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Original Article

Predesigned chimeric deep inferior epigastric perforator and inguinal lymph node flap for combined breast and lymphedema reconstruction: A comprehensive algorithmic approach

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ABSTRACT

The combined use of a deep inferior epigastric perforator (DIEP) flap coupled with vascularized inguinal lymph nodes (VILNs) for simultaneous breast and lymphedema reconstruction has already been well established, and promising results have been reported. However, a standardized approach for the planning and shaping of this combined flap is still lacking. We aimed to propose a comprehensive algorithmic approach for delayed unilateral breast and lymphedema reconstruction using a predesigned abdominal flap associated with inguinal lymph node transfer.

We present in detail the preoperative measurements and surgical technique of the chimeric flap, which combines a predesigned DIEP template and a preselected inguinal lymph node flap, based on the preoperative computed tomography angiography and SPEC-

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CT findings, respectively; four different flap types are described according to the location of the pedicles of the two flap components. Our results of a series of 34 consecutive female patients with unilateral mastectomy and arm lymphedema, who underwent this combined predesigned reconstructive procedure, are retrospectively analyzed and reported.

We recorded a high survival rate of the chimeric flaps in our series, with only one case of partial ischemic loss of a DIEP skin island. In the majority of our patients, the pedicles of the combined flaps were located in opposite positions. After a mean 35-month follow-up, we recorded a 47% mean volume difference reduction of the lymphedematous compared to the unaffected arm; no donor-site lymphedema was documented. Self-evaluation questionnaires showed high patient satisfaction rates regarding breast reconstruction. This algorithmic approach provides standardized guidance for accurate design and transfer of the DIEP-VILN chimeric flap while achieving highly satisfactory outcomes for both breast and lymphedema reconstruction.

Meetings where the manuscript was presented

- 31st EURAPS Annual Meeting Virtual Edition, May 2021
- 11th Congress of World Society for Reconstructive Microsurgery, Cancun Mexico, June 2022
- Plastic Surgery Congress, Gold Coast Australia, June 2022
- ESPRAS Congress, Porto Portugal, October 2022
- 12th Congress of World Society for Reconstructive Microsurgery, Singapore, August 2023

Introduction

Breast cancer–related lymphedema (BCRL) is a debilitating consequence that may occur following breast cancer treatment. The reported incidence of this complication in breast cancer survivors ranges widely from 6% to 60% and is mainly related to axillary lymph node dissection, radiotherapy, infection, and obesity.[1–3] Various microsurgical procedures, including lymphaticovenous anastomoses (LVAs) and vascularized lymph node transfers, have been utilized to treat BCRL,[4–9] while recently, preventive surgical operations have also been attempted to reduce the risk of secondary upper-limb lymphedema (ULL) in post-mastectomy patients.[10,11]

In 2012, Saaristo et al. were the first to publish promising results of simultaneous autologous breast and ULL reconstruction using a free chimeric abdominal flap combined with inguinal lymph node transfer.[12] Since then, several studies have documented the benefits of this combined procedure in terms of effective simultaneous breast and lymphatic restoration in a single operation.[13–17] However, no consensus has yet been reached regarding the preparation and design of the chimeric flap, the imaging, and selection of the lymph nodes, as well as the transfer, and shaping of the combined deep inferior epigastric perforator (DIEP) and vascularized inguinal lymph node (VILN) free flap.

In this study, we propose an algorithmic approach for delayed simultaneous breast and ULL reconstruction using a chimeric predesigned DIEP flap associated with a preselected inguinal lymph node flap transfer, aiming to provide standardized guidance for safe preparation, elevation, and setting of this combined flap. We also report our results of a series of 34 consecutive female patients with unilateral mastectomy and BCRL, who underwent this combined predesigned reconstructive procedure. The study adheres to the STROBE guidelines.

Figure 1. A. Preoperative view of a 56-year-old patient, presenting left mastectomy and left upper arm Stage II lymphedema. B, C. Coronal and transverse SPECT-CT views of the groin areas of the same patient showing the preselected lymph nodes over the left inguinal area. D. Preoperative markings of the chimeric DIEP-VILN flap; the DIEP skin island (outlined with blue ink) is based on the measurements of the contralateral breast and centered over the selected perforator on the right hemiabdomen (red arrow), while the preselected lymph node flap (λ) is marked over the left inguinal site (green arrow)

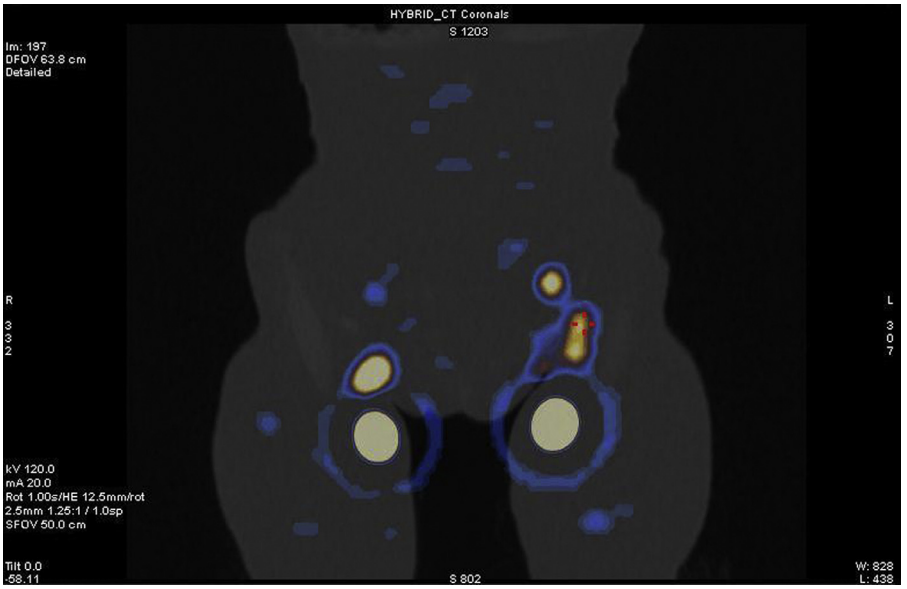

Figure 1. Continued

Methods

Before surgery, all patients planned for a combined autologous breast and lymphedema reconstruction by the senior authors (E.D. and D.D.), undergo the same preoperative evaluation, starting with measurements of the contralateral breast and clinical assessment of the abdominal tissues. A computed tomography angiography (CTA) of the abdominal wall is routinely performed to map the deep inferior epigastric artery perforators and select the dominant one.

Preoperative volumetric measurement of both arms is performed using the truncated cone formula based on 4-cm intervals serial perimeter measurements;[18] volume differences are calculated as the excess volume ratio of the lymphedematous arm compared to the contralateral healthy one. Lymphedema of the involved upper limb is classified according to the Staging System of the International Society of Lymphology (ISL).[19] Preoperative imaging investigation includes bilateral upper-limb lymphoscintigraphy, and indocyanine-green (ICG) lymphography to document the lymphatic status of the involved extremity. Additionally, a single-photon emission computed tomography (SPECT-CT) of both groin areas is routinely performed to visualize and select the most radioactive inguinal lymph nodes for transfer.[20] Patient demographics, medical records, previous surgeries, and history of radiation are recorded. Physiotherapy by lymphedema-certified therapists starts 2 weeks before surgery with manual lymphatic drainage and bandaging of the lymphedematous arm.

After surgery, patients are evaluated 1 to 2 weeks after discharge for recipient and donor site healing. Physiotherapy of the involved upper limb commences the day after surgery and continues for the next 4 weeks. Patients are instructed to wear elastic sleeves for at least another 5 months.

Postoperatively, qualitative and quantitative assessments are performed to evaluate the outcomes of both breast and lymphedema reconstruction. Patients are seen at 3, 6, 9, and 12 months for volumetric measurements; thereafter, follow-up visits continue twice per year. ICG lymphography is performed for postoperative assessment of the operated arm, after a minimum of 12 months following surgery. Additionally, ICG lymphography of both lower limbs is performed to investigate any iatrogenic lymphatic flow disturbances of the donor leg. Self-assessment questionnaires are used to measure patient satisfaction, at a minimum 12-month follow-up.

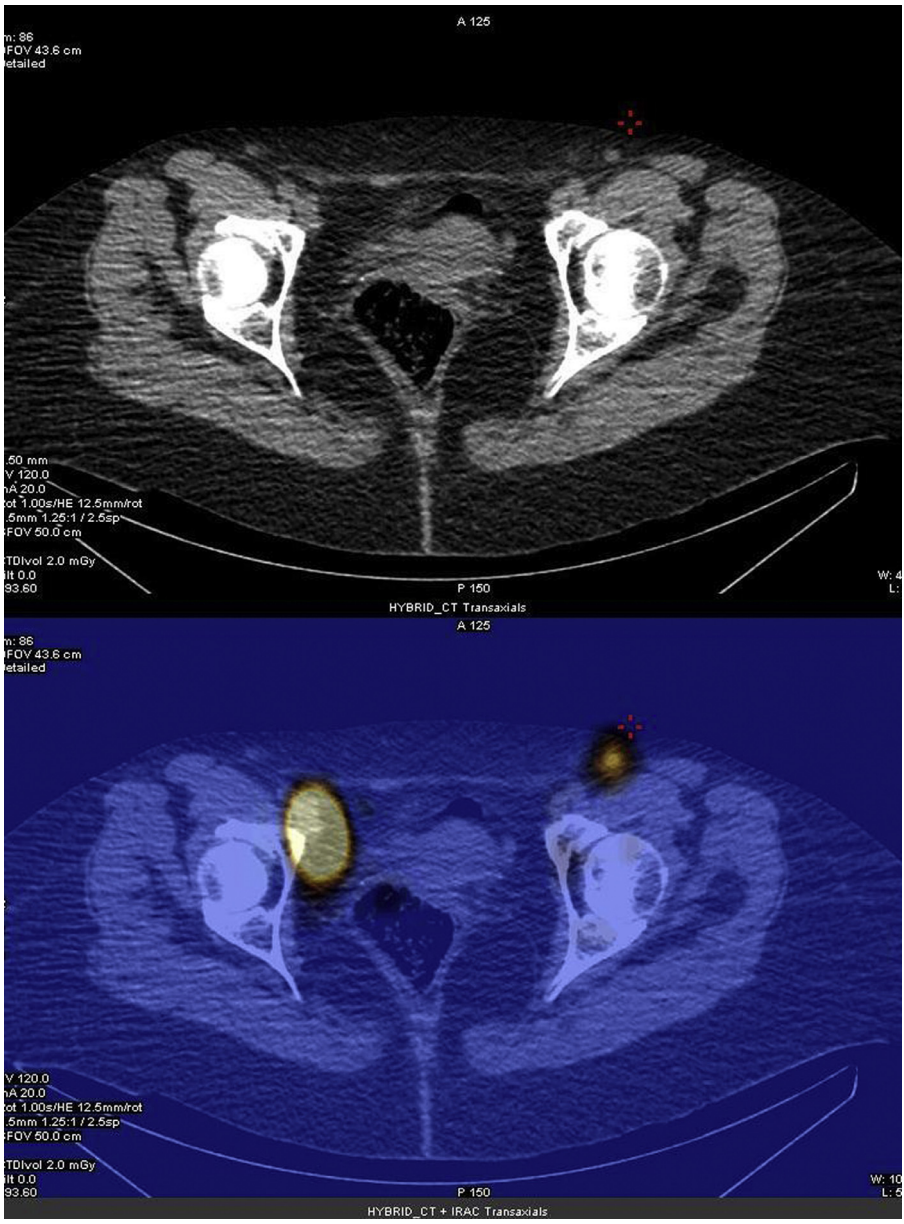

Figure 1. Continued

Design of the combined flap

On the day before surgery, the chimeric flap, i.e., the DIEP skin island and the preselected lymph nodes, are drawn on the abdominal wall of the patient. For marking the DIEP island, a two-dimensional template based on the measurements of the contralateral breast is prepared and drawn on the patient's abdomen, centered over the selected perforator, following the CTA-assisted pre-designed breast shaping technique.[21]

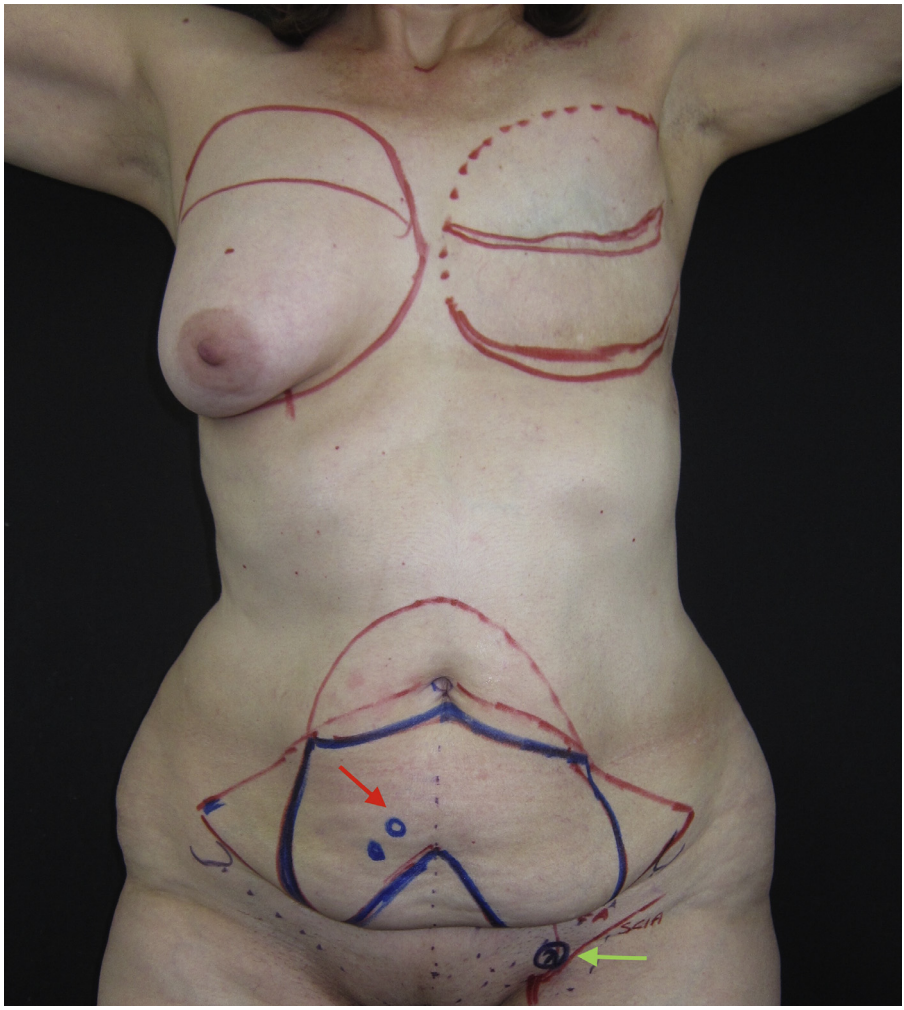

Figure 1. Continued

With the patient in the supine position, the selected lymph nodes are also marked on the inguinal skin, based on the findings of the SPECT-CT.[20] Having drawn both the DIEP skin pattern and the inguinal lymph node flap, an adipose tissue bridge connecting the two flaps is outlined (Figure 1).

Types of chimeric flap

Before drawing the skin template of the DIEP flap, it is essential to consider: (a) the mastectomy side, right or left, (b) the side of the selected lymph nodes, at the right or left inguinal area, and (c) the side of the dominant DIE perforator, at the right or left hemiabdomen. Therefore, four different chimeric flap types are described (Figure 2):

- Type A: the selected lymph nodes and the dominant DIE perforator are both ipsilateral to the mastectomy side
- Type B: the selected lymph nodes are ipsilateral, and the dominant DIE perforator is contralateral to the mastectomy side

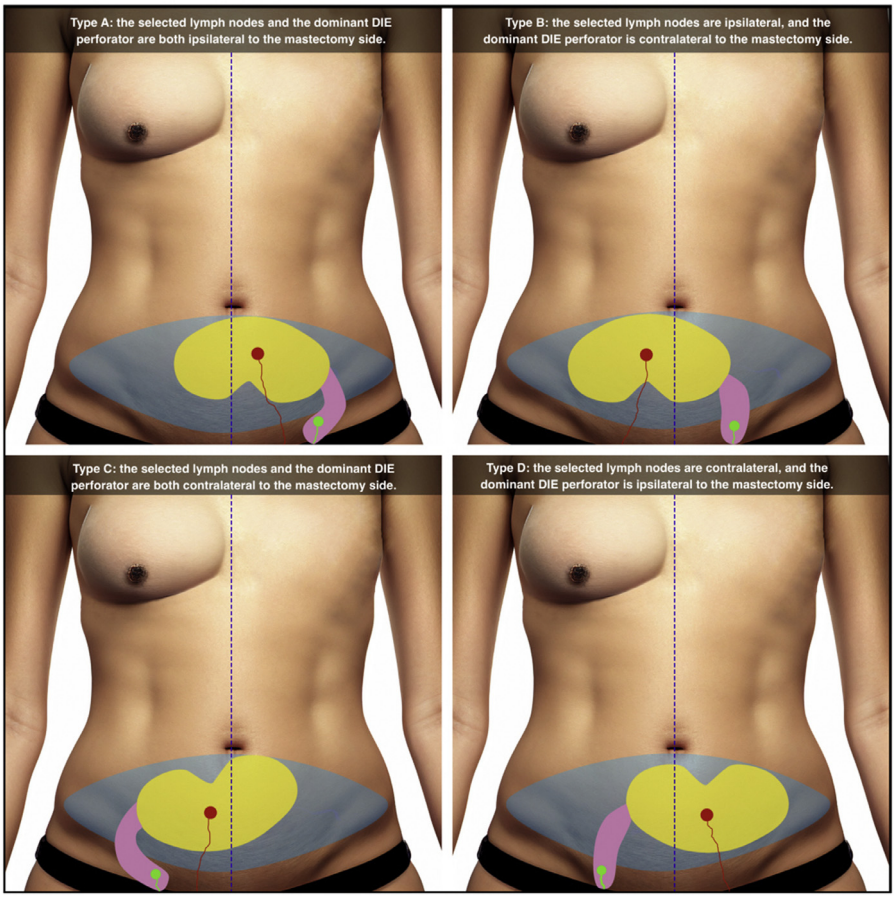

Figure 2. The four types of the predesigned chimeric DIEP-VILN. The gray area illustrates the standard abdominal incision for the DIEP flap elevation; the yellow area illustrates the template of the predesigned DIEP flap, centralized over the selected perforator (red dot); the pink area illustrates the subcutaneous bridge connecting the two components of the chimeric flap, i.e., the DIEP skin island and the inguinal lymph node flap (green dot)

- Type C: the selected lymph nodes and the dominant DIE perforator are both contralateral to the mastectomy side
- Type D: the selected lymph nodes are contralateral, and the dominant DIE perforator is ipsilateral to the mastectomy side

As depicted in Figure 2, in Type A and B cases, the breast template of the DIEP skin island is drawn in an “orthograde” fashion, and the combined flap is simply transferred “upwards” to the recipient area. In Type C and D cases, the breast template is drawn in the “reverse” fashion and the combined flap is transferred to the thorax after 180-degree rotation, allowing the placement of the lymph nodes into the axilla.

Surgical technique

The dissection of the chimeric flap starts with the preparation of the lymph node flap component, through a skin incision over the selected inguinal side, along the lower border of the predesigned DIEP skin island. The lymph node flap is elevated superficial to the deep fascia, lateral to the femoral

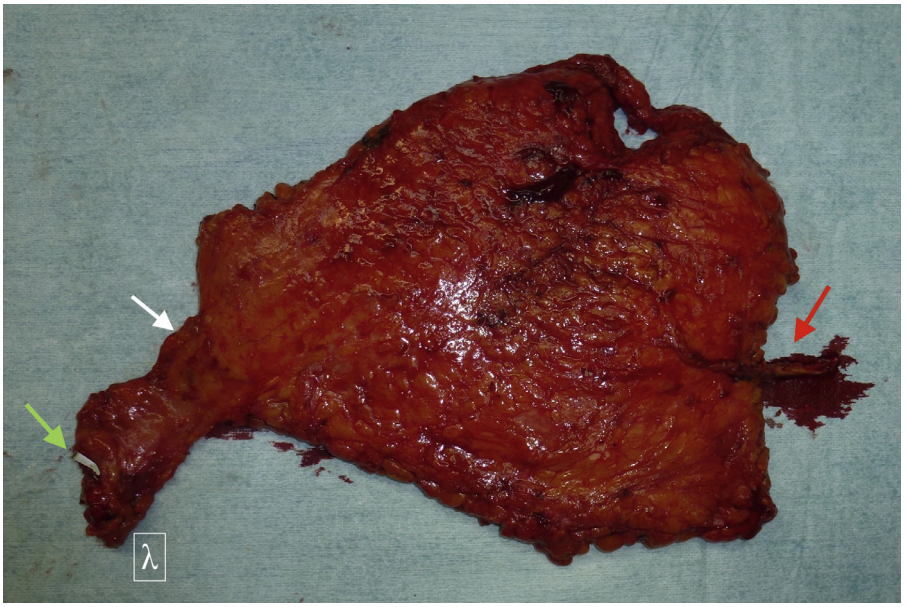

Figure 3. Ventral view of the chimeric DIEP-VILN flap of the patient described in Figure 1, showing the vascular pedicle of the DIEP flap component (red arrow) and the clipped vascular pedicle (green arrow) of the lymph node component (λ); a subcutaneous bridge (white arrow) connects the two components of this combined flap.

vessels, and above the inguinal crease, always remaining attached caudally to the abdominal flap. The VILN flap's nourishing vessels may be either the superficial circumflex iliac (SCI) or the superficial inferior epigastric (SIE) vessels, depending on their size and vicinity to the selected lymph nodes; they are dissected down to their origin from the femoral vessels, providing a minimum 4-5 cm long vascular pedicle. Special care is taken to identify any afferent lymphatic vessels coming toward the selected nodes; these are distally ligated and marked with blue ink so that they will later be oriented toward the corresponding axillary lymphatics when placing the flap in the recipient site.

Thereafter, the DIEP flap is elevated in the usual way, as already described.[21] The selected perforator artery and veins are dissected down to their origin from the deep inferior epigastric vessels, providing a minimum of 10 cm-long vascular pedicle. Before discarding the abdominal tissue outside the preplanned template, a subcutaneous bridge of minimum 6-8 cm long, connecting the two chimeric flap components, is meticulously prepared, allowing a tension-free placement and revascularization of the lymph node flap in the axillary fossa (Figure 3). The triangular area of the DIEP skin pattern delimited by the vertical lines, is de-epithelialized while the abdominal flap is still attached in situ.

Meanwhile, the recipient site is prepared to accommodate the bipedicle chimeric flap. The internal mammary vessels are prepared for the anastomoses with the vascular pedicle of the DIEP flap. The axillary scar tissue is meticulously resected, and descending branches (artery and vein) of the thoracodorsal vessels are dissected to a minimum length of 5cm, distally ligated, rotated upward, and prepared for the anastomoses with the lymph node-flap vascular pedicle. Two pairs of microanastomoses are always performed: the DIEP pedicle is first anastomosed in an end-to-end fashion on the internal mammary vessels, followed by the lymph node flap revascularization on the thoracodorsal vascular branches.

After the completion of microvascular anastomoses, the lymph nodes are placed into the axillary fossa in the vicinity of the efferent lymphatic vessels of the arm, and stabilized with loose 4/0 absorbable sutures. The DIEP skin island is then tailored to produce a three-dimensional breast conus

Figure 4. A. A 47-year-old patient with left mastectomy and Stage II left upper-limb lymphedema; the volume difference ratio between arms was 28%. B. Preoperative drawings of a Type B chimeric DIEP-VILN flap; the DIEP skin island (traced with purple ink) is centered over the selected right hemiabdomen perforator (purple dot) and the preselected lymph node flap is marked on the left inguinal area, indicated with the green letter "λ". C. Patient's appearance 3 years following the reconstruction; comparative measurements revealed a 17% volume difference ratio between the operated and the unaffected arm

and sutured in situ. The volume and projection of the reconstructed breast are assessed for symmetry with the contralateral breast.

Results

Patients

From June 2012 to June 2022, a total of 34 consecutive female patients (aged 37-61 years, mean 45.6 years) with unilateral mastectomy and ipsilateral breast cancer–related arm lymphedema, underwent a delayed breast and lymphedema reconstruction using a predesigned chimeric DIEP-VILN flap. The patients' body mass index ranged from 22.4 to 39kg/m^2 (mean 26.5kg/m^2). All patients had previously undergone axillary lymph node dissection; 30 out of 34 patients had received radiotherapy as

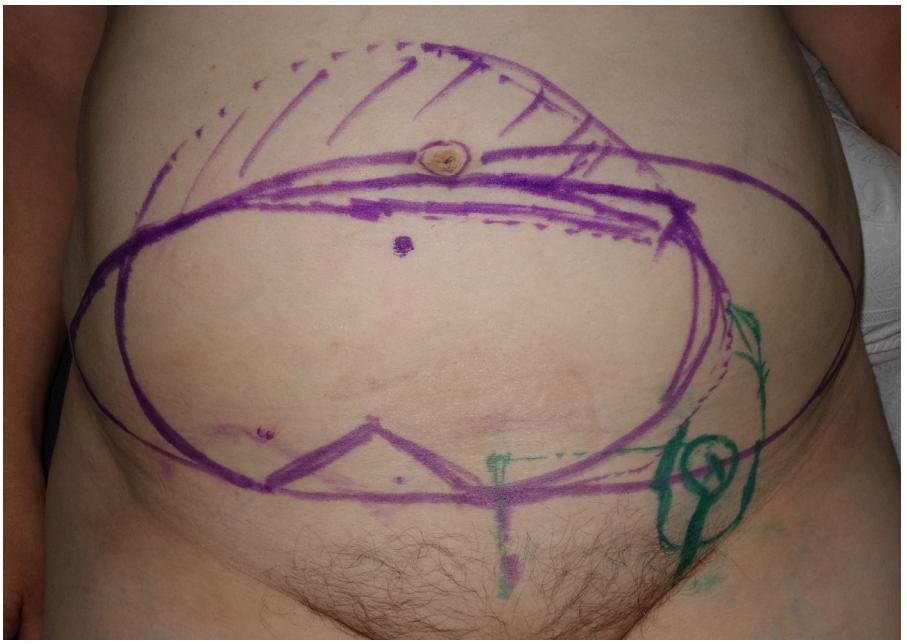

Figure 4. Continued

an adjunct breast cancer treatment. The mean onset of lymphedema symptoms was 3.6 years, with a range of 14 months to 12 years. Based on the ISL classification,[19] 10 patients were classified as Stage I, 21 patients as Stage II, and three patients as Stage III. Comparative volumetric measurements of both upper extremities showed an average volume excess of 33% between the arms.

Flaps

In 24 cases, the selected lymph nodes were ipsilateral to the mastectomy, and the chimeric flaps (Type A=7, Type B=17) were prepared and transferred in an "orthograde" manner. In 10 patients, lymph node donor sites were contralateral to the mastectomy, and the chimeric flaps (Type C=2, Type D=8) were transferred after a 180-degree rotation. In all cases, two pairs of micro-anastomoses were performed. The SIE vessels were used to supply the VILN flap component in 25 cases, and the SCI vessels in nine patients.

Complications

Out of 34, 33 chimeric flaps achieved complete survival, with one case of partial distal DIEP flap necrosis that required subsequent surgical debridement. Recipient site minor delayed wound healing problems were observed in four patients, while six patients experienced donor-site wound complications, including delayed wound healing in five cases and groin seroma in one case. No donor-site lower extremity or genitalia lymphedema was documented, and none of the patients reported functional impairment or feeling of heaviness of the donor lower limb.

Outcomes of lymphedema and breast reconstruction

After a mean follow-up of 35 months (range 14-70 months), all patients reported symptomatic and functional improvement of their lymphedematous arm, including tissue softening, less pain, and reduced feeling of heaviness.

Figure 4. Continued

Lymphedema improvement was documented in all patients with comparative measurements of upper-limb volumes that revealed a 47% mean volume difference (Figure 4); the mean excess volume ratio was reduced from 33% (ranging from 9%-71%) preoperatively, to 17.5% (ranging from -2% to 35%) postoperatively. ICG examination of the operated limbs revealed a downstage of the dermal backflow pattern between one (in 20 patients) or two stages (in 6 patients), according to Yamamoto's classification.[22] Eight patients showed no changes in the postoperative ICG lymphography of the operated limb; none of our patients showed worsening of the lymphatic circulation after surgery.

As for the breast reconstruction, in six patients minor secondary revisions on the reconstructed breast, including lipofilling on the upper pole (n=5) and scar revision (n=1), were performed. Patient satisfaction based on self-evaluation questionnaires showed high satisfaction rates (very satisfied: 21 patients, satisfied: 12 patients, not satisfied: 1 patient). No correlation between patients' satisfaction and flap Type was documented.

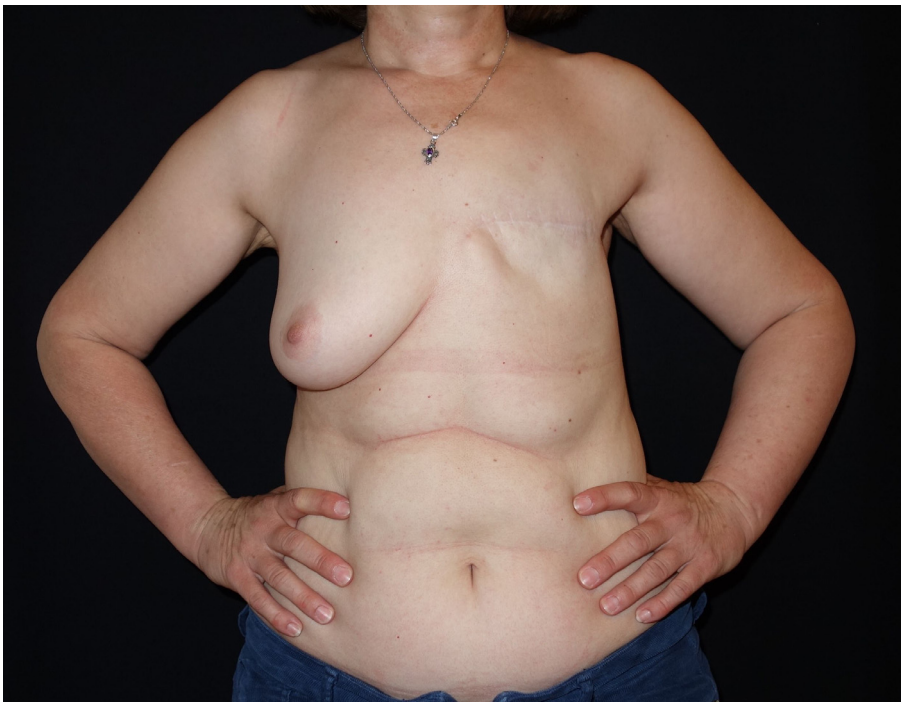

Figure 5. A, B. Preoperative views of a 43-year-old patient with a left mastectomy and Stage I left arm lymphedema. C. Preoperative markings of the selected DIE perforator over the left hemiabdomen and the preselected lymph nodes (λ) over the right groin area; a Type D flap was planned to be used. D, E. Postoperative results at the 30-month follow-up showing a symmetrical breast reconstruction outcome, and a volume difference reduction ratio from 13% preoperatively, to minus 2% postoperatively.

Discussion

In the last decade, the combined autologous breast reconstruction associated with vascularized lymph node transfer has been widely used to simultaneously address breast and post-mastectomy ULL reconstruction in a single procedure.[12] Several donor sites have been suggested for this combined approach, e.g., the free abdominal-based flap combined with inguinal lymph nodes, the latissimus dorsi-based vascularized lymph node transfer,[23] or the gastroepiploic lymph node flap associated with the DIEP flap;[24] however, the chimeric flap coupling the inguinal lymph nodes to a DIEP or muscle-sparing transverse rectus abdominis myo-cutaneous (MS-TRAM) flap remains the mainstay for simultaneous breast and BCRL reconstruction in post-mastectomy patients.[13,15-17,25,26]

Although many studies have shown promising results, the overall surgical approach regarding the preparation of the chimeric flap, the preoperative imaging and selection of the lymph nodes, as well as the shaping of this combined flap, have not yet been standardized.

In 2015, Nguyen et al. proposed an algorithm for the design and transfer of the chimeric DIEP-VILN flap, considering the uni- or bilaterality of the breast reconstruction, the lymph node donor site, and the recipient vessels of the flap.[13] According to the authors, the lymph nodes are preferably harvested contralaterally, and the abdominal flap pedicle is ipsilateral to the mastectomy side. Therefore, the chimeric flap is rotated 180º, and anastomoses are performed on the internal mammary vessels and thoracodorsal branches for the DIEP and VILN components, respectively. In bilateral breast reconstructions, the combined hemi-abdominal flap with the ipsilateral inguinal lymph nodes is rotated 90º and revascularized on thoracodorsal branches. Although this approach aims to optimize simultaneous autologous breast and ULL reconstruction, there are still questions to be discussed regarding the execution, and efficacy of the procedure.

Figure 5. Continued

In the present study, we describe a comprehensive algorithm that provides a guided and precise preparation, elevation, and setting of the combined DIEP-VILN flap in unilateral mastectomy-BCRL patients. The new aspects introduced by our approach compared to Nguyen's algorithm, include not only the initial planning of both predesigned components of the chimeric flap but also the precise shaping of the breast template, the transfer, and the setting of the combined flap in the recipient area.

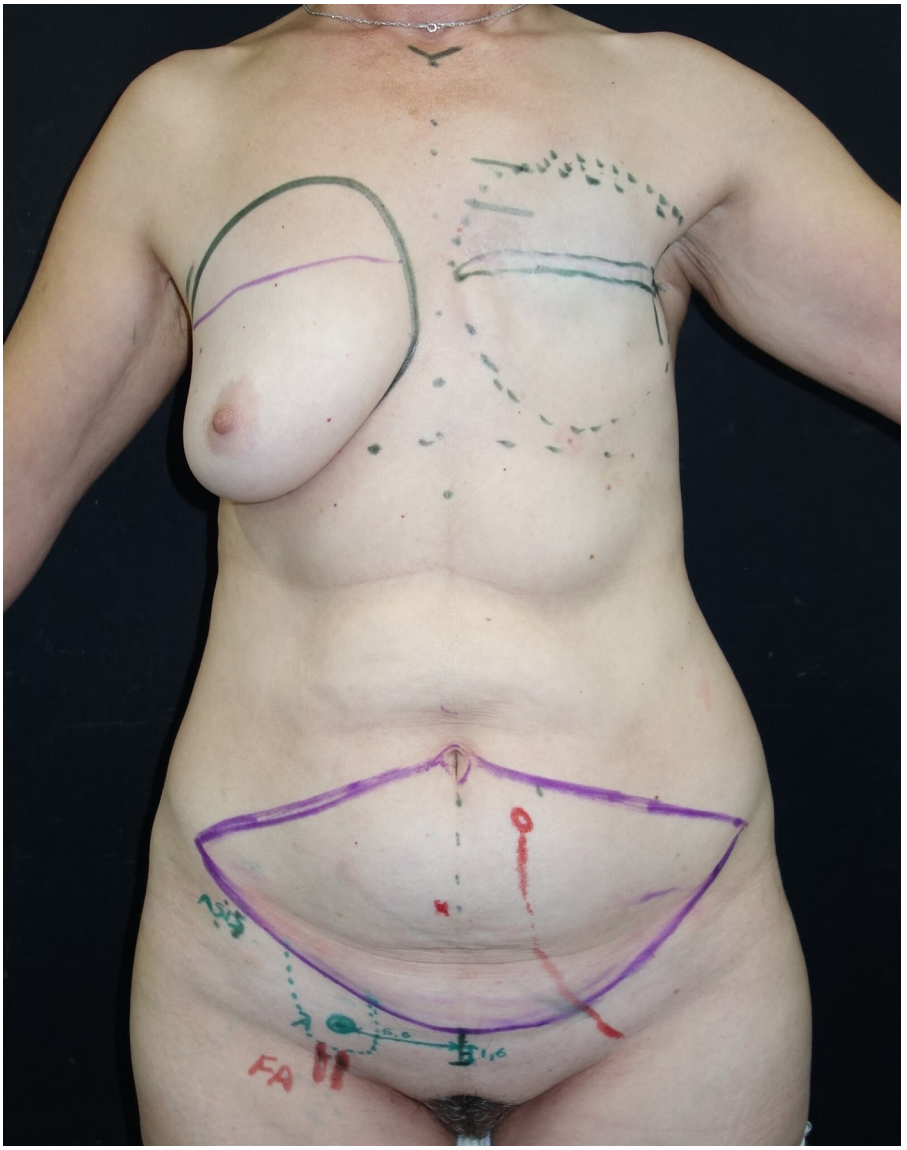

Figure 5. Continued

Aiming to standardize this procedure, it is mandatory, before marking the chimeric flap on the abdominal wall, to consider the location of the preselected lymph nodes regarding the mastectomy side. As previously described, when the selected lymph nodes are ipsilateral to the mastectomy side (Type A and B flaps), the DIEP skin template is outlined in an "orthograde" fashion; when the selected lymph nodes are contralateral to the mastectomy side (Type C and D flaps), the DIEP template is drawn in a "reverse" way, and the chimeric flap transferred to the chest after 180º rotation, to place the lymph node flap component into the axilla (Figure 5). Of note, in cases of Type A and Type C flaps, where both the preselected DIE perforator and lymph nodes belong to the same side, it is important to plan a curved adipose tissue connecting bridge, which will provide extra length and allow a better rotation

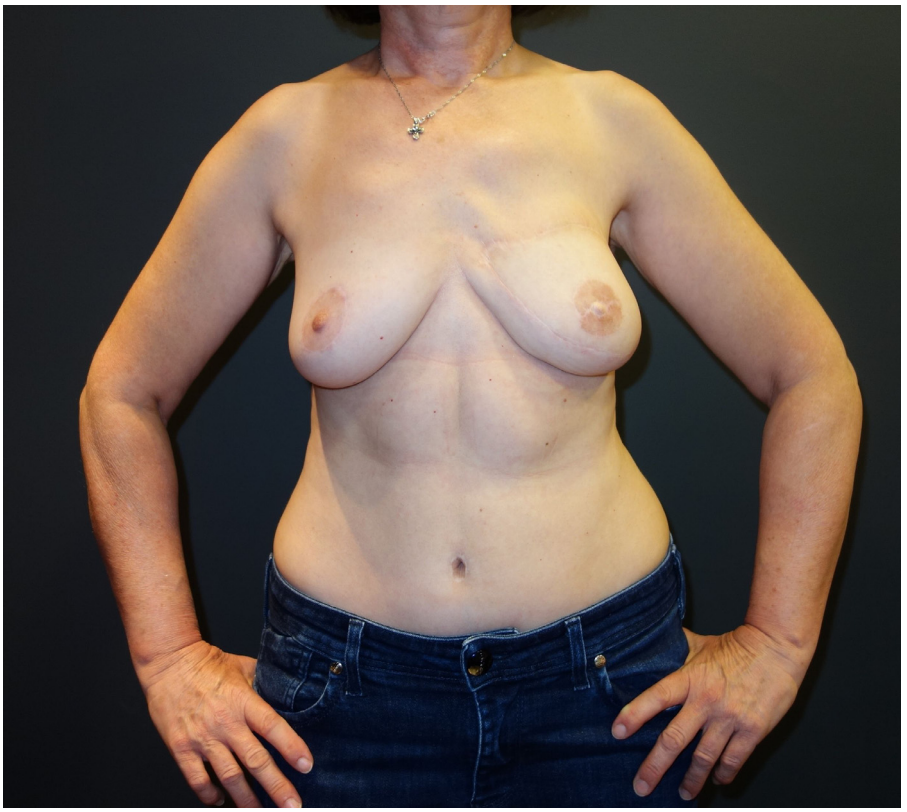

Figure 5. Continued

and tension-free placement of the lymph nodes into the axillary fossa (Figure 2). Another important point during flap insertion is the optimal orientation between the afferent lymphatic vessels of the lymph node flap and the efferent lymphatics of the recipient site, which can significantly contribute to the restoration of the lymphatic flow of the involved upper limb. It is worth noting that the type of flap used in our series was not associated with any significant intraoperative technical difficulties or complications; Type B and Type D chimeric flaps, having the two pedicles placed on contralateral sites, were used in the majority of our cases, and may be considered somewhat easier to harvest.

In all our cases, microvascular arterial and venous anastomoses were performed both medially on the internal mammary vessels, and laterally on thoracodorsal branches, for the revascularization of the DIEP and VILN flap-components, respectively; we believe that even if adequate perfusion of the transferred lymph nodes is confirmed after the chimeric flap's revascularization on the internal mammary vessels, at least one extra venous anastomosis should be performed in the axillary region, to ensure better outflow and avoid venous congestion of the transplanted tissues. The main thoracodorsal pedicle is suggested to be preserved, as an alternative option for future breast reconstruction.

Our long-term results confirm the safety and efficacy of this predesigned combined flap approach. Breast reconstruction outcomes showed good symmetry between breasts, with only a few patients (5 out of 34) requiring minor revisions to further enhance aesthetic outcomes. Furthermore, a significant response to the lymphatic surgery was recorded, with a mean excess volume-ratio reduction from 33% preoperatively to 17.5%, postoperatively. No patient developed donor-site lymphedema, nor any lymphatic flow disturbances of the donor leg, as confirmed by the comparative postoperative lower limb ICG lymphography.

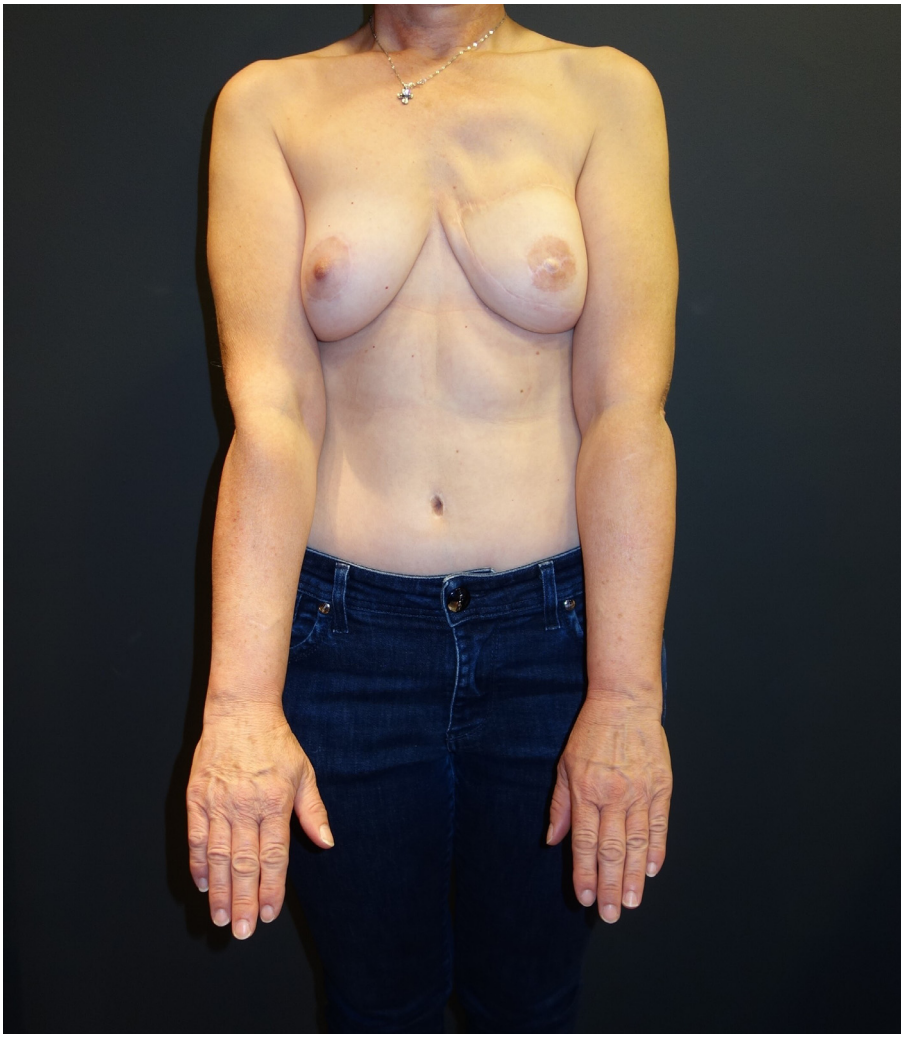

Figure 5. Continued

According to most authors, lymph node flap selection is based only on reverse lymphatic mapping to avoid harvesting the nodes draining the donor's lower limb.[27] In the present study, the use of the SPECT-CT guided lymph node harvesting technique not only contributes to identifying the most functional lymph nodes for transfer, but most importantly, it minimizes the risk of iatrogenic donor-site lymphedema;[20] therefore, intraoperative reverse lymphatic mapping was not required, nor was it used in our series.

A limitation of using this algorithm is related to bilateral mastectomy patients; in those cases, the hemi-DIEP flap should be combined with the ipsilateral lymph nodes, depending on the side of the preselected ones.

In conclusion, our algorithmic approach using a predesigned chimeric DIEP-VILN flap provides a valuable tool for reconstructive surgeons when planning a delayed unilateral combined breast and lymphedema reconstruction. It successfully addresses the triad of structural, functional, and aesthetic reconstruction, and enhances the safety of the procedure minimizing the risk of iatrogenic donor-site

lymphedema; furthermore, it emphasizes the importance of a detailed preoperative patient assessment and imaging for accurate and standardized planning of the entire procedure.

Declaration of competing interest

None.

Funding

None

Ethical approval

Not required.

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