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Strategically shifting paradigms: the new era of DIEP flaps with minimally invasive mastectomy: a retrospective cross-sectional study

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Abstract

Background The free deep inferior epigastric artery perforator (DIEP) flap is the gold standard in autologous breast reconstruction. Asian patients often present with a smaller body mass index with relatively insufficient tissue. To restore appropriate symmetry, a larger flap inset ratio must be transferred. Supercharging of the second vein or inclusion of bilateral pedicle is commonly required. Current paradigm shifts in mastectomy has also resulted in more minimally invasive surgeries (MIS) espousing smaller lateral incisions, leading to a significant change in available recipient vessels. This study aimed to demonstrate our experience in changing strategies of DIEP flaps following the evolution of mastectomy techniques.

Methods Between October 2008 and March 2022, retrospective data was gathered for 278 patients who underwent breast reconstruction surgery utilizing DIEP flaps by a single plastic surgeon. These patients were divided into two distinct groups based on their operation dates, with November 2018 marking a pivotal moment when the first MIS, including endoscopic-assisted and robot-assisted mastectomy, was introduced.

Results A total of 278 patients were included. Bipedicle vessel utilization for flap supercharge saw a significant increase (15.9% vs. 7%, $p < 0.001$), while the use of the superior inferior epigastric vein (SIEV) decreased (5.1% vs. 17.1%, $p = 0.01$). Preceding MIS, SIEV was the primary choice for flap supercharge (96.0%, $p < 0.001$), whereas post-introduction, the contralateral DIEP pedicle gained prominence (75.9%, $p < 0.001$). There was also an increased utilization of thoracodorsal artery and lateral thoracic artery following MIS.

Conclusion These findings underscore the profound impact of MIS on the strategic choices made in DIEP flap-based breast reconstruction.

Trial registration This study is retrospectively registered on ClinicalTrials.gov (NCT06321549).

Keywords Minimally invasive mastectomy, DIEP, Breast reconstruction, Microsurgery, Breast cancer

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Background

Breast cancer is now the most common cancer worldwide, accounting for 30% of new cases of cancer in 2021. With an estimated increased rate of 5% per year, [1] there is a growing demand of breast reconstruction after mastectomy, aiming to restore not only the breast shape but also self-esteem for the patients. For decades, breast implants and autologous tissue transfer were both commonly used for breast reconstruction. Autologous breast reconstruction, encompassing procedures such as the transfer of the latissimus dorsi flap, transverse rectus abdominis muscle (TRAM) flap, and deep inferior epigastric artery perforator (DIEP) flap, has traditionally been regarded as yielding a superior and enduring aesthetic result. This is achieved through the restoration of a natural breast mound, which not only offers a long-term maintenance of shape but also exhibits a heightened resilience to the effects of radiotherapy [2, 3].

Among the different flaps, the free DIEP flap has long been considered the gold standard in autologous breast reconstruction for offering sizable flaps with lengthy pedicle in different breast shaping and minimal donor site morbidities [4]. Asian patients typically exhibit a smaller body mass index (BMI) and tend to possess relatively limited abdominal tissue. In contrast to their Western counterparts, who frequently undergo simultaneous bilateral breast reconstruction employing bilateral DIEP flaps, the majority of Asian patients typically undergo unilateral breast reconstruction using a free DIEP flap. This approach often involves a higher flap inset ratio, usually more than 50% of usage, to attain symmetrical reconstruction. According to the perfusion zone of DIEP flap, inclusion of zone III and IV flap might result in inadequate arterial inflow and venous return, which may further increase the risk of fat necrosis. Some studies even indicate decrease arterial inflow over the portion across the midline of the flap [5]. Most of the previous study on angiosome and even perforasome of DIEP flap agree that a single pedicle or a single dominant perforator does not perfuse the zone IV well. A mean perfusion ratio of 67.8% ± 11.5% based on unilateral pedicle has been mentioned by Part JW and colleagues. In order to inset a larger percentage of the flaps for unilateral breast reconstruction, increase the arterial flow is important to minimize fat necrosis [5–9]. Besides arterial flow, venous augmentation was shown to be helpful in enhance the DIEP viability by increase the flap volume (when zone III and zone IV were included) and decrease partial flap loss [10]. The inclusion of SIEV was also important if the patients' venous system is superficial dominant [11–13]. To optimize flap perfusion and mitigate the risk of venous congestion, the supercharge technique, involving the addition of a second vein or even the incorporation of bilateral pedicles, is frequently required. Consequently, a higher percentage of the flap is utilized in these cases, reflecting the unique considerations and strategies involved in breast reconstruction for Asian patients. For the efficacy of supercharge the flap with SIEV, previous studies showed that SIEV supercharge enhance the DIEP viability by increase the flap volume (when zone III and zone IV were included) and decrease partial flap loss [10]. Due to high ratio of DIEP flap demand in breast reconstruction for Asian woman, we used to supercharge the DIEP flap with SIEV to improve venous outflow while venous congestion was observed intraoperatively. Also, because of the way we inset the flap (as mentioned in the discussion part), anastomosis of bilateral pedicle can convert the zone III portion of flap to zone I, which will be helpful in enhancing the perfusion of medial portion of the reconstructed breast and decrease the risk of fat necrosis.

Meanwhile, there is increasing emphasis for an excellent aesthetic outcome for breast reconstruction. This is reflected by the increasing popularity of nipple-sparing mastectomy (NSM) as well as development of minimally invasive surgeries aiming to minimize the length of the mastectomy scar (usually within 5 cm), whilst also placing the mastectomy incision in the remote lateral chest wall that can be easily hidden from the anterior view (Fig. 1) [14]. Minimally invasive mastectomies are popular in Asian where women who tend to have relatively smaller breast but a higher predisposition towards hypertrophic scarring. This trend in minimally invasive techniques with remote incisions has necessitated a change in the preferred recipient vessels for vascular anastomosis, shifting from the usual central high flow internal mammary vessels (internal mammary artery/vein, IMA/V) to the relatively lower flow thoracodorsal vessels (thoracodorsal artery/vein, TDA/V) and lateral thoracic vessels (lateral thoracic artery/vein, LTA/V) near the lateral chest wall [14].

In the context of minimal invasive mastectomy, breast reconstruction using free DIEP flaps necessitates careful consideration of two key factors: flap inset and maintenance of optimal flap perfusion. As highlighted earlier, Asian patients often require a higher flap inset ratio due to their relatively limited abdominal tissue. To accommodate these factors in our clinical practice, we have adopted variations in flap transfer techniques and an inclination towards the inclusion of bilateral pedicles for unilateral breast reconstruction, as opposed to solely augmenting venous outflow by incorporating the superficial inferior epigastric vein (SIEV). In light of these clinical experience, this study seeks to provide a comprehensive review of our strategy for DIEP flap transfer

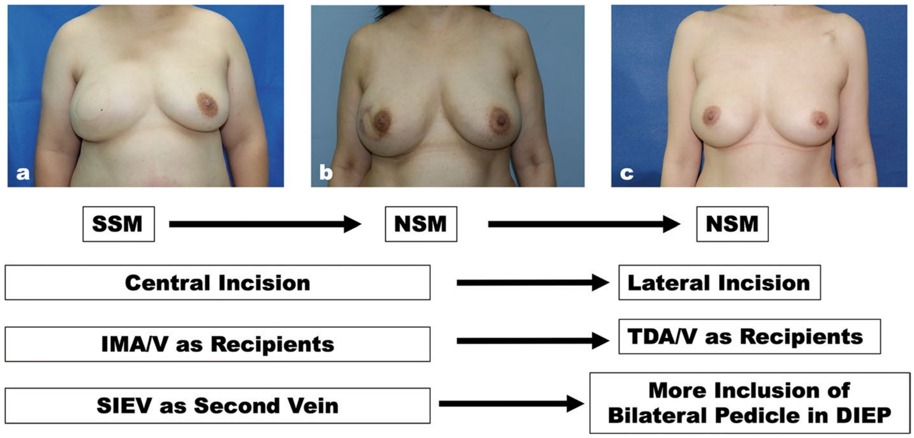

Fig. 1 Three different cases of right breast mastectomy and immediate reconstruction with free DIEP flaps. **A** Skin-sparing mastectomy and free DIEP flap reconstruction via central incision. **B** Nipple-sparing mastectomy and free DIEP flap reconstruction via incision in anterior chest wall. **C** Nipple-sparing mastectomy and free DIEP flap reconstruction via a 5 cm incision on the lateral chest wall. The different cases represent the shifting of mastectomy trend and its impact on recipient vessel selection as listed below

in Asian women, particularly in response to the evolving landscape of mastectomy techniques.

Materials and methods

Patient enrollment

In a retrospective analysis, data sourced from a single experienced reconstructive surgeon's practice at a medical institution spanning from October 2008 to March 2022 was examined. This study encompassed all patients who underwent breast reconstruction procedures with DIEP flaps within this timeframe. To facilitate a comprehensive and systematic examination, these patients were stratified into two distinct groups: Group A, comprising individuals who underwent surgery prior to November 2018, and Group B, encompassing those who underwent surgery after November 2018. The selection of November 2018 as a temporal reference point was predicated on the milestone of the medical center's inaugural minimally invasive mastectomy procedure conducted at that juncture. As for the NSM, it is a decision first made by the breast surgeon and further confirmed with the patient in a shared decision manner. The indication of NSM is that the main tumor is 2 or more cm away from the nipple and no evidence of nipple involvement in preoperative image study. When a decision of NSM was made, the breast surgeon performed nipple core biopsy for frozen section intraoperatively to confirm that the preserved nipple was free of cancer. Our center started to offer minimally invasive mastectomy, which was defined as mastectomies under the assistance of endoscope or Da Vinci Robot via a small lateral incision in Nov 2018. Nov 2018 was selected as a cutting point of two different era of mastectomy technique. We believe that the shifting of incision from anterior breast or IMF to a small incision on the lateral chest wall changed our surgical planning in doing a free flap transfer, such as the selection of recipient vessels and monitor skin paddle positioning. An example of different monitor skin paddle positioning can be found in publication by Laporta R and colleagues [15]. In adherence to rigorous inclusion criteria, all enrolled patients were required to have a minimum follow-up duration of six months post-reconstruction. Patients who did not meet this follow-up duration was excluded from the study.

Study design

This study was approved by the institution review board (IRB number: 202201562B0). Demographic data for the patients were collected and presented in Table 1. Data for the mastectomy technique and DIEP free flap had been prospectively documented in our institution at the point of intervention as part of our protocol. These data were then collected and analyzed. Among flap anastomosis related factors, two venous anastomoses referred to flaps supercharged with SIEV and bilateral pedicles refers to the transfer of the entire DIEP flap with anastomosis of bilateral pedicles for unilateral breast reconstruction. The term "bipedicled flap" mentioned in this article referred to the flap with bilateral pedicle anastomosis, both the arteries and veins.

Post-operative complications encompassed several aspects, including fat necrosis, which was defined as the detection of lesions larger than 1 cm, through breast sonography or histopathological report following resection. Additionally, this category encompassed revision surgeries necessitated for aesthetic refinements, such as

Table 1 Demographic and breast cancer characteristics

	All (N=278)		Group A (N=140)		Group B (N=138)		P value
Age, years	45.94	(19-67)	45.36	(19-65)	46.53	(29-67)	0.246
BMI	24.35	(17- 43)	24.34	(17-39)	24.36	(18-43)	0.978
Smoking	2	(0.7%)	0	(0.0%)	2	(1.5%)	0.242
Comorbidity							
Hypertension	20	(7.2%)	9	(6.4%)	11	(8.0%)	0.650
Diabetes mellitus	5	(1.8%)	2	(1.4%)	3	(2.2%)	0.682
Pathology							***0.003***
DCIS	51	(18.6%)	22	(15.9%)	29	(21.3%)	
IDC	157	(57.3%)	94	(68.1%)	63	(46.3%)	
LCIS	1	(0.4%)	1	(0.7%)	0	(0.0%)	
ILC	13	(4.7%)	4	(2.9%)	9	(6.6%)	
IC	45	(16.5%)	14	(10.2%)	31	(22.8%)	
Benign lesions	7	(2.6%)	3	(2.2%)	4	(2.9%)	
Pathological stage							0.440
Unknown	22	(7.9%)	11	(7.9%)	11	(8.0%)	
0	45	(16.2%)	22	(15.7%)	23	(16.7%)	
1	90	(32.4%)	43	(30.7%)	47	(34.1%)	
2	96	(34.5%)	54	(38.6%)	42	(30.4%)	
3	25	(9.0%)	10	(7.1%)	15	(10.8%)	
PMRT	58	(20.9%)	27	(19.3%)	31	(22.6%)	0.556

BMI Body mass index, *DCIS* Ductal carcinoma in situ, *IDC* Invasive ductal carcinoma, *LCIS* Lobular carcinoma in situ, *ILC* Invasive lobular carcinoma, *IC* Invasive carcinoma, *PMRT* Post mastectomy radiotherapy

procedures like lipofilling, scar revision, flap rotation, or surgical excision to address fat necrosis.

Statistics

All statistical analysis was performed using the software SPSS 23rd edition. Statistical significance was determined with a threshold of $p < 0.05$. Descriptive statistics were employed to summarize both absolute and mean results. An independent T-test was utilized to analyze binary data, while the chi-square test or Fisher's exact test was used to examine proportional responses.

Results

A total of 278 female patients were included in the study, with a mean age of 45.94 (19–67) year-old and a mean BMI of 24.35 (17–43) kg/m^2. Surgical details such as technique, timing of mastectomy, abdominal scar or minimally invasive approach were presented in Table 2. The majority of patients in both groups underwent immediate reconstruction following the mastectomy, with proportions of 80.7% in group A and 88.4% in group B, respectively.

In group A, 54 patients (39.1%) underwent modified radical mastectomy (MRM), while an equal number of 54 patients (39.1%) opted for skin-sparing mastectomy (SSM). NSM was chosen by a smaller fraction of patients, only 28 (20.3%). In contrast, in group B, a significantly higher percentage, 95 patients (68.8%), underwent NSM, which was notably different from the patients in group A. This difference was statistically significant, and in line with the development of minimally invasive mastectomy ($p < 0.001$).

Furthermore, the location of the mastectomy incision varied between the two groups. In group A, the incision was made over the central breast region for the majority of patients, specifically in 133 cases (95.0%). Conversely, in group B, the incision was shifted to the lateral chest in a majority of cases, with 94 patients (68.1%) undergoing this approach. This difference in incision location was statistically significant ($p < 0.001$).

The analysis of flap-related parameters, as presented in Table 3, revealed notable differences between patients in Group A and Group B. Specifically, patients in Group B exhibited a shorter flap length (29.71 cm vs. 24.46 cm, $p < 0.001$), a smaller harvested flap weight (682.27 g vs. 590.57 g, $p = 0.005$), and a reduced weight of the flap used for inset (486.96 g vs. 436.11 g, $p = 0.013$), along with a smaller mastectomy specimen weight (442.32 g vs. 370.15 g, $p = 0.001$). While there was a higher flap inset ratio in Group B, this difference did not achieve statistical significance.

Table 2 Mastectomy related surgical factors

	All(N=278)	Group A(N=140)	Group B(N=138)	P value
Reconstruction side				0.81
Left	148 (53.2%)	76 (54.3%)	72 (52.2%)	
Right	130 (46.8%)	64 (45.7%)	66 (47.8%)	
Bilateral	12 (4.31%)	0 (0.0%)	12 (8.70%)	
Timing				0.097
Immediate	235 (84.5)	113 (80.7%)	122 (88.4%)	
Delayed	43 (15.5%)	27 (19.3%)	16 (11.6%)	
Mastectomy				***<0.001***
MRM	56 (20.1%)	54 (39.1%)	10 (1.4%)	
PM	2 (0.7%)	2 (1.4%)	0 (0%)	
SSM	87 (31.3%)	54 (39.1%)	33(23.9%)	
NSM	123 (44.2%)	28 (20.3%)	95 (68.8%)	
Incision				***<0.001***
Medial	177 (63.5%)	133 (95.0%)	44 (31.9%)	
Lateral	101 (36.5%)	7 (5.0%)	94 (68.1%)	
Endoscopic mastectomy	5 (1.8%)	0 (0%)	5 (3.6%)	***0.029***
Robotic mastectomy	62 (22.3%)	0 (0%)	62 (44.9%)	***<0.001***
Mastectomy size, gram (range)	404.56 (70-1050)	442.32 (70-1050)	370.15 (95-975)	***0.001***
Abdominal scar				0.144
Transverse scar	74 (26.6%)	32 (22.9%)	42 (30.4%)	0.144
Midline scar	8 (2.9%)	5 (3.6%)	3(2.2 %)	0.174
Other scar	35 (12.6%)	16 (11.4%)	19 (13.8%)	0.723

MRM Modified radical mastectomy, *PM* Partial mastectomy, *SSM* Skin-sparing mastectomy, *NSM* Nipple-sparing mastectomy

In Group A, the IMA served as the primary recipient vessel in the majority of cases, with 128 patients (91.4%) utilizing this vessel. In contrast, Group B displayed a different pattern, where only 54 patients (39.1%) utilized the IMA as the recipient vessel. Instead, the TDA was employed in 67 patients (48.6%), and the LTA was selected in 17 patients (12.3%) ($p < 0.001$). The significant increase in the usage of recipient vessels from the lateral chest wall observed in Group B reflects the trend toward minimally invasive mastectomy with smaller lateral incisions. This approach limits the exploration and utilization of recipient vessels in the central chest wall ($p < 0.001$).

The supercharging of the SIEV for additional venous drainage was performed in 31 patients, encompassing 24 patients (17.1%) in Group A and 7 patients (5.1%) in Group B ($p = 0.01$). To enhance flap perfusion, 23 (8.3%) flaps were transferred based on bilateral pedicles, which includes the inclusion of bilateral deep inferior epigastric arteries and veins. Specifically, this was done in one patient (0.7%) from Group A and 22 patients (15.9%) from Group B ($p < 0.001$). With a similar flap inset ratio, the observed trend of shifting from venous supercharging with the SIEV to the usage of bilateral pedicles to enhance both arterial and venous flow underscores a strategic shift aimed at improving flap softness in future procedures. Along with the difference in flap design, there is also significant difference of the selection of the main recipient artery and vein. While the internal mammary vessels were used as the main recipient source in Group A, there was a significantly higher usage of lateral chest wall vessels in the Group B. This shift towards the use of lateral chest wall vessels arises from the limitation of performing microsurgery from the small lateral incision, and the physical limitation in reaching central chest vessels (IMA) from a lateral incision.

In cases of bipedicled DIEP, if the internal mammary vessels were selected as recipient vessels, both antegrade and retrograde IMA/V would be used as recipients. However, when the mastectomy incision was placed in the lateral chest wall (usually 5 cm or lesser), identification of second recipient artery with good arterial flow is sometimes difficult. Intra-flap anastomosis between the branches of the two sets of deep inferior epigastric artery/vein (DIEA/V) had to be performed to ensure vascular perfusion of all zones of the flap (Fig. 2). This was performed in four out of the 12 (33.3%) patients undergoing bipedicled DIEP for unilateral breast reconstruction, with the TDA/V or LTA/V as first recipient vessels. This reflected that in 66.7% of the cases with limited exposure and lateral incision, only one recipient artery with

Table 3 Flap harvested and transferred characteristics

Flap Characteristics					
	All (*N*=278)	**Group A** (*N*=140)	**Group B** (*N*=138)		***P* value**
Flap length, cm (range)	28.59 (15-40)	29.71 (22-40)	27.45 (15-34)		***<0.001***
Flap width, cm (range)	11.73 (9-16)	11.70 (10-15)	11.75 (9-16)		0.651
Flap harvest weight, gram (range)	639.44 (204-2100)	687.27 (220-2100)	590.57 (204-1716)		***0.005***
Flap used weight, gram (range)	461.72 (135-1245)	486.96 (135-1245)	436.11 (182-954)		***0.013***
Flap used, % (range)	75.0 (26.6-100%)	73.6 % (26.6-100%)	76.5% (41.4-100%)		0.073
Flap Transferred Characters					
	All (*N*=278)	**Group *A***(*N*=140)		**Group B** (*N*=138)	***P* value**
Usage of SIEV	31 (11.2%)	24 (17.1%)		7 (5.1%)	***0.01***
Inclusion of bilateral pedicles	23 (8.3%)	1 (0.7%)		22 (15.9%)	***<0.001***
Location of recipient artery					***<0.001***
Medial	182 (65.5%)	128 (91.4%)		54 (39.1%)	
Lateral	96 (34.5%)	12 (8.6%)		84 (60.9%)	
Location of recipient vein					***<0.001***
Medial	182 (65.5%)	128 (91.4%)		54 (39.1%)	
Lateral	96 (34.8%)	12 (8.7%)		84 (60.9%)	
Recipient artery selection					***<0.001***
IMA	182 (65.5%)	128 (91.4%)		54 (39.1%)	
TDA	78 (28.1%)	11(7.9%)		67 (48.6%)	
LTA	18 (6.5%)	1 (0.7%)		17 (12.3%)	
Recipient vein selection					***<0.001***
IMV	182 (65.5%)	128 (91.4%)		54 (39.1%)	
TDV	57 (20.5%)	10 (7.1%)		47 (34.1%)	
LTV	39 (14.0%)	2 (1.5%)		37 (26.8%)	
Perforator number					0.232
1	147 (52.9%)	66 (48.9%)		81 (58.7%)	
2	102 (36.7%)	57 (42.2%)		45 (32.6%)	
3	18 (6.5%)	11 (8.1%)		7 (5.1%)	
4	3 (1.1%)	1 (0.7%)		1 (0.7%)	
One pedicle versus two pedicles					***<0.001***
One pedicle	255 (91.7%)	139 (99.3%)		116 (84.1%)	
Two pedicles	23 (8.3%)	1 (0.7%)		22 (15.9%)	
Second vein					***<0.001***
SIEV	31 (57.4%)	24 (96.0%)		7 (24.1%)	
Contralateral DIEV[(a)]	23 (42.6%)	1 (4.0%)		22 (75.9%)	
Re-exploration	17 (6.3%)	7 (5.0%)		10 (7.2%)	0.455
Debridement	29 (10.7%)	14 (10.0%)		15 (10.9%)	0.844
Fat necrosis	42 (15.1%)	26 (18.6%)		16 (11.6%)	0.132
Aesthetic revision	64 (23.0%)	37 (26.4%)		27 (19.6%)	0.201

SIEV Superior inferior vein, *IMA/IMV* Internal mammary artery/vein, *TDA/TDV* Thoracodorsal artery/vein, *LTA/LTV* Lateral thoracic artery/vein, *DIEV* Deep inferior epigastric vein, [(a)]usually its accompanying DIEA was also anastomosed to recipient artery

satisfactory flow can be identified. The second recipient vessel selection was provided in Table 4. No statistical comparison was provided due to insufficient number in several groups.

In terms of overall complications, fat necrosis occurred in 42 patients (15.1%), including 26 (18.6%) from Group A and 16 (11.6%) from Group B ($p=0.132$). Revision surgery was reported in 64 patients (23.0%), including 37 (26.4%) from Group A and 27 (19.6%) from Group B ($p=0.201$). There was no statistically significant difference in the incidence of overall fat necrosis or revision surgeries between Group A and B.

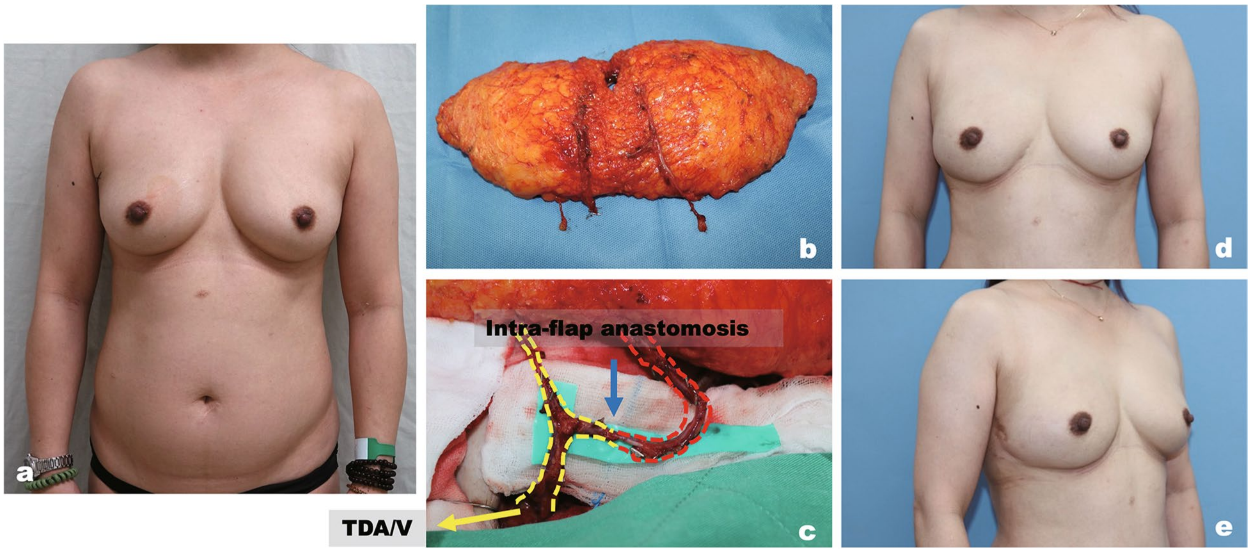

Fig. 2 A 45-year-old female patient with right breast ductal carcinoma in situ that received robot-assisted nipple-sparing mastectomy and free deep inferior gastric artery perforator (DIEP) flap breast reconstruction. **A** Pre-operative appearance of her breast and the thin belly. **B** A DIEP flap based on bilateral pedicle was harvested for reconstruction. **C** The left pedicle (red color) was connected (blue arrow) to the side branches of right pedicle (yellow color) of the DIEP flap after the right pedicle was anastomosed to the thoracodorsal artery and vein. **D** and **E** postoperative anterior view and right lateral view of the breast at follow up of 1 year

Table 4 Different second recipient vessels for the second pedicle of free DIEP Flap transfer

	All (*N*=23)	Group A (*N*=1)	Group B (*N*=22)
2nd Recipient artery when IMA was the first recipient artery	(*N*=11)	(*N*=1)	(*N*=10)
Retrograde IMA	11(4.0%)	1(0.7%)	10(7.2%)
TDA	0(0.0%)	0(0.0%)	0(0.0%)
LTA	0(0.0%)	0(0.0%)	0(0.0%)
Branch of DIEA	0(0.0%)	0(0.0%)	0(0.0%)
2nd Recipient artery when TDA/LTA was the first recipient artery	(*N*=12)	(*N*=0)	(*N*=12)
Retrograde IMA	0(0.0%)	0(0.0%)	0(0.0%)
Branch of TDA	3(1.1%)	0(0.0%)	3(2.2%)
LTA	5(1.8%)	0(0.0%)	5(3.6%)
Branch of DIEA	4(1.4%)	0(0.0%)	4(2.9%)
2nd Recipient vein when IMV was the first recipient vein	(*N*=11)	(*N*=1)	(*N*=10)
Retrograde IMV	11(4.0%)	1 (0.3%)	10(7.2%)
TDV	0(0.0%)	0(0.0%)	0(0.0%)
LTV	0(0.0%)	0(0.0%)	0(0.0%)
Branch of DIEV	0(0.0%)	0(0.0%)	0(0.0%)
2nd Recipient vein when TDV/LTV was the first recipient vein	(*N*=12)	(*N*=0)	(*N*=12)
Retrograde IMV	0(0.0%)	0(0.0%)	0(0.0%)
Branch of TDV	1(0.3%)	0(0.0%)	1(0.7%)
LTV	7(2.5%)	0(0.0%)	7(5.1%)
Branch of DIEV	4(1.4%)	0(0.0%)	4(2.9%)

SIEV Superficial inferior epigastric vein, *IMA/IMV* Internal mammary artery/vein, *TDA/TDV* Thoracodorsal artery/vein, *LTA/LTV* Lateral thoracic artery/vein, *DIEV* Deep inferior epigastric vein

Discussion

This retrospective study provides a comprehensive overview of the changing strategies employed in free DIEP flap breast reconstruction, which have evolved in response to advancements in mastectomy types and techniques. The results indicate a notable shift, particularly following the introduction of minimally invasive mastectomy at our center. Subsequently, an increasing number of free DIEP flaps were transferred using a small lateral incision, with recipient vessels sourced from the lateral chest wall, such as the TDA/V and long LTA/V. Furthermore, there was a trend towards employing more DIEP flaps based on bilateral pedicles for unilateral breast reconstruction, as opposed to resorting to a second vein (typically the SIEV) for venous-only supercharging without additional arterial augmentation.

The oncological and aesthetic success of the NSM has now led to the increasing popularity of minimally invasive mastectomies, including endoscopic-assisted and robot-assisted ones. Despite the lack of a significant difference in BMI between patients among the two groups, a trend towards a smaller mastectomy specimen and smaller size of DIEP flap harvested was observed with the widespread adoption of minimally invasive mastectomy in Group B. These findings suggest that patients feasible for minimally invasive mastectomy often have smaller breast size and consequently lesser abdominal tissue. For beginners, a smaller/non-ptotic breast has been suggested in robot-assisted mastectomy [16]. However, after mounting learning curve, the size/shape of breast should no longer be considered a significant problem, especially with the use of free DIEP flaps for reconstruction.

For better aesthetic outcome with less visible scar, laterally shifting incision over anterior axillary line hide the scar even when the patients wear the sleeveless clothes. Skin paddle, which can be removed later, for flap monitoring was also designed at this location.

Despite a shift towards the smaller lateral incision, the use of autologous tissue transfer remains one of the main methods for breast reconstruction due to its longevity and more natural aesthetic outcome, [2, 3] as well as better tolerance for radiotherapy [17, 18]. When considering the use of autologous tissue in the setting of the newer minimally invasive mastectomy techniques, free tissue transfer requires a different strategic approach to be successful. The first significant difference was a shift in the choice of recipient vessels for microvascular anastomosis, with an increased adoption of TDA and LTA as opposed to the traditional IMA. First introduced in 1979, the thoracodorsal artery was the most common recipient vessels before the popularization of the IMA [19]. The TDA has been gradually superseded by the IMA for better vascular size match with the DIEP flap vessels [20] and better flap centralization on the chest wall [14, 21]. However, the central position of IMA on the chest wall makes it difficult to approach via a limited lateral incision. Previous research has shown comparable reliability and aesthetic outcomes with the use of TDA and LTA, [14, 20–22] leading to their increased usage in patients undergoing mastectomy with a lateral incision. As presented in Table 3, a significantly higher utilization of recipient vessels in the lateral chest wall was reported in group B. Although there are several recipient vessels available in the lateral chest wall, the selection is limited by the physical dimensions of the small lateral incision. The TDA and LTA became the two main recipient arteries that could be easily utilized in the lateral chest. Circumflex scapular vessel (CSA/CSV) was another accessible vessel via the incision at the axillary area. With two commitment veins, it provided an easily accessible second vein for supercharge when there's concern of venous congestion [20]. However, due to deeper and more posterior location from the inferolateral incision made for minimally invasive mastectomy, it might require more dissection time from the anterior axillary incision we made in minimally invasive mastectomy [23].

Ensuring robust blood flow of the free flap is crucial for maintaining long-lasting perfusion and viability of the reconstructed breast with minimal necrosis. To decrease flap necrosis rates, we performed venous supercharging with the SIEV in cases of larger flap inset ratio in Group A. In contrast, the use of bipedicled DIEP flaps with dual set of microvascular anastomoses allowed both arterial and venous supercharging in group B. The flap inset ratio was also larger in group B, which reflected our confidence in using a bigger flap when there is a dual set of pedicles perfusing the whole flap. Besides the inset ratio, our inset method also played a role in selecting for dual set of pedicles and microanastomosis. The senior author preferred to turn the DIEP flap 180 to 270 degree for flap inset and breast shaping. With this approach, the vessels can be inset in their original lie. This is important when there is more than one perforator, in order to avoid kinking of the perforators. The adipose tissue in center of the DIEP flap, especially around the umbilicus, tend to be thicker. By performing the inset in this manner, the fuller central part of the DIEP can be placed in the inferior-lateral aspect of the reconstructed breast, recreating the shape of the ideal breast mound. In the lateral incision situation, if we only use an unipedicled DIEP with this inset technique, zone III would end up being in the medial portion of the breast if we use contralateral pedicle, putting that region at a higher risk of fat necrosis. If significant fat necrosis occurs, the medial portion of the breast is notoriously difficult to be revised without additional scarring, which is especially important if the patient prefers to bare her cleavage. Therefore, a bipedicled DIEP with dual anastomosis would convert this zone III to a zone I due to vascularization from the additional DIEP pedicle, decreasing the risk of fat necrosis. This is reflected by our data in the significant higher usage of bipedicled DIEP in Group B.

In comparison to the IMA, which offers a flow rate of 25 ± 10 ml/min, the flow from the thoracic artery measured at 12 ± 3 ml/min [24]. Although previous reports have indicated similar post-anastomosis flow for both the IMA and TDA, [24] the utilization of the TDA as the recipient artery, coupled with a larger flap inset ratio, has encouraged us to perform more bilateral pedicle DIEP flaps in Group B. In the past, we placed significant emphasis on venous drainage, influenced by findings from studies involving Taiwanese women that demonstrated equally efficient flow distribution to zone IV [25]. However, it's worth noting that the assessment of flap perfusion in the reference study was limited to intraoperative evaluation and did not include a long-term follow-up. Venous congestion has been identified as a frequent complication of DIEP flap reconstruction, with reported incidence rates ranging from 4 to 10% [10]. This complication is likely a consequence of increasing utilization of the DIEP flap zones. Fat necrosis, which occurs in 12% to 45% of cases, [26, 27] is another consequence of venous insufficiency and may result in loss of softness and development of painful firmness in the reconstructed breast. Several studies have investigated possible factors that may influence the incidence of fat necrosis, and Kroll S et al. have concluded that implementing stricter criteria for DIEP flap reconstruction, such as usage of a smaller flap and ensuring presence of at least one sufficient perforator, can reduce the risk of fat necrosis and partial flap loss [28]. Furthermore, the inclusion of zone III or zone IV of the flap, which entails utilizing more than half of the flap tissue, may also be associated with an increased risk of fat necrosis [11, 29]. For patients who require a higher flap inset ratio, enhancing both the venous and arterial flow is an important strategy.

Supercharging the flap with a second vein (usually the SIEV) has been suggested as an effective approach to reduce the risk of venous congestion and its associated complications of loss and fat necrosis [10, 30–34]. This technique improves the overall circulation in the vascular territory by decreasing the venous congestion in the flap. This technique was the previous traditional standard of care, as can be seen in our data from Group A in which 17.1% of the patients received SIEV supercharging. Supercharge of SIEV is technically challenging due to its location at the edge of the flap, causing it to be prone to kinking. With the increased flap inset ratio, limited incision in lateral chest wall, and the increasing usage of TDA as recipient artery with concern about the flow it provides, there is difficulty in using the SIEV for supercharging. Hence, there is a concomitant increase of the utilization of bilateral pedicle of DIEP flap in Group B (15.9%) for supercharging. Results from Xu H et.al echoed the concept of bipedicle technique in DIEP flap with a lower risk of partial flap loss without increasing risk of abdominal complication [35]. Besides, our data reported an average flap use percentage of 73.6% and 76.5% in both groups, which indicating inclusion of portion across the midline of flap (including zone III and zone IV). According to the study conducted by Holm C et al., decreased arterial inflow was reported in portion which crosses the midline of the flap under ICG fluoroscopy [5]. Avoided usage of more than 70% of flap was also suggested by other studies. Therefore, inclusion of contralateral pedicle in patient with more than 70% of flap use might be helpful in enhancing the arterial inflow of flap. Besides, the incision placement and incision length were also important factors for our decision making regarding the selection between inclusion of bilateral pedicle and SIEV. It is sometimes difficult to supercharge the SIEV and perform a safe flap transfer and breast shaping via the limited small incision in the lateral chest wall.

The inclusion of bilateral pedicles in the DIEP flap transfer requires bilateral fasciotomies in the anterior rectus sheath and may potentially increase the risk of donor site morbidities. However, with well planning and practice, the complications were compatible to unilateral pedicle dissection [36, 37]. To reduce complications, we try to preserve all encountered motor nerves of the rectus abdominis muscle during flap dissection. If we must transect the nerve, the transected nerves were repaired. In advance, with the increased adoption of robotic assisted mastectomy, robot-assisted dissection of DIEP was also adopted in some of our patients [38]. Via dissection from the intra-abdominal space, extensive fasciotomy could be avoided during dissection of bilateral pedicle. The robot-assisted DIEP flap harvest was a new technique, and its effectiveness of minimizing donor site morbidities will be further investigated in the future when we accumulate more clinical experience.

The use of TDA also has several drawbacks, including its deep location in the axillary space that is associated with difficult exposure, potentially higher risk of seroma due to additional dead space [21] and a prolonged surgical time, especially when the breast surgeons only perform sentinel lymph node sampling instead of a full axillary lymph node dissection [14]. In addition, the use of TDA for microvascular anastomosis may preclude the possibility of using the LD flap as a salvage procedure [20]. Based on our experience, we have summarized an algorithm for the selection of recipient vessels and blood

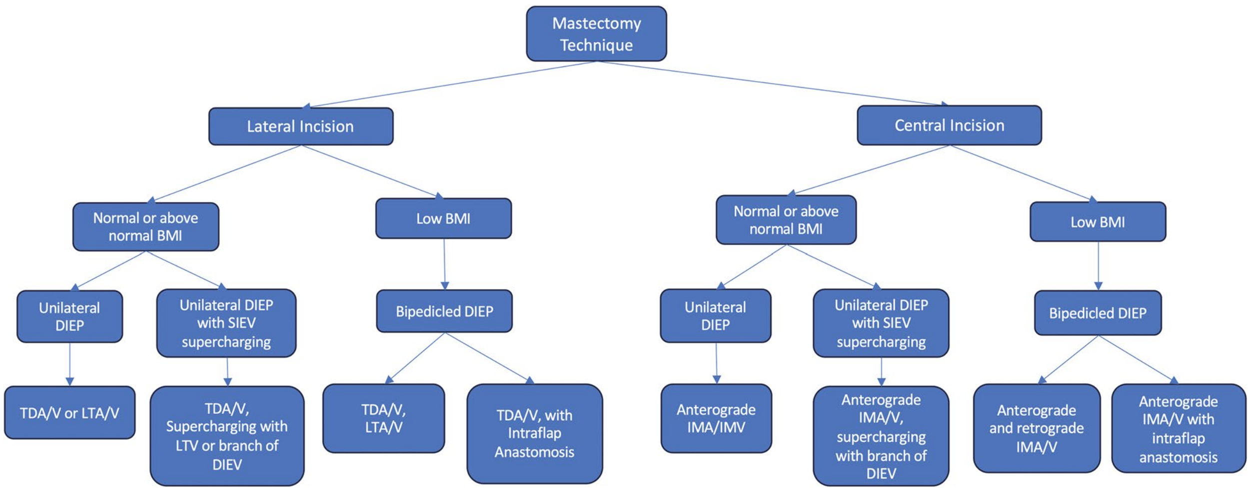

Fig. 3 Algorithm of flap design and recipient vessel selection in accordance with the mastectomy type

vessels for flap supercharge during the breast reconstruction with DIEP flap (Fig. 3). During the pre-operative evaluation, bipedicle anastomosis of DIEP flap would be planned if the patients presented with small BMI, insufficient abdominal tissue or a midline abdominal scar. For other patients without these characteristics, supercharge of the SIEV remains important in unilateral pedicle flap when intraoperative venous insufficiency is considered. The selection of recipient vessel then depends on the mastectomy incision. IMA is still considered the primary choice due to its robust blood flow and central location, when it is reachable via a central or large latera incision. TDA or LTA can be used as alternatives once IMA was too distant to approach via the lateral incision.

Conclusion

The strategic approach to breast reconstruction with the DIEP flap would need to evolve in tandem to the trends of mastectomy technique. Flap design, transfer and shaping technique should adapt to the changes in the breast cancer treatment.

Abbreviations

DIEP	Deep inferior epigastric artery perforator
MIS	Minimally invasive surgeries
TRAM	Transverse rectus abdominis muscle
BMI	Body mass index
NSM	Nipple-sparing mastectomy
IMA/V	Internal mammary artery/vein
TDA/V	Thoracodorsal artery/vein
LTA/V	Lateral thoracic artery/vein
SIEV	Superficial inferior epigastric vein
MRM	Modified radical mastectomy
SSM	Skin-sparing mastectomy
DIEA/V	Deep inferior epigastric artery/vein

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Authors' contributions

TEL, DCFC, WLK, HPT, and JJH collected and interpreted the data. TEL, AWLW, WLK, HPT, and JJH were responsible for the conception and design of the article. All authors participated in the manuscript writing and substantively revised it. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Review Board of Chang Gung Medical Foundation (Date: October 3, 2022; No: 202201562B0). The IRB approves the waiver of the participants' consent.

Consent for publication

The authors affirm that human research participants provided informed consent for publication of the images in Figure.

Competing interests

The authors declare no competing interests.

Research registration

This study is retrospectively registered on ClinicalTrials.gov (NCT06321549).

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