Review Article

Breast reconstruction with latissimus dorsi flap: a comprehensive review and case series

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Abstract: The latissimus dorsi flap (LDF) has gained popularity given its versatile nature and broad applicability in breast reconstruction. Its resurgence has been attributed to its ability to be enhanced using implant or high-volume fat grafting, rendering it a primary option for selected patients. The aim of this review is to tackle current indications and subjects of controversy regarding use of complete-autologous and implant-enhanced LDF in breast reconstruction. Also, a case-series showcasing the authors' experience with this versatile reconstructive option is presented. A search across Web of Science and PubMed MEDLINE from inception through January 3, 2023, was conducted. Articles reporting postoperative outcomes of autologous breast reconstruction with LDF were included. Regarding the case series, electronic medical records of patients who underwent total mastectomy and autologous breast reconstruction with LDF from January 2011 to December 2021 were retrospectively reviewed. Data on demographic and oncologic characteristics, and surgical characteristics and outcomes were extracted. Our review suggests that LDF is suitable for patients who lack alternative donor site, have a history of abdominoplasty or no access to microsurgery, smokers or obese. Latissimus dorsi (LD) harvesting has almost complete shoulder function recovery in the long-term. Thoracodorsal nerve division does not cause volume loss or animation deformity. Multisite multilayer fat grafting, beveling the edges of the skin paddle and fat, folding the LD muscle and plicating the paddle allow adequate projection and contour achievement. Our case-series included 234 reconstructions. Almost half of the patients had immediate fat transfer during reconstruction (51.3%). The rate of recipient site hematoma was 3.0%, seroma was 7.7%, wound disruption 32.1%, wound disruption events requiring unplanned procedures was 13.7%, and surgical site infection (SSI) was 12.4%. The LDF is reliable and safe for immediate or delayed breast reconstruction or salvage after reconstruction failure. Its versatility, reliable anatomy, easy dissection, and relative low complication rate have revived this modality as valuable opportunity for breast reconstruction in this era.

Keywords: Female; treatment outcome; breast; superficial back muscles; myocutaneous flap

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Introduction

The latissimus dorsi (LD) muscle has been adopted by plastic surgeons as one of the workhorse flaps for breast reconstruction. Its use was first described by Iginio Tansini in 1896 as a cutaneous flap to cover a defect secondary to breast cancer surgery (1). He then renewed the procedure to incorporate the LD muscle in the flap in 1906. His method was widely used throughout Europe between 1910 and 1920, but it was not until the 1970s that the LD flap (LDF) was standardized as an approach for autologous breast reconstruction (2).

Its reliable and consistent pedicle, reproducible surgical technique, avoidance of microvascular anastomoses, and the varied shapes and orientations it can take, have rendered this flap well recognized (3). Nonetheless, this technique is not without drawbacks or shortcomings. These limitations include donor site seroma and dehiscence (4,5), and the not-uncommon possibility of requiring implant insertion if the volume of the LDF is insufficient (6). Moreover, the emergence of pedicled abdominal-based flaps and free tissue transfer have toned down the interest in the LDF over the following years.

The LDF has recently regained popularity. Factors associated with this resurgence comprise the capacity for high-volume fat grafting to increase the flap's volume, the advent of quilting sutures at the donor site to avoid seromas (7), and the paucity of reimbursement for free tissue transfer. Outcomes regarding the implementation of this flap for breast reconstruction are still heterogeneous. Therefore, the aim of this review was to tackle the current indications and subjects of controversy regarding the use of complete autologous and implant-enhanced LDF in breast reconstruction. Furthermore, we presented a case series showcasing our experience with this versatile reconstructive option. We hypothesized that breast reconstruction with LDF is a safe alternative demonstrating a low total flap loss rate (<5%) and low rate of postoperative revisions.

Methods

Literature review

We performed a narrative review implementing a systematic search across Web of Science and PubMed MEDLINE from inception through January 3rd, 2023, to retrieve relevant studies. We included articles reporting postoperative outcomes of autologous breast reconstruction with LDF. The following terms were used in different combinations using the Boolean operator "AND": "latissimus dorsi", "breast", "cancer", "reconstruction", and "flap". We included case reports, case series, longitudinal studies, randomized-controlled trials, meta-analyses, and systematic reviews (*Figure 1*). We excluded articles on chest wall reconstruction or reconstruction in transgender or non-binary individuals.

Case series

We retrospectively reviewed the electronic medical records of patients who underwent total mastectomy and autologous breast reconstruction with the LDF between January 2011 and December 2021. Institutional Review Board approval was obtained. The indication for LDF in the setting of breast reconstruction has been reported in previous articles from our institution (6). Each reconstruction was regarded as an individual research subject. Patients who had partial mastectomy were excluded.

Briefly, the shape and size of the skin paddle vary with individual breast types and body habitus, but a thorough assessment of the skin tension should guide the incision patterns in every case. The typical width for the paddle in our series often exceeded 10 cm. Forty-five-degree beveled skin incisions are usually performed to incorporate supra-Scarpa and sub-Scarpa fat within the flap. The thoracodorsal pedicle is identified and protected, with preservation of the serratus branch.

Our current approach includes LDF with immediate fat transfer (LIFT) for selected cases (8). In these patients, fat is processed using the REVOLVE fat system (LifeCell, Co., Bridgewater, NJ, USA) and is injected in a latticed, multilayer fashion using a 3-mm Coleman cannula and 10-mL syringe. After fat grafting, the LD muscle is usually folded on itself twice to attain optimal projection, and the skin paddle is imbricated or plicated to achieve adequate breast shape.

In patients with previous history of radiation, lack of soft-tissue coverage for immediate prosthesis placement, lack of adequate dorsal soft-tissue to achieve optimal breast volume after reconstruction, and patients with a high risk of ischemic complications desiring implant-based reconstruction, implant-enhanced LDF reconstruction was used. If an implant or tissue expander was required or used during reconstruction, the LD muscle was then used to cover the inferior pole of the prosthesis, like a sling. Quilting sutures for donor site closure were used in ≥99% of the cases. For drain removal, the minimum drain output was 30-cc per day for 48 consecutive hours.

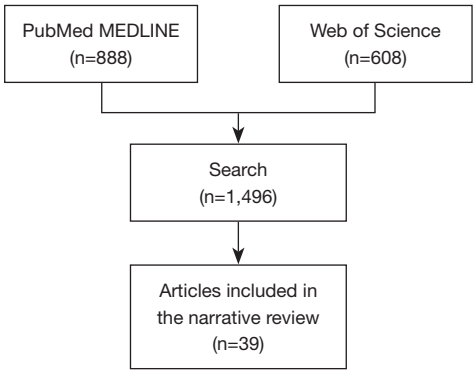

Figure 1 Narrative review flowchart.

Further details of the surgical technique for LDF has been previously reported in other reports (6). The plane for lipo-injection (e.g., subcutaneous fat, LD muscle, pectoralis major muscle), volume of fat delivered, the percentage of skin paddle that was de-epithelialized, and the use of SPY fluorescence imaging (Stryker, Kalamazoo, MI, USA) depended on the surgeon's predilection.

Data extraction

We extracted data on the demographic characteristics, medical comorbidities, smoking status, length of follow-up, American Society of Anesthesiologists (ASA) classification, preoperative hematocrit, oncologic data for diagnosis and staging, surgical characteristics for reconstruction and surgical outcomes, postoperative complications, and revision procedures. Complications evaluated in this series included the rate of hematoma, hematoma requiring return to the operating room (RTOR) for evacuation, seroma, red blood cell (RBC) transfusion requirements, fat necrosis, wound disruption (dehiscence or mastectomy flap necrosis/partial LDF necrosis), wound disruption requiring debridement ± excision, surgical site infection (SSI), pneumonia, and atelectasis. We used binomial logistic regression models to evaluate the association of current smoking or obesity (≥30 kg/m^2) with each specific complication. All analyses were performed using R statistical software, version 4.0.0 (R Core Team, 2020).

Results

Demographic and oncologic data

Overall, 234 reconstructions were performed during the observation period (*Table 1*). Most procedures were

Table 1 Demographic information

Baseline variables	Frequency	Percent/ Median [IQR]
Reconstructions	234	100.0
Race/ethnicity		
White/Caucasian	183	78.2
Black/African American	33	14.1
Other	18	7.7
Age (years)		54 [46–60.7]
<65	206	88.0
≥65	28	12.0
Marital status		
Single	51	21.8
Married	123	52.6
Divorced/separated	41	17.5
Widowed	14	6.0
Unknown	5	2.1
BMI (kg/m^2)		31.6 [27.2–36.8]
<30	97	41.5
≥30	137	58.5
Smoking status		
Never	133	56.8
Current	16	6.8
Former	85	36.3
Diabetes mellitus	39	16.7
Hypertension	99	42.3
Thyroid disease	40	17.1
Hyperlipidemia	86	36.8
Asthma/COPD	41	17.5
Menopausal state		
Premenopausal	82	35.0
Postmenopausal	152	65.0
ASA physical status		
ASA II	137	58.5
ASA III	96	41.0
ASA IV	1	0.4
Preoperative hematocrit (%)		41 [39–43]
Follow-up (weeks)		161 [83.7–225]

IQR, interquartile range; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists.

Table 2 Oncologic data

Oncologic variables	Frequency	Percentage
Reconstructions	234	100.0
Indication		
Therapeutic	164	70.1
Prophylactic	70	29.9
Side		
Right	119	50.9
Left	115	49.1
Mutation	80	34.2
Diagnosis		
No malignancy	70	29.9
IDC	116	49.6
ILC	17	7.3
DCIS	23	9.8
Phyllodes	8	3.4
Stage		
Stage 0	23	9.8
Stage 1	77	32.9
Stage 2	44	18.8
Stage 3	17	7.3
Tumor size		
Tis	23	9.8
T1	63	26.9
T2	52	22.2
T3–T4	23	9.8
Node involvement		
N1	35	15.0
N2–N3	12	5.1
ER negative	33	14.1
PR negative	46	19.7
HER2 positive	21	9.0
Pre-mastectomy radiotherapy	28	12.0
Neoadjuvant chemotherapy	55	23.5
Adjuvant radiotherapy	55	23.5
After reconstruction	28	12.0
Before reconstruction	27	11.5
Adjuvant chemotherapy	79	33.8

IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma; DCIS, ductal carcinoma in situ; ER, estrogen receptor; PR, progesterone receptor; HER2, human epidermal growth factor receptor 2.

performed on White/Caucasian (78.2%) or Black/African American patients (14.1%). The median age of patients was 54 years [interquartile range (IQR), 46–60.7 years] and the median body mass index (BMI) was 31.6 kg/m^2 (IQR, 27.2–36.8 kg/m^2). The proportion of reconstructions performed in current and former smokers was 6.8% and 36.3%, respectively. The percentage of reconstructions performed in patients with medical comorbidities such as diabetes was 16.7%, hypertension was 42.3%, thyroid disease was 17.1%, hyperlipidemia was 36.8%, and asthma/chronic obstructive pulmonary disease (COPD) was 17.5%. Most reconstructions were performed in patients with a physical classification ASA II (58.5%) and ASA III (41.0%). The median preoperative hematocrit was 41% (IQR, 39–43%). Patients were followed up over a median period of 161 weeks (IQR, 83.7–225 weeks).

The percentage of reconstructions performed after therapeutic or oncologic total mastectomy was 70.1%, while prophylactic or risk-reducing mastectomies were performed in 29.9% of the patients. The oncologic data on diagnosis and staging is reported in *Table 2*. Twelve percent of the reconstructions were performed in patients with pre-mastectomy radiotherapy, while 23.5% of reconstructions were performed in patients who received neoadjuvant chemotherapy. Overall, 23.5% of the breasts were exposed to adjuvant radiotherapy and 33.8% of the reconstructions were performed in patients who required adjuvant chemotherapy.

Surgical characteristics

Most procedures were skin-sparing mastectomies (94.4%). According to the classification of Lotan *et al.* (9), the most common patterns for mastectomy incisions were transverse (63.7%) and the wise pattern (15.8%). SPY fluorescence imaging was used to assess perfusion of mastectomy skin flaps in 13.2% of the cases (*Table 3*). The proportion of procedures performed as bilateral reconstructions was 65.0%, while unilateral reconstructions were performed in 35.0% of the cases. Most procedures were immediate reconstructions (69.7%). Previous implant-based breast reconstruction (IBBR) was attempted in 18.8% of the reconstructions. Nerve blocks were performed in 41 cases (17.5%). The proportions of reconstructions in which the LDF was partially and totally de-epithelialized were 42.3% and 31.6%, respectively. The thoracodorsal nerve was only transected in 4 cases (1.7%). In 16.7% of the reconstructions, implant-enhanced LDFs were employed

Table 3 Surgical characteristics

Surgical characteristics	Frequency	Percent/ Median [IQR]
Reconstructions	234	100.0
Type of mastectomy		
SSM	221	94.4
NSM	13	5.6
Mastectomy pattern		
Transverse pattern	149	63.7
Wise pattern	37	15.8
Vertical pattern	15	6.4
Other patterns	33	14.1
SPY fluorescence imaging	31	13.2
Laterality		
Unilateral	82	35.0
Bilateral	152	65.0
Timing		
Immediate	163	69.7
Delayed	71	30.3
Type of block		
No block	193	82.5
PEC	10	4.3
SER	2	0.9
PEC + SER	19	8.1
Paravertebral	4	1.7
Epidural	6	2.6
Period		
2013–2015	44	18.8
2016–2018	98	41.9
2019–2021	92	39.3
Previous IBBR	44	18.8
Skin paddle de-epithelialization		
No de-epithelialization	61	26.1
Partial de-epithelialization	99	42.3
Total de-epithelialization	74	31.6
TD nerve transection		
Intact	230	98.3
Cut	4	1.7
Immediate implant placement	39	16.7
LIFT (mL)	120	51.3
Total volume of FG		125 [110–170]
FG injected in the LD		70 [50–100]
FG injected in the PMM	107	89.2/ 60 [50–84.5]
FG injected in the mastectomy flaps	10	8.3/ 35 [12.5–63.75]

IQR, interquartile range; SSM, skin-sparing mastectomy; NSM, nipple-sparing mastectomy; PEC, pectoralis muscle; SER, serratus muscle; IBBR, implant-based breast reconstruction; TD, thoracodorsal; LIFT, latissimus dorsi flap with immediate fat transfer; FG, fat grafting; IQR, interquartile range; LD, latissimus dorsi; PMM, pectoralis major muscle.

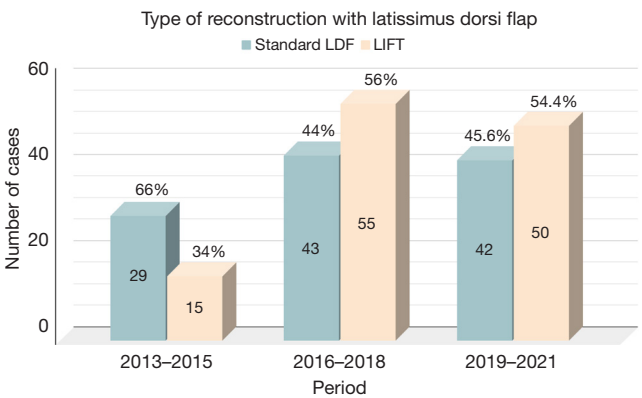

Figure 2 Proportion of breast reconstructions performed with LIFT and the standard LDF during different periods. LIFT, latissimus dorsi flap with immediate fat transfer; LDF, latissimus dorsi flap.

(immediate implant placement).

For reconstructions undergoing LIFT (51.3%), the median volume of total fat transferred during the procedure was 125 mL (IQR, 110–170 mL) (*Figure 2*). The median volume of fat delivered directly into the LDF was 70 mL (IQR, 50–100 mL). Fat grafting at the time of reconstruction was also injected into the pectoralis major muscle in 89.2% of the cases that had LIFT and the median volume was 60 mL (IQR, 50–84.5 mL) (*Table 3*).

Table 4 Surgical outcomes

Surgical outcomes	Frequency	Percent/ Median [IQR]
Reconstructions	234	100.0
Anesthesia time (min)	234	518 [420–610]
Unilateral	82	392 [320–447.5]
Bilateral	152	590 [517.2–626]
Immediate	163	555 [480–619]
Delayed	71	380 [318.5–472.5]
EBL (mL)		200 [100–250]
LOS (days)		3 [2–3]
Duration of drains (days)		
Recipient site drains		13 [9–15]
Donor site drains		13 [11–17]
Delayed implant placement	4	1.7
Revision with secondary fat grafting	102	43.6
Volume of secondary fat grafting[‡] (mL)		150 [105–280]
Revisions for excision of excess tissue		
Breast revision[†]	95	40.6
Donor site revision[†]	38	16.2

[†], soft-tissue rearrangement, soft tissue reinforcement, or excision of excess tissue; [‡], volume of fat only transferred during secondary or revision procedures. IQR, interquartile range; EBL, estimated blood loss; LOS, length of stay.

Surgical outcomes

Overall, the anesthesia time was 518 min (IQR, 420–610 min). When stratified for the timing of the procedures, the median anesthesia time of immediate and delayed reconstructions was 555 min (IQR, 480–619 min) and 380 min (IQR, 318.5–472.5 min), respectively. The median estimated blood loss was 200 mL (IQR, 100–250 mL) and the median length of stay was 3 days. The median time for drain removal was 13 days for both, the recipient site and donor site (*Table 4*). Delayed implant insertion was required in 1.7% of the cases to achieve an optimal volume. Revision procedures with secondary fat grafting were performed in 43.6% of the reconstructions. The median volume of autologous fat delivered during these secondary/revision procedures was 150 mL (IQR, 105–280 mL). Revision procedures to address excess of skin or excess of soft tissue were required in 40.6% of the reconstructions (recipient site) and in 16.2% of the donor sites.

Flap re-exploration was not required (0.0%). One LDF exhibited signs of congestion after harvest and was inset in a delayed fashion (0.4%). Transfusion of RBC was required in 4.3% of the reconstructions (*Table 5*). Four patients had healthcare-associated pneumonia (1.7%). The rate of recipient site hematoma was 3.0%, seroma was 7.7%, wound disruption was 32.1%, wound disruption events requiring unplanned procedures was 13.7%, and SSI was 12.4%. Capsular contracture was reported in 9 cases (3.8%) and prosthetic devices were removed in 14 reconstructions (6.0%).

We evaluated the effect of obesity and active smoking on postoperative complications. After evaluating all complications, obesity (≥30 kg/m^2) was associated with a higher risk of mastectomy flap necrosis on univariable analysis [18.2% versus 6.2%; odds ratio (OR) =3.385; 95% CI: 1.332–8.606; P=0.0104]. After adjusting for hypertension, type of mastectomy (skin sparing versus nipple sparing), laterality of reconstruction (unilateral and bilateral), timing of reconstruction (immediate versus delayed), and LIFT, obesity was no longer a risk factor for mastectomy flap necrosis (OR =2.258; 95% CI: 0.791–6.445; P=0.128). We did not find any association between active/current smoking and the risk of any specific complication.

Donor site complications recorded in our series included hematoma in 0.4%, seroma in 7.3%, wound disruption in 15.4%, vacuum-assisted closure (VAC) therapy to address wound-related complication in 3.8%, SSI in 5.1%, and hernia in 0.4% of the cases (*Table 5*).

Discussion

Indications for LDF

The LDF used for reconstruction is reliable and versatile, and almost any patient is a good candidate for it (10). In many instances it is used in salvage or delayed reconstructions (11). Traditionally, the LDF is employed in patients who are not advised to undergo a prosthetic reconstruction, whether direct-to-implant or preceded by a tissue expander as a delayed-immediate reconstruction (8,12). The LDF is also desirable in patients who lack other suitable donor sites, namely the abdominal region. In this sense, patients who are excessively thin or obese, who had previous radiation therapy, or who have a history of abdominal body contouring surgeries are not candidates

Table 5 Postoperative complications

Complications	Counts	Percentage
Recipient site complications		
Fat necrosis	40	17.1
Delayed LDF inset	1	0.4
Hematoma	7	3.0
RTOR	1	0.4
Transfusion	10	4.3
Seroma	18	7.7
Seroma aspiration	6	2.6
Wound disruption	75	32.1
Dehiscence	54	23.1
Mastectomy flap necrosis	31	13.2
Debridement ± excision	32	13.7
SSI	29	12.4
Abscess drainage	9	3.8
Atelectasis	8	3.4
Pneumonia	4	1.7
Capsular contracture	9	3.8
Prosthesis malposition	4	1.7
Prosthesis removal	14	6.0
Painful spasms	25	10.7
Flap re-exploration	0	0.0
Flap loss	0	0.0
Donor site complications		
Fat necrosis	6	2.6
Hematoma	1	0.4
Seroma	17	7.3
Wound disruption	36	15.4
Dehiscence	31	13.2
Skin flap necrosis	7	3.0
Debridement ± excision	16	6.8
VAC therapy	9	3.8
SSI	12	5.1
Abscess drainage	4	1.7
Hernia	1	0.4
Paresthesia	1	0.4

LDF, latissimus dorsi flap; RTOR, return to the operating room; SSI, surgical site infection; VAC, vacuum-assisted closure.

for abdominal-based flaps and are thus candidates for a LDF (13). In addition, the LDF is also a good alternative when microsurgical techniques for tissue transfer are not available or are not convenient. The ability to graft high-volume fat has also permitted the implementation of the LDF without the need for an implant in cases that were once impossible, like in patients with moderate-to-large breasts who ask for total autologous reconstruction but whose back lacks sufficient volume. In this study, we presented one of the largest series of breast reconstruction using the LDF with an extensively detailed examination of several demographic factors, preoperative and intraoperative characteristics, and postoperative outcomes.

Evidence base for LD breast reconstruction

Many patients express their desire to avoid using prostheses and have the option to undergo autologous reconstruction. In addition, those who have previously sustained breast radiation treatment resulting in shrinking of the surrounding soft tissue, or who have a prospect of future radiation therapy with an increased risk for capsular contracture, are suitable for autologous reconstruction (11).

Different factors can make the LDF more appropriate for breast reconstruction compared to alternative therapeutic methods. Patients with a history of abdominoplasty may not be perfect candidates for breast reconstruction using the abdominal donor site because perforator arteries are typically transected. This would compromise the blood supply to the transverse rectus abdominis myocutaneous (TRAM) or the deep inferior epigastric perforator (DIEP) flap, whether free or pedicled. Even though revascularization occurs and reperfusion of the perforators of the rectus muscle takes place, the arteries' diameter may not be sufficient to supply adequate blood flow to the abdominal flap following breast reconstruction. Furthermore, LDF may be more advisable in patients who wish to bear children given that TRAM flap harvesting might result in decreased abdominal wall compliance (14). Another reason why LDF is a viable option is the feasibility of donor site closure in most cases regardless of the size of the flap's skin paddle that was harvested.

In terms of safety, the LDF has also been shown to have an extremely satisfactory safety profile compared to abdomen-based free tissue transfer without affecting the aesthetic component of the reconstruction (8). In a contemporary study, Demiri *et al.* compared the surgical outcomes of free DIEP flap and extended fat-augmented

LDF for breast reconstruction (15). Patients who received fat-augmented LDF for breast reconstruction were younger (P<0.001) and had a lower BMI (P=0.004) (15). While a lower rate of flap-related complications was evident using the fat-augmented LDF (11.1% versus 24.2%, P=0.003), a lower rate of donor-site complications was evident with free DIEP flap reconstructions (20.2% versus 36.1%, P=0.001) (15). Remarkably, the donor-site complications reported with LDF were less sever (e.g., seroma, wound dehiscence, and dog ear) compared to the ones reported using free tissue transfer (e.g., abdominal flap ischemia, abdominal wall bulging, or hematoma) (15). Patient-reported outcomes of both group exhibited similar results for image and shape of the reconstruction, breast symmetry, donor site aesthetic, and overall satisfaction (15).

The LDF is also applicable when microsurgical techniques for free tissue transfer are not available or convenient. Many patients do not have access to microsurgeons. In fact, a study by Kulkarni *et al.* suggests that 81% of practicing United States (US) plastic surgeons do not perform any type of microsurgical breast reconstruction (16). Sixty-three percent of surgeons who do not perform those procedures report lack of reimbursement as the main justification, while 68% claim that time commitment is the main barrier (16). Alternatively, pedicled TRAM has been favored when the former is not available or convenient. Nonetheless, this comes at a cost of an increased likelihood of abdominal morbidity, especially in cases when bilateral TRAM flap reconstructions are planned (17). Consequently, the LD myocutaneous flap serves both purposes of completing an autologous reconstruction without the need for microsurgery and avoiding donor site complications that arise from a pedicled TRAM flap.

Although free tissue transfer may be superior in terms of better vascularization resulting in fewer postoperative complications (18), there is evidence that indicates it may not be recommended in selected patients such as smokers or obese patients. Chang *et al.* demonstrated that smokers are at significantly higher risk of developing skin-free flap necrosis (18.9% versus 9%; P=0.005) and donor site complications (25.6% versus 14.2%; P=0.007) after free TRAM flap transfer compared to nonsmokers (19). Also, obesity puts patients at an increased risk for perfusion complications following abdominal free tissue transfer reconstruction (OR =1.97; 95% CI: 1.07–3.61; P=0.03) (20). In this setting, a LDF reconstruction may be favored in obese patients as it has a decreased risk for flap necrosis given its reliable vascular pedicle (10). For instance, in a recent study from our institution, we did not find a significant difference for donor and recipient site morbidity using the LDF between obese and non-obese patients. Similarly, in our series presented in this review, the risk of any breast complication was not increased by obesity or active smoking on univariable or multivariable analysis. In parallel, donor site wound healing compromise has been demonstrated in smokers undergoing abdominal free tissue transfer, but no strong evidence has supported this for LDF reconstruction (6).

In comparison to previous studies, high rates of complications were evident in our analysis for both the recipient- and donor-site (21). For instance, twenty-three patients underwent immediate breast reconstruction with LIFT in a series reported by Santanelli di Pompeo exhibiting no complications (21). The mean age was 52.3 years, similar to our series, but the BMI was significantly lower when compared to the one of our patients (24.77 kg/m^2). Data regarding comorbidities and adjuvant chemotherapy and radiotherapy were not reported in the series presented by Santanelli di Pompeo. In another contemporary study evaluating outcomes of LDF without implants, the rates of hematoma (4.7%) and seroma (4.7%) were comparable to our results (hematoma, 3.0%; seroma, 7.7%) (22). In the same study, Leuzzi *et al.* reported a rate of SSI of 2.4%, which was significantly lower compared to the SSI rate presented in our study (22). Remarkably, in our series, only 3.8% of the breasts required any intervention to manage SSI (abscess drainage). Further analysis evaluating the series of Leuzzi and collaborators also demonstrated that most of the reconstructions were delayed (95.2%) in comparison to our study, in which most procedures were immediate reconstructions (69.7%). This may also explain the high rate of wound disruption events found after LDF reconstruction found in our series, as this complication pertains more to the vascularization of the native mastectomy flaps, rather than the LDF itself (23,24).

Controversies

Whether the LD flap harvest leaves the shoulder and upper extremity with functional deficit has been controversial in the literature. Laitung *et al.* assessed the shoulder function of 19 patients following LD free flap harvesting (25). Thirteen had normal range of motion while 6 had only between 5° to 30° residual deficits (25). Fifteen reported normal subjective arm function (25). Also, they compared the shoulder power of the treated group with the shoulder power of the control

group with respect to the non-dominant and dominant shoulders respectively. No significant difference between the two groups was found (mean power =11.7 versus 13.1 kg, P=0.10 in non-dominant shoulders; mean power =12.4 versus 14.6 kg, P=0.13 in dominant shoulders) (25). Russell *et al.* studied the extent of functional deficit following removal of LD muscle and deduced that mild to moderate weakness (ranging from 1.3% to 34.4% weaker compared to the normal unoperated side) was noted in 17 out of 23 patients, and total active shoulder motion was decreased in 18 out of 23 patients, ranging from 0.9% to 44.8% compared to the normal unoperated side. However, both muscle strength and range of motion improved after a few months due to the recruitment of synergistic muscle units (26).

Brumback *et al.* investigated the entire function of the LD muscle in 17 patients who have undergone pedicled LDF harvest using instruments that target only shoulder movements involving the LD muscle (27). The authors concluded that forced extension was only weaker when the arm was flexed at 60 degrees compared to controls (27). None of the 17 patients experienced any limitations in their activity of daily life, nor sports-related activities restrictions or adjustments (27). Similarly, a prospective study of 20 patients demonstrated that despite the decrease in isometric strength of adduction (17%, P<0.001) and extension (21%, P<0.001) 12 months post-LDF harvest, this did not hinder the ability of patients to perform their activities of daily living (28). Another one-year prospective study examining shoulder function following LDF breast reconstruction showed that range of motion and shoulder strength scale scores recovered to the pre-operative baseline after 12 months of surgery (P>0.005 for all) (29). Lohana *et al.* also maintained that even bilateral extended autologous LDF breast reconstruction did not result in significant long-term shoulder dysfunction [preoperative DASH score: 1; DASH score 6 weeks postoperatively: 26 (P<0.001); DASH score one year after surgery: <12 (P<0.001)] (30).

Conflicting outcomes have been reported regarding donor site morbidity for function. Fraulin *et al.* showed that LD muscle transfer resulted in significant power and endurance deficit of shoulder adduction and extension during dynamic muscle testing (31). Women who have undergone unilateral pedicled LD muscle transfer showed significant differences in both work and peak torque (that is, endurance and power, respectively) measurements of shoulder extension and adduction on the Kinetic Communicator test between operated and non-operated shoulders (P<0.05) (31). Forthomme *et al.* also demonstrated weakness primarily on adduction after isokinetic assessment 6 months post LD transfer (33%±9%) (32). Although LD function deficits are initially evident after LD muscle transfer, this weakness in adduction and extension seems minimal and only pronounced in terms of fatigue after prolonged use, with almost complete recovery in the long term (33).

Previous studies have demonstrated an association between the standard LDF for breast reconstruction and important postoperative complications, like back seroma (up to 80%), infection, hematoma, or delay in wound healing (5,34-36). In this setting, contemporary studies have shown that the muscle-sparing LDF can reduce the axillary bulk after flap inset, generate less contour deformity of the back, and can significantly reduce donor site morbidity (34,37). Fauconnier *et al.* performed a study comparing postoperative complications following standard LDF versus muscle-sparing LDF for breast reconstruction (34). The authors reported that the duration of surgery (135±72 versus 173.7±47.8 min, P<0.001) and length of stay (3.8±1.6 versus 4.1±1.6 days, P<0.001) were reduced using a muscle-sparing LDF technique for breast reconstruction compared to the standard LDF. Furthermore, the rate of complications regarding seroma formation was significantly lower using the muscle-sparing technique versus standard LDF (3% versus 55.6%, P<0.001). Other flaps used for breast reconstruction include the thoracodorsal artery perforator (TDAP) flap or propeller TDAP flap, which have been used in a similar fashion achieving smaller breast volumes (38).

There are questions regarding the acceptable volume for tissue transfer and how thoracodorsal nerve preservation contributes to animation deformity and volume maintenance. Some authors have argued that leaving the nerve intact results in distortion of the breast shape as some of the contractile function of the LD muscle is retained, even when the origin or insertion of the muscle has been partially or completely detached. This would compromise a patient's daily activity as the disfiguration could happen during actions as simple as pulling or reaching with the arms (3). Szychta *et al.* conducted a prospective study of 29 patients split into a group whose thoracodorsal nerve was divided, and a group whose nerve was left intact (39). The former group reported similar satisfaction when it comes to breast tissue consistency (P>0.05) and symmetry (P>0.05), but described less pain (P<0.0001), less animation deformity (P<0.0001), and

higher overall satisfaction (P=0.0001) compared to the group for which the nerve was preserved (39).

However, the conclusion of nerve preservation causing unwanted animation of the breast has been refuted by other studies. Patel and colleagues retrospectively studied 125 patients with 170 flaps and showed that there was no significant difference in spasticity or unwanted muscle movement between those who had their nerve preserved compared to those whose nerve was transected (5.6% and 3.7% respectively, P=0.55), concluding that cutting off the nerve would not be beneficial in that matter (40).

On the other hand, given that many believe that muscle contraction and animation deformity could be avoided by dividing the nerve, it has been proposed that flap denervation would result in muscle atrophy and volume loss. Kääriäinen *et al.* refuted the idea that denervation results in muscle atrophy by demonstrating that the flap volume was maintained on magnetic resonance imaging (MRI) one year after surgery explained by fat replacement of the muscle seen on histology (41). In fact, there was no significant difference in LD flap thickness change between the intact nerve group and the denervated group (middle thickness, P=0.18; lateral thickness, P=0.91). Taking into consideration these findings, it does not seem that cutting off the nerve is worth risking injuring the vascular pedicle as volumetric outcomes are comparable with division or preservation of the nerve (10).

Regarding the acceptable volume for tissue transfer, it has traditionally been adopted that larger-breasted women are not candidates for LD muscle reconstruction as it was thought to have insufficient coverage (42). To counter this limitation, multiple technical modifications have been used. One prior example is the fleur-de-lis technique for total autologous flap reconstruction, which has been adapted for the sake of increasing flap volume (43). However, it has been associated with high donor site morbidity including the risk of seroma, hernia, and prolonged drainage (42).

Other newer approaches have involved increasing the amount of subcutaneous fat to reach the desired volume (8,44). This consists of beveling the edges of the skin paddle as well as the supra- and sub-Scarpa fat, resulting in an increased flap volume needed for breast reconstruction, with an even and gradual contour (10). The fat that remains attached to the muscle is efficiently vascularized and has good soft tissue coverage (10). However, this technique also has shortcomings like a high risk of seroma (4).

A recent powerful approach to increase volume of the flap is to combine fat grafting with LDF transfer (8). Fat grafting can be performed during the initial or later stages of reconstruction, and aimed at several recipient sites including the mastectomy skin flaps, the LD skin paddle, the LD muscle, the serratus, and the pectoralis major muscles (45). Zhu *et al.* demonstrated a multilayer and multisite fat grafting approach, achieving an average grafting volume of 176 mL per breast, and reaching a maximum of 300 mL. Complete wound healing, 100% flap survival, and no fat grafting-related complications or seromas were evident at the end of the study (45). Another report of 29 patients who have undergone immediate fat grafting-enhanced LDF reconstruction echoed these results, with an average grafting volume of 101 mL and no increased flap risk or fat grafting-related complications (21).

Finally, there have been debates on the quality of aesthetic outcomes, whether at the donor site or the ultimate breast reconstruction. Given the recent breakthroughs regarding the ability for multisite multilayer fat grafting, the increasing amount of subcutaneous fat that can be incorporated within the flap before transfer, and the possibility of beveling the edges of the skin paddle and the fat, more desirable contours are being achieved compared to the ones achieved by placing an implant under a thin mastectomy flap. Moreover, the ability to fold the LD muscle and to plicate or imbricate the paddle, has given the potential for achieving decent projection and appropriate breast shape (6).

Even though the success of surgery is usually based on the evaluation of complications and the surgeon's assessment of the aesthetic outcomes, it is of utmost importance to recognize the patients' perspective on the latter, especially since some aspects of it are only fully appreciated by patients (e.g., feel or the movement of the breasts) (46). Lindegren *et al.* conducted a study on 24 irradiated patients who have undergone post-mastectomy reconstruction with either DIEP or LDF and evaluated aesthetic outcome satisfaction among plastic surgeons and patients (47). They showed that plastic surgeons were more pleased with the size (P=0.024) and shape (P=0.039) of the DIEP flap, while on the contrary, patients were happier with the size (P=0.046), shape (P=0.017), and overall appearance (P=0.018) of the LDF when patients' and surgeons' views were compared (47). On the other hand, both patients (P=0.036) and surgeons (P=0.001) viewed the donor scar of the LDF as superior compared to the scar of the DIEP flap reconstruction. Patients were all satisfied with the LDF compared to surgeons (47).

Regarding the rate of postoperative revisions, several retrospective series have reported a revision rate of up to 50% following LDF reconstruction (24,48-50). In our

study, the rate of postoperative revisions to address soft tissue excess was 40.6%. Interestingly, when compared to other reconstructive alternatives, previous studies have demonstrated a higher rate of additional surgeries using LDF compared to abdominal-based free flaps following unilateral, delayed breast reconstruction after postmastectomy radiotherapy (92.1% versus 67.3%; P<0.001) (51). Other series comparing the rate of revision procedures between LIFT and abdominal free tissue transfer have demonstrated comparable or similar outcomes between groups (52).

Even though some studies conveyed that LDFs are associated with an increased chance of revision surgeries this has not been consistent in the literature (51). Bennett *et al.* demonstrated in their study comparing the two-year complication rates of different postmastectomy breast reconstruction techniques, that the LDF reconstruction was the exception among autologous flap reconstruction. The LDF for reconstruction did not exhibit higher odds of re-operative complications compared with expander-implant techniques (OR =1.03; 95% CI: 0.46–2.29; P=0.94) while other forms of autologous reconstruction did (e.g., TRAM flap, DIEP flap) (53).

Current status

The pedicled LDF is reliable and safe for post-mastectomy breast reconstruction. It is often used in salvage or delayed reconstruction. Women who are not candidates for tissue expansion or lack other suitable donor sites, namely the abdominal site, but still wish for autologous tissue reconstruction may opt for this technique. In addition, it is an effective procedure when microsurgical techniques for tissue transfer are not available. LD muscle harvesting was not shown to result in significant or pronounced functional deficits in the long term, rendering it an effective and safe approach for post-mastectomy autologous reconstruction.

The LD myocutaneous flap use can result in desirable aesthetic outcomes and a high patient satisfaction rate. The breakthrough advances in the ability for multi-layer multi-site fat grafting and increasing the subcutaneous fat layer that can be recruited with the flap, have allowed large-breasted women to have a decent volume that was once impossible without an implant or aggressive harvesting. Also, the acts of beveling the edges of the flap and plicating the muscle have allowed for better projection and finer contours.

Future directions

Given that fat grafting accompanying the LDF reconstruction has recently gained considerable recognition, future studies should aim at assessing the long-term retention of breast volume, as well as the long-term aesthetic outcomes resulting from this procedure. Moreover, since multisite fat grafting includes intramuscular fat grafting into the pectoralis major muscle, it is of interest to study its sequelae on the upper extremity function and whether it has any compromise on the arm strength. Finally, even though the use of LD muscle in breast reconstruction has been compared to other approaches such as abdominal-based flaps, it is important to revisit this comparison using high-volume fat-grafted LDF.

Limitations

Given that this is not a systematic review, unpublished data might be missing. Also, limiting the search to two databases might have resulted in the omission of parts of the literature and missing evidence. However, potential citations of selected articles were reviewed and evaluated by three reviewers for additional pertinent articles for inclusion.

A preplanned methodology defining the outcome measures is lacking. Hence, the conclusions have been founded on the findings of the identified studies. Also, quality assessment of the studies was not performed. Thus, the validity and generalizability of the results might be compromised.

On the other hand, we presented a retrospective case series, which may limit the quality and generalizability of the data given the lack of a comparison group, inability to establish cause and effect, and inability to control for potential confounders. In addition, data abstractors were not blinded to the study purpose, which may have resulted in information bias. Finally, the lack of randomized controlled studies evaluating the LDF outcomes has resulted in a lack of strong empirical evidence of the success of this procedure, which should be sought in future works.

Conclusions

LDF use in breast reconstruction, whether total autologous or implant-based, has been gaining considerable attention given its broad indications. The LDF use drawbacks like donor site seroma and healing compromise have been decreasing after the advent of quilting sutures at the donor

site and progressive retention sutures. Its capacity for high-volume fat grafting has granted its use in women who were previously not candidates and allowed large-breasted women to have a decent volume that was once impossible without an implant. Thus, the LDF modality has been markedly revived and serves as a valuable and versatile opportunity for breast reconstruction with an extremely low rate of total flap loss. Following reconstruction with LDF, a higher rate of postoperative recipient- and donor-site revisions should be expected.

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