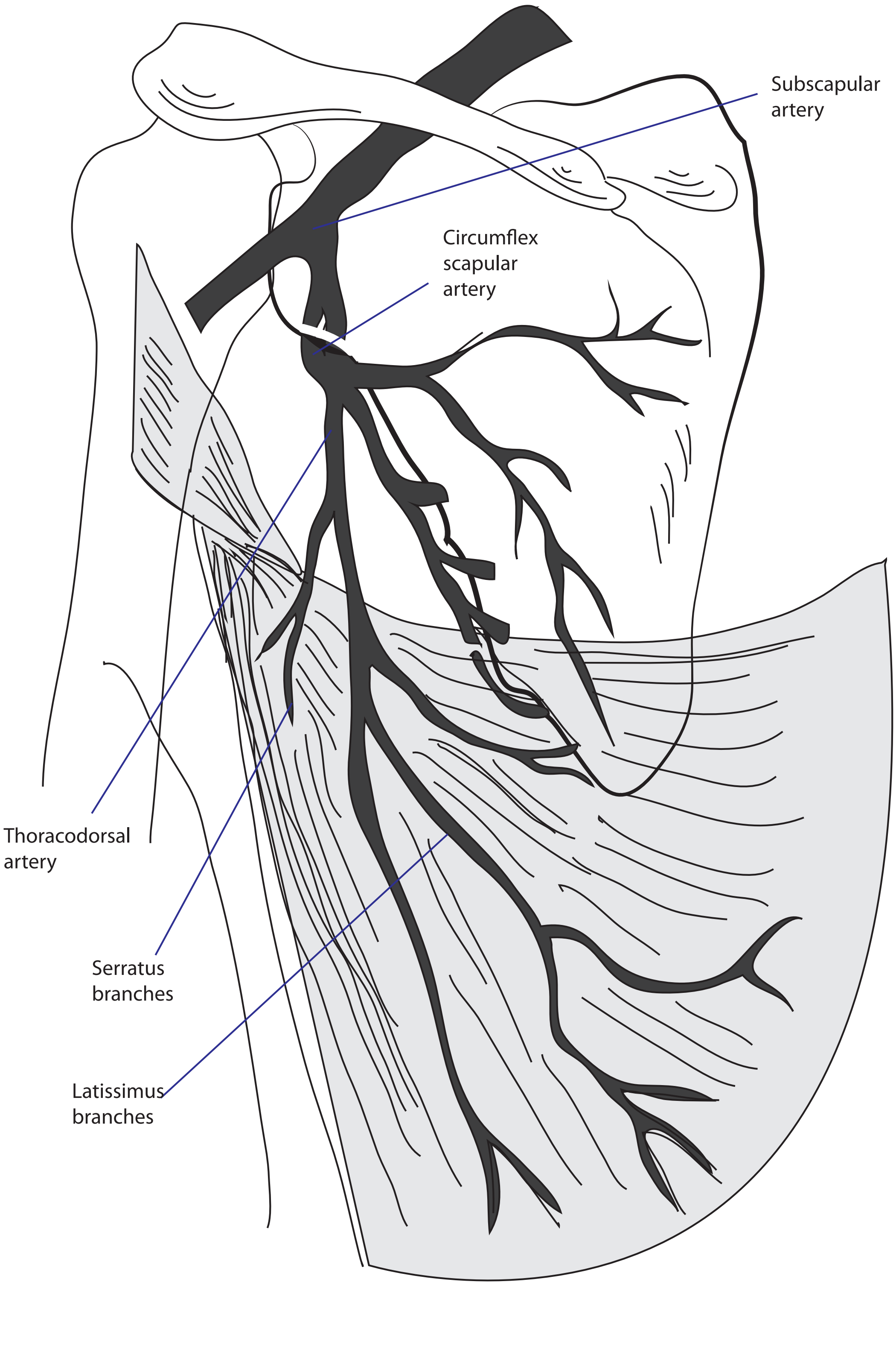

Figure 24. Vascular pedicle of latissimus dorsi musculocutaneous flap. (*Modified from Schusterman.*[177])

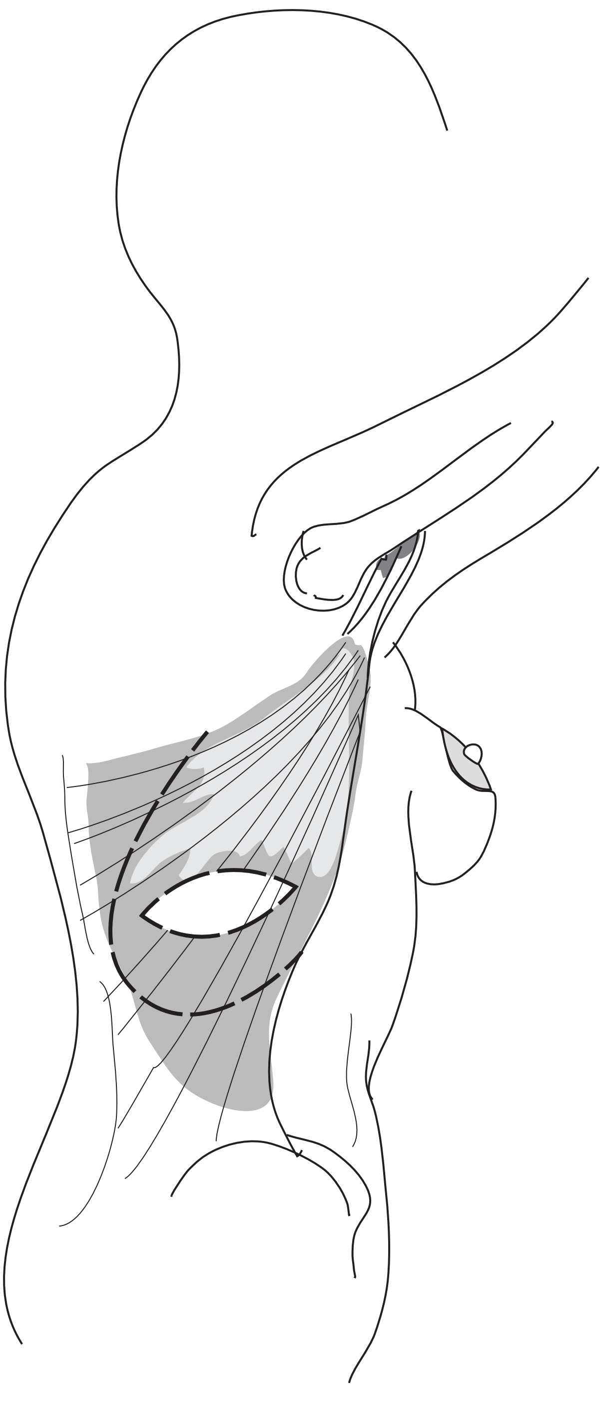

Figure 25. Skin island on latissimus dorsi musculocutaneous flap for reconstruction of small defects. Most defects should be overcorrected to allow for future atrophy and wound contraction. It is prudent to harvest flaps that incorporate most of the muscle. (*Modified from Spear.*[96])

Anatomic studies by Harris et al.[189] corroborated the findings presented by Moon and Taylor[188] that the area of choke vessels is superior to the umbilicus. The normal direction of flap blood flow is therefore reversed. As a result of these and similar studies, most surgeons now center the design of the TRAM flap slightly higher on the abdomen, just below the umbilicus rather than over the suprapubic area.

Many of the vascular problems associated with the TRAM flap probably stem from venous congestion rather than from arterial insufficiency. Carramenha e Costa et al.[184] noted two vertical rows of perforators lying along the rectus abdominis muscle: one in the lateral third of the muscle and the other in the medial third. Perforating vessels are concentrated in the periumbilical area. Venous drainage from the anterior skin flap is from the superficial venous plexus across the midline and through the perforators into the deep system. Venous insufficiency probably occurs when attempts are made to preserve the lateral third of the muscle with transection of the lateral venous drainage system. The problems can be averted if both the medial and lateral rows of perforators are included in the muscle pedicle.

Perfusion of the Transverse Lower Abdominal Skin Paddle

Anatomic dissections of the transverse abdominal skin island by Scheflan and Dinner[32,34] led to their description of perfusion zones corresponding to a centrally perfused skin ellipse with declining perfusion at either end. Specifically, the skin overlying the muscle at or below the umbilicus (zone I or II) was via a few perforators from the DIEA and SIEA. At the periphery of the abdominal wound lips (zones III and IV), perfusion is maintained via communications between the SIEA and the superficial circumflex iliac artery.

Shortly after the original publication, Dinner et al.[190] revised the perfusion model and renamed the contralateral zones III and IV, noting that perfusion of these zones is random compared with the ipsilateral circulation. Unfortunately, despite this correction,

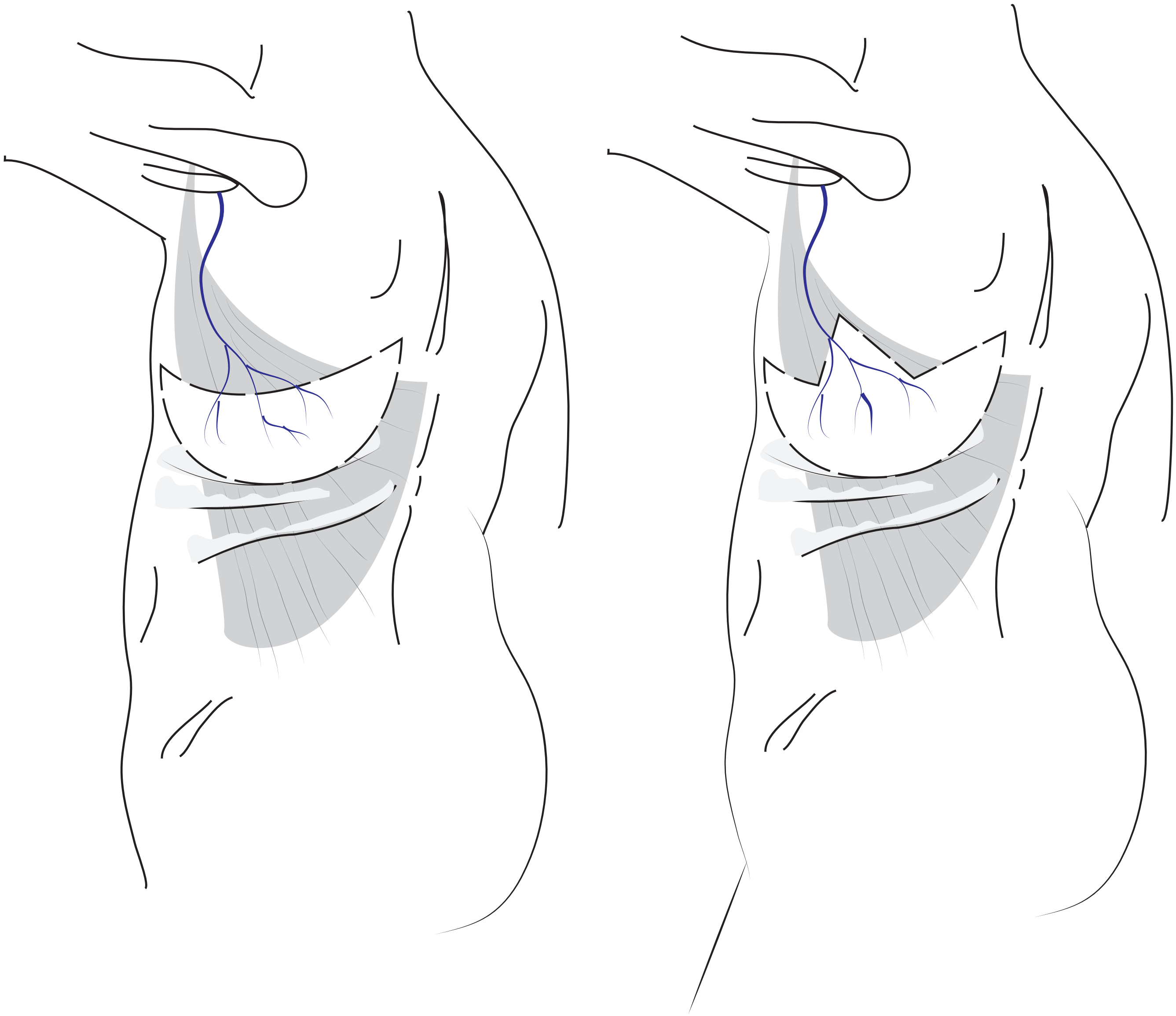

Figure 26. Larger LDMF skin islands for larger mastectomy defects. On flap inset, the ends of the crescent are pulled up to form a cone. (*Modified from Spear.*[96])

the lower abdominal perfusion zones continue to be frequently misrepresented in the plastic surgery literature.

There is both anatomic and physiological evidence to support the ipsilateral circulation being consistently stronger than the contralateral circulation in the transverse lower abdominal flap. Moon and Taylor[188] noted that the skin paddle spanned four angiosomes and three choke vascular territories, with midline crossover occurring at the subdermal and fascial level. At zone IV, the authors noted branches superiorly and laterally to the subdermal plexus but no filling below the Scarpa fascia.

Ohjimi et al.[191] studied flap circulation using ex vivo angiography and noted strong ipsilateral connections between the DIEA and the lateral

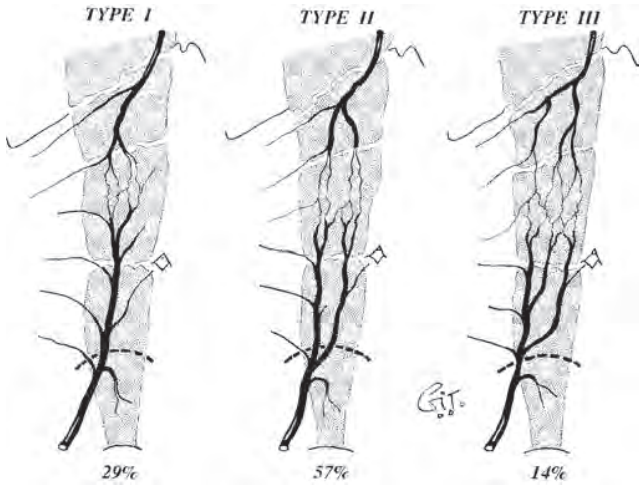

Figure 27. Patterns of vascular supply to the rectus abdominis muscle from deep superior and inferior epigastric arteries. (*Reprinted with permission from Moon and Taylor.*[188])

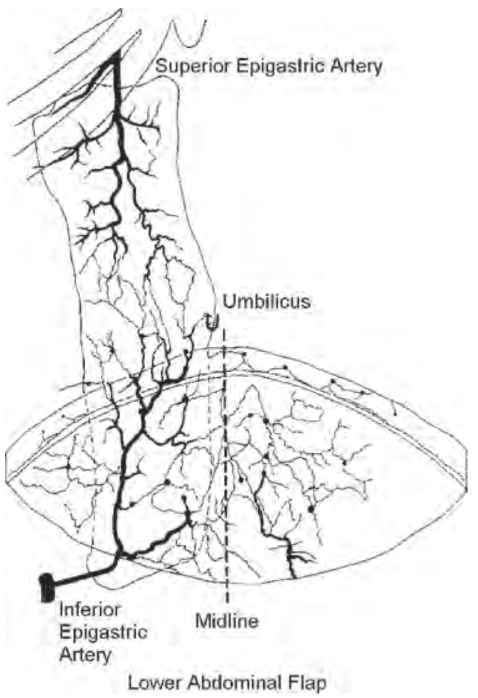

Figure 28. Blood supply of the transverse lower abdominal flap based on the deep inferior epigastric artery. (*Reprinted with permission from Moon and Taylor.*[188])

intercostal arteries. In contrast, only two or three arteries crossed the flap midline. Arterial density was always less contralaterally.

Hallock[192] used laser Doppler flowmetry to assess in vivo blood flow in free TRAM flaps and found significantly decreased flow in contralateral skin territories than ipsilaterally ($P = 0.005$). Holm et al.[193] used laser-induced fluorescence of indocyanine green to demonstrate tissue perfusion intraoperatively for the DIEP flap. The authors reported that perfusion of the zone adjacent to the territory of the vascular pedicle occurred faster and was of higher intensity than its counterpart across the midline. Zone IV was always the least perfused.[193]

As noted above, Moon and Taylor[188] described a single, centrally placed vessel in 29% of their specimens. Harris et al.[189] simulated selective muscle-splitting flap harvest by occluding the medial and lateral thirds of the rectus muscle and showed a decrease in arterial pressure in 80% of patients. Because of this decrease in perfusion, they advise against selective harvest of the rectus muscle.

The combined surgical experience has proved that a flap elevated on a single vessel can carry the cutaneous territory of an adjacent vessel. Beyond this point, the risk of necrosis grows with distance from the primary blood supply, so that tertiary areas are questionable and quaternary areas are unreliable (Fig. 29).[188]

Lower Abdominal Flap Innervation

The motor branches of the intercostal nerves travel on the undersurface of the rectus abdominis muscle and penetrate the muscle in its midportion. Removal of the central third of the rectus in a TRAM flap makes denervation likely even when a lateral strip of muscle is preserved.[188,194]

Pedicled TRAM Flap

The pedicled TRAM flap relies on the DSEA pedicle for perfusion.[27] The TRAM flap is most often mobilized on the contralateral vascular pedicle[195]

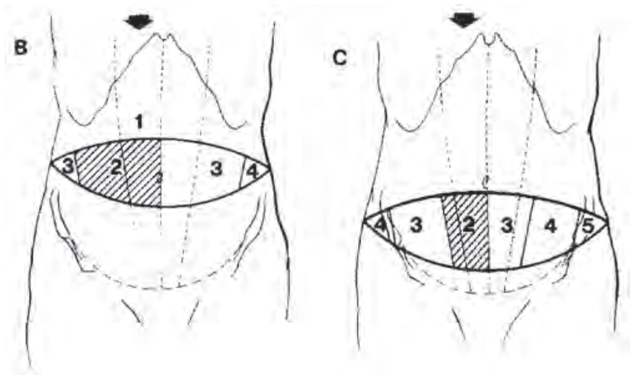

Figure 29. Perfusion zones of the middle and lower island designs of a TRAM flap. The skin on the side of the vascular pedicle has a stronger blood supply than does the skin on the contralateral side. (*Reprinted with permission from Moon and Taylor.*[188])

and is inset vertically[35,196] (Fig. 30). More transverse placement of the island has been suggested to increase mound projection[197] and to correct wide mastectomy defects extending into the lateral chest.[198] The flap should not be rotated more than 90° during inset to prevent torsion and kinking of the pedicle.

A contralateral pedicle can produce superior cosmetic results because it is transferred to the mastectomy site through a tunnel along the opposite side of the sternum. The muscle can be split, which helps with closure of the abdomen. A disadvantage of this operation is the disruption of the inframammary fold and the medial bulge caused by the transferred rectus muscle.

Ipsilateral pedicle TRAM flap breast reconstruction usually is reserved for cases in which scars preclude use of the contralateral pedicle. Clugston et al.[199] presented a series of 252 consecutive ipsilateral TRAM flap reconstructions in 190 patients. The authors found several advantages of breast reconstruction with the ipsilateral pedicled TRAM flap, including the following:

- Simplicity and versatility of flap shaping (Fig. 31)[199]
- Improved maintenance of the inframammary fold
- Lack of disruption of the natural xiphoid hollow
- Easy transfer of the thick periumbilical portion of the skin paddle to the inferior breast mound, where projection is most desired
- Less pedicle tension during inset
- Less bulk of muscle from split muscle harvest
- Increased flap reliability and a lower incidence of partial flap necrosis compared with the contralateral pedicle TRAM

The only absolute contraindication to breast reconstruction with a TRAM flap is previous ligation of the DSEA pedicle. A relative contraindication is multiple scars on the abdomen.

The breast volume to be expected from a particular TRAM flap can be calculated preoperatively[200] (Fig. 32), and the flap design is adjusted to match the weight of the mastectomy specimen. If considerable volume discrepancy exists between the resected tissue and the proposed reconstruction, the operative plan might have to be changed to bring in additional bulk, such as by a double-pedicle TRAM, free tissue transfer, or supplemental augmentation. For unilateral reconstruction of a large breast, both muscles are transposed to the mastectomy site and are stacked.

Moon and Taylor[188] and others[179,197,201] suggested "delay" of the TRAM flap by ligating the ipsilateral DIEA and SIEA before transfer in an attempt to improve flap viability.[179,183] Codner et al.[202] showed that perfusion in the mid-rectus portion of the TRAM flap rose from a baseline 13.3 mmHg in non-delayed controls to 40.3 mmHg after delay. This difference is statistically and clinically significant ($P < 0.05$) and represents a considerable increase in arterial flow to the TRAM flap after the delay procedure (Fig. 33).[202]

The improvement from delay becomes clinically evident after 1 week. TRAM flap perfusion is not

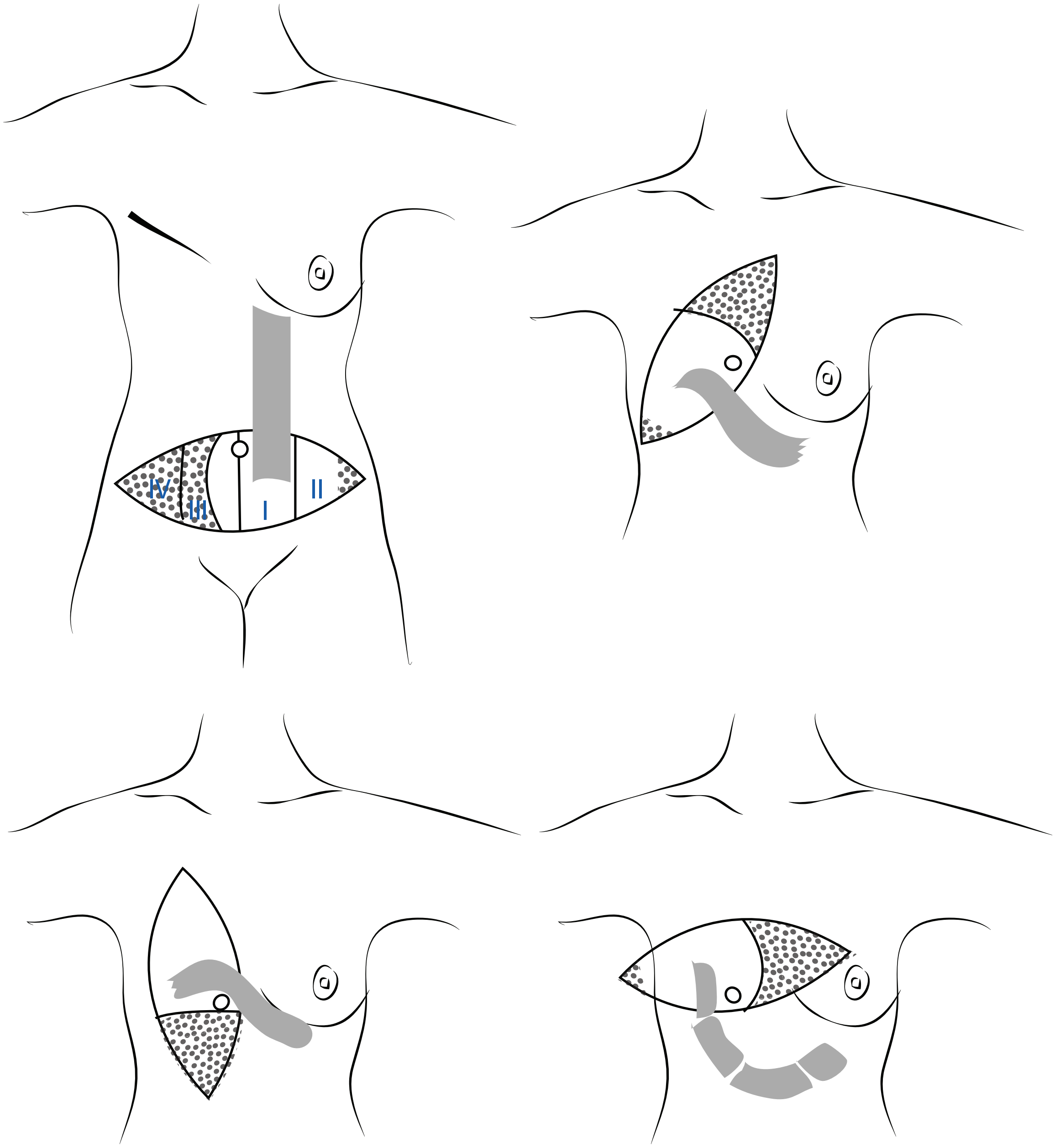

Figure 30. Reliable zones of perfusion to the unipedicle TRAM flap and common patterns of flap inset in contralateral breast reconstruction. (*Modified from Shestak.*[35])

further enhanced by extending the time of delay to 2 weeks before breast reconstruction.[203] The advantages of a surgically delayed TRAM flap are as follows:[204]

- It is applicable to patients who are not candidates for free-tissue transfer and those who want to avoid the added abdominal-wall morbidity of the double-pedicled TRAM flap.

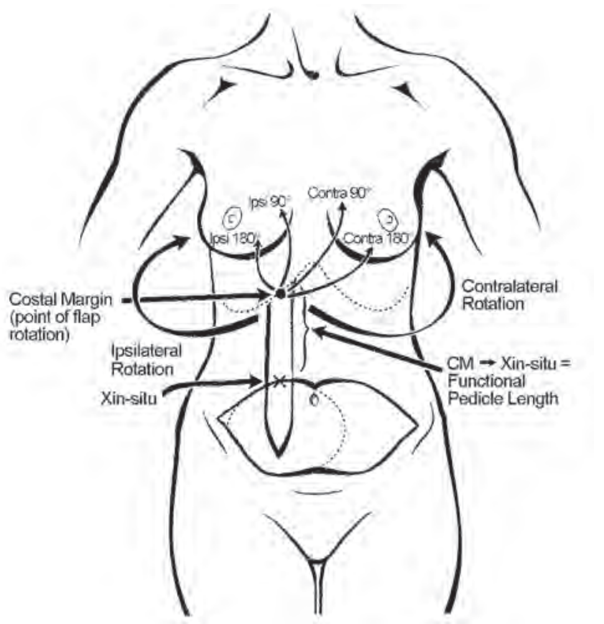

Figure 31. Options for transposition of unipedicled TRAM flap in ipsilateral and contralateral breast reconstruction. Rotation of ipsilateral flap by 90° simplifies inset and breast mound shaping. *Ipsi*, ipsilateral; *Contra*, contralateral. (*Reprinted with permission from Clugston et al.*[199])

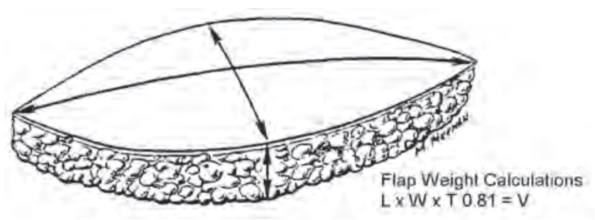

Figure 32. Formula for calculating volume of abdominal ellipse needed in breast reconstruction with the TRAM flap. (*Reprinted with permission from Wagner et al.*[200])

- It is available to plastic surgeons who are not comfortable with microsurgical breast reconstruction.
- It might be the only effective option in some cases of previous abdominal scarring.

The study by Restifo et al.[204] showed the effect of a 1-week flap delay on blood flow within the superior epigastric artery (SEA) (Fig. 34). The caliber and flow of the SEA after delay approximated those of the DIEA before its ligation.

Ribuffo et al.[205] used laser Doppler flowmetry and echo color Doppler imaging to evaluate the effect of flap delay on 18 patients undergoing breast reconstruction with the TRAM flap. Ten patients who underwent standard TRAM flap breast reconstruction without delay served as controls. Doppler flow measurements documented a sizable increase in cutaneous blood flow in delayed flaps. Delayed flaps also showed less fluctuation in perfusion levels, increased diameter of the SEA, and a lower resistivity index than did standard TRAM flaps. The authors concluded that the delay procedure ensures greater reliability of the TRAM flap in all patients and especially in those at high risk for flap necrosis, such as smokers and obese persons.

The delay procedure improves the arterial and venous supply to the flap by opening the choke vessels and promoting the development of regurgitant valves.[202–204] Delay might particularly improve the reliability of the TRAM flap in obese patients[206] who are known to be prone to flap complications.[32,207–209]

Hartrampf[198] listed risk factors associated with breast reconstruction with the TRAM flap (Table 1). The risk scores for each patient seeking reconstruction are added to determine whether she is a candidate for the TRAM flap technique. Two risk factors and a combined score of <5 place a patient in the borderline category. Three risk factors or a score of >5 means the patient is not a candidate for reconstruction with the TRAM flap.[198] In a series presented by Hartrampf and Bennett,[207] 98% of patients judged the operation to be worth their time and effort. For patients who are at high risk, have a midline lower abdominal scar, or require extensive soft-tissue reconstruction, Hartrampf recommends use of the double-pedicled TRAM flap.[200,207,210]

Advantages of the TRAM flap are that it accomplishes reconstruction with autologous tissue, leaves an acceptable donor-site scar, and serves as a simultaneous abdominoplasty. Disadvantages are a high tissue-to-blood supply ratio, protracted recovery time with abdominal discomfort, potential for hernia

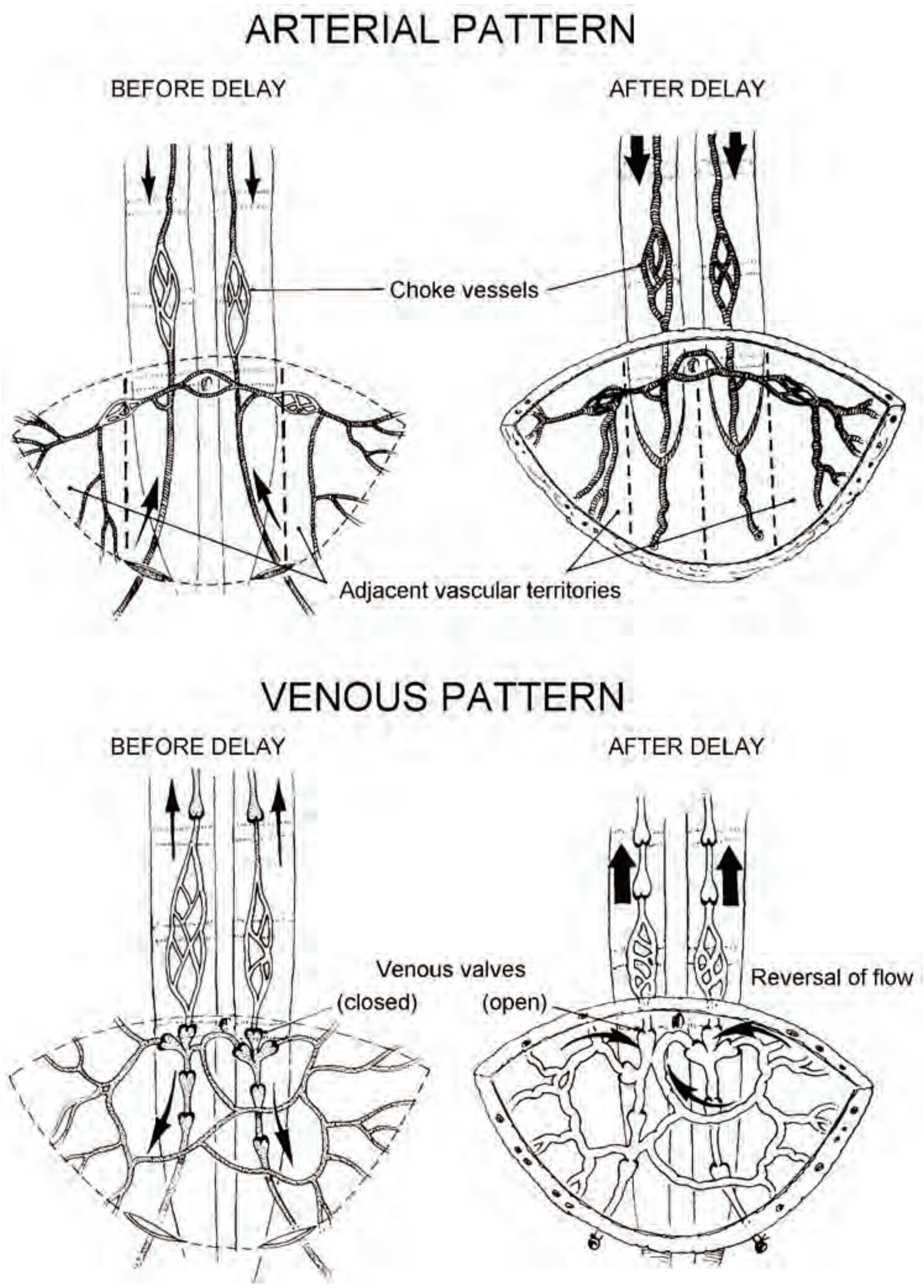

Figure 33. Changes in TRAM flap circulation after surgical delay. Arterial and venous patterns are shown. (*Reprinted with permission from Codner et al.*[202])

or bulge from weakness of the abdominal wall, and limitations imposed by previous abdominal scars.

For bilateral reconstructions, the rectus muscles are separated at the linea alba and the adipocutaneous paddle is divided in the midline, allowing the flap to be split and used as ipsilateral pedicled TRAM flaps. Delay is unnecessary with the bipedicled TRAM flap because of its robust blood supply. Primary closure of

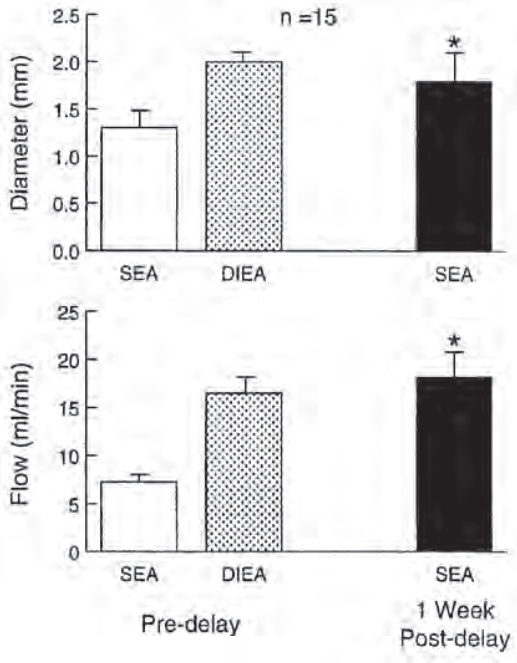

Figure 34. Blood flow in SEA 1 week after surgical delay. (*Reprinted with permission from Restifo et al.*[204])

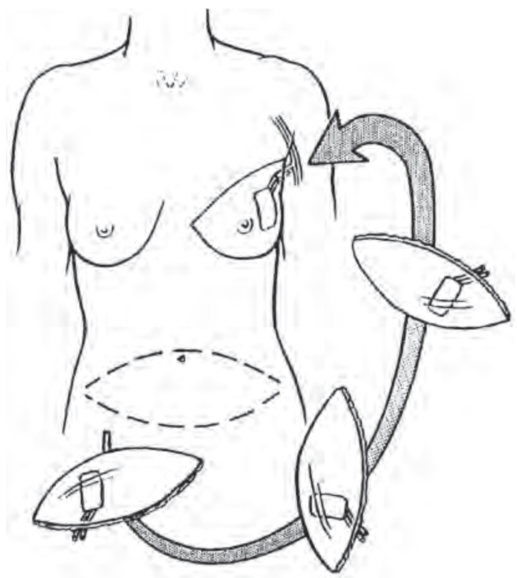

Figure 35. Technique of unilateral breast reconstruction with free TRAM flap. (*Reprinted with permission from Grotting et al.*[214])

the fascia is not usually possible, mandating the use of synthetic mesh. Muscle-sparing techniques can be used in an attempt to reduce donor-site morbidity. The medial bulge from the recti might require surgical revision later.

Paige et al.[211] compared operative morbidity in 257 patients who had undergone breast reconstruction by either unilateral or bilateral unipedicled TRAM flaps. Little difference was observed in the incidence of fat necrosis or hernia formation. Risk factors for both groups included obesity, smoking, and previous radiation. The authors concluded that bilateral unipedicled TRAM flaps are not associated with additional risk of complications compared with unilateral unipedicled TRAM flaps.

Free TRAM Flap

In 1979, Holmström[26] was the first to use the normally discarded tissue from an abdominoplasty as a free flap for post-mastectomy reconstruction. Today, free flaps from the lower abdominal wall are the first choice in breast reconstruction with autogenous tissue.

The free TRAM flap is based on the deep inferior epigastric pedicle, which is the dominant blood supply to the abdominal wall. The diameter of the artery is typically between 2.5 and 3 mm, and the two accompanying venae comitantes are between 2 and 3.5 mm in caliber. The vascular pedicle of the flap is up to 15 cm long. The skin paddle encompasses a large surface area, from the abdominal midline to just lateral to the anterior superior iliac spine.[19] The free TRAM flap or DIEP flap is now the first choice of many surgeons for breast reconstruction with autologous tissue.

Multiple reports of large series of successful reconstructions by several authors attest to the excellent results that are possible with the free TRAM flap technique.[19,26,212–218] Schusterman et al.[217] reported the results achieved in 163 patients (211 free TRAM flaps; 48 patients underwent bilateral reconstruction). When available, the thoracodorsal vessels were used for the anastomoses, particularly when the reconstruction was immediately post-mastectomy; otherwise, the axillary vessels were chosen as recipients. End-to-end anastomoses were used in 88% of the cases, and vein grafts were necessary in only four. Three flaps (1.4%) were totally lost, and 15 instances (7.1%) of partial flap loss or fat necrosis occurred. Fat necrosis developed in 12% of the 99 patients who were current or past smokers and in 3% of nonsmokers. Symptomatic bulge or overt hernia was noted in 11 cases (5.2%) but became less frequent after the authors began harvesting only the central third of the muscle directly over the perforators (muscle-split technique).

Grotting[218] reported a series of 167 free TRAM breast reconstructions in 140 patients. In almost every case, the contralateral inferior epigastric artery and vein were anastomosed end-to-end to the thoracodorsal artery and vein, which had been transected just proximal to the serratus branch. This entailed rotation of the flap of 180° (Fig. 35).[214] In bilateral free TRAM flap reconstructions, Grotting et al.[214] used the ipsilateral rectus muscle for each side, rotating the right TRAM 90° clockwise and the left TRAM 90° counterclockwise (Fig. 36).

No total flap losses, eight instances of vessel thrombosis (all vessels were eventually saved), and two partial flap losses occurred. Grotting[218] found the free TRAM flap to be superior to the pedicled TRAM flap for breast reconstruction in that it poses less risk of abdominal wall morbidity, avoids a medial bulge in the upper abdomen from tunneling of the rectus muscle, and is associated with fewer instances of fat necrosis because of better flap vascularity.

Elliott et al.[216] also reported favoring the free TRAM flap over the pedicled TRAM flap technique for immediate breast reconstruction. Comparing the results obtained with 40 free TRAM flaps and 86 conventional TRAM flaps transferred in this setting, the authors found shorter hospitalization times and decreased incidence of fat necrosis with the microvascular technique.

The advantages of a free TRAM flap over a pedicled TRAM flap include the following:

- Better vascularization of the skin paddle
- Less fat necrosis
- Preservation of the inframammary fold
- Freedom of flap orientation
- Reduced donor-site morbidity

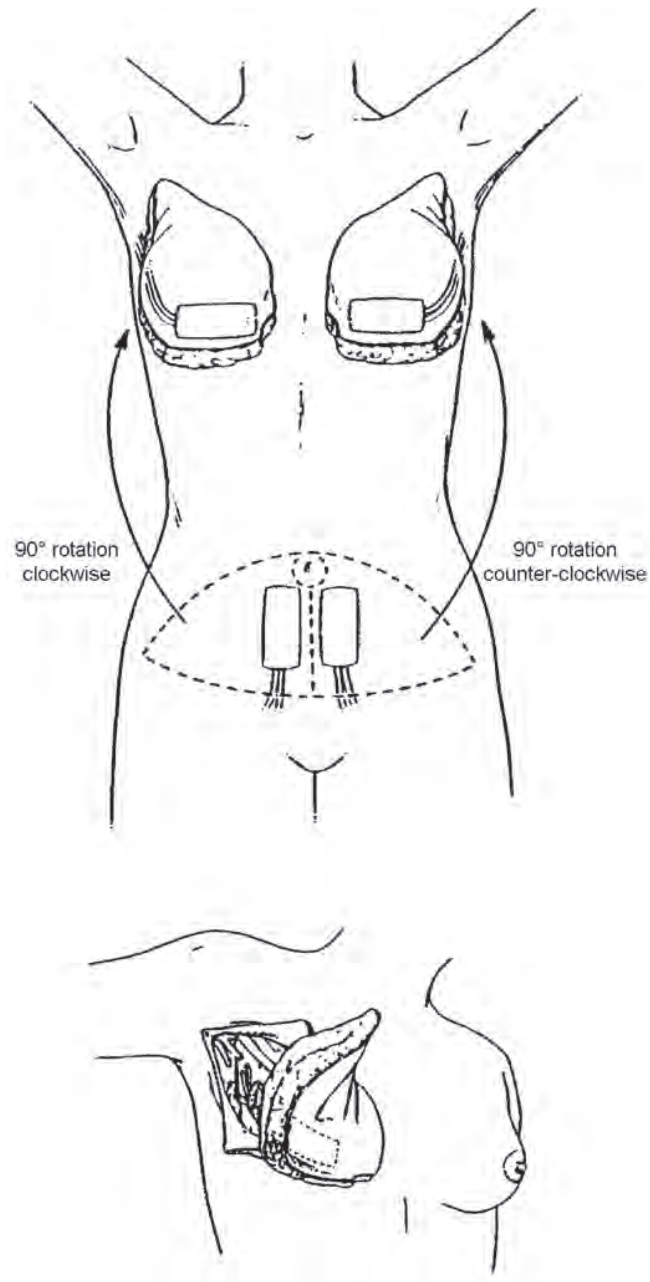

Figure 36. Bilateral breast reconstruction with free TRAM flap. (*Reprinted with permission from Grotting et al.*[214])

- All four zones of abdominal skin can be reliably transferred (the inferior vascular pedicle is sturdier than the superior epigastric vessels on which the conventional flap is usually elevated)
- Less muscle need be taken with the flap, reducing the potential for functional impairment postoperatively
- The skin island can be designed lower in the abdomen
- Less medial fullness (from the tunneled pedicle) and a better shape to the reconstructed breast

If the free TRAM flap is not available, and depending on the patient's body habitus and degree of motivation toward the reconstruction, several options for microvascular transfer of autologous tissues still exist. Unfortunately, these alternative donor sites do not adapt themselves to breast reconstruction as easily as the free TRAM flap does.

Dupin et al.[219] found several disadvantages to the traditional subscapular system as recipient vessels for free TRAM flap breast reconstruction, as follows:

- In secondary reconstructions (especially in radiated cases), dissection of axillary vessels is very difficult.
- The thoracodorsal artery frequently is small (<2 mm) and sometimes found to have insufficient flow, necessitating anastomosis to the circumflex scapular artery more proximal in the subscapular system.
- Medial placement of the breast mound is restricted, and lateral fullness of the flap is a common problem.
- Injury to the thoracodorsal artery might inadvertently occur during the axillary dissection, rendering its use impossible.
- The arterial anastomosis can avulse with shoulder motion.
- Brachial plexus symptoms, although transient, can occur, and some patients develop stiff shoulder resulting from the restriction of shoulder motion. These patients require therapy and/or injection.
- Anastomosis in the axilla is technically difficult for the assistant, because he or she is operating across the chest.

Because microsurgery during respiratory motions can be difficult as the vessels move in and out of the visual field, we recommend hand ventilation during the anastomosis, with the anesthetist occasionally holding respirations for placement of sutures.

Outcome Studies

Baldwin et al.[220] compared the outcome of bilateral breast reconstruction using free TRAM flaps and pedicled TRAM flaps. The average operating time for free TRAMs was almost 10 hours, compared with 6.6 hours for conventional TRAM flaps. The average blood loss with free TRAM flaps was 575 mL; with conventional TRAM flaps, it was 313 mL. Early in the series, three free TRAM flaps were totally lost, necessitating an alternative method of reconstruction. Partial flap loss was nil when using free TRAM flaps but occurred in 13% of cases when using conventional TRAM flaps. The authors emphasized the importance of a great deal of microsurgical expertise before attempting these procedures.

Edsander-Nord et al.[221] reviewed quality of life, patient satisfaction, and aesthetic outcome after pedicled (n = 27) and free (n = 26) TRAM flap breast reconstruction. Both patients and surgeons felt that free TRAM flaps resulted in better symmetry, although patient satisfaction and quality of life were equally high.

A similar study conducted by Moran and Serletti[222] compared the outcomes of breast reconstruction with free and pedicled TRAM flaps in 114 obese patients. No differences were shown between groups regarding age or preoperative risk factors, operative time, or length of hospital stay. The average follow-up was 24 months. Complications occurred in 26% (20 of 78 flaps) of free TRAM flaps and in 33% (12 of 36 flaps) of pedicled TRAM flaps. The study indicates that free TRAM flaps might help reduce partial flap loss in obese patients.

Abdominal muscle function is always compromised to some degree by harvesting a TRAM flap, especially if a bilateral technique is used.[223] In a series of more than 300 breast reconstructions with the TRAM flap presented by Hartrampf,[224] 17% of patients with single-pedicle and 64% with double-pedicle TRAM flaps lost their ability to do sit-ups after the surgery. For elderly patients who have lax skin and for patients who are obese or have protuberant abdomens, the author recommended designing the flap higher on the abdomen to avoid fascial closure below the umbilicus and risk further weakness of the abdominal wall.[198]

Lejour and Dome[225] tested the abdominal wall function of 57 patients 6 months to 2 years after breast reconstruction with TRAM flap. No patient had full muscle function of either the recti or external oblique muscles. Taking the rectus muscle from both sides resulted in markedly more abdominal weakness than if the single-pedicle technique had been used. The authors concluded that the functional compromise associated with a unilateral TRAM was acceptable but restricted their use of bilateral pedicles and substituted a free TRAM transfer when the whole width of the flap skin was needed for the reconstruction.

Kind et al.[226] confirmed that pedicled TRAM flap harvest "causes a greater insult to the abdominal wall than does free TRAM flap harvest" but found that "the ultimate clinical effect of the sacrifice of even an entire rectus abdominis muscle appears to be well tolerated by most patients."

Petit et al.[227] advised counseling prospective patients regarding the abdominal sequelae of pedicled TRAM flap breast reconstruction. Despite potential problems with scars, abdominal wall weakness, decreased abdominal strength, and back pain, the authors purported that the final cosmetic result of TRAM flap breast reconstruction justifies the risk.

Zienowicz and May[228] recommended routine polypropylene mesh reconstruction of the TRAM flap harvest site on the abdominal wall. Mesh reinforcement not only strengthens the fascial closure but also enhances the aesthetic outcome of the abdominoplasty. In their series of 65 consecutive patients who underwent mesh reconstruction of the donor site, abdominal hernia developed in 1.5% and mesh-related infection in 1.5% after a mean follow-up of 56.4 months.

Shestak et al.[229] reported successful repair of large lower abdominal hernias after TRAM flap breast reconstruction in 11 patients by intraperitoneal application of polypropylene mesh. No recurrence developed during the 8- to 36-month follow-up. Technical points discussed in the article include placement of the PROLENE mesh (Ethicon, Somerville, NJ) intraperitoneally and fixation to the abdominal wall with full-thickness mattress sutures (Fig. 37).[229]

Spear et al.[230] evaluated abdominal sensibility after TRAM flap breast reconstruction in 25 patients. All had undergone surgery a minimum of 1 year before the evaluation. Compared with 10 women in the control group who had never undergone abdominal surgery, the study group had significantly decreased sensation in the midline supraumbilical and infraumbilical regions ($P = 0.005$).

The only absolute contraindication to breast reconstruction with the free TRAM flap is previous ligation of the deep inferior epigastric pedicle. An ipsilateral pedicle will place the better vascularized tissue toward the midline. When a free TRAM flap is based on the ipsilateral rectus muscle, most of the flap fullness will be in the vertical plane. Flaps based on the contralateral rectus lie more transversely, and most of the bulk is horizontally oriented.

Muscle-sparing techniques have been suggested to reduce donor-site morbidity of free TRAM flap breast reconstruction. Certain techniques can result in segmental denervation of the medial part of the rectus muscle and therefore offset any advantages of

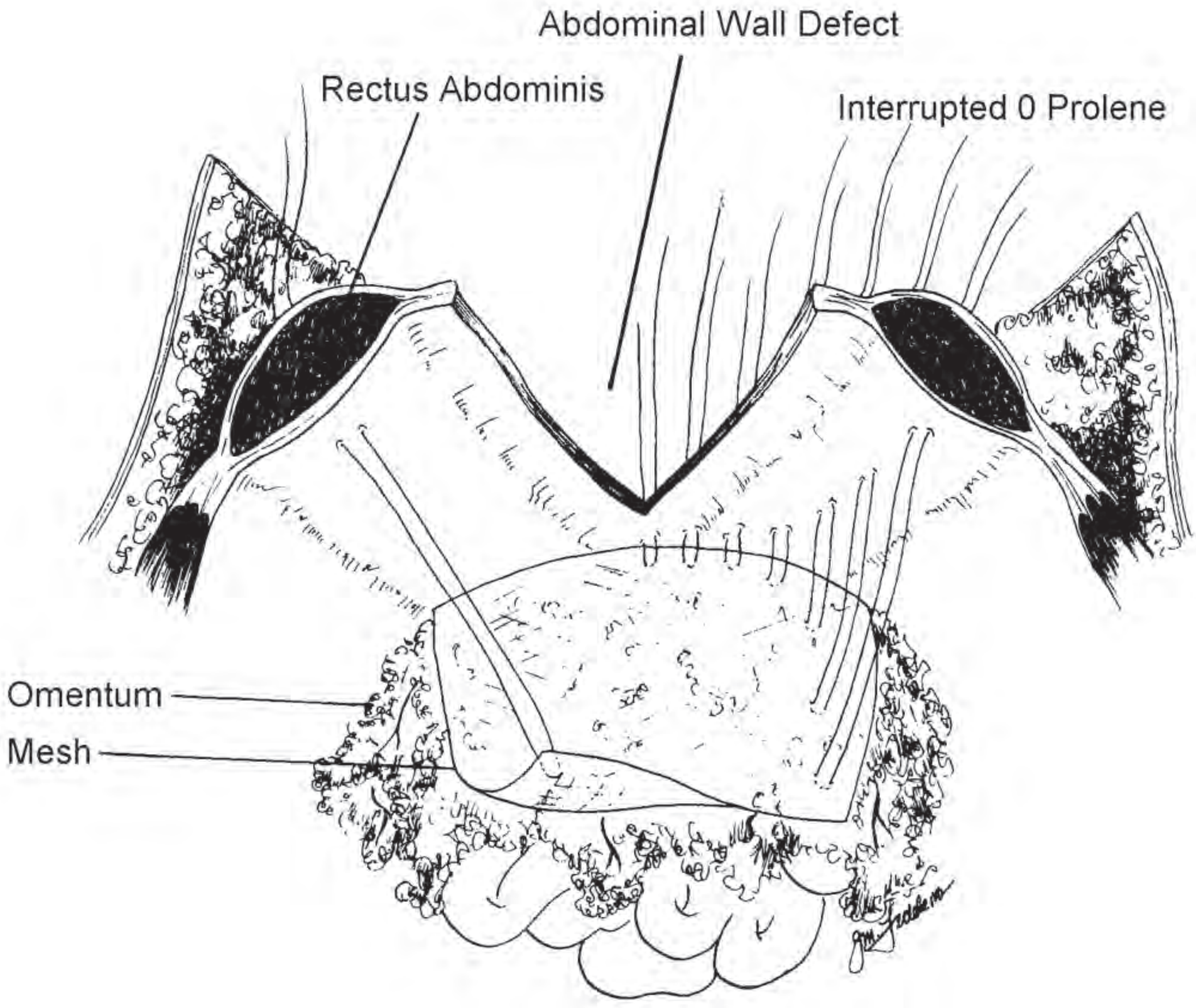

Figure 37. Abdominal hernia after TRAM flap harvest is repaired with PROLENE mesh placed intraperitoneally and fixed to the abdominal wall with mattress sutures. (*Reprinted with permission from Shestak et al.*[229])

muscle sparing. Outcome comparisons across series of muscle-sparing TRAM flap procedures and other abdominal flap procedures are difficult because of important technical differences among the various surgeons.

DIEP Flap

The DIEP flap is perfused by perforators from the DIEA and accompanying veins (Fig. 38).[96] The flap is essentially a TRAM flap minus the muscle, and the same adipocutaneous paddle as the free TRAM flap can be reliably transferred without the rectus abdominis muscle. To minimize donor-site morbidity, pain, and recovery time, the muscle fibers of the rectus are separated longitudinally but are not transected, and the intercostal nerves are preserved.

Typically, three to seven large perforators from the DIEA are concentrated in the periumbilical region. When two main intramuscular branches are present, the lateral branch (which gives off a lateral

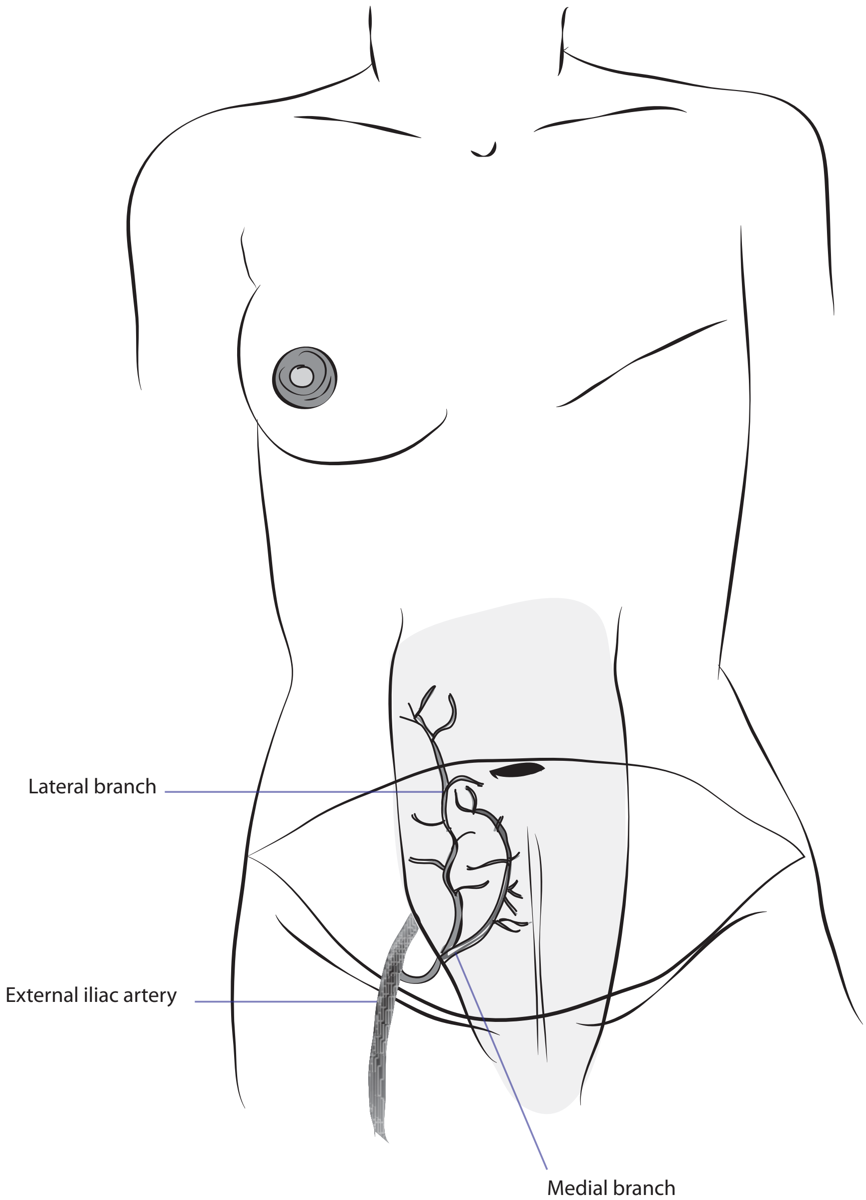

Figure 38. Marking the typical DIEP free flap for breast reconstruction. (*Modified from Spear.*[96])

row of perforators in the lateral third of the muscle) anastomoses with the lower four intercostal arteries. The medial branch (which gives off a medial row of perforators in the medial third of the muscle) also gives off an umbilical branch before terminating in choke vessel anastomoses with the SEA above the umbilicus.

Blondeel et al.[231,232] and Allen and Treece[38] investigated the potential benefits of DIEP flaps with sensory nerve repair in restoring sensation to the breast after reconstruction. The authors reported less donor-site morbidity of DIEP flaps compared with conventional TRAM flaps. Although the operation is technically more demanding, it also allows for the possibility of sensory return in breast reconstruction. Blondeel et al.[232] concluded, "Our data reconfirm the possibility of spontaneous return of sensation in pedicled and/or free lower abdominal flaps without nerve repair. Nerve repair in free DIEP flaps nevertheless does restore sensation earlier postoperatively, increases the quality and quantity of sensation in the flap, and has a higher chance of providing erogenous sensation."

Absolute contraindications specific to DIEP flap breast reconstruction include history of previous abdominoplasty, abdominal liposuction, and active smoking. Multiple abdominal incisions are a relative contraindication, and preoperative imaging can be considered to evaluate the integrity of the perforator system.

The flap is harvested through standard abdominoplasty incisions approximately 12 cm wide at the midline and extending laterally to the anterior superior iliac spines. The flap is harvested from lateral to medial, taking care to identify the superficial inferior epigastric pedicle. If the artery is of sufficient size, a SIEA flap can be harvested. Otherwise, the SIEV is dissected for a few centimeters and tagged to be used in case of venous compromise later. As dissection proceeds toward the midline, the lateral perforator row is encountered first (Figs. 39–41).[96,177]

More perforators tend to be found in the lateral row than in the medial row, and the lateral row perforators are easier to dissect through the rectus. The lateral perforators typically assume a short perpendicular intramuscular course, in contrast to the longer oblique intramuscular course of the medial row perforators. If zone IV is to be carried with the flap, the medial row of perforators must be included in the flap dissection.[233,234] Either one dominant perforator or two or three smaller perforators in the same intramuscular septum can be harvested. In their series, Gill et al.[235] raised 25% of flaps on one perforator, 50% on two, and 25% on three or more perforators. Interestingly, the authors found significantly fewer complications when one perforator was used compared with two or more perforators ($P = 0.026$).

Once a suitable perforator is found, the anterior rectus sheath is opened to allow intramuscular dissection and ligation of tiny intramuscular branches. Topical instillation of lidocaine helps prevent muscle twitching when using the diathermy device. Administration of a paralytic agent by the anesthesiologist is extremely useful to minimize inadvertent damage to perforators during dissection. Dissection continues until a pedicle of sufficient length and caliber is obtained, and either the rectus sheath incision is extended obliquely or a separate incision is made at the lateral inferior border of the rectus muscle near the inguinal ligament (Fig. 42).[236]

Care must be taken to preserve the segmental intercostal motor nerves, which run medially and superficial to the pedicle, for future innervation of the medial aspect of the muscle. Sensory nerves to the flap typically run with the perforators and can be coapted to the lateral branch of the fourth intercostal nerve.

At the recipient site, if a large perforator from the internal mammary artery (IMA) with an accompanying vein is present, it is usually found at the second or third intercostal space. Otherwise, the internal mammary vessels are dissected. If the interspaces are too narrow, either a portion of the rib cartilage above and below the artery or the entire third intercostal cartilage can be excised for access (Fig. 43).[96] Anastomosis is performed, and the flap is applied (Fig. 44).[96] De-epithelialization is variable depending on the amount of native breast skin that has been preserved. It is anecdotally known that because of its often inadequate perfusion, zone IV skin is routinely excised by many surgeons.

The flap generally is raised contralateral to the reconstruction site for easier inset and to place the thick central adipose layer in the medial and inferior portions of the reconstructed breast. A two-team approach with simultaneous preparation of the recipient site and harvest of the flap works well. If primary reconstruction is being performed, an SSM is preferred and the breast envelope is filled with the flap until it matches the opposite breast. Weighing the mastectomy specimen is helpful in gauging the final size of the recreated breast.

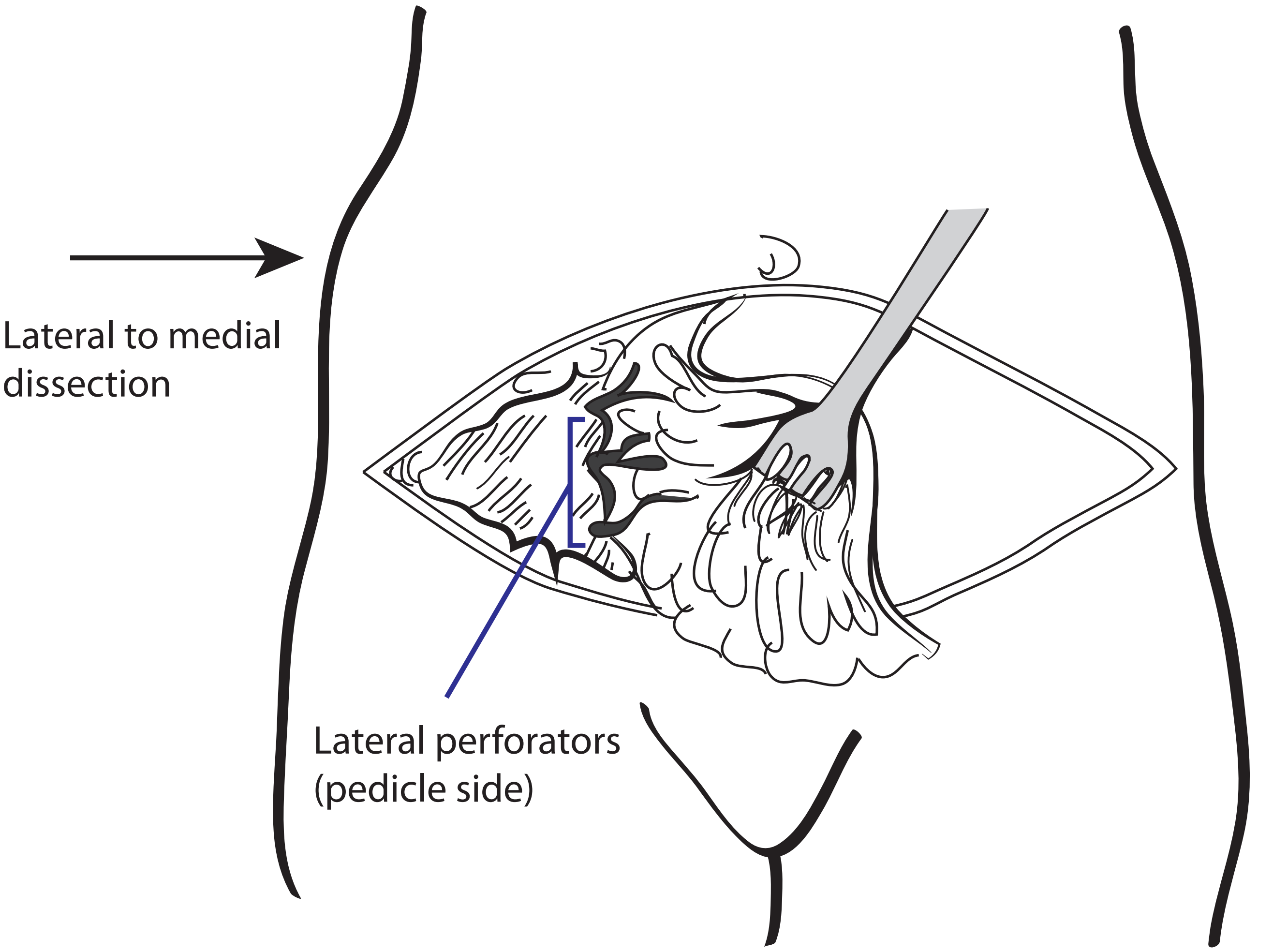

Figure 39. Technique of breast reconstruction with the DIEP flap, which is harvested from lateral to medial. (*Modified from Schusterman.*[177])

SIEA Flap

Grotting[237] first described using a superficial inferior epigastric artery flap for breast reconstruction in 1991. The SIEA flap is based on the SIEA and SIEV, which arise from the common femoral artery and saphenous bulb, respectively. Donor-site morbidity from SIEA flap harvest is minimal because the vessels are dissected at the level of the Scarpa fascia with no incision made at the rectus fascia.

The main disadvantage of the SIEA flap is a highly variable SIEA in both caliber and cutaneous territories. Flap harvest often is limited to a hemi-flap to avoid tissue necrosis (Fig. 45).[96]

Chevray,[238] reporting on a series of 47 consecutive abdominal breast reconstructions, was able to perform SIEA transfer in 30% of patients. In their series of 215 consecutive breast reconstructions with abdominal tissue, Allen and Heitland[239] reported a 40% SIEA rate.

On the basis of their anatomic studies, Boyd et al.[179] and Taylor and Daniel[240] determined that the superficial inferior epigastric artery was absent in 35% of cases, whereas Reardon et al.[241] noted a patent SIEA in 91% of their dissections. The SIEA was located within 1 cm of the midpoint of the inguinal ligament in 15 cases and within 2.5 cm of

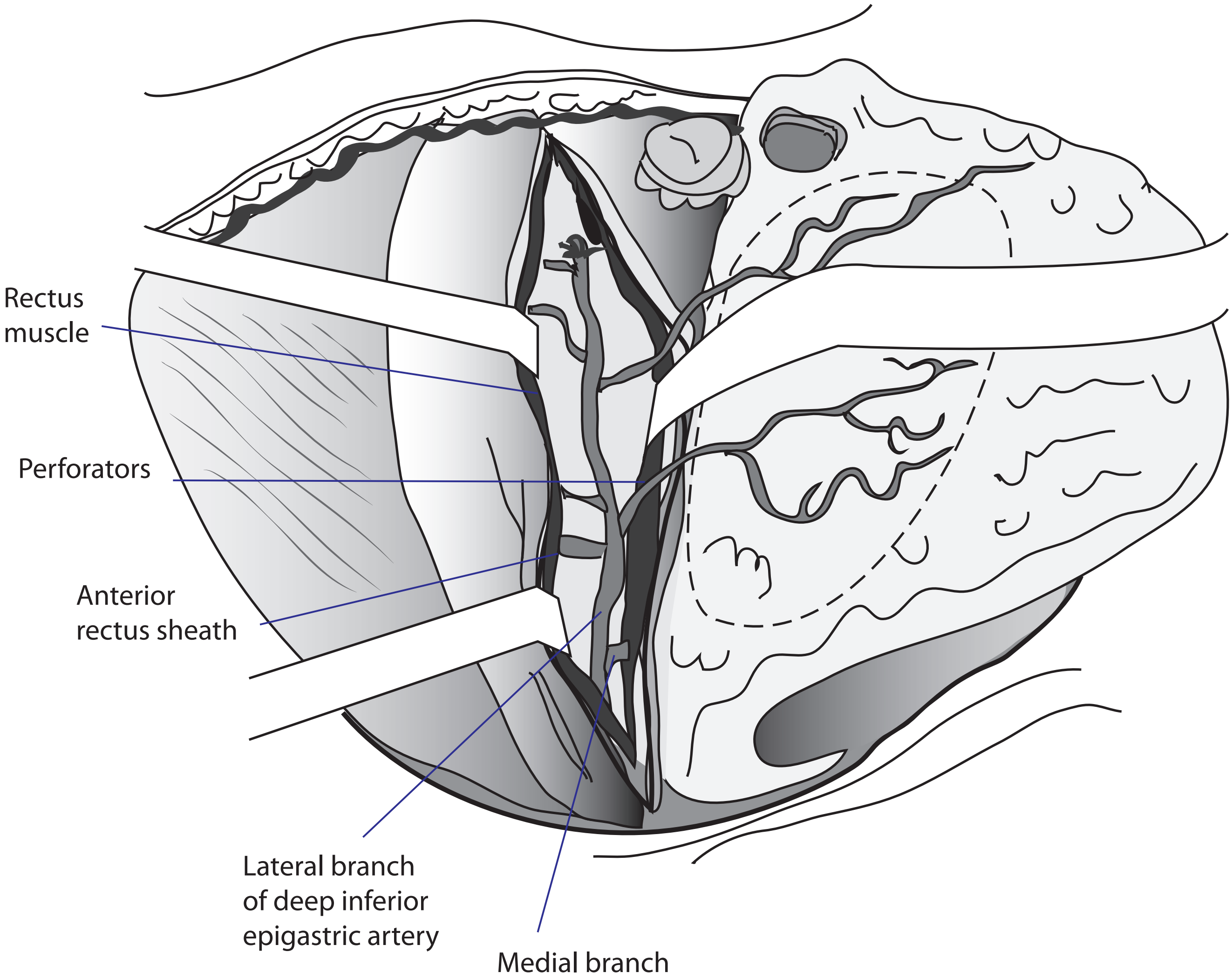

Figure 40. Technique of breast reconstruction with the DIEP flap. The main DIEA vascular pedicle is located, and the muscle-perforating vessels of the lateral branch are seen coursing through the rectus sheath. (*Modified from Spear.*[96])

the midpoint in four cases. The pedicle length ranged from 3 to 7 cm and the vessel caliber from 1.2 to 2.5 mm.[240,241]

The flap markings are the same as for the DIEP flap (Fig. 46).[96] The vessels are followed to their respective origins at the common femoral artery and saphenous vein. Vessels of at least 1 mm in diameter at the level of the inferior incision can be safely used for flap transfer.

The flap might be difficult to inset if the pedicle is located superficial and peripheral within the flap. The preferred recipient vessels are the IMA and internal mammary vein (IMV) (Fig. 47).[96] The part of the flap with the poorest perfusion is positioned laterally. The inferior portion of the flap can be folded over to redirect the pedicle superiorly and to keep it from kinking (Fig. 48).[96]

In the series presented by Chevray,[238] one flap loss and two cases of partial flap necrosis occurred in 14 SIEA breast reconstructions. Granzow et al.[242,243] presented the results of 210 breast reconstructions with SIEA flaps (174 patients). In all cases, the internal mammary vessels were used as recipient

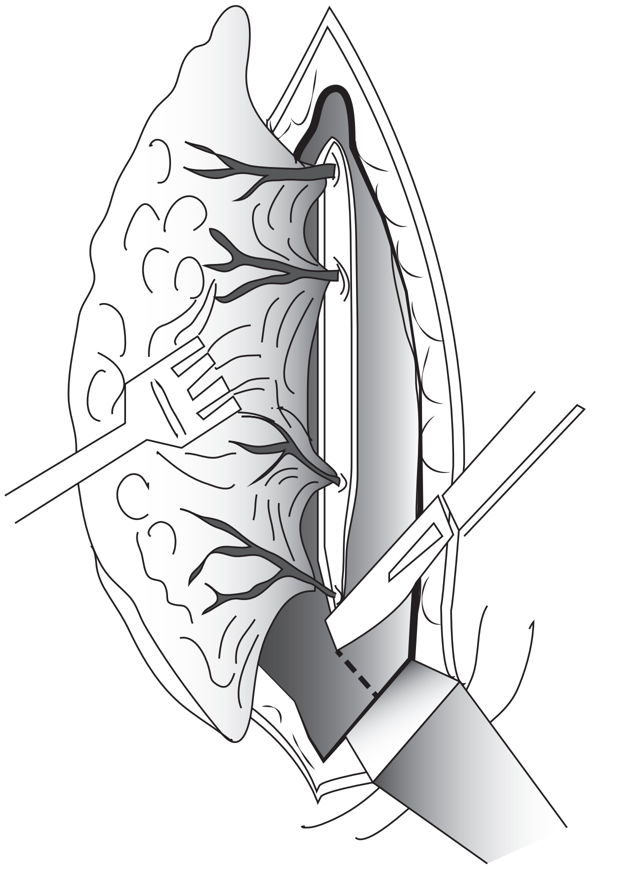

Figure 41. Technique of breast reconstruction with the DIEP flap. The anterior rectus fascia is incised, and the main flap perforators are dissected free of the muscle. (*Modified from Schusterman.*[177])

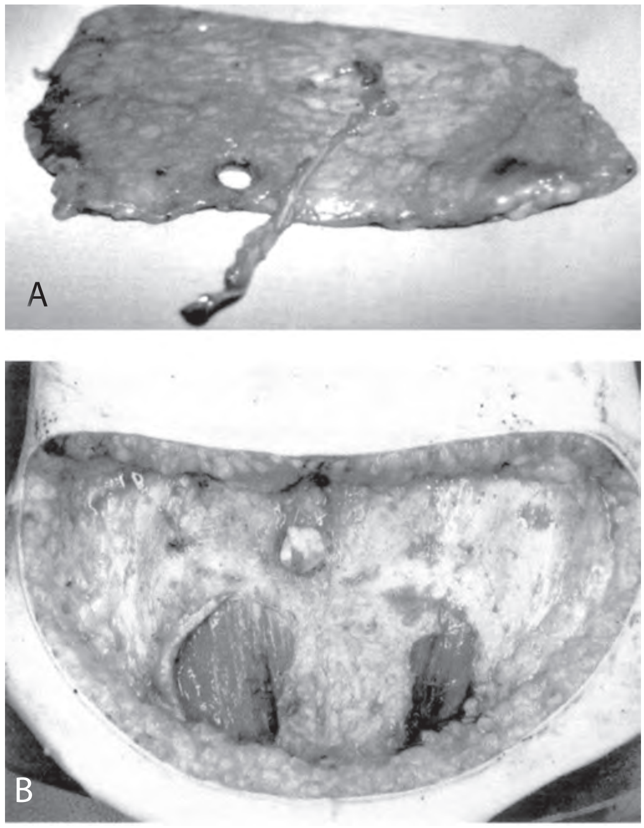

Figure 42. *A*, Single-perforator DIEP flap with 15-cm arterial pedicle. No muscle or fascia has been removed. *B*, Abdomen after bilateral DIEP flap procedure. The rectus abdominis muscle is in continuity after longitudinal myotomy, and the anterior rectus sheath is partially reflected. (*Reprinted with permission from Nahabedian et al.*[236])

vessels. The arterial diameter at the pedicle was 1.5 to 2.5 mm, and the vein was 2.0 to 4.0 mm. No flap losses occurred. Fat necrosis occurred in 13%. Donor-site seromas occurred in 4%. No hernias or unsightly abdominal bulges occurred in the series.

Complications

Ducic et al.[244] and Spear et al.[245] examined the effects of various risk factors on the outcome of breast reconstruction with abdominal flaps. Of 224 pedicled TRAM flaps in 200 patients during a 10-year period, 73.2% were unipedicled and 9.4% were transferred after delayed procedures. Flap complications were recorded in 43.5% of patients. Donor-site complications and other complications occurred in 35.5% and 7.5% of patients. Flap necrosis occurred in 9.8%, fat necrosis in 17.9%, and abdominal hernia in 1.5%. Compared with nonsmokers, both active and former smokers (defined as patients who quit smoking at least 4 weeks before surgery) were more likely to experience multiple flap complications. Active smokers had a higher rate of TRAM flap infection, and former smokers showed delayed wound healing compared with nonsmokers.[245]

Mehrara et al.[246] analyzed the frequency of complications in 1195 microsurgical breast reconstructions in 952 patients. Flaps used in their

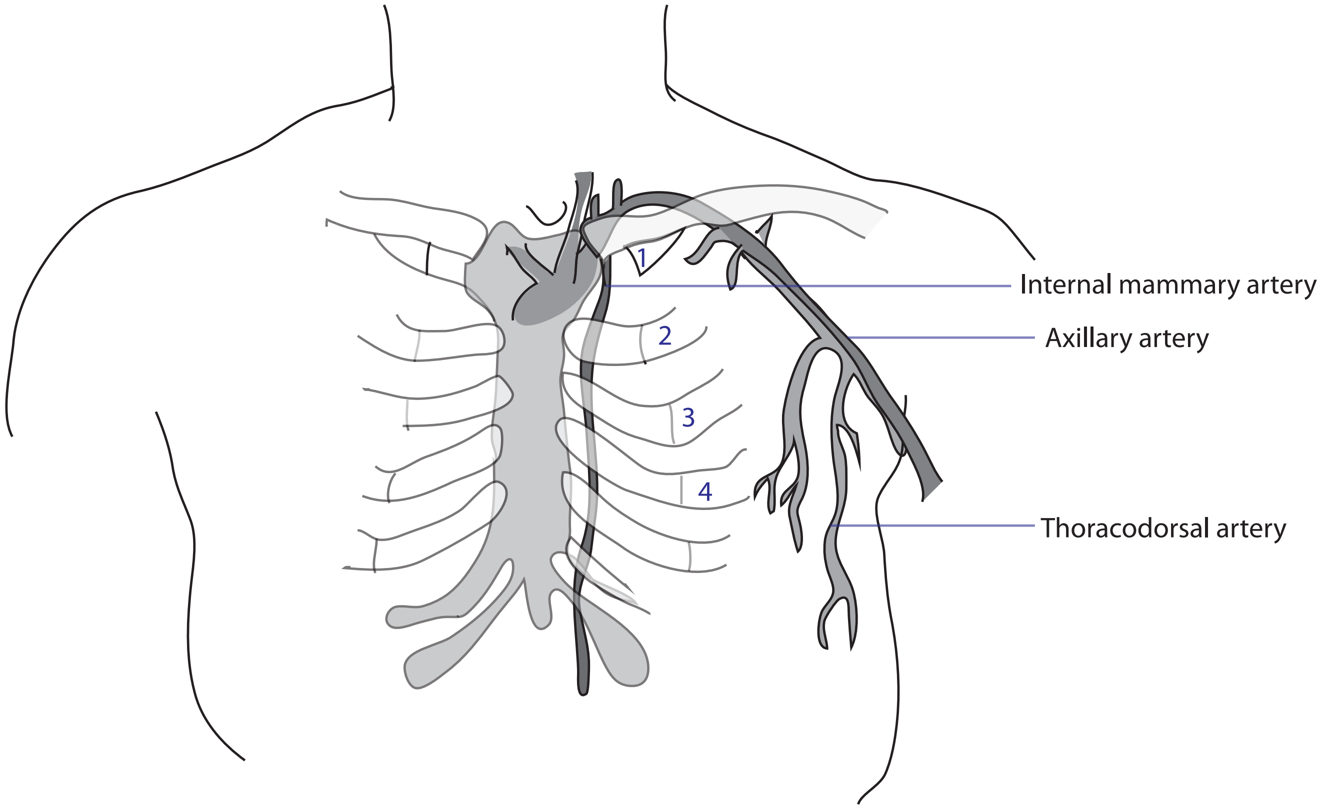

Figure 43. Internal mammary artery usually is reached via a large perforator at the second or third intercostal space. (*Modified from Spear.*[96])

series were predominantly the free TRAM (81.8%) and the superior gluteal musculocutaneous flap (10.1%). The overall complication rate was 27.9%, the majority of which (21.7% of total) were minor. Six (0.5%) instances of total flap loss occurred. Obesity was a major predictor of complications, but smoking was not. Neoadjuvant chemotherapy was also an independent predictor of complications and was associated with wound-healing problems and fat necrosis. Previous abdominal surgery in patients receiving TRAM flaps increased the risk of partial flap loss, fat necrosis, and donor-site complications.

Chang et al.[247,248] examined the effects of obesity[247] and smoking[248] on complications associated with free TRAM flap breast reconstruction. Flap complications occurred in 222 (23.7%) of 936 flaps, and donor-site complications occurred in 106 (14.8%) of 718 patients. Obese and overweight patients had significantly higher total flap loss (P = 0.001), flap hematoma (P = 0.007), flap seroma (P = 0.003), mastectomy skin flap necrosis (P = 0.001), donor-site infection (P = 0.016), donor-site seroma (P < 0.001), and hernia (P = 0.039) compared with patients of healthy weight. Smokers experienced a higher incidence of mastectomy flap necrosis than did nonsmokers, particularly in cases of immediate breast reconstruction, and donor-site complications were more common in smokers than in former smokers or nonsmokers. Compared with nonsmokers, smokers had significantly higher rates of abdominal flap necrosis (P = 0.025) and hernia (P = 0.016). Patients with a smoking history of more than 10 pack-years had a significantly higher complication rate overall than those with less than 10-pack years (P = 0.049).

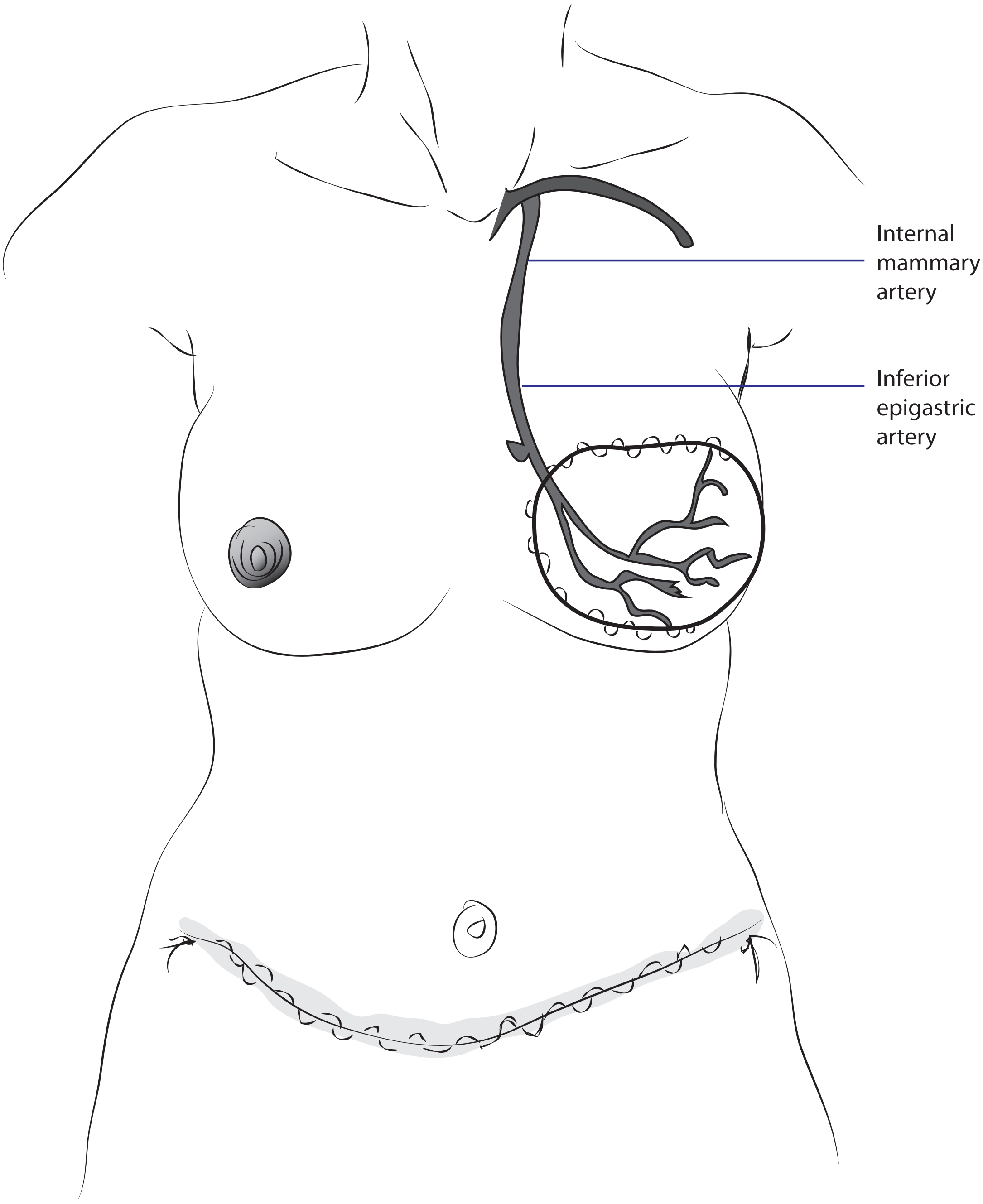

Figure 44. Anastomosis of the internal mammary artery and vein with the inferior epigastric artery and vein and inset of the DIEP flap on the breast. (*Modified from Spear.*[96])

Excellent results with the DIEP flap have been reported.[233,235,238,246,249–257] Gill et al.[235] reviewed a 10-year experience with 758 DIEP flaps and reported partial flap loss in 2.5% and total flap loss in fewer than 1%. Fat necrosis occurred in 13% and abdominal hernia in 0.7%. Analysis of other series comprising 1200+ flaps[252,253] reveals a total flap failure rate of 1%, partial flap failure and/or fat necrosis rate of 8%, and abdominal wall bulging in fewer than 1%.

Venous compromise is a concern when performing DIEP flap harvest. Gill et al.[235] noted

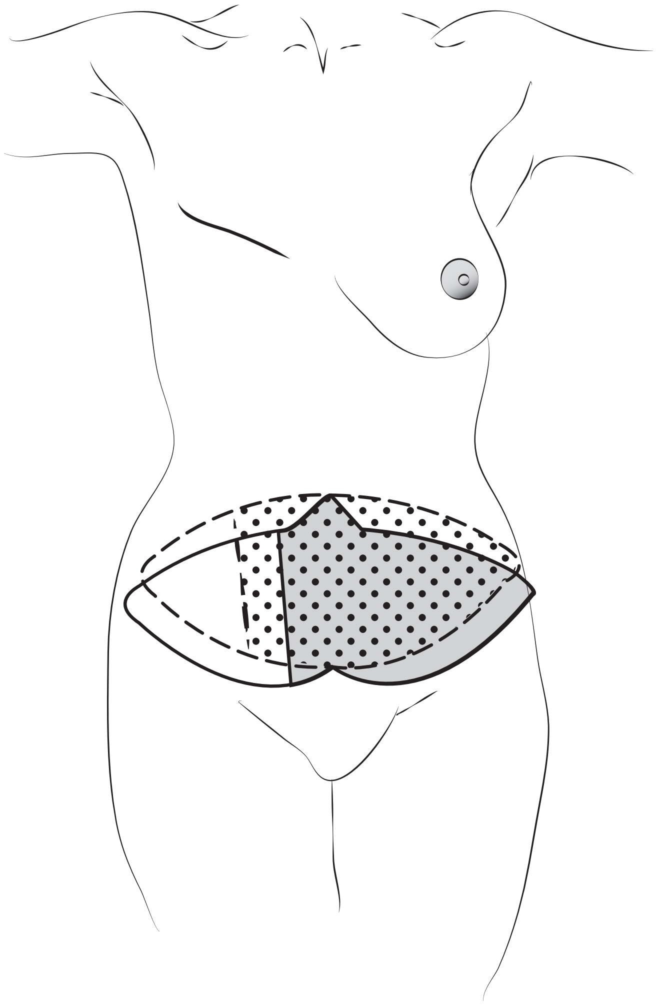

Figure 45. SIEA flap design (*shaded area*) compared with DIEA perforator flap design (*dotted area*). (*Modified from Spear.*[96])

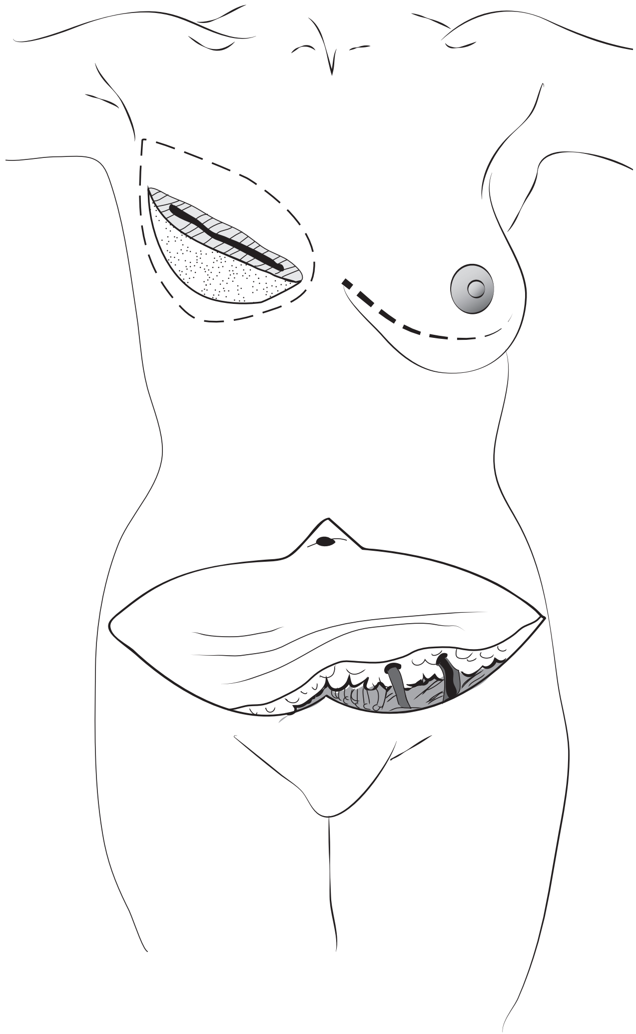

Figure 46. SIEA flap is dissected, and recipient site is prepared to receive transferred flap. *Dotted zone*, de-epithelialized area; *striped zone*, excision. (*Modified from Spear.*[96])

that problems with the vein or venous anastomosis were almost eight times more likely than problems with the artery or arterial anastomosis. Blondeel et al.[234] reported venous insufficiency in 2.1% of 240 DIEP flaps, occurring in the presence of a superficial inferior epigastric vein that was larger than usual, and zero in 271 free TRAM flaps. An anatomic study revealed that the superficial inferior epigastric vein connected with the deep inferior epigastric vein through the venae comitantes. Large lateral branches crossing the midline were found in 18% of cases, whereas 45% had indirect connections through a deeper network of smaller veins and 36% had no demonstrable branches crossing the midline. The higher number of venae comitantes in the TRAM flap might provide additional venous drainage and prevent venous compromise.

Nahabedian et al.[236] compared outcome measures in 177 patients after breast reconstruction with 223 flaps, including 89 patients receiving muscle-sparing TRAM flaps (113 flaps) and 88 receiving DIEP flaps (110 flaps). In the TRAM flap group, eight (7.1%) cases of fat necrosis, three (2.7%) cases of venous congestion, and two (1.8%) cases of total flap necrosis occurred. Abdominal bulge occurred in three women after

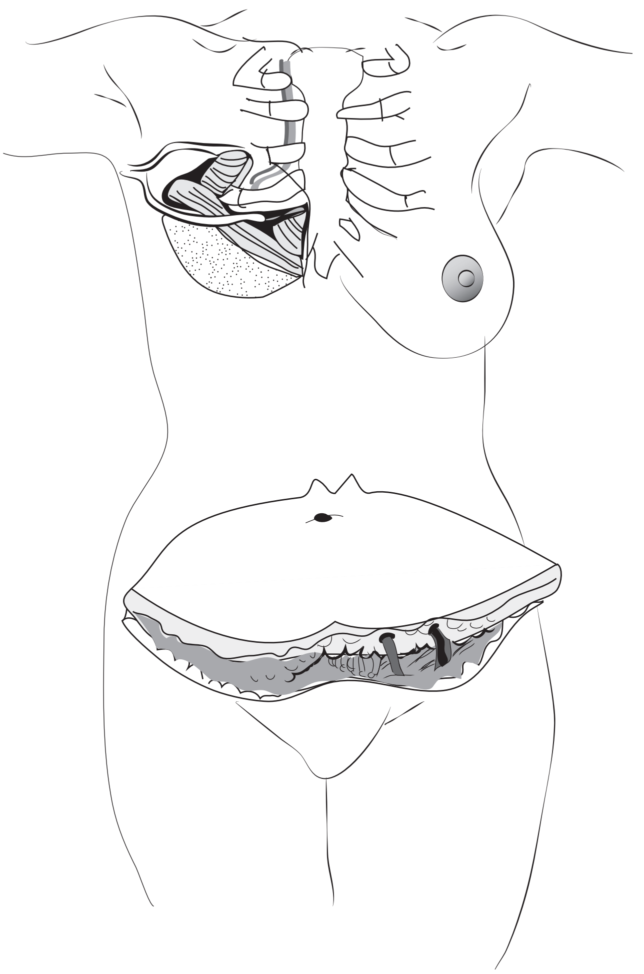

Figure 47. Internal mammary vessels are dissected distally for maximal length of the recipient vessels. (*Modified from Spear.*[96])

unilateral reconstruction and in five after bilateral reconstruction. In the DIEP flap group, fat necrosis occurred in seven (6.4%) flaps, venous congestion in five (4.5%), and total necrosis in three (2.7%). Abdominal bulge occurred in one woman after unilateral reconstruction and in one after bilateral reconstruction.

In obese patients, the DIEP flap might be associated with a lower rate of complications than other forms of autologous reconstruction. Garvey et al.[251] reviewed the records of 71 women who underwent DIEP flap reconstruction after mastectomy. The patients were arbitrarily sorted into healthy weight, overweight, and obese groups. No substantial difference in flap complications could be attributed to body weight. Fascial laxity of the abdominal wall was equally uncommon among the groups.

In another study, Garvey et al.[250] compared outcomes among 190 women who had undergone unilateral post-mastectomy breast reconstruction with 96 DIEP flaps and 94 pedicled TRAM flaps. The incidence of fat necrosis was higher in the pedicled TRAM group (59%) than in the DIEP group (18%). Abdominal wall hernia was more frequent after pedicled TRAM (16%) than after DIEP flap (1%). The rate of abdominal wall bulge was similar.

Donor-Site Morbidity

In cases in which a tension-free closure of the anterior rectus sheath is not possible after a TRAM flap transfer, the defect is repaired with inlay mesh using interrupted non-absorbable suture to reduce the risk of hernias and abdominal bulge.[258] The use of acellular dermal matrix has also been described.[259] Muscle-sparing techniques and DIEP flap harvest usually allow primary approximation of the anterior rectus sheath without tension.

An objective evaluation of donor-site morbidity after abdominal flap transfer for breast reconstruction includes the ability to do sit-ups, isokinetic dynamometry, questionnaires, computed tomography (CT), and magnetic resonance imaging (MRI). In some studies, postoperative motor strength at the abdominal donor site is greater with DIEP flaps than with free TRAM or free muscle-sparing TRAM flaps. Whether this translates into a clinically significant difference is difficult to assess.[238,260]

In an analysis of 177 breast reconstructions performed by Nahabedian et al.,[236] the patients in the free muscle-sparing TRAM flap group and those in the DIEP flap group could statistically do sit-ups equally well: 97% of patients with unilateral TRAM and 100% of patients with unilateral DIEP reconstructions could do sit-ups; 83% of patients with bilateral TRAM and 95% of patients with

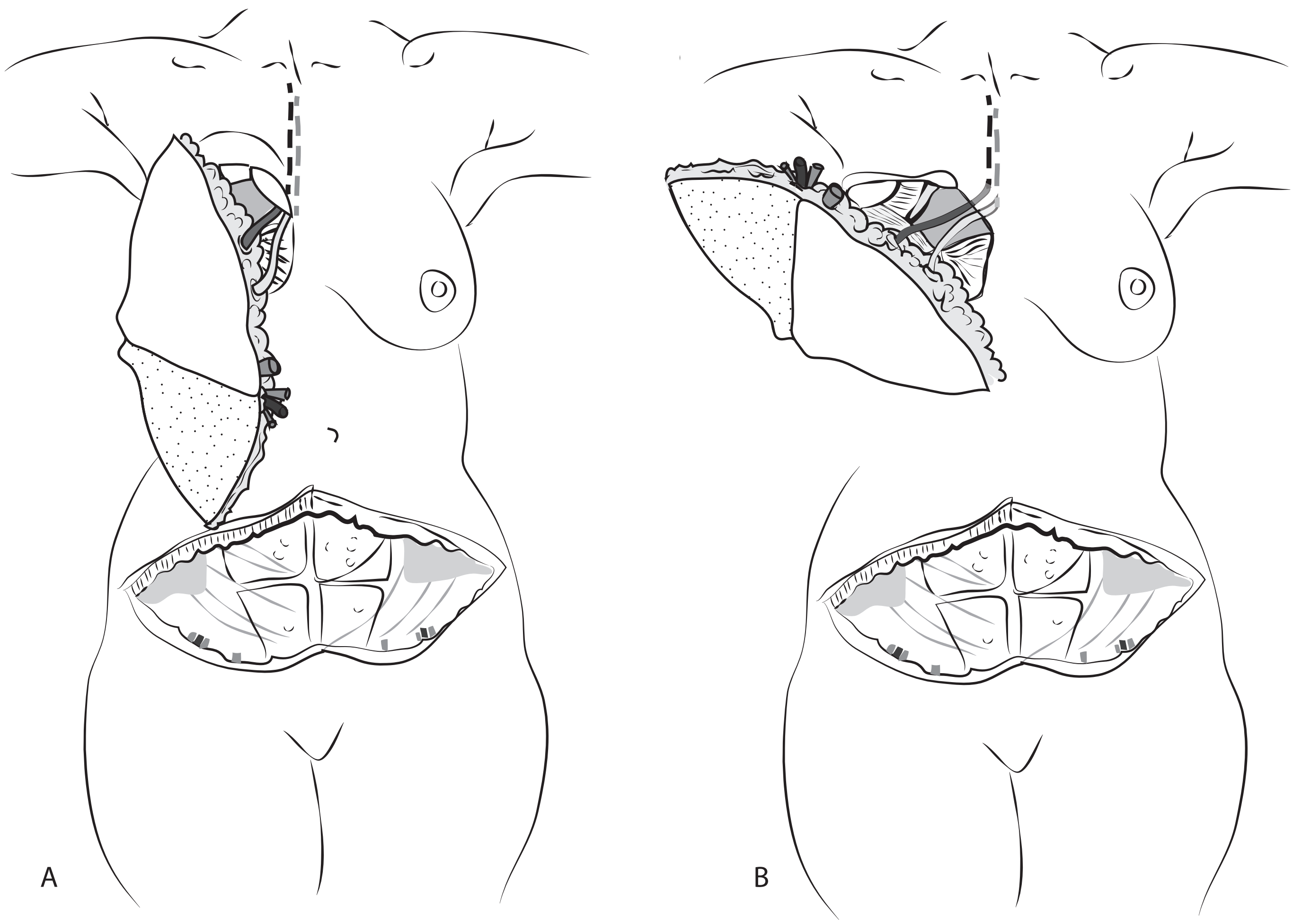

Figure 48. Vessel anastomosis is performed, and flap is inset. The portion represented by the *dotted area* is discarded. *A*, Contralateral flap. *B*, Ipsilateral flap. (*Modified from Spear.*[96])

bilateral EIEP reconstructions could do sit-ups. The objective findings mirrored the questionnaire answers received from the women in this series.

Futter et al.[261] compared outcomes among three groups of patients: group 1, after DIEP flap breast reconstruction (23 patients); group 2, after free muscle-sparing TRAM flap (27 patients); and group 3, non-operated control participants (32 patients). Isokinetic dynamometry showed significant weakness of the abdominal and back extensor muscles in the TRAM group compared with the DIEP flap group ($P = 0.005$) and with the control group ($P = 0.005$). The DIEP flap group tended to have weaker abdominal muscles than those in the control group, but this finding was not statistically significant ($P > 0.05$). Postoperative questionnaires revealed a higher pain level and more functional difficulties after TRAM flap reconstruction. In a later study,[262] the authors determined that preoperative abdominal exercises did not prevent abdominal morbidity in patients undergoing DIEP flap breast reconstruction.

Blondeel et al.[231] evaluated donor-site morbidity at 2 months and at 1 year postoperatively in three groups of patients: 18 who had undergone unilateral free DIEP flap breast reconstruction, 20 who had undergone free TRAM flap reconstruction, and 20 non-operated control participants. Intraoperative segmental nerve stimulation, visual evaluation, and postoperative CT were used to quantify any damage to the rectus muscle. By isometric dynamometry at 1-year follow-up, patients who had received TRAM flaps showed significant reduction in truncal strength over the other groups ($P < 0.05$). Based on questionnaire responses, some patients who had received TRAM flaps experienced impairment of activities of daily living whereas the other groups were unaffected by the surgery.

Edsander-Nord et al.[221] compared functional outcomes after pedicled TRAM flap (n = 23) and free TRAM flap (n = 19) breast reconstruction. Dynamometry showed a transient decrease in abdominal strength in both groups at 6 months. Abdominal strength was fully restored at 1 year in all patients. Other series confirmed these findings.[231,236,260,263]

Radiotherapy

Autologous reconstruction after radiotherapy is associated with an increased risk of flap-related complications.[264–268] Kroll et al.[264] compared the results of breast reconstruction with latissimus dorsi and TRAM flaps in 82 patients who had histories of previous radiation versus similar reconstructions in 202 patients who had not received radiation treatment. Complications were significantly more frequent in the patients who had received radiation than in those who had not (39% versus 25%; $P = 0.03$), and aesthetic outcomes were slightly poorer in the patients who had received radiation.

Williams et al.[265,266] evaluated 108 patients who received preoperative radiotherapy plus pedicled TRAM flap breast reconstruction. The findings in this group were compared with those of 572 patients who did not receive radiation treatment before similar reconstruction. Overall complication rates were similar, but fat necrosis (17.6% versus 10.1%) and major infection were more common in the radiotherapy group. In a later study, the authors assessed 19 patients who had undergone pedicled TRAM flap reconstruction plus postoperative radiotherapy and found increased complication rates overall after radiation. However, no significant difference was observed in outcome based on the timing of radiation in relation to surgery at 4 years of follow-up ($P > 0.05$). The incidence of fibrosis was higher (31.6%) in women who received radiation after reconstruction, but fat necrosis was not increased as a result of radiotherapy.

Tran et al.[267] compared 32 patients who had undergone immediate free TRAM flap reconstruction and then radiation therapy with 70 patients who received radiation therapy before undergoing TRAM flap reconstruction. Although early complications did not differ significantly between groups ($P = 0.32$), the incidence of late complications (≥1 year after surgery) was significantly higher in the immediate reconstruction group compared with the delayed reconstruction group (87.5% versus 8.6%; $P < 0.001$). An additional flap was required to complete the reconstruction in 28% of patients in the immediate group because of flap shrinkage and/or contracture and distorted contour.

Rogers and Allen[268] studied women who had undergone breast reconstruction with a DIEP flap with (n = 30) or without (n = 30) radiation and found significant differences between the groups in terms of score changes for symmetry ($P = 0.015$), aesthetic proportion ($P = 0.008$), and appearance of the superior pole ($P = 0.003$). The rates of fat necrosis ($P = 0.006$), fibrosis ($P < 0.001$), and flap contracture ($P = 0.023$) were also significantly higher among the radiated group.

Spear et al.[269] examined 171 pedicled TRAM reconstructions and noted similar rates of flap complications (approximately 50%) whether the patients had received radiation pre- or postoperatively or had not received radiation. Radiation of any type did adversely affect the aesthetic appearance, symmetry, contracture, and hyperpigmentation of the reconstructed breast compared with non-radiated control breasts.

SGAP AND IGAP FLAPS

Indications

An SGAP or IGAP flap is indicated when the abdominal donor site is unavailable because of insufficient tissue or the presence of multiple abdominal scars, and the patient prefers a gluteal donor-site scar. The gluteal artery perforator flaps are associated with decreased donor-site morbidity compared with musculocutaneous gluteal flaps.[270] Absolute contraindications to gluteal artery perforator flap use are a history of previous liposuction at the donor site and active smoking.

Anatomy

The superior and inferior gluteal arteries originate from the internal iliac artery and exit the pelvis superior and inferior to the piriformis muscle, respectively. The superior gluteal artery enters the gluteus maximus muscle approximately one-third of the distance along the line drawn between the posterior superior iliac spine and the greater trochanter (Fig. 49).[96]

Flap Harvest

The SGAP flap is marked with the patient prone. A point one-third the distance along a line from the posterior superior iliac crest to the greater trochanter marks the site of the superior gluteal artery, and the Doppler probe is used to identify perforators along that line (Fig. 50).[96] A horizontal skin paddle tends to produce a more favorable scar and lessens the need for future revisions (Figs. 51 and 52).[96]

For unilateral reconstruction, the patient is placed in the lateral decubitus position to permit a two-team approach. For bilateral reconstruction, the operation begins with the patient supine with mastectomy and/or preparation of the chest vessels and the patient is then placed prone for simultaneous flap harvest. The flap is divided down to the gluteus maximus, and considerable beveling often is needed both superiorly and inferiorly to harvest enough tissue for good breast reconstruction. The flap is elevated from the muscle in the subfascial plane, and the perforators are approached from lateral to medial. A single large perforator usually is used (preferably lateral for easier dissection). Alternatively, several perforators lying in the same plane and in the direction of the gluteus maximus muscle fibers serve as well. The muscle is then separated in the direction of the muscle fibers to carefully dissect out the perforators (Fig. 53).[96]

The inferior gluteal artery passes through the greater sciatic foramen accompanied by the greater sciatic nerve, the internal pudendal vessels, and the posterior femoral cutaneous nerve. This oblique course through the gluteus maximus muscle dictates a longer pedicle for the IGAP than for the SGAP. Laterally positioned perforators have longer intramuscular courses and therefore give rise to longer pedicles compared with more medial perforators.

For the IGAP flap, the gluteal fold is noted with the patient in a standing position. The inferior limit of the flap is marked 1 cm inferior and parallel to the gluteal fold. The patient is then placed in the lateral position and the Doppler probe is used to locate perforating vessels from the inferior gluteal artery (Fig. 54).[271]

The sciatic nerve does not need to be exposed while the IGAP flap is being raised, although care must be taken to preserve the posterior femoral cutaneous nerve and the dense, lighter-colored medial fat pad that overlies the ischium to prevent postoperative discomfort when sitting. The sacral fascia is incised, revealing multiple communicating arterial and venous branches, and the dissection continues until the pedicle is of sufficient length and diameter. As mentioned above, the artery usually is the limiting factor.

The internal mammary vessels are preferred for the anastomosis because flap inset is easier. This is especially true when transferring an SGAP flap, which typically has a shorter pedicle than the IGAP flap.[272]

In a review of 142 gluteal artery perforator flaps, Guerra et al.[270] reported 98% overall flap survival, partial flap necrosis in 4%, and seroma in 2%. Flap pedicle dissection can be tedious, and care must be taken not to mistake the primary pedicle for a branch and not to clip the perforator. The need

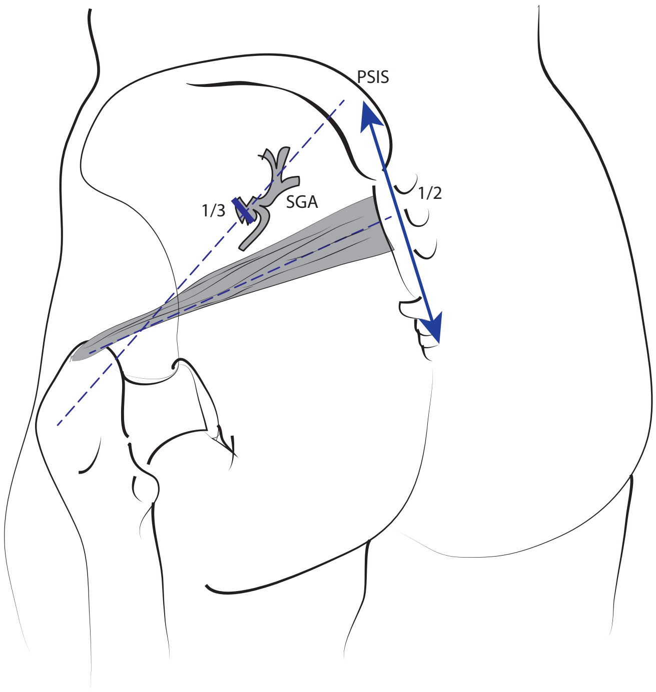

Figure 49. Superior gluteal artery (*SGA*) exits pelvis approximately one-third of the way along a line extending from the posterior superior iliac spine (*PSIS*) to the greater trochanter (*T*). (*Modified from Spear.*[96])

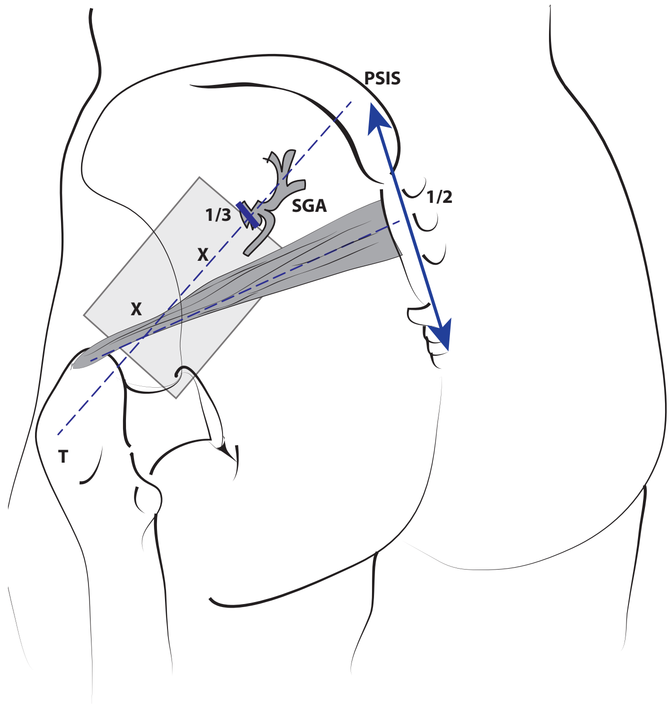

Figure 50. Perforators (*X*) usually are located lateral and distal to the exit point of the superior gluteal artery (*SGA*). *T*, greater trochanter; *PSIS*, posterior superior iliac spine. (*Modified from Spear.*[96])

to reposition the patient and growing dissatisfaction with the resultant distortion of the buttock contour and aesthetic units have led many surgeons to either modify the gluteal artery perforator flap design (more superior and lateral for SGAP) or choose other sources of tissue.

TMG AND TUG FLAPS

The TUG flap has recently gained popularity as an alternative to abdominal-based autologous breast reconstruction. The first anatomic study of a TMG flap was described by Yousif et al.[273] in 1992. The TUG flap was first reported in the literature for breast reconstruction in 2004 by Wechselberger and Schoeller[274] and by Arnez et al.[275] Both groups described their experiences with a small number of flaps for small to moderate-sized breast reconstruction in patients who either were not candidates for or did not desire an abdominal-based or latissimus flap. Women who have undergone previous abdominal surgery (e.g., abdominoplasty, liposuction, or gynecological procedures that might have damaged the DIEP system) and those who have inadequate abdominal volume, desire a thigh lift, and/or do not want donor-site morbidity associated with latissimus flap harvest can be excellent candidates for a TUG flap. The gracilis muscle flap is well known to most reconstructive surgeons, has consistent anatomy, is easy to harvest, and has minimal donor-site morbidity.

Anatomy

The patient is marked in a standing position, as is done for a thigh lift. The gracilis landmarks and its pedicle are identified 10 cm from the pelvic insertion. The skin paddle is centered over the pedicle. The

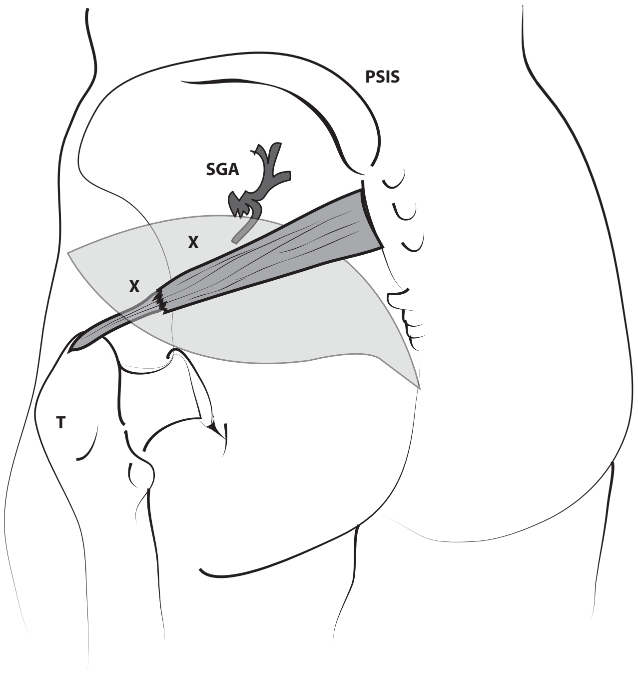

Figure 51. Design of SGAP flap is mostly horizontal with a slight oblique tilt laterally. *T*, greater trochanter; *X*, perforators; *SGA*, superior gluteal artery; *PSIS*, posterior superior iliac spine. (*Modified from Spear.*[96])

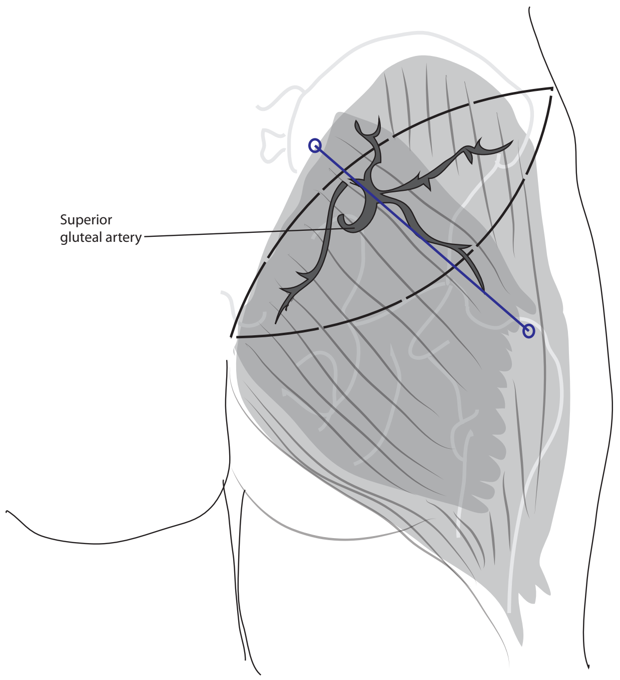

Figure 52. More obliquely oriented skin island of the SGAP flap. (*Modified from Spear.*[96])

superior mark is 1 cm below the inguinal crease, which classically extends from anterior to the posterior mid-axial line of the thigh. Limiting the anterior incision minimizes the risk of injury to the lymphatic system and minimizes visible scarring. The anterior dissection should proceed superficially until the saphenous vein is encountered to maximally preserve all lymphatic tissue because very little adipose tissue typically is available to recruit in this region. The lower marking is based on pinch test assessment of tissue laxity to create an elliptical skin paddle that incorporates the proximal third of the muscle and permits direct closure without excessive tension. The pedicle, a branch of the medial circumflex femoral artery, is 6 cm long and 1 to 2 mm in diameter for both artery and vein. Some variations in the pedicle have been noted, and surgeons should proceed cautiously to identify and preserve all critical branches of the main perforators. By coning the flap configuration to increase projection, immediate nipple reconstruction can be performed using the excess tissue at the peak of the cone. The flap typically is transferred contralaterally because of pedicle orientation and can be stacked for extra volume. Beveling the flap dissection to incorporate additional adipose tissue in the inferior and mostly posterior regions is helpful to increase flap volume. Caution must be taken not to bevel substantially in the cranial direction to avoid harvesting the ischial fat pad, which serves an important role during sitting. Autologous fat grafting is also a useful tool for flap volume augmentation and can be performed either primarily or secondarily. The TUG flap is considered a reasonable first-line choice for patients with smaller breasts and favorable habitus and is commonly a second-line option to abdominal-based flaps with

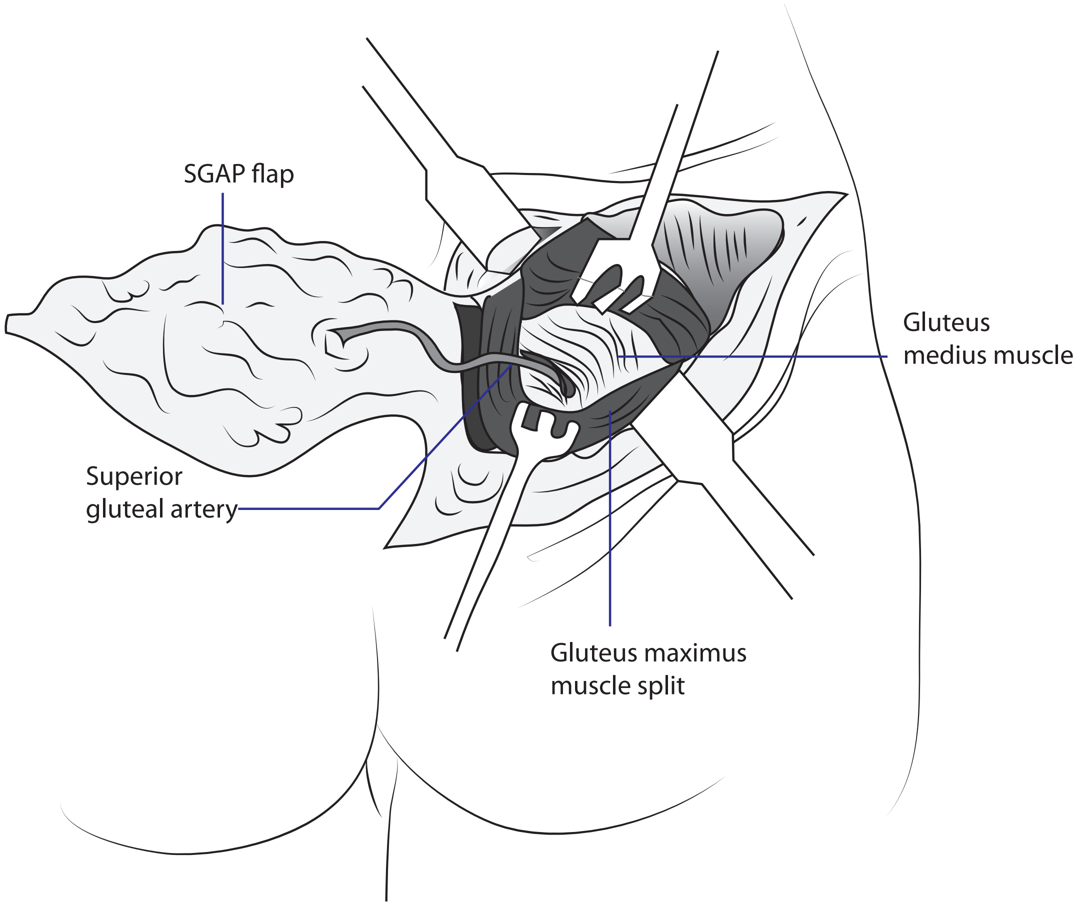

Figure 53. Superior gluteal vessels are dissected through the retracted gluteus maximus muscle. (*Modified from Spear.*[96])

minimal donor-site morbidity.

Schoeller et al.[276] subsequently described their experience with 111 patients with three flap failures, two partial necroses, 10 wound healing complications, five hematomas, and 49 sensory disturbances in the posterior thigh. The series had 12 take-backs, nine of which were successfully salvaged. Several subsequent studies[277–280] reported similar problems, primarily with seroma, hematoma, and wound dehiscence, and modifications to address the concerns, such as flap inset and increasing flap volume. Vega et al.[277] achieved 100% success with 27 flaps with intraoperative thrombosis of 14% and a major complication rate of 7%. Fattah et al.[278] presented a report of 12 patients with 19 flaps and only one flap loss. Buntic et al.[279] applied 32 flaps to 20 patients with no flap losses, one take-back, eight donor-site wound complications, and five seromas. Saint-Cyr et al.[280] described 13 patients with 24 flaps with modification to incorporate extra volume, which was complicated by one seroma, two dehiscences, and two partial flap losses. Anecdotal experiences suggest that postoperative infection is likely an under-reported complication. Unpublished data by Venkat Ramakrishnan (82 flaps, 54 patients) showed 23 cases (28%) of infection, mostly Gram-negative organisms, suggesting a need for appropriate broad-spectrum antibiotic coverage for thigh-based flaps.

PAP FLAP

Allen et al.[281] recently described a new flap based on the PAP to capture posterior thigh tissue for breast

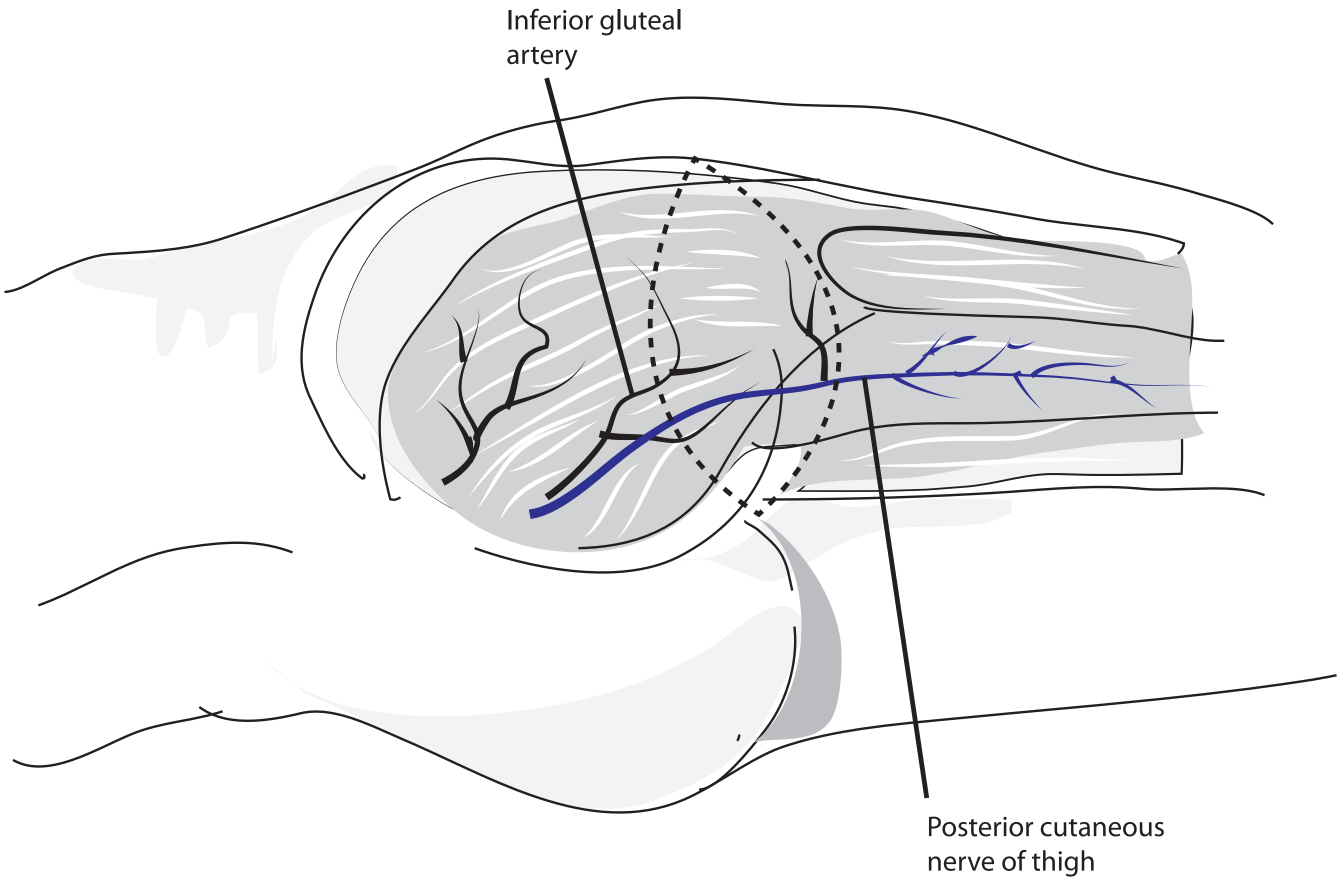

Figure 54. Illustration of the anatomy of the inferior gluteal free flap shows the continuation of the inferior gluteal artery running with the posterior cutaneous nerve of the thigh. (*Modified from Kroll.*[271])

reconstruction in 27 patients. The ideal patient has small to moderate-sized breasts and typically is not a candidate for other autologous tissue transfer because of previous surgical intervention or body habitus. This flap avoids sacrificing any muscle function and minimizes risks of lymphedema by avoiding dissection anteriorly near lymphatic channels.

The posterior thigh tissue is bordered by the iliotibial tract and adductor muscles horizontally and the gluteal fold and popliteal fossa vertically. The profunda femoris artery enters the posterior compartment of the thigh and typically gives off three main perforators. The first perforator supplies the adductor magnus and gracilis, and the second and third perforators supply the semimembranosus, biceps femoris, and vastus lateralis.

Preoperative planning with CT or MRI in addition to handheld Doppler probe is used to map the perforators. The markings are 1 cm inferior to the gluteal fold and approximately 7 cm below, designed as an ellipse so the scar does not extend onto the visible lateral or medial thigh outside of the gluteal fold, typically 27 cm transversely. Early flaps were harvested with the patient prone, necessitating repositioning, but the authors later transitioned to a supine frog leg position. For patients with limited hip abduction, this flap is more technically challenging to harvest in a supine position and instead can be harvested prone.

The medial perforators that enter posterior to the gracilis muscle tend to be larger and easier to harvest when the patient is in a supine position.

Pedicle length is up to 13 cm (average, 9.9 cm), with an average artery size of 2.2 cm and an average vein size of 2.9 cm. Flap size ranged from 235 to 695 g (mean, 385 g). The buttocks contour remains undisturbed, the anterior lymphatic channels are not injured during dissection, the scar is not visible anteriorly, and the posterior femoral nerve is available for flap neurotization. In this single case series, only two flaps suffered <10% fat necrosis and donor-site morbidity included one seroma and one hematoma.[281] Similar to the TUG flap, limited beveling during the dissection permits the surgeon to improve the flap volume. Postoperatively, patients are permitted to ambulate and to sit the next day unless there is concern regarding excessive tension of the donor-site closure. Broad-spectrum antibiotics to include Gram-negative organisms should be considered. Early anecdotal experience with the PAP flap is encouraging, and this flap is a nice addition to the armamentarium of the breast reconstructive surgeon.

PREOPERATIVE IMAGING FOR PERFORATOR FLAPS

As perforator flaps have gained popularity among surgeons and patients, additional tools have been considered to improve perforator dissection and selection. Simple Doppler ultrasonography, computed tomographic angiography (CTA), magnetic resonance angiography (MRA), dynamic infrared thermography (DIRT), fluorescent angiography, and near-infrared spectroscopy are imaging modalities that currently are used in perforator flap reconstruction. Static preoperative imaging can be used to map the location of dominant perforators but does not provide dynamic evaluation of tissue perfusion. Patients with previous surgical injury or trauma to the proposed flap perforators might benefit from imaging to confirm whether the flap can be safely performed or whether conversion to an alternative tissue source is necessary. Preoperative imaging is more commonly recommended in planning non-abdominal-based flaps, such as SGAP, IGAP, thoracodorsal artery perforator, and PAP flaps. However, concern remains regarding the additional costs, inconvenience to the patient, additional radiation exposure, and discovery of incidentalomas.[282]

Ultrasonography is minimally invasive and does not expose the patient to radiation, but a handheld Doppler probe can result in false positive results as high as 46%.[283] CTA is a widely available imaging modality that can precisely localize perforators with the use of intravenous injection of contrast material. Rozen et al.[284,285] found CTA to be superior to Doppler ultrasonography and identified different branching patterns for the DIEA. Using CTA can decrease operative time and increase the number of perforators included in the flap.[286] Further technological advancements allow three-dimensional reconstructions, which can clarify the extent of intramuscular dissection needed for medial versus lateral row perforators and thereby expedite perforator identification and selection. To avoid the risks of radiation exposure, MRA has emerged as an alternative tool and several authors[287,288] have found excellent correlation between imaging and intraoperative findings. Schaverien et al.[289] found decreased DIEP flap harvest time and reduction in partial flap failure. Thermal imaging with DIRT applies a technique of surface cooling and then rewarming; an infrared camera detects hot spots to correlate with perforator location. This technology was used by de Weerd et al.[290] in 23 patients undergoing DIEP flap reconstruction. Rapid rewarming was associated with more dominant perforators.[290] Fluorescent angiography, the SPY Elite system, is the newest modality used by surgeons to identify perforators and the cutaneous perfusion territory. SPY imaging can provide useful information to the surgeon regarding perfusion of the DIEP flap based on medial or lateral perforators across the midline or laterally to design the flap to minimize fat necrosis. The technology can also verify patency of the anastomoses and identify venous congestion intraoperatively.

RECIPIENT VESSELS

The transition from axillary lymph node dissection to SLN biopsy has resulted in a change in breast reconstruction practices. For example, dissection of axillary tissue to expose the thoracodorsal vessels is less frequent and the internal mammary arteriovenous pedicle is more commonly used for anastomosis. In addition, problem of injury to the thoracodorsal vessels from axillary surgery to remove additional nodes has largely been resolved.

IMA Anatomy

Clark et al.[291] described the anatomy of the internal mammary vessels as observed in 10 fresh cadavers. At the level of the third rib, the vein was at least 3 mm in diameter on the left in 40% of cases and on the right in 70% of cases. The veins became smaller at the level of the fourth rib, bifurcating on the left in 90% and on the right in 40% of cases. At or below the fourth interspace, the IMV became unsuitable for consistent venous anastomosis. The authors recommended approaching the recipient internal mammary vessels at the level of the third rib (Fig. 43).[96]

The recommendation was echoed by Feng,[292] who also found the right IMA and IMV (mean diameters of 2.52 and 2.89 mm, respectively) to be consistently and significantly larger than the left internal mammary vessels (2.30 and 2.31 mm, respectively) ($P = 0.046$ for arterial difference; $P = 0.002$ for venous difference). At the level of the third rib, the diameter of the IMA is significantly larger than that of the thoracodorsal artery ($P < 0.001$) (Fig. 55).[96,292] The caliber of the veins is similar, however. In relation to the DIEA, the IMA tends to be larger in diameter and the thoracodorsal artery is smaller.[292] Feng concluded that the internal mammary recipient site is an important and sometimes superior alternative to the axillary recipient site because of its larger artery, especially when the axilla is scarred. For smaller free flaps, such as a hemi-TRAM flap as is used in bilateral TRAM flap reconstructions, the internal mammary site is valuable because it allows exact placement of a smaller flap in the breast area.[292] At the cranial edge of the fourth rib, both the IMA and IMV have a diameter of at least 1 mm.[293]

Outcomes Studies

Many authors report using the IMA and IMV as recipient vessels in free TRAM flap breast reconstruction. Dupin et al.[219] reviewed their experience with 110 consecutive free flap breast reconstructions with the IMA and IMV as recipient vessels. The overall successful transfer rate in their series was 99%.

The internal mammary vessels are ideally located close to the recipient tissue bed, allowing for maximal flap mobility and freedom during insetting, which can result in a superior aesthetic result without lateral fullness. Medial breast mound shaping is possible, with slight ptosis and good symmetry. The IMA also accommodates a variety of flaps, including those with shorter pedicles that might not reach the chest wall from the axilla. Vath et al.[294] presented a report of 912 consecutive free-flap breast reconstructions that were performed during an 8-year period and noted that 591 (65%) were immediate and 321 (35%) were delayed. In four (0.4 %) cases, the internal mammary vessels were not used. The overall flap survival rate in that series was 99%.

Dupin et al.[219] and Shaw[295] noted the following advantages of the internal mammary vessels over the thoracodorsal vessels in breast reconstruction:

- No need to dissect in the axilla, which can be difficult in secondary cases
- No brachial plexus palsy from axillary dissection
- Size match between the internal mammary vessels and those of the DIEA system
- Excellent arterial flow
- No lateral fullness, which can be a problem when the axillary vessels are used
- Breast mound placement can be as medial as desired
- Surgeon and assistant comfort is enhanced

Concerns regarding the use of the internal

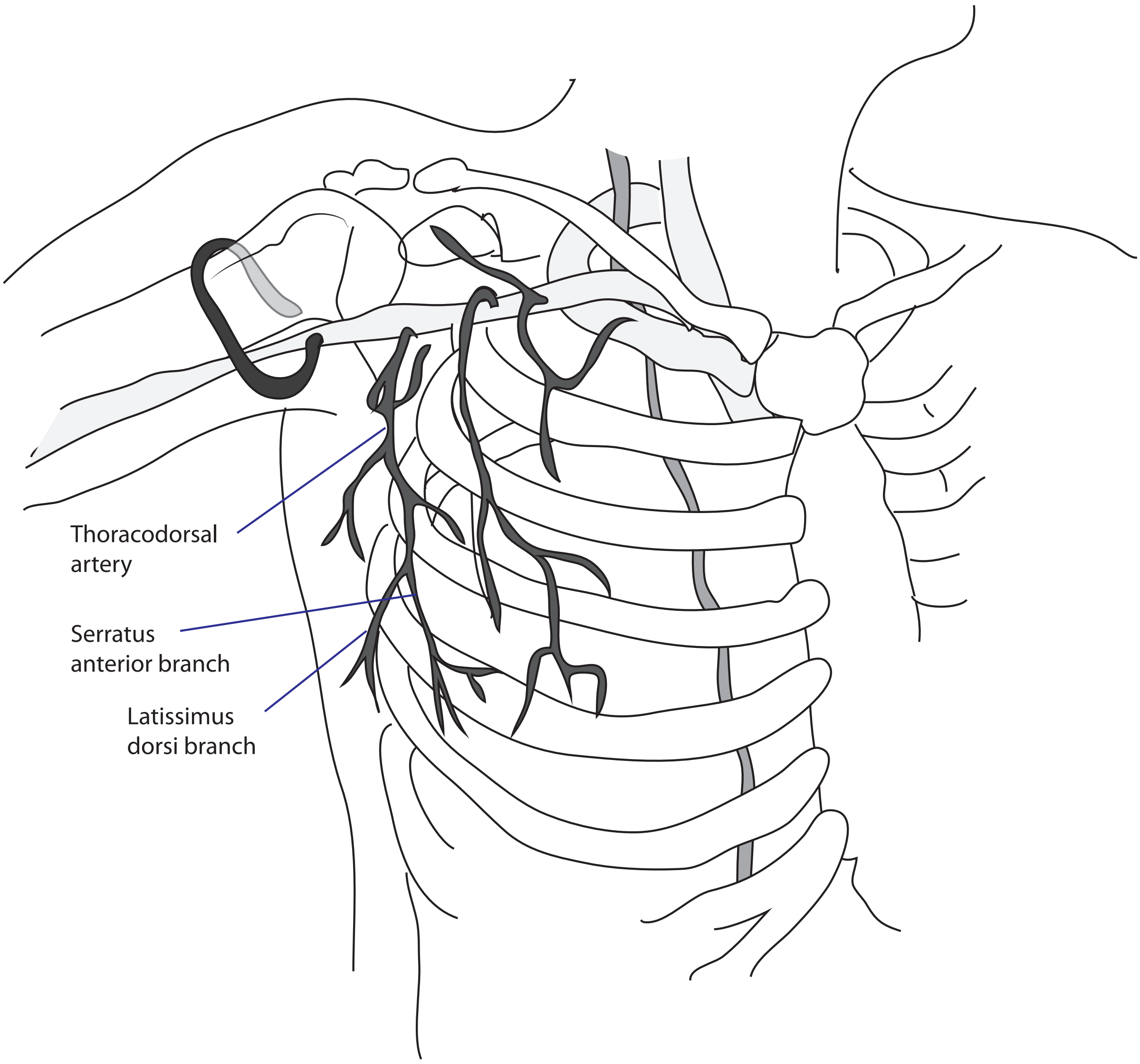

Figure 55. Anatomy of the thoracodorsal and internal mammary vessels, either of which can be used as recipients for the inferior gluteal artery flap anastomosis. (*Modified from Spear.*[96])

mammary vessels relate to chest wall contour deformity and potential need of the vessels in future coronary artery bypass grafting. Contour defects from missing costal cartilage are a difficult problem in this very conspicuous cosmetic site. Schwabegger et al.[296] reported five substantial contour defects in 36 cases. Majumber and Batchelor[297] avoided contour defects in their series of 27 cases by carefully placing subcutaneous TRAM flap tissue over the defect.

Disadvantages of the internal mammary vessels compared with the thoracodorsal vessels as recipients for free TRAM flap breast reconstruction include the following:[295]

- Exposure can be difficult without a more medial incision and a more visible scar.
- Extra time is needed for dissection of the ribs, intercostal muscles, and vessels.
- The IMV have much thinner walls and require greater attention during the dissection.

- The IMA is lost as a potential graft vessel for any future coronary bypass surgery.
- A rib must be resected.
- Additional dissection and time are needed if sentinel node biopsy is indicated.

Gill et al.[235] successfully reached the recipient vessels via the second or third rib interspace without cartilage excision. In cases of narrow interspace, the authors excised a portion of rib cartilage above and below the entry wound to avert contour deformity.

To rule out heart disease, Nahabedian et al.[298] evaluated 240 candidates for breast reconstruction who were 50 years or older at the time of initial consultation. Only two (0.8%) women were found to have coronary artery disease, and they received implants alone. The internal mammary vessels were used in 35 of 114 free tissue transfers with no adverse sequelae. The low rate of coronary artery disease in this patient group and the range of alternative grafts for coronary revascularization suggest that use of the internal mammary vessels, if required in this population, will not adversely affect future coronary procedures.

Although research has shown that either the internal mammary or thoracodorsal vessels can be used safely to yield acceptable results, surgeons should be prepared with a backup conversion plan in case the intended recipient vessels appear unusable for free-tissue transfer.[299]

Effect of Radiotherapy

In the delayed setting after axillary dissection and radiotherapy, the scarred bed can jeopardize thoracodorsal vessel dissection[297,300] and adversely affect microvascular anastomosis.[292,301] Radiation does not seem to negatively affect internal mammary vessels.[219] A study using Doppler ultrasonography to compare radiated versus non-radiated internal mammary vessels found no negative consequences of radiation on vessel diameter or blood flow.[302]

Temple et al.[303] compared the use of internal mammary and thoracodorsal recipient vessels in 123 patients who underwent delayed TRAM flap reconstruction after radiotherapy. Free flaps were completed in 106 patients and conventional pedicled transfers in 17 because of unusable recipient vessels. Among the patients receiving free flaps, the internal mammary vessels were used for anastomosis in 45 and the thoracodorsal vessels in 55. Six patients had anastomoses to other vessels. The internal mammary vessels were rejected in 11 (20%) of 56 cases, and the thoracodorsal vessels were rejected in 19 (26%) of 74. In cases with unusable internal mammary vessels, five (45%) of 11 had inadequate veins and three (27%) of 11 had inadequate arteries. In three (27%) cases, both vessels were inadequate. Among 19 cases with unusable thoracodorsal vessels, 16 (84%) of 19 were excessively scarred and two (11%) had inadequate vessels. In one (5%) of the 19 patients, the vessels were absent. Outcomes were similar regardless of recipient vessels used.

IMA Perforators

In selected cases, it might be possible to use the IMA perforators to minimize morbidity at the recipient site.[304] An anatomic study of 40 hemithoraxes by Taylor and Palmer[183] located the largest internal thoracic artery perforator in the first four rib spaces and most commonly (60% of the time) in the second intercostal space. A study by Munhoz et al.[305] of 32 parasternal regions from 16 fresh cadavers found 22 perforators, 64% of which were at the second intercostal space and 50% of which contained one artery and one vein. The mean external perforator diameter was 0.85 mm. Clinically, the authors followed the course of 36 patients who underwent 38 DIEP and two SGAP flap breast reconstructions (31 immediate, four bilateral). Anastomoses to perforators at the second and third intercostal spaces were successful in 13 (33%) cases.

Haywood et al.[306] selected perforators that were larger than 1.5 mm in diameter in the second or third interspace and found that anastomoses to those vessels was successful in 21 (39%) of 54 consecutive cases. No flap losses, either complete or partial, occurred. Delayed reconstruction was performed in 50% of cases.

AUTOLOGOUS FAT GRAFTING

Autologous fat grafting remains a controversial topic after an initial statement presented in 1987 by the American Society of Plastic Surgery (ASPS) that fat grafting would compromise breast cancer detection and should therefore be prohibited.[307] The statement was subsequently challenged by Coleman and Saboeiro.[308] Even recently, in 2009, the ASPS Fat Graft Task Force[309] was unable to make specific recommendations because of limited scientific data on the safety and efficacy of this particular type of fat transfer. However, the Task Force did assign a grade of B to fat grafting to the breast for both aesthetic and reconstructive purposes, indicating it as a "recommendation." This was based on level I through level V evidence supporting the safety of the fat-grafting technique.

Further, the European experience has launched an increasing interest in autologous fat grafting in the United States for an ever expanding variety of clinical applications, addressing both cosmetic and reconstructive cases. Today, autologous fat grafting is used for correction of facial aging, breast reconstruction, breast and buttocks augmentation, acceleration of healing in radiated wounds, and hand rejuvenation. Although the European experience includes fat grafting to address lumpectomy defects and augmentation of the contralateral breast for symmetry, concern remains regarding oncological safety. Surgeons must also be aware of and be prepared to address potential postoperative issues, including infection, fat necrosis, oil cysts, microcalcifications, hematoma, seroma, possible interference with cancer detection, and the need for multiple sessions. Similar radiographic changes often are noted after reduction mammoplasty. Experienced radiologists should therefore be able to distinguish these postoperative changes shown by ultrasonography or mammography from malignant changes that necessitate further evaluation or biopsy.[310] Another theoretical concern is the angiogenic growth factors associated with fat stem cells from the transfer and the possibility of affecting local recurrence. However, no clinical evidence currently exists to support this theory and further prospective data are needed.

Rigotti et al.[311] evaluated 137 patients who received fat grafting after mastectomy for a median follow-up duration of 7.6 years and found no difference in relapse rate. One of the largest series, presented by Delay et al.,[312] included 880 procedures performed over 10 years. The authors noted no increased rate of recurrence or development of new cancer. Complications were minimal: one donor-site infection, six recipient site infections, one pneumothorax, and a 3% fat necrosis rate. These data are in agreement with data from the Milan-Paris-Lyon multi-center study published by Petit et al.,[313] which found a 2.8% complication rate, overall oncological occurrence of 5.6%, and locoregional recurrence of 2.4% in 513 patients (646 lipofilling procedures). One of the largest United States case series (107 patients), presented by Losken et al.,[314] reported an 11% complication rate and 25% need for repeated grafting, especially in patients who had received radiation treatment. These studies suggest that autologous fat grafting has a relatively low complication rate and is likely oncologically safe but that future studies are needed to delineate the safety of this procedure.

Fat Grafting for Contour and Volume

Most commonly, fat grafting is used to address contour irregularities or volume asymmetry after either implant or tissue reconstruction. However, the volume of fat injected at each session is limited, necessitating multiple stages. Spear et al.[315] described their experience with 37 patients and 43 breast contour deformities. The patient cohort experienced one case of cellulitis and three cysts. The authors noted substantial improvement in 21% of the cases, minimal to moderate improvement in 64%, and no improvement in 15%. In 200 cases, Sinna et al.[316] used autologous fat grafting to enhance the volume of the extended latissimus dorsi flap for breast reconstruction. The authors averaged 176 mL per session (244 total sessions) and noted very satisfactory results in 80% of the patients and 1.5% complications. de Blacam et al.[317] also found low complication rates with good improvement in volume and contour in 49 patients (68 breasts), with 52% requiring multiple sessions.

Total Breast Reconstruction with Fat Grafting

Total breast reconstruction with fat alone cannot be achieved in a single procedure, but two common techniques are currently available. One option uses internal expansion with a tissue expander to stretch the skin envelope and then sequential deflations during fat injection procedures, requiring a final stage for implant removal. Alternatively, external expansion using the Brava Breast Enhancement and Shaping System (Brava, LLC; Miami, FL), which consists of a rigid bra with negative pressure, has been used to expand the breast skin externally before injection of fat into the space created. This requires considerable patient compliance and motivation, as the system must be worn for several weeks before each procedure. Khouri et al.[318] reported a 6-year experience with cosmetic augmentation, achieving a mean volume of 233 mL per breast in 81 patients. The first reported case of complete breast reconstruction using fat only was published by Babovic.[319] An alternative technique, described by Serra-Renom et al.,[320] uses puckering stitches, cone formation, and inframammary fold repositioning with serial fat grafting.

Fat Grafting and Radiation

Autologous fat grafting can also function to improve radiation-damaged tissue and decrease the morbidity associated with implant reconstruction in high-risk patients. Serra-Renom et al.[321] studied 65 mastectomized patients who received radiation and subsequently reconstruction with subpectoral implants and fat grafting to create new subcutaneous tissue and noted no capsular contracture beyond Baker grade I at a mean follow-up of 1 year. Sarfati et al.[322] essentially pretreated the radiated skin flaps with one to three sessions of fat grafting to thicken the tissue (mean, 115 mL per session) before implant reconstruction. Three minor complications and one explantation occurred in 28 patients. Salgarello et al.[323] achieved similar success with 16 patients who had undergone radiation and who presented for delayed reconstruction by performing several sessions of fat grafting before implant placement. Fat grafting might be a useful tool to combat the effects of radiation damage and to improve outcomes in patients with implant-based reconstruction.

Additional studies are required to prove the efficacy and safety of fat grafting in the breast. Data on optimizing injection volume, long-term graft survival and volume, complications, incidence and discrimination of postoperative changes shown by imaging, local recurrence rates, stem cell enrichment, and comparative studies of the graft harvesting, processing, and delivery techniques are needed. Autologous fat grafting, however, is a promising technique in reconstructive breast surgery with the potential to enhance or even supplant implants and tissue-based breast reconstruction.

REFERENCES

1. Halsted WS. The results of radical operations for the cure of cancer of the breast. In, *Transactions of the Meeting of the American Surgical Association*. Boston: American Surgical Association; 1907:61–79. Also available at http://books.google.com/books, last accessed, October 6, 2013.

2. Czerny V. Plastischer Ersatz der Brustdrusse durch ein Lipom: Drei Plastiche Operationen [in German]. *Verhandl Deutsch Gesellsch Chir* 1895;24:216.

3. Ombredanne L. Restauration autoplastique du sein après amputation totale [in French]. *Trb Med* 1906;4:325.

4. Tansini I. Sopra il mio nuovo processo di amputazione della mammella [in Italian]. *Gazetta Medica Italiana* 1906;57:141.

5. Maxwell GP. Iginio Tansini and the origin of the latissimus dorsi musculocutaneous flap. *Plast Reconstr Surg* 1980;65:686–692.

6. D'Este S. La technique de l'amputation de la mamelle pour carcinome mammaire [in French]. *Rev Chir* 1912;45:194.

7. Losken A, Jurkiewicz MJ. History of breast reconstruction. *Breast Dis* 2002;16:3–9.

8. Gillies H, Millard DR. *The Principles and Art of Plastic Surgery*. Boston: Little Brown; 1957.

9. Yannilos HG. The use of composite tube pedicle in the reconstruction of breast defect with subsequent cosmetic repair of the donor breast. *Plast Reconstr Surg* 1950;6:396–399.

10. Harris HI. Automammaplasty. *J Int Coll Surg* 1949;12:827–839.

11. Millard DR Jr. Breast reconstruction after a radical mastectomy. *Plast Reconstr Surg* 1976;58:283–291.

12. Cronin TD, Gerow FJ. Augmentation mammaplasty: A new "natural feel" prosthesis. In: *Transactions of the Third International Congress of Plastic and Reconstructive Surgery*. Amsterdam: Excerpta Medica; 1964:41–49.

13. Snyderman RK, Guthrie RH. Reconstruction of the female breast following radical mastectomy. *Plast Reconstr Surg* 1971;47:565–567.

14. Uroskie TW Jr, Colen LB. History of breast reconstruction. *Semin Plast Surg* 2004;18:65–69.

15. Grotting JC, Beckenstein MS, Arkoulakis NS. The art and science of autologous breast reconstruction. *Breast* 2003;9:350–360.

16. Orticochea M. Use of the buttock to reconstruct the breast. *Br J Plast Surg* 1973;26:304–309.

17. Arnold PG, Hartrampf CR, Jurkiewicz MJ. One-stage reconstruction of the breast, using the transposed greater omentum: Case report. *Plast Reconstr Surg* 1976;57:520–522.

18. Fujino T, Harasina T, Aoyagi F. Reconstruction for aplasia of the breast and pectoral region by microvascular transfer of a free flap from the buttock. *Plast Reconstr Surg* 1975;56:178–181.

19. Fujino T, Harashina T, Enomoto K. Primary breast reconstruction after a standard radical mastectomy by a free flap transfer: Case report. *Plast Reconstr Surg* 1976;58:371–374.

20. Le-Quang C. Secondary microsurgical reconstruction of the breast and free inferior gluteal flap [in French]. *Ann Chir Plast Esthet* 1992;37:723–741.

21. Schneider WJ, Hill HL Jr, Brown RG. Latissimus dorsi myocutaneous flap for breast reconstruction. *Br J Plast Surg* 1977;30:277–281.

22. Muhlbauer W, Olbrisch R. the latissimus dorsi myocutaneous flap for breast reconstruction. *Chir Plast (Berlin)* 1977;4:27.

23. McCraw JB, Dibbell DG, Carraway JH. Clinical definition of independent myocutaneous vascular territories. *Plast Reconstr Surg* 1977;60:341–352.

24. Bostwick J III, Vasconez LO, Jurkiewicz MJ. Breast reconstruction after a radical mastectomy. *Plast Reconstr Surg* 1978;61:682–693.

25. Serafin D, Georgiade NG. Transfer of free flaps to provide well-vascularized, thick cover for breast reconstructions after radical mastectomy. *Plast Reconstr Surg* 1978;62:527–536.

26. Holmström H. The free abdominoplasty flap and its use in breast reconstruction: An experimental study and clinical case report. *Scand J Plast Reconstr Surg* 1979;13:423–427.

27. Hartrampf CR, Scheflan M, Black PW. Breast reconstruction with a transverse abdominal island flap. *Plast Reconstr Surg* 1982;69:216–225.

28. Robbins TH. Rectus abdominis myocutaneous flap for breast reconstruction. *Aust N Z J Surg* 1979;49:527–530.

29. Drever JM. Total breast reconstruction. *Ann Plast Surg* 1981;7:54–61.

30. Dinner MI, Labandter HP, Dowden RV. The role of the rectus abdominis myocutaneous flap in breast reconstruction. *Plast Reconstr Surg* 1982;69:209–215.

31. Bunkis J, Walton RL, Mathes SJ, Krizek TJ, Vasconez LO. Experience with the transverse lower rectus abdominis operation for breast reconstruction. *Plast Reconstr Surg* 1983;72:819–829.

32. Scheflan M, Dinner MI. The transverse abdominal island flap: Part I. Indications, contraindications, results, and complications. *Ann Plast Surg* 1983;10:24–35.

33. Sakai S, Takahashi H, Tanabe H. The extended vertical rectus abdominis myocutaneous flap for breast reconstruction. *Plast Reconstr Surg* 1989;83:1061–1069.

34. Scheflan M, Dinner MI. The transverse abdominal island flap: Part II. Surgical technique. *Ann Plast Surg* 1983;10:120–129.

35. Shestak KC. Breast reconstruction with a pedicled TRAM flap. *Clin Plast Surg* 1998;25:167–182.

36. Radovan C. Breast reconstruction after mastectomy using the temporary expander. *Plast Reconstr Surg* 1982;69:195–208.

37. Becker H. Breast reconstruction using an inflatable breast implant with detachable reservoir. *Plast Reconstr Surg* 1984;73:678–683.

38. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. *Ann Plast Surg* 1994;32:32–38.

39. Allen RJ, Tucker C Jr. Superior gluteal artery perforator free flap for breast reconstruction. *Plast Reconstr Surg* 1995;95:1207–1212.

40. Grotting JC. The free abdominoplasty flap for immediate breast reconstruction. *Ann Plast Surg* 1991;27:351–354.

41. Carlson GW, Bostwick J III, Styblo TM, Moore B, Bried JT, Murray DR, Wood WC. Skin-sparing mastectomy: Oncologic and reconstructive considerations. *Ann Surg* 1997;225:570–578.

42. Freeman BS. Subcutaneous mastectomy for benign breast lesions with immediate or delayed prosthetic replacement. *Plast Reconstr Surg Transplant Bull* 1962;30:676–682.

43. Toth BA, Lappert P. Modified skin incisions for mastectomy: The need for plastic surgical input in preoperative planning. *Plast Reconstr Surg* 1991;87:1048–1053.

44. Skoll PJ, Hudson DA. Skin-sparing mastectomy using a modified Wise pattern. *Plast Reconstr Surg* 2001;110:214–217.

45. Hidalgo DA. Aesthetic refinement in breast reconstruction: Complete skin-sparing mastectomy with autogenous tissue transfer. *Plast Reconstr Surg* 1998;102:63–72.

46. Schuster RH, Kuske RR, Young VL, Fineberg B. Breast reconstruction in women treated with radiation therapy for breast cancer: Cosmesis, complications, and tumor control. *Plast Reconstr Surg* 1992;90:445–454.

47. Evans GR, Schusterman MA, Kroll SS, Miller MJ, Reece GP, Robb GL, Ainslie N. Reconstruction and the radiated breast: Is there a role for implants? *Plast Reconstr Surg* 1995;96:1111–1118.

48. Spear SL, Onyewu C. Staged breast reconstruction with saline-filled implants in the irradiated breast: Recent trends and therapeutic implications. *Plast Reconstr Surg* 2000;105:930–942.

49. Cunnick GH, Mokbel K. Skin-sparing mastectomy. *Am J Surg* 2004;188:78–84.

50. Disa JJ, Cordeiro PG, Heerdt AH, Petrek JA, Borgen PJ, Hidalgo DA. Skin-sparing mastectomy and immediate autologous tissue reconstruction after whole-breast irradiation. *Plast Reconstr Surg* 2003;111:118–124.

51. Rainsbury RM. Skin-sparing mastectomy. *Br J Surg* 2006;93:276–281.

52. No authors listed. NIH Consensus Conference: Treatment of early-stage breast cancer. *JAMA* 1991;265:391–395.

53. Peyser PM, Abel JA, Straker VF, Hall VL, Rainsbury RM. Ultra-conservative skin-sparing "keyhole" mastectomy and immediate breast and areola reconstruction. *Ann R Coll Surg Engl* 2000;82:227–235.

54. Simmons RM, Fish SK, Gayle L, La Trenta GS, Swistel A, Christos P, Osborne MP. Local and distant recurrence rates in skin-sparing mastectomies compared with non-skin-sparing mastectomies. *Ann Surg Oncol* 1999;6:676–681.

55. Carlson GW. Trends in autologous breast reconstruction. *Semin Plast Surg* 2004;18:79–87.

56. DeBono R, Thompson A, Stevenson JH. Immediate versus delayed free TRAM breast reconstruction: An analysis of perioperative factors and complications. *Br J Plast Surg* 2002;55:111–116.

57. Newman MI, Samson MC. The application of laser-assisted indocyanine green fluorescent dye angiography in microsurgical breast reconstruction. *J Reconstr Microsurg* 2009;25:21–26.

58. Newman MI, Samson MC, Tamburrino JF, Swartz KA. Intraoperative laser-assisted indocyanine green angiography for the evaluation of mastectomy flaps in immediate breast reconstruction. *J Reconstr Microsurg* 2010;26:487–492.

59. Komorowska-Timek E, Gurtner GC. Intraoperative perfusion mapping with laser-assisted indocyanine green imaging can predict and prevent complications in immediate breast reconstruction. *Plast Reconstr Surg* 2010;125:1065–1073.

60. Zenn MR. Fluorescent angiography. *Clin Plast Surg* 2011;38:293–300.

61. Pestana IA, Coan B, Erdmann D, Marcus J, Levin LS, Zenn MR. Early experience with fluorescent angiography in free-tissue transfer reconstruction. *Plast Reconstr Surg* 2009;123:1239–1244.

62. Liu DZ, Mathes DW, Zenn MR, Neligan PC. The application of indocyanine green fluorescence angiography in plastic surgery. *J Reconstr Microsurg* 2011;27:355–364.

63. Woerdeman LA, Hage JJ, Hofland MM, Rutgers EJ.

A prospective assessment of surgical risk factors in 400 cases of skin-sparing mastectomy and immediate breast reconstruction with implants to establish selection criteria. *Plast Reconstr Surg* 2007;119:455–463.

64. Carlson GW, Losken A, Moore B, Thornton J, Elliott M, Bolitho G, Denson DD. Results of immediate breast reconstruction after skin-sparing mastectomy. *Ann Plast Surg* 2001;46:222–228.

65. Barton FE Jr, English JM, Kingsley WB, Fietz M. Glandular excision in total glandular mastectomy and modified radical mastectomy: A comparison. *Plast Reconstr Surg* 1991;88:389–394.

66. Carlson GW, Grossl N, Lewis MM, Temple JR, Styblo TM. Preservation of the inframammary fold: What are we leaving behind? *Plast Reconstr Surg* 1996;98:447–450.

67. Beer GM, Varga Z, Budi S, Seifert B, Meyer VE. Incidence of the superficial fascia and its relevance in skin-sparing mastectomy. *Cancer* 2002;94:1619–1625.

68. Magno L, Bignardi M, Micheletti E, Bardelli D, Plebani F. Analysis of prognostic factors in patients with isolated chest wall recurrence of breast cancer. *Cancer* 1987;60:240–244.

69. Kennedy MJ, Abeloff MD. Management of locally recurrent breast cancer. *Cancer* 1993;71:2395–2409.

70. Slavin SA, Schnitt SJ, Duda RB, Houlihan MJ, Koufman CN, Morris DJ, Troyan SL, Goldwyn RM. Skin-sparing mastectomy and immediate reconstruction: Oncologic risks and aesthetic results in patients with early-stage breast cancer. *Plast Reconstr Surg* 1998;102:49–62.

71. Medino-Franco H, Vasconez LO, Fix RJ, Heslin MJ, Beenken SW, Bland KI, Urist MM. Factors associated with local recurrence after skin-sparing mastectomy and immediate breast reconstruction for invasive breast cancer. *Ann Surg* 2002;235:814–819.

72. Carlson GW, Styblo TM, Lyles RH, Bostwick J, Murray DR, Staley CA, Wood WC. Local recurrence after skin-sparing mastectomy: Tumor biology or surgical conservatism? *Ann Surg Oncol* 2003;10:108–112.

73. Gilliland MD, Barton RM, Copeland EM III The implications of local recurrence of breast cancer as the first site of therapeutic failure. *Ann Surg* 1983;197:284–287.

74. Carlson GW, Styblo TM, Lyles RH, Jones G, Murray DR, Staley CA, Wood WC. The use of skin-sparing mastectomy in the treatment of breast cancer: The Emory experience. *Surg Oncol* 2003;12:265–269.

75. Kroll SS, Khoo A, Singletary SE, Ames FC, Wang BG, Reece GP, Miller MJ, Evans GR, Robb GL. Local recurrence risk after skin-sparing and conventional mastectomy: A 6-year follow up. *Plast Reconstr Surg* 1999;104:421–425.

76. Toth BA, Forley BG, Calabria R. Retrospective study of the skin-sparing mastectomy in breast reconstruction. *Plast Reconstr Surg* 1999;104:77–84.

77. Newman LA, Kuerer HM, Hunt KK, Kroll SS, Ames FC, Ross MI, Feig BW, Singletary SE. Presentation, treatment, and outcome of local recurrence after skin-sparing mastectomy and immediate breast reconstruction. *Ann Surg Oncol* 1998;5:620–626.

78. Rubio IT, Mirza N, Sahin AA, Whitman G, Kroll SS, Ames FC, Singletary SE. Role of specimen radiography in patients treated with skin-sparing mastectomy for ductal carcinoma in situ of the breast. *Ann Surg Oncol* 2000;7:544–548.

79. Spiegel AJ, Butler CE. Recurrence following treatment of ductal carcinoma in situ with skin-sparing mastectomy and immediate breast reconstruction. *Plast Reconstr Surg* 2003;111:706–711.

80. Foster RD, Esserman LJ, Anthony JP, Hwang ES, Do H. Skin-sparing mastectomy and immediate breast reconstruction: A prospective cohort study for the treatment of advanced stages of breast carcinoma. *Ann Surg Oncol* 2002;9:462–466.

81. Jensen JA. When can the nipple-areola complex safely be spared during mastectomy? *Plast Reconstr Surg* 2002;109:805–807.

82. Vlajcic Z, Zic R, Stanec S, Lambasa S, Petrovecki M, Stanec Z. Nipple-areola complex preservation: Predictive factors of neoplastic nipple-areola complex invasion. *Ann Plast Surg* 2005;55:240–244.

83. Sacchini V, Pinotti JA, Barros AC, Luini A, Pluchinotta A, Pinotti M, Boratto MG, Ricci MD, Ruiz CA, Nisida AC, Veronesi P, Petit J, Arnone P, Bassi F, Disa JJ, Garcia-Etienne CA, Borgen PI. Nipple-sparing mastectomy for breast cancer and risk reduction: Oncologic or technical problem? *J Am Coll Surg* 2006;203:704–714.

84. Cunnick G, Mokbel K. Oncological considerations of skin-sparing mastectomy. *Int Semin Surg Oncol* 2006;3:14.

85. Laronga C, Kemp B, Johnston D, Robb GL, Singletary SE. The incidence of occult nipple-areola complex involvement in breast cancer patients receiving a skin-sparing mastectomy. *Ann Surg Oncol* 1999;6:609–613.

86. Gerber B, Krause A, Reimer T, Müller H, Küchenmeister I, Makovitzky J, Kundt G, Friese K. Skin-sparing mastectomy with conservation of the nipple-areola complex and autologous reconstruction is an oncologically safe procedure. *Ann Surg* 2003;238:120–127.

87. Simmons RM, Brennan M, Christos P, King V, Osborne M. Analysis of nipple/ areolar involvement with mastectomy: Can the areola be preserved? *Ann Surg Oncol* 2002;9:165–168.

88. Fisher B, Anderson S, Redmond CK, Wolmark N, Wickerham DL, Cronin WM. Reanalysis and results after 12 years of follow-up in a randomized clinical trial comparing total mastectomy with lumpectomy with or without irradiation in the treatment of breast cancer. *N Engl J Med* 1995;333:1456–1461.

89. Sufi PA, Gittos M, Collier DS. Envelope mastectomy with immediate reconstruction (EMIR). *Eur J Surg Oncol* 2000;26:367–370.

90. Mosahebi A, Ramakrishnan V, Gittos M, Collier DS. Envelope mastectomy and immediate reconstruction (EMIR), improving outcome without oncological compromise. *J Plast Reconstr Aesthet Surg* 2006;59:1025–1030.

91. Anton MA, Eskenazi LB, Hartrampf CR Jr. Nipple reconstruction with local flaps: Star and wrap flaps. *Perspect Plast Surg* 1991;5:67–78.

92. Eng JS. Bell flap nipple reconstruction: A new wrinkle. *Ann Plast Surg* 1996;36:485–488.

93. Little JW III, Munasifi T, McCulloch DT. One-stage reconstruction of a projecting nipple: The quadripod flap. *Plast Reconstr Surg* 1983;71:126–133.

94. Kroll SS, Hamilton S. Nipple reconstruction with the double-opposing-tab flap. *Plast Reconstr Surg* 1989;84:520–525.

95. Losken A, Mackay GJ, Bostwick J III. Nipple reconstruction using the C-V flap technique: A long-term evaluation. *Plast Reconstr Surg* 2001;108:361–369.

96. Spear SL (ed). *Surgery of the Breast: Principles and Art.* 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

97. Barton FE Jr. Latissimus dermal-epidermal nipple reconstruction. *Plast Reconstr Surg* 1982;70:234–237.

98. Shestak KC, Gabriel A, Landecker A, Peters S, Shestak A, Kim J. Assessment of long-term nipple projection: A comparison of three techniques. *Plast Reconstr Surg* 2002;110:780–786.

99. Kroll SS, Reece GP, Miller MJ, Evans GR, Robb GL, Baldwin BJ, Wang BG, Schusterman MA. Comparison of nipple projection with the modified double-opposing tab and star flaps. *Plast Reconstr Surg* 1997;99:1602–1605.

100. Heitland A, Markowicz M, Koellensperger E, Allen R, Pallua N. Long-term nipple shrinkage following augmentation by an autologous rib cartilage transplant in free DIEP flaps. *J Plast Reconstr Aesthet Surg* 2006;59:1063–1067.

101. Nahabedian MY, Tsangaris TN. Breast reconstruction following subcutaneous mastectomy for cancer: A critical appraisal of the nipple-areola complex. *Plast Reconstr Surg* 2006;117:1083–1090.

102. Nahabedian MY. Secondary nipple reconstruction using local flaps and AlloDerm. *Plast Reconstr Surg* 2005;115:2056–2061.

103. Becker H. The use of intradermal tattoo to enhance the final result of nipple-areola reconstruction. *Plast Reconstr Surg* 1986;77:673–676.

104. Spear SL, Arias J. Long-term experience with nipple-areola tattooing. *Ann Plast Surg* 1995;35:232–236.

105. El-Ali K, Dalal M, Kat CC. Tattooing of the nipple-areola complex: Review of outcome in 40 patients. *J Plast Reconstr Aesthet Surg* 2006;59:1052–1057.

106. Adair FE. Role of surgery and irradiation in cancer of the breast. *JAMA* 1943;121:553–559.

107. Pierce SM, Recht A, Lingos TI, Abner A, Vicini F, Silver B, Herzog A, Harris JR. Long-term radiation complications following conservative surgery (CS) and radiation therapy (RT) in patients with early stage breast cancer. *Int J Radiat Oncol Biol Phys* 1992;23:915–923.

108. Lazovich D, Solomon CC, Thomas DB, Moe RE, White E. Breast conservation therapy in the United States following the 1990 National Institutes of Health Consensus Development Conference on the treatment of patients with early stage invasive breast carcinoma. *Cancer* 1999;86:628–637.

109. Veronesi U, Saccozzi R, Del Vecchio M, Banfi A, Clemente C, De Lena M, Gallus G, Greco M, Luini A, Marubini E, Muscolino G, Rilke F, Salvadori B, Zecchini A, Zucali A. Comparing radical mastectomy with quadrantectomy, axillary dissection, and radiotherapy in patients with small cancers of the breast. *N Engl J Med* 1981;305:6–11.

110. Blichert-Toft M, Rose C, Anderson JA, Overgaard M, Axelsson CK, Andersen KW, Mouridsen HT. Danish randomized trial comparing breast conservation therapy with mastectomy. *J Natl Cancer Inst Monogr* 1992;11:19–25.

111. Veronesi U, Banfi A, Salvadori B, Luini A, Saccozzi R, Zucali R, Marubini E, Del Vecchio M, Broacchi P, Marchini S. Breast conservation is the treatment of choice in small breast cancer: Long-term results of a randomized trial. *Eur J Cancer* 1990;26:668–670.

112. Veronesi U, Marubini E, Mariani L, Galimberti V, Luini A, Veronesi P, Salvadori B, Zucali R. Radiotherapy after breast-conserving surgery in small breast carcinoma: Long-term results of a randomized trial. *Ann Oncol* 2001;12:997–1003.

113. Veronesi U, Cascinelli N, Mariani L, Greco M, Saccozzi R, Luini A, Aquilar M, Marubini E. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. *N Engl J Med* 2002;347:1227–1232.

114. Fisher B, Anderson S, Bryant J, Margolese RG, Deutsch M, Fisher ER, Jeong JH, Wolmark N. Twenty-year follow-up of a randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus irradiation for the treatment of invasive breast cancer. *N Engl J Med* 2002;347:1233–1241.

115. Woerdeman LA, Kortmann JB, Hage JJ. Routine histologic examination of 728 mastectomy scars: Did it benefit our patients? *Plast Reconstr Surg* 2006;118:1288–1292.

116. Kroll SS, Singletary SE. Repair of partial mastectomy defects. *Clin Plast Surg* 1998;25:303–310.

117. Asgeirsson KS, Rasheed T, McCulley SJ, Macmillan RD. Oncological and cosmetic outcomes of oncoplastic breast conserving surgery. *Eur J Surg Oncol* 2005;31:817–823.

118. McCulley SJ, Macmillan RD. Therapeutic mammaplasty: Analysis of 50 consecutive cases. *Br J Plast Surg* 2005;58:902–907.

119. Losken A, Elwood ET, Styblo TM, Bostwick J III. The role of reduction mammaplasty in reconstructing partial mastectomy defects. *Plast Reconstr Surg* 2002;109:968–977.

120. Clough KB, Lewis JS, Couturaud B, Fitoussi A, Nos C, Falcou MC. Oncoplastic techniques allow extensive resections for breast-conserving therapy of breast carcinomas. *Ann Surg* 2003;237:26–34.

121. Papp C, Wechselberger G, Schoeller T. Autologous breast reconstruction after breast-conserving cancer surgery. *Plast Reconstr Surg* 1998;102:1932–1938.

122. Masetti R, Pirulli PG, Magno S, Franceschini G, Chiesa F, Antinori A. Oncoplastic techniques in the conservative surgical treatment of breast cancer. *Breast Cancer* 2000;7:276–280.

123. Brierley JD, Paterson IC, Lallemand RC, Rostom AY. The influence of breast size on late radiation reaction following excision and radiotherapy for early breast cancer. *Clin Oncol* 1991;3:6–9.

124. Gray JR, McCormick B, Cox L, Yahalom J. Primary breast irradiation in large-breasted or heavy women: Analysis of cosmetic outcome. *Int J Radiat Oncol Biol Phys* 1991;21:347–354.

125. Moody AM, Mayles WP, Bliss JM, A'Hern RP, Owen JR, Regan J, Broad B, Yarnold JR. The influence of breast size on late radiation effects and association with radiotherapy dose inhomogeneity. *Radiother Oncol* 1994;33:106–112.

126. Spear SL, Pelletiere CV, Wolfe AJ, Tsangaris TN, Pennanen MF. Experience with reduction mammaplasty combined with breast conservation therapy in the treatment of breast cancer. *Plast Reconstr Surg* 2003;111:1102–1109.

127. Boice JD Jr, Persson I, Brinton LA, Hober M, McLaughlin JK, Blot WJ, Fraumeni JF Jr, Nyrén O. Breast cancer following breast reduction surgery in Sweden. *Plast Reconstr Surg* 2000;106:755–762.

128. Petit JY, Garusi C, Greuse M, Riestiens M, Youssef O, Luini A, De Lorenzi F. One hundred and eleven cases of breast conservation treatment with simultaneous reconstruction at the European Institute of Oncology (Milan). *Tumori* 2002;88:41–47.

129. Kroll SS, Ames F, Singletary SE, Schusterman MA. The oncologic risks of skin preservation at mastectomy when combined with immediate reconstruction of the breast. *Surg Gynecol Obstet* 1991;172:17–20.

130. Dixon JM, Venizelos B, Chan P. Latissimus dorsi mini-flap: A technique for extending breast conservation. *Breast* 2002;11:58–65.

131. Gendy RK, Able JA, Rainsbury RM. Impact of skin-sparing mastectomy with immediate reconstruction and breast-sparing reconstruction with miniflaps on the outcomes of oncoplastic breast surgery. *Br J Surg* 2003;90:433–439.

132. National Cancer Institute. *Surveillance Epidemiology and End Results.* Available at http://seer.cancer.gov/, last accessed, October 6, 2013.

133. Albornoz CR, Bach PB, Mehrara BJ, Disa JJ, Pusic AL, McCarthy CM, Cordeiro PG, Matros E. A paradigm shift in U.S. breast reconstruction: Increasing implant rates. *Plast Reconstr Surg* 2013;131:15–23.

134. Overgaard M, Hansen PS, Overgaard J, Rose C, Andersson M, Bach F, Kjaer M, Gadeberg CC, Mouridsen HT, Jensen MB, Zedeler K. Postoperative radiotherapy in high-risk premenopausal women with breast cancer who receive adjuvant chemotherapy: Danish Breast Cancer Cooperative Group 82b Trial. *N Engl J Med* 1997;337:949–955.

135. Ragaz J, Jackson SM, Le N, Plenderleith IH, Spinelli JJ, Basco VE, Wilson KS, Knowling MA, Coppin CM, Paradis M, Coldman AJ, Olivotto IA. Adjuvant radiotherapy and chemotherapy in node-positive premenopausal women with breast cancer. *N Engl J Med* 1997;337:956–962.

136. Whelan TJ, Julian J, Wright J, Jadad AR, Levine ML. Does locoregional radiation therapy improve survival in breast cancer? A meta-analysis. *J Clin Oncol* 2000;18:1220–1229.

137. Recht A, Edge SB, Solin LJ, Robinson DS, Estabrook A, Fine RE, Fleming GF, Formenti S, Hudis C, Kirshner JJ, Krause DA, Kuske RR, Langer AS, Sledge GW Jr, Whelan TJ, Pfister DG, American Society of Clinical Oncology. Postmastectomy radiotherapy: Clinical practice guidelines of the American Society of Clinical Oncology. *J Clin Oncol* 2001;19:1539–1569.

138. Pomahac B, Recht A, May JW, Hergrueter CA, Slavin SA. New trends in breast cancer management: Is the era of immediate breast reconstruction changing? *Ann Surg* 2006;244:282–288.

139. Miller MJ. Immediate breast reconstruction. *Clin Plast Surg* 1998;25:145–156.

140. Khoo A, Kroll SS, Reece GP, Miller MJ, Evans GR, Robb GL, Baldwin BJ, Wang BG, Schusterman MA. A comparison of resource costs of immediate and delayed breast reconstruction. *Plast Reconstr Surg* 1998;101:964–970.

141. Neyt MJ, Blondeel PN, Morrison CM, Albrecht JA. Comparing the cost of delayed and immediate autologous breast reconstruction in Belgium. *Br J Plast Surg* 2005;58:493–497.

142. Georgiade GS, Riefkohl R, Cox E, McCarty KS, Seigler HF, Georgiade NG, Snowhite JC. Long-term clinical outcome of immediate reconstruction after mastectomy. *Plast Reconstr Surg* 1985;76:415–420.

143. Noguchi M, Earashi M, Ohta N, Kitagawa H, Kinoshita K, Thomas M, Taniya T, Miyazaki I, Yamada T, Nakagawa M. Mastectomy with and without immediate breast reconstruction using a musculocutaneous flap. *Am J Surg* 1993;166:279–283.

144. Langstein HN, Cheng MH, Singletary SE, Robb GL, Hoy E, Smith TL, Kroll SS. Breast cancer recurrence after immediate reconstruction: Patterns and significance. *Plast Reconstr Surg* 2003;111:712–722.

145. Van Diest PJ, Torrenga H, Borgstein PJ, Pijpers R, Bleichrodt RP, Rahusen FD, Meijer S. Reliability of intraoperative frozen section and imprint cytological investigation of sentinel lymph nodes in breast cancer. *Histopathology* 1999;35:14–18.

146. Turner RR, Hansen NM, Stern SL, Giuliano AE. Intraoperative examination of the sentinel lymph node for breast carcinoma staging. *Am J Clin Pathol* 1999;112:627–634.

147. Weiser MR, Montgomery LL, Susnik B, Tan LK, Borgen PI, Cody HS. Is routine intraoperative frozen-section examination of sentinel lymph nodes in breast cancer worthwhile? *Ann Surg Oncol* 2000;7:651–655.

148. Schrenk P, Woelfl S, Bogner S, Moser F, Wayand W. The use of sentinel node biopsy in breast cancer patients undergoing skin sparing mastectomy and immediate autologous reconstruction. *Plast Reconstr Surg* 2005;116:1278–1286.

149. Kronowitz SJ, Kuerer HM. Sentinel lymph node biopsy followed by delayed mastectomy and reconstruction. *Am J Surg* 2005;189:251–252.

150. Kronowitz SJ, Hunt KK, Kuerer HM, Babiera G, McNeese MD, Buchholz TA, Strom EA, Robb GL. Delayed-immediate breast reconstruction. *Plast Reconstr Surg* 2004;113:1617–1628.

151. Brady B, Fant J, Jones R, Grant M, Andrews V, Livingston S, Kuhn J. Sentinel lymph node biopsy followed by delayed mastectomy and reconstruction. *Am J Surg* 2003;185:114–117.

152. Kronowitz SJ, Chang DW, Robb GL, Hunt KK, Ames FC, Ross MI, Singletary SE, Symmans WF, Kroll SS, Kuerer HM. Implications of axillary sentinel lymph node biopsy in immediate autologous breast reconstruction. *Plast Reconstr Surg* 2002;109:1888–1896.

153. Pinsolle V, Grinfeder C, Mathoulin-Pelissier S, Faucher A. Complications analysis of 266 immediate breast reconstructions. *J Plast Reconstr Aesthet Surg* 2006;59:1017–1024.

154. Alderman AK, Wilkins EG, Kim HM, Lowery JC. Complications in postmastectomy breast reconstruction: Two-year results of the Michigan Breast Reconstruction Outcome Study. *Plast Reconstr Surg* 2002;109:2265–2274.

155. Dean C, Chetty U, Forrest AP. Effects of immediate breast reconstruction on psychosocial morbidity after mastectomy. *Lancet* 1983;459–462.

156. Stevens LA, McGrath MH, Druss RG, Kister SJ, Gump FE, Forde KA. The psychological impact of immediate breast reconstruction for women with early breast cancer. *Plast Reconstr Surg* 1984;73:619–628.

157. Wellisch DK, Schain WS, Noone RB, Little JW III. Psychosocial correlates of immediate versus delayed reconstruction of the breast. *Plast Reconstr Surg* 1985;76:713–718.

158. Rosenqvist S, Sandelin K, Wickman M. Patients' psychological and cosmetic experience after immediate breast reconstruction. *Eur J Surg Oncol* 1996;22:262–266.

159. Elder EE, Brandberg Y, Björklund T, Rylander R, Lagergren J, Jurell G, Wickman M, Sandelin K. Quality of life and patient satisfaction in breast cancer patients after immediate breast reconstruction: A prospective study. *Breast* 2005;14:201–208.

160. Wilkins EG, Cederna PS, Lowery JC, Davis JA, Kim HM, Roth RS, Goldgarb S, Izenberg PH, Houin HP, Shaheen KW. Prospective analysis of psychosocial outcomes in breast reconstruction: One-year postoperative results from the Michigan Breast Reconstruction Outcome Study. *Plast Reconstr Surg* 2000;106:1014–1027.

161. American Society of Plastic Surgeons. *2012 Plastic Surgery Statistics Report.* http://www.plasticsurgery.org/news-and-resources/2012-plastic-surgery-statistics.html. Last accessed November 23, 2013.

162. Maxwell GP, Falcone PA. Eighty-four consecutive breast reconstructions using a textured silicone tissue expander. *Plast Reconstr Surg* 1992;89:1022–1036.

163. Spear SL, Majidian A. Immediate breast reconstruction in two stages using textured, integrated-valve tissue expanders and breast implants: A retrospective review of 171 consecutive breast reconstructions from 1989 to 1996. *Plast Reconstr Surg* 1998;101:53–63.

164. Nava MB, Cortinovis U, Ottolenghi J, Riggio E, Pennati A, Catanuto G, Greco M, Rovere GQ. Skin-reducing mastectomy. *Plast Reconstr Surg* 2006;118:603–613.

165. Handel N, Cordray T, Gutierrez J, Jensen JA. A long-term study of outcomes, complications, and patient satisfaction with breast implants. *Plast Reconstr Surg* 2006;117:757–772.

166. Cordeiro PG, McCarthy CM. A single surgeon's 12-year experience with tissue expander/implant breast reconstruction: Part 1. A prospective analysis of early complications. *Plast Reconstr Surg* 2006;118:825–831.

167. Forman DL, Chiu J, Restifo RJ, Ward BA, Haffty B, Ariyan S. Breast reconstruction in previously irradiated patients using tissue expanders and implants: A potentially unfavorable result. *Ann Plast Surg* 1998;40:360–364.

168. Vandeweyer E, Deraemaecker R. Radiation therapy after immediate breast reconstruction with implants. *Plast Reconstr Surg* 2000;106:56–60.

169. Krueger EA, Wilkins EG, Strawderman M, Cederna P, Goldfarb S, Vicini FA, Pierce LJ. Complications and patient satisfaction following expander/implant breast reconstruction with and without radiotherapy. *Int J Radiat Oncol Biol Phys* 2001;49:713–721.

170. Ascherman JA, Hanasono MM, Newman MI, Hughes DB. Implant reconstruction in breast cancer patients treated with radiation therapy. *Plast Reconstr Surg* 2006;117:359–365.

171. Goodwin SJ, McCarthy CM, Pusic AL, Bui D, Howard M, Disa JJ, Corderio PG, Mehrara BJ. Complications in smokers after postmastectomy tissue expander/implant breast reconstruction. *Ann Plast Surg* 2005;55:16–20.

172. De Frene B, Van Landuyt K, Hamdi M, Blondeel P, Roche N, Voet D, Monstrey S. Free DIEAP and SGAP flap breast reconstruction after abdominal/gluteal liposuction. *J Plast Reconstr Aesthet Surg* 2006;59:1031–1036.

173. Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. *Br J Plast Surg* 1989;42:645–648.

174. Spear SL, Davison SP. Aesthetic subunits of the breast. *Plast Reconstr Surg* 2003;112:440–447.

175. Pulzl P, Schoeller T, Wechselberger G. Respecting the aesthetic unit in autologous breast reconstruction improves the outcome. *Plast Reconstr Surg* 2006;117:1685–1693.

176. Delay E, Gounot N, Bouillot A, Zlatoff P, Rivoire M. Autologous latissimus breast reconstruction: A 3-year clinical experience with 100 patients. *Plast Reconstr Surg* 1998;102:1461–1478.

177. Schusterman MA (ed). *Microsurgical Reconstruction of the Cancer Patient.* Philadelphia: Lippincott-Raven; 1997.

178. Milloy FJ, Anson BJ, McAfee DK. The rectus abdominis muscle and the epigastric arteries. *Surg Gynecol Obstet* 1960;110:293–302.

179. Boyd JB, Taylor GI, Corlett R. The vascular territories of the superior epigastric and the deep inferior epigastric systems. *Plast Reconstr Surg* 1984;73:1–16.

180. Taylor GL, Corlett RJ, Boyd JB. The versatile deep inferior epigastric (inferior rectus abdominis) flap. *Br J Plast Surg* 1984;37:330–350.

181. Gottlieb ME, Chandrasekhar B, Terz JJ, Sherman R. Clinical applications of the extended deep inferior epigastric flap. *Plast Reconstr Surg* 1986;78:782–792.

182. Taylor GI. Clinical applications of the extended deep inferior epigastric flap [letter]. *Plast Reconstr Surg* 1986;78:788.

183. Taylor GI, Palmer JH. The vascular territories (angiosomes) of the body: Experimental study and clinical applications. *Br J Plast Surg* 1987;40:113–141.

184. Carramenha e Costa MA, Carriquiry C, Vasconez LO, Grotting JC, Herrera RH, Windle BH. An anatomic study of the venous drainage of the transverse rectus abdominis musculocutaneous flap. *Plast Reconstr Surg* 1987;79:208–217.

185. Taylor GI. An anatomic study of the venous drainage of the transverse rectus abdominis musculocutaneous flap [letter]. *Plast Reconstr Surg* 1987;79:214.

186. Miller LB, Bostwick J III, Hartrampf CR Jr, Hester TR Jr, Nahai F. The superiorly based rectus abdominis flap: Predicting and enhancing its blood supply based on an anatomic and clinical study. *Plast Reconstr Surg* 1988;81:713–724.

187. Taylor GI. The superiorly based rectus abdominis flap: Predicting and enhancing its blood supply based on an anatomic and clinical study [letter]. *Plast Reconstr Surg* 1988;81:721.

188. Moon HK, Taylor GI. The vascular anatomy of rectus abdominis musculocutaneous flaps based on the deep superior epigastric system. *Plast Reconstr Surg* 1988;82:815–832.

189. Harris NR II, Webb MS, May JW Jr. Intraoperative physiologic blood flow studies in the TRAM flap. *Plast Reconstr Surg* 1992;90:553–561.

190. Dinner MI, Dowden RV, Scheflan M. Refinements in the use of the transverse abdominal island flap for postmastectomy reconstruction. *Ann Plast Surg* 1983;11:362–372.

191. Ohjimi H, Era K, Fujita T, Tanaka T, Yabuuchi R. Analyzing the vascular architecture of the free TRAM flap using intraoperative ex vivo angiography. *Plast Reconstr Surg* 2005;116:106–113.

192. Hallock GG. Physiological studies using laser Doppler flowmetry to compare blood flow to the zones of the free TRAM flap. *Ann Plast Surg* 2001;47:229–233.

193. Holm C, Mayr M, Höfter E, Ninkovic M. Perfusion zones of the DIEP flap revisited: A clinical study. *Plast Reconstr Surg* 2006;117:37–43.

194. Duchateau J, Declety A, Lejour M. Innervation of the rectus abdominis muscle: Implications for rectus flaps. *Plast Reconstr Surg* 1988;82:223–228.

195. Vasconez LO, Psillakis J, Johnson-Giebeik R. Breast reconstruction with contralateral rectus abdominis myocutaneous flap. *Plast Reconstr Surg* 1983;71:668–677.

196. Elliott LF, Hartrampf CR Jr. Tailoring of the new breast using the transverse abdominal island flap. *Plast Reconstr Surg* 1983;72:887–893.

197. Maxwell GP. Technical alternatives in transverse rectus abdominis breast reconstruction. *Perspect Plast Surg* 1987;1:1–25.

198. Hartrampf CR Jr. The transverse abdominal island flap for breast reconstruction; A 7-year experience. *Clin Plast Surg* 1988;15:703–716.

199. Clugston PA, Gingrass MK, Azurin D, Fisher J, Maxwell GP. Ipsilateral pedicled TRAM flaps: The safer alternative? *Plast Reconstr Surg* 2000;105:77–82.

200. Wagner DS, Michelow BJ, Hartrampf CR Jr. Double-pedicle TRAM flap for unilateral breast reconstruction. *Plast Reconstr Surg* 1991;88:987–997.

201. Taylor GI. Intraoperative physiologic blood flow studies in the TRAM flap [letter]. *Plast Reconstr Surg* 1992;90:559–561.

202. Codner MA, Bostwick J III, Nahai F, Bried JT, Eaves FF. TRAM flap vascular delay for high-risk breast reconstruction. *Plast Reconstr Surg* 1995;96:1615–1622.

203. Restifo RJ, Syed SA, Ward BA, Scoutt LM, Taylor K. Surgical delay in TRAM flap breast reconstruction: A comparison of 7- and 14-day delay periods. *Ann Plast Surg* 1997;38:330–334.

204. Restifo RJ, Ward BA, Scoutt LM, Brown JM, Taylor KJ. Timing, magnitude, and utility of surgical delay in the TRAM flap: II. Clinical studies. *Plast Reconstr Surg* 1997;99:1217–1223.

205. Ribuffo D, Muratori L, Antoniadou K, Fanini F, Martelli E, Marini M, Messineo D, Trinci M, Scuderi N. A hemodynamic approach to clinical results in the TRAM flap after selective delay. *Plast Reconstr Surg* 1997;99:1706–1714.

206. Wang HT, Hartzell T, Olbrich KC, Erdmann D, Georgiade GS. Delay of transverse rectus abdominis myocutaneous flap reconstruction improves flap reliability in the obese patient. *Plast Reconstr Surg* 2005;116:613–620.

207. Hartrampf CR Jr, Bennett GK. Autogenous tissue reconstruction in the mastectomy patient: A critical review of 300 patients. *Ann Surg* 1987;205:508–519.

208. Kroll SS, Netscher DT. Complications of TRAM flap breast reconstruction in obese patients. *Plast Reconstr Surg* 1989;84:886–892.

209. Kroll SS. Necrosis of abdominoplasty and other secondary flaps after TRAM flap breast reconstruction. *Plast Reconstr Surg* 1994;94:637–643.

210. Ishii CH Jr, Bostwick J III, Raine TJ, Coleman JJ III, Hester TR. Double-pedicle transverse rectus abdominis myocutaneous flap for unilateral breast and chest wall reconstruction. *Plast Reconstr Surg* 1985;76:901–907.

211. Paige KT, Bostwick J III, Bried JT, Jones G. A comparison of morbidity from bilateral, unipedicled and unilateral, unipedicled TRAM flap breast reconstructions. *Plast Reconstr Surg* 1998;101:1819–1827.

212. Arnez ZM, Smith RW, Eder E, Solinc M, Kersnic M. Breast reconstruction by the free lower transverse rectus abdominis musculocutaneous flap. *Br J Plast Surg* 1988;41:500–505.

213. Arnez ZM, Bajec J, Bardsley AF, Scamp T, Webster MD. Experience with 50 free TRAM flap breast reconstructions. *Plast Reconstr Surg* 1991;87:470–482.

214. Grotting JC, Urist MM, Maddox WA, Vasconez LO. Conventional TRAM flap versus free microsurgical TRAM flap for immediate breast reconstruction. *Plast Reconstr Surg* 1989;83:828–844.

215. Pennington DG, Pelly AD. The rectus abdominis myocutaneous free flap. *Br J Plast Surg* 1980;33:277–282.

216. Elliott LF, Eskenazi L, Beegle PH Jr, Podres PE, Drazan L. Immediate TRAM flap breast reconstruction: 128 consecutive cases. *Plast Reconstr Surg* 1993;92:217–227.

217. Schusterman MA, Kroll SS, Miller MJ, Reece GP, Baldwin BJ, Robb GL, Altmyer CS, Ames FC, Singletary SE, Ross MI. The free transverse rectus abdominis musculocutaneous flap for breast reconstruction: One center's experience with 211 consecutive cases. *Ann Plast Surg* 1994;32:234–242.

218. Grotting JC. Immediate breast reconstruction using the free TRAM flap. *Clin Plast Surg* 1994;21:207–221.

219. Dupin CL, Allen RJ, Glass CA, Bunch R. The internal mammary artery and vein as a recipient site for free-flap breast reconstruction: A report of 110 consecutive cases. *Plast Reconstr Surg* 1996;98:685–692.

220. Baldwin BJ, Schusterman MA, Miller MJ, Kroll SS, Wang BG. Bilateral breast reconstruction: Conventional versus free TRAM. *Plast Reconstr Surg* 1994;93:1410–1417.

221. Edsander-Nord A, Brandberg Y, Wickman M. Quality of life, patients' satisfaction, and aesthetic outcome after pedicled or free TRAM flap breast surgery. *Plast Reconstr Surg* 2001;107:1142–1155.

222. Moran SL, Serletti JM. Outcome comparison between free and pedicled TRAM flap breast reconstruction in the obese patient. *Plast Reconstr Surg* 2001;108:1954–1962.

223. Hartrampf CR Jr. Abdominal wall competence in transverse abdominal island flap operations. *Ann Plast Surg* 1984;12:139–146.

224. Hartrampf CR Jr. Breast reconstruction with a transverse abdominal island flap: A retrospective evaluation of 335 patients. *Perspect Plast Surg* 1987;1:123–135.

225. Lejour M, Dome M. Abdominal wall function after rectus abdominis transfer. *Plast Reconstr Surg* 1991;87:1054–1068.

226. Kind GM, Rademaker AW, Mustoe TA. Abdominal-wall recovery following TRAM flap: A functional outcome study. *Plast Reconstr Surg* 1997;99:417–428.

227. Petit JY, Rietjens M, Ferreira MA, Montrucoli D, Lifrange E, Martinelli P. Abdominal sequelae after pedicled TRAM flap breast reconstruction. *Plast Reconstr Surg* 1997;99:723.

228. Zienowicz RJ, May JW Jr. Hernia prevention and aesthetic contouring of the abdomen following TRAM flap breast reconstruction by the use of polypropylene mesh. *Plast Reconstr Surg* 1995;96:1346–1350.

229. Shestak KC, Fedele GM, Restifo RJ. Treatment of difficult TRAM flap hernias using intraperitoneal synthetic mesh application. *Plast Reconstr Surg* 2001;107:55–66.

230. Spear SL, Hess CL, Elmaraghy MW. Evaluation of abdominal sensibility after TRAM flap breast reconstruction. *Plast Reconstr Surg* 2000;106:1300–1304.

231. Blondeel PN, Vanderstraeten GG, Monstrey SJ, Van Landuyt K, Tonnard P, Lysens R, Boeckx WD, Matton G. The donor site morbidity of free DIEP flaps and free TRAM flaps for breast reconstruction. *Br J Plast Surg* 1997;50:322–330.

232. Blondeel PN, Demuynck M, Mete D, Monstrey SJ, Van Landuyt K, Matton G, Vanderstraeten GG. Sensory nerve repair in perforator flaps for autologous breast reconstruction: Sensational or senseless? *Br J Plast Surg* 1999;52:37–44.

233. Blondeel PN. One hundred free DIEP flap breast reconstructions: A personal experience. *Br J Plast Surg* 1999;52:104–111.

234. Blondeel PN, Arnstein M, Verstraete K, Depuydt K, Van Lunduyt KH, Monstry SJ, Kroll SS. Venous congestion and blood flow in free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps. *Plast Reconstr Surg* 2000;106:1295–1299.

235. Gill P, Hunt J, Guerra AB, Dellacroce FJ, Sullican SK, Boraski J, Metzinger SE, Dupin CL, Allen RJ. A 10-year retrospective review of 758 DIEP flaps for breast reconstruction. *Plast Reconstr Surg* 2004;113:1153–1160.

236. 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;115:436–446.

237. Grotting JC. The free abdominoplasty flap for immediate breast reconstruction. *Ann Plast Surg* 1991;27:351–354.

238. Chevray PM. Breast reconstruction with superficial inferior epigastric artery flaps: A prospective comparison with TRAM and DIEP flaps. *Plast Reconstr Surg* 2004;114:1077–1085.

239. Allen RJ, Heitland AS. Superficial inferior epigastric artery flap for breast reconstruction. *Semin Plast Surg* 2002;16:35–43.

240. Taylor GI, Daniel RK. The anatomy of several free flap donor sites. *Plast Reconstr Surg* 1975;56:243–253.

241. Reardon C, O'Ceallaigh S, O'Sullivan S. An anatomical study of the superficial inferior epigastric vessels in humans. *Br J Plast Surg* 2004;57:515–519.

242. Granzow JW, Chiu ES, Levine JL, Gautam A, Hellman A, Rolston W, Kuo B, Saullo T, Heitland AS, Allen RJ. Autologous breast reconstruction using the superficial inferior epigastric artery flap revisited. *Plast Reconstr Surg* 2005;116:133.

243. Granzow JW, Levine JL, Chiu ES, Allen RJ. Breast reconstruction using perforator flaps. *J Surg Oncol* 2006;94:441–454.

244. Ducic I, Spear SL, Cuoco F, Hannan C. Safety and risk factors for breast reconstruction with pedicled transverse rectus abdominis musculocutaneous flaps: A 10-year analysis. *Ann Plast Surg* 2005;55:559–564.

245. Spear SL, Ducic I, Cuoco F, Hannan C. The effect of smoking on flap and donor-site complications in pedicled TRAM breast reconstruction. *Plast Reconstr Surg* 2005;116:1873–1880.

246. Mehrara BJ, Santoro TD, Arcilla E, Watson JP, Shaw WW, Da Lio AL. Complications after microvascular breast reconstruction: Experience with 1195 flaps. *Plast Reconstr Surg* 2006;118:1100–1111.

247. Chang D, Wang B, Robb GL, Reece GP, Miller MJ, Evans GR, Langstein HN, Kroll SS. The effect of obesity on flap and donor site complications in free TRAM flap breast reconstruction. *Plast Reconstr Surg* 2000;105:1640–1648.

248. Chang DW, Reece GP, Wang B, Robb GL, Miler MJ, Evans GR, Langstein HN, Kroll SS. Effect of smoking on complications in patients undergoing free TRAM flap breast reconstruction. *Plast Reconstr Surg* 2000;105:2374–2380.

249. Allen RJ. DIEP versus TRAM for breast reconstruction. *Plast Reconstr Surg* 2003;111:2478.

250. Garvey PB, Buchel EW, Pockaj BA, Casey WJ III, Gray RJ, Hernández JL, Samson TD. DIEP and pedicled TRAM flaps: A comparison of outcomes. *Plast Reconstr Surg* 2006;117:1711–1721.

251. Garvey PB, Buchel EW, Pockaj BA, Gray RJ, Samson TD. The deep inferior epigastric perforator flap for breast reconstruction in overweight and obese patients. *Plast Reconstr Surg* 2002;110:466–457.

252. 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.

253. Hamdi M, Blondeel P, Van Landuyt K, Tondu T, Monstrey S. Bilateral autogenous breast reconstruction using perforator free flaps: A single center's experience. *Plast Reconstr Surg* 2004;114:83–92.

254. Tønseth KA, Hokland BM, Tindholdt TT, Abyholm FE, Stavem K. Patient-reported outcomes after breast reconstruction with deep inferior epigastric perforator flaps. *Scand J Plast Reconstr Surg Hand Surg* 2007;41:173–177.

255. Drazan L, Vesely J, Hyza P, Castagnetti F, Stupka I, Justan I, Novak P, Monni N. Bilateral breast reconstruction with DIEP flaps: 4 years' experience. *J Plast Reconstr Aesthet Surg* 2008;61:1309–1315.

256. Munhoz AM, Arruda E, Montag E, Aldrighi C, Aldrighi JM, Gemperli R, Ferreira MC. Immediate skin-sparing mastectomy reconstruction with deep inferior epigastric perforator (DIEP) flap: Technical aspects and outcome. *Breast J* 2007;13:470–478.

257. Schaverien MV, Perks AG, McCulley SJ. Comparison of outcomes and donor-site morbidity in unilateral free TRAM versus DIEP flap breast reconstruction. *J Plast Reconstr Aesthet Surg* 2007;60:1219–1224.

258. Serletti JM. Breast reconstruction with the TRAM flap: Pedicled and free. *J Surg Oncol* 2006;94:532–537.

259. Glasberg SB, D'Amico RA. Use of regenerative human acellular tissue (AlloDerm) to reconstruct the abdominal wall following pedicle TRAM flap breast reconstruction surgery. *Plast Reconstr Surg* 2006;118:8–15.

260. Bajaj AK, Chevray PM, Chang DW. Comparison of donor-site complications and functional outcomes in free muscle-sparing TRAM flap and free DIEP flap breast reconstruction. *Plast Reconstr Surg* 2006;117:737–750.

261. Futter CM, Webster MH, Hagan S, Mitchell SL. A retrospective comparison of abdominal muscle strength following breast reconstruction with a free TRAM or DIEP flap. *Br J Plast Surg* 2000;53:578–583.

262. Futter CM, Weiler-Mithoff E, Hagen S, Van de Sijpe K, Coorevits PL, Litherland JC, Webster MH, Hamdi M, Blondeel PN. Do pre-operative abdominal exercises prevent post-operative donor site complications for women undergoing DIEP flap breast reconstruction? A two-centre, prospective randomized controlled trial. *Br J Plast Surg* 2003;56:674–683.

263. Yan XQ, Yang HY, Zhao YM, You L, Xu J. Deep inferior epigastric perforator flap for breast reconstruction: Experience with 43 flaps. *Chin Med J* 2007;120:380–384.

264. Kroll SS, Schusterman MA, Reece GP, Miller MJ, Smith B. Breast reconstruction with myocutaneous flaps in previously irradiated patients. *Plast Reconstr Surg* 1994;93:460–471.

265. Williams JK, Bostwick J III, Bried JT, Mackay G, Landry J, Benton J. TRAM flap breast reconstruction after radiation treatment. *Ann Surg* 1995;221:756–766.

266. Williams JK, Carlson GW, Bostwick J III, Bried JT, Mackay G. The effects of radiation treatment after TRAM flap breast reconstruction. *Plast Reconstr Surg* 1997;100:1153–1160.

267. Tran NV, Chang DW, Gupta A, Kroll SS, Robb GL. Comparison of immediate and delayed free TRAM flap breast reconstruction in patients receiving postmastectomy radiation therapy. *Plast Reconstr Surg* 2001;108:78–82.

268. Rogers NE, Allen RJ. Radiation effects on breast reconstruction with the deep inferior epigastric perforator flap. *Plast Reconstr Surg* 2002;109:1919–1926.

269. Spear SL, Ducic I, Low M, Cuoco F. The effect of radiation on pedicled TRAM flap breast reconstruction: Outcomes and implications. *Plast Reconstr Surg* 2005;115:84–95.

270. Guerra AB, Metzinger SE, Bidros RS, Gill PS, Dupin CL, Allen RJ. Breast reconstruction with gluteal artery perforator (GAP) flaps: A critical analysis of 142 cases. *Ann Plast Surg* 2004;52:118–125.

271. Kroll SS. *Breast Reconstruction with Autologous Tissue.* New York: Springer-Verlag; 2000.

272. Guerra AB, Soueid N, Metzinger SE, Levine J, Bidros RS, Erhard H, Allen RJ. Simultaneous bilateral breast reconstruction with superior gluteal artery perforator (SGAP) flaps. *Ann Plast Surg* 2004;53:305–310.

273. Yousif NF, Matloub HS, Kolachalam R, Grunert BK, Sanger JR. The transverse gracilis musculocutaneous flap. *Ann Plast Surg* 1992;29,482–490.

274. Wechselberger G, Schoeller T. The transverse myocutaneous gracilis free flap: A valuable tissue source in autologous breast reconstruction. *Plast Reconstr Surg* 2004;114:69–73.

275. Arnez ZM, Pogorelec D, Planinsek F, Ahcan U. Breast reconstruction by the free transverse gracilis (TUG) flap. *Br J Plast Surg* 2004;57:20–26.

276. Schoeller T, Huemer GM, Wechselberger G. The transverse musculocutaneous gracilis flap for breast reconstruction: Guidelines for flap and patient selection. *Plast Reconstr Surg* 2008;112:29–38.

277. Vega SJ, Sandeen SN, Bossert RP, Perrone A, Ortiz L, Herrera H. Gracilis myocutaneous free flap in autologous breast reconstruction. *Plast Reconstr Surg* 2009;124:1400–1409.

278. Fattah A, Figus A, Mathur B, Ramakrishnan VV. The transverse myocutaneous gracilis flap: Technical refinements. *J Plast Reconstr Aesthet Surg* 2010;63:305–313.

279. Buntic RF, Horton KM, Brooks D, Althubaiti GA. Transverse upper gracilis flap as an alternative to abdominal tissue breast reconstruction: Technique and modifications. *Plast Reconstr Surg* 2011;128:607e–613e.

280. Saint-Cyr M, Wong C, Oni G, Maia M, Trussler A, Mojallal A, Rohrich RJ. Modifications to extend the transverse upper gracilis flap in breast reconstruction: Clinical series and results. *Plast Reconstr Surg* 2012;129:24e–36e.

281. Allen RJ, Haddock NT, Ahn CY, Sadeghi A. Breast reconstruction with the profunda artery perforator flap. *Plast Reconstr Surg* 2012;129:16e–23e.

282. See MS, Pacifico MD, Harley OJ, Francis I, Smith RW, Jones ME. Incidence of "Incidentalomas" in over 100 consecutive CT angiograms for preoperative DIEP flap planning. *J Plast Reconstr Aesthet Surg* 2010;63:106–110.

283. Giunta RE, Geisweid A, Feller AM. The value of preoperative Doppler sonography for planning free perforator flaps. *Plast Reconstr Surg* 2000;105:2381–2386.

284. Rozen WM, Phillips TJ, Ashton MW, Stella DL, Taylor GI. Preoperative imaging of DIEA perforator flaps: A comparative study of computed tomographic angiography and Doppler ultrasound. *Plast Reconstr Surg* 2008;121 [suppl 1]:1S–8S.

285. Rozen WM, Ashton MW, Grinsell D. The branching pattern of the deep inferior epigastric artery revisited in-vivo: A new classification based on CT angiography. *Clin Anat* 2010;23:87–92.

286. Casey WJ III, Chew RT, Rebecca AM, Smith AA, Collins JM, Pockaj BA. Advantages of preoperative computed tomography in deep inferior epigastric artery perforator flap breast reconstruction. *Plast Reconstr Surg* 2009;123:1148–1155.

287. Chernyak V, Rozenblit AM, Greenspun DT, Levine JL, Milikow DL, Chia FA, Erhard HA. Breast reconstruction with deep inferior epigastric artery perforator flap: 3.0-T gadolinium-enhanced MR imaging for preoperative localization of abdominal wall perforators. *Radiology* 2009;250:417–424.

288. Greenspun D, Vasile J, Levine JL, Erhard H, Studinger R, Chernyak V, Newman T, Prince M, Allen RJ. Anatomic imaging of abdominal perforator flaps without ionizing radiation: Seeing is believing with magnetic resonance imaging angiography. *J Reconstr Microsurg* 2010;26:37–44.

289. Schaverien M, Ludman CN, Neil-Dwyer J, Perks GB, Akhtar N, Rodrigues JN, Benetatos K, Raurell A, Rasheed T, McCulley SJ. Contrast-enhanced magnetic resonance angiography for preoperative imaging in DIEP flap breast reconstruction. *Plast Reconstr Surg* 2011;128:56–62.

290. de Weerd, Weum S, Mercer JB. The value of dynamic infrared thermography (DIRT) in perforator selection and planning of free DIEP flaps. *Ann Plast Surg* 2009;63:274–279.

291. Clark CP III, Rohrich RJ, Copit S, Pittman CE, Robinson J. An anatomic study of the internal mammary veins: Clinical implications for free-tissue transfer breast reconstruction. *Plast Reconstr Surg* 1997;99:400–404.

292. Feng LJ. Recipient vessels in free-flap breast reconstruction: A study of the internal mammary and thoracodorsal vessels. *Plast Reconstr Surg* 1997;99:405–416.

293. Hefel L, Schwabegger A, Ninković M, Wechselberger G, Moriggl B, Waldenberger P, Anderl H. Internal mammary vessels: Anatomical and clinical considerations. *Br J Plast Surg* 1995;48:527–532.

294. Vath SD, Dupin CL, Allen RJ. Internal mammary vessels as a recipient site for free flap breast reconstruction. *Semin Plast Surg* 2002;16:109–118.

295. Shaw WW. The internal mammary artery and vein as a recipient site for free-flap breast reconstruction: A report of 110 consecutive cases [letter]. *Plast Reconstr Surg* 1996;98:690–692.

296. Schwabegger AH, Gschnitzer C, Ninkovic MM. Contour deformity at the internal mammary recipient site. *Br J Plast Surg* 1999;52:674.

297. Majumder S, Batchelor AG. Internal mammary vessels as recipients for free TRAM breast reconstruction: Aesthetic and functional considerations. *Br J Plast Surg* 1999;52:286–289.

298. Nahabedian MY, Momen B, Galdino G, Manson PN. Breast reconstruction with free TRAM or DIEP flap: Patient selection, choice of flap, and outcome. *Plast Reconstr Surg* 2002;110:466–477.

299. Hamdi M, Blondeel P, Van Landuyt K, Monstrey S. Algorithm in choosing recipient vessels for perforator free flap in breast reconstruction: The role of the internal mammary perforators. *Br J Plast Surg* 2004;57:258–265.

300. Serletti JM, Moran SL, Orlando GS, Fox I. Thoracodorsal vessels as recipient vessels for the free TRAM flap in delayed breast reconstruction. *Plast Reconstr Surg* 1999;104:1649–1655.

301. Ninković MM, Schwabegger AH, Anderl H. Internal mammary vessels as a recipient site. *Clin Plast Surg* 1998;25:213–221.

302. Evans GR, David CL, Loyer EM, Strom E, Waldron C, Ortega R, Ainslie N, Wang B, Janjan N. The long-term effects of internal mammary chain irradiation and its role in the vascular supply of the pedicled transverse rectus abdominis musculocutaneous flap breast reconstruction. *Ann Plast Surg* 1995;35:342–348.

303. Temple CL, Strom EA, Youssef A, Langstein HN. Choice of recipient vessels in delayed TRAM flap breast reconstruction after radiotherapy. *Plast Reconstr Surg* 2005;115:105–113.

304. Nahabedian MY. The internal mammary artery and vein as recipient vessels for microvascular breast reconstruction: Are we burning a future bridge? *Ann Plast Surg* 2004;53:311–316.

305. Munhoz AM, Ishida LH, Montag E, Sturtz GP, Saito FL, Rodrigues L, Gemperli R, Ferreira MC. Perforator flap breast reconstruction using internal mammary perforator branches as a recipient site: An anatomical and clinical analysis. *Plast Reconstr Surg* 2004;114:62–68.

306. Haywood RM, Raurell A, Perks AG, Sassoon EM, Logan AM, Phillips J. Autologous free tissue breast reconstruction using the internal mammary perforators as recipient vessels. *Br J Plast Surg* 2003;56:689–691.

307. [No authors listed]. Report on autologous fat transplantation: ASPRS Ad-Hoc Committee on New Procedures, September 30, 1987. *Plast Surg Nurs* 1987;7: 140–141.

308. Coleman SR, Saboeiro AP. Fat grafting to the breast revisited: Safety and efficacy. *Plast Reconstr Surg* 2007;119:775–787.

309. Gutowski KA, ASPS Fat Graft Task Force. Current applications and safety of autologous fat grafts: A report of the ASPS fat graft task force. *Plast Recontr Surg* 2009;124:272–280.

310. Danikas D, Theodorou SJ, Kokkalis G, Vasiou K, Kyriakopoulou K. Mammographic findings following reduction mammoplasty. *Aesthetic Plast Surg* 2001;25:283–285.

311. Rigotti G, Marchi A, Stringhini P, Baroni G, Galié M, Molino AM, Mercanti A, Micciolo R, Sbarbati A. Determining the oncological risk of autologous lipoaspirate grafting for post-mastectomy breast reconstruction. *Aesthetic Plast Surg* 2010;34:475–480.

312. Delay E, Garson S, Tousson G, Sinna R. Fat injection to the breast: Technique, results, and indications based on 880 procedures over 10 years. *Aesthet Surg J* 2009;29:360–376.

313. Petit JY, Lohsiriwat V, Clough KB, Sarfati I, Ihrai T, Rietjens M, Versonesi P, Rossetto F, Scevola A, Delay E. The oncologic outcome and immediate surgical complications of lipofilling in breast cancer patients: A multicenter study: Milan-Paris-Lyon experience of 646 lipofilling procedures. *Plast Reconstr Surg* 2011;128:341–346.

314. Losken A, Pinell XA, Sikoro K, Yezhelyev MV, Anderson E, Carlson GW. Autologous fat grafting in secondary breast reconstruction. *Ann Plast Surg* 2011;66:518–522.

315. Spear SL, Wilson HB, Lockwood MD. Fat injection to correct contour deformities in the reconstructed breast. *Plast Reconstr Surg* 2005;116:1300–1305.

316. Sinna R, Delay E, Garson S, Delaporte T, Tousson G. Breast fat grafting (lipomodelling) after extended latissimus dorsi flap breast reconstruction: A preliminary report of 200 consecutive cases. *J Plast Reconstr Aesthet Surg* 2010;63:1769–1777.

317. de Blacam C, Momoh AO, Colakoglu S, Tobias AM, Lee BT. Evaluation of clinical outcomes and aesthetic results after autologous fat grafting for contour deformities of the reconstructed breast. *Plast Reconstr Surg* 2011;128:411e–418e.

318. Khouri RK, Eisenmann-Klein M, Cardoso E, Cooley BC, Kacher D, Gombos E, Baker TJ. Brava and autologous fat transfer is a safe and effective breast augmentation alternative: Results of a six-year, eighty-one patients prospective multicenter study. *Plast Reconstr Surg* 2012;129:1173–1187.

319. Babovic S. Complete breast reconstruction with autologous fat graft: A case report. *J Plast Reconstr Aesthet Surg* 2010;63:e561–e563.

320. Serra-Renom JM, Muñoz-Olmo J, Serra-Mestre JM. Breast reconstruction with fat grafting alone. *Ann Plast Surg* 2011;66:598–601.

321. Serra-Renom JM, Muñoz-Olmo J, Serra-Mestre JM. Fat grafting in postmastectomy breast reconstruction with expanders and prostheses in patients who have received radiotherapy: Formation of new subcutaneous tissue. *Plast Reconstr Surg* 2010;125:12–18.

322. Sarfati I, Ihrai T, Kaufman G, Nos C, Clough KB. Adipose-tissue grafting to the post-mastectomy irradiated chest wall: Preparing the ground for implant reconstruction. *J Plast Reconstr Aesthet Surg* 2011;64:1161–1166.

323. Salgarello M, Visconti G, Barone-Adesi L. Fat grafting and breast reconstruction with implant: Another option for irradiated breast cancer patients. *Plast Reconstr Surg* 2012;129:317–329.

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