Evaluation of internal mammary perforators as a recipient vessels for deep inferior epigastric perforator flap delayed breast reconstruction in Egyptian population

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Background
Nowadays, the standard practice in microsurgical reconstructive breast surgery is focusing on providing good esthetic outcome with minimal morbidity. Therefore, attention is no longer given to the donor site only but also to the recipient area. Thus, internal mammary perforators (IMPs) are adopted to be used as recipient vessels in autologous free flap breast reconstruction as it carries many advantages in comparison with the internal mammary, or thoracodorsal vessels. Our aim in this study was to evaluate the clinical reliability and to test the efficacy of using these perforators as recipient vessels in Egyptian population especially fatty patients coming after radiotherapy for delayed breast reconstruction.
Patients and methods
A prospective analysis was performed on 16 Egyptian patients who visited Ain Shams University hospitals over the course of 2 years, from September 2020 to September 2022.Deep inferior epigastric perforator flap breast reconstructions were performed by a single surgeon on all patients. The use of IMP vessels was attempted, and intraoperative measurements of the vessels and flaps were collected.
Results
All of the included patients underwent delayed breast reconstruction surgery. In four (25.0%) patients, IMP vessels were used. The subcutaneous plane (57.1%) is where the majority of the perforator vessels are situated. The third intercostal space held 64.3% of the perforator vessels, whereas the second held 35.7% of them. The diameter of IMPs was considerably less than that of internal mammary arteries. With the exception of one patient who needed debridement due to fat necrosis, all recipients were appropriate and trustworthy as recipient vessels without experiencing any serious morbidities such flap loss, fat necrosis, or mastectomy skin flap necrosis.
Conclusion
Despite their relatively small size, IMP vessels are trustworthy and safe to employ as recipient vessels in free flap breast reconstruction because they achieve a less-invasive procedure than using internal mammary vessels.

Keywords:
delayed breast reconstruction, free deep inferior epigastric perforator flap, internal mammary perforators and radiation

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Introduction

The leading cause of cancer-related mortality among women globally is breast cancer. Although rates are lower in underdeveloped nations, breast cancer is more common in the majority of industrialized nations. Every year, breast cancer affects more than 180 000 American women [1]. Breast cancer accounts for 33% of female cancer cases in Egypt, where it is the second greatest cause of death for females. Each year, more than 22 000 new cases are identified. Egyptian women had the highest cancer incidence rate (157.0 per 100 000). By 2050, breast cancer incidence rates are predicted to have tripled in between Egyptian women [2].

Breast cancer guidelines have been established, breast cancer screening programs have been started, and breast centers offering an interdisciplinary and comprehensive therapeutical approach for breast cancer have all frequently been established. Surgical breast cancer treatment has also frequently become less radical and invasive. This has led to an increase in early breast cancer identification and treatment, better survival rates, and better esthetic outcomes as a

result [3]. Additionally, providing autologous free tissue transfer to patients in need of breast reconstruction has become common and widely practiced [4].

Breast reconstruction aims to minimize morbidity while producing an esthetically pleasing breast. The superficial inferior epigastric artery (SIEA) flap and deep inferior epigastric perforator (DIEP) flap, which do not need the incision or excision of the rectus abdominis muscle or fascia, are being used to reduce abdominal donor-site morbidity [5].

Similar to how the pectoralis major muscle, costal cartilage, or intercostal muscle are not cut or removed, recipient-site morbidity can be reduced by employing internal mammary perforator (IMP) arteries. As expertise employing internal mammary vessels as recipient vessels has developed, so has the knowledge of their surgical anatomy [6].

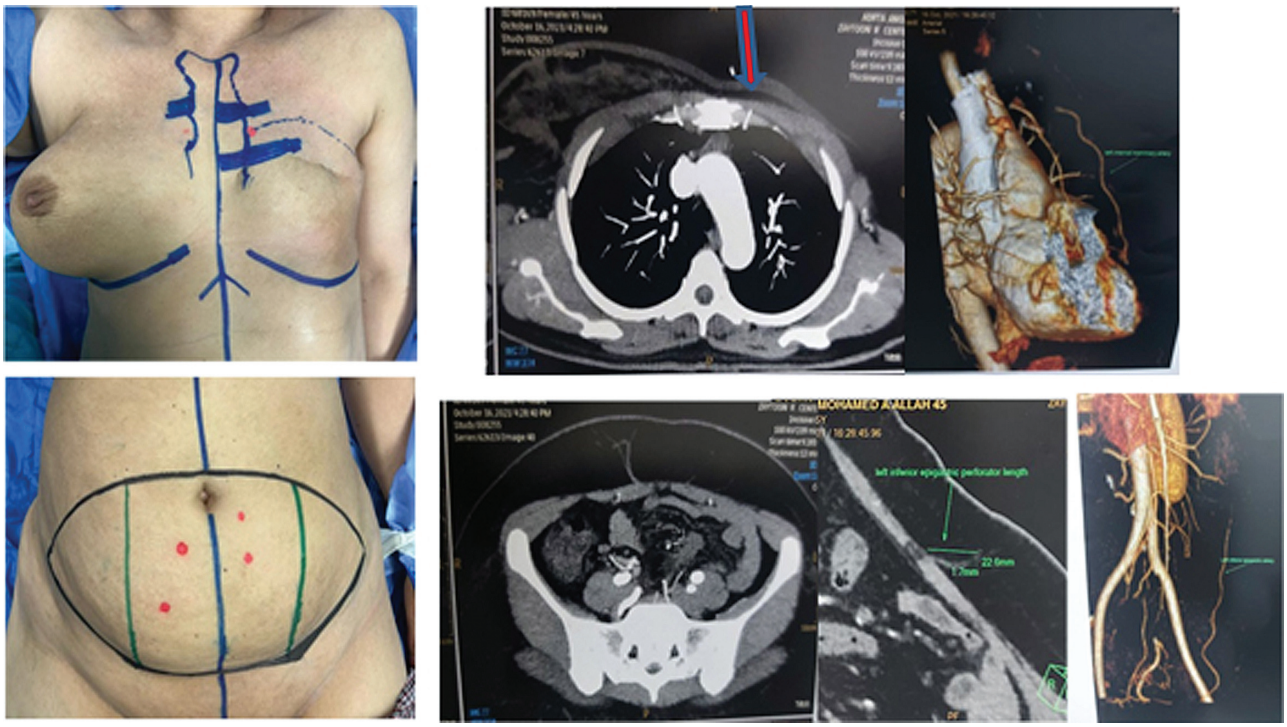
IMP vessels have a number of benefits over internal mammary vessels, including easier and less-invasive recipient vessel preparation without the need to cut or excise the pectoralis major muscle, costal cartilage, or intercostal muscle, and easier microvascular surgery owing to reduced respiratory and cardiac chest wall motion and a more superficial location. We anticipate that these benefits will lead to less recipient-site morbidity. There are benefits to IMP recipient vessels over internal mammary recipient vessels, although it is unknown if the IMP recipient vessels are equally trustworthy. In addition, there are uncertainties that dividing IMP vessels may further devascularize mastectomy skin flaps, increasing the risk of necrosis [7], and that smaller IMP arteries may not be able to support a free flap for breast reconstruction or that their smaller caliber may make them more susceptible to vessel thrombosis [8].

Although internal mammary artery perforators are not yet regarded as conventional recipient vessels, their use in autologous breast reconstruction has been documented. The safety of using these vessels, particularly in big flaps placed after radiation therapy or in delayed breast reconstruction, is yet unknown. This naturally prompted us to research the feasibility of using IMPs as recipients for free flap breast reconstruction in the Egyptian population.

Patients and methods

At hospitals of Ain Shams University, we conducted our prospective exploratory study from September 2020 to September 2022, focusing on microsurgical breast reconstruction. For delayed breast

Figure 1



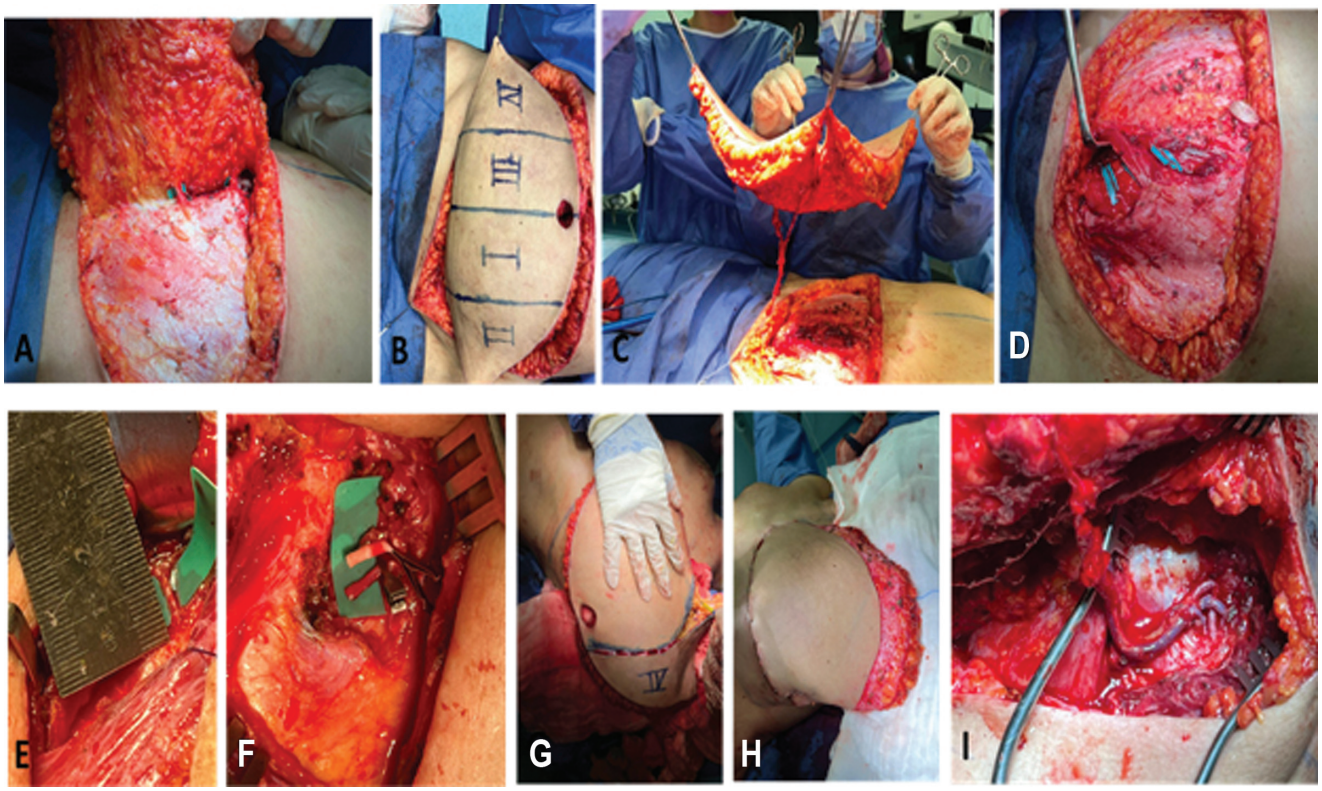
Preoperative planning and marking of the internal mammary and deep inferior epigastric perforators on chest and abdomen, respectively, using handheld Doppler under the guidance of CT angiographic scan. CT, computed tomography.

reconstruction following mastectomy, 16 female patients were sent to us and got their postoperative radiation. All patients got free DIEP flap reconstruction. The use of IMP vessels as recipient vessels was attempted.

After proper assessment and complete oncological evaluation, patients were counseled about the procedure and included in the study. Preoperative workup was done; investigating the patients with computed tomographic angiographic scan of the chest and abdomen for assessment of the IMP and DIEP vessels, getting idea about their location, length, and diameter. Moreover, a hand-held Doppler was used for locating the DIEP vessels on the anterior abdominal wall and to map the IMP vessels at the second, third, or fourth intercostal spaces. In Fig. 1, in each instance, a two-team strategy was used, with each team working in tandem to prepare the recipient site while the other team doing DIEP flap harvest. To identify the IMP vessels, dissection in the subcutaneous plane in the second, third, and fourth intercostal spaces is tried while creating the breast pocket for the flap by undermining the mastectomy flaps. If the perforator is of good caliber and adequate blood flow, dissection is continued under the microscope. Then, length of the perforator is assessed if suitable for easy microanastomosis or not. Pectoralis muscle splitting could be performed to get a long length of the perforators. Then, we recorded the clinical finding of the IMPs' characteristics in relation to the preoperative radiological findings (site, diameter, length, blood flow inside the perforator, availability of venae comitantes, and the need of pectoralis muscle dissection). If the perforators were not found in the superficial plane, pectoralis major muscle is explored with dissection to find the perforators. If the IMP vessels are not suitable, without cartilage removal, dissection is proceeded to expose the internal mammary vessels through the intercostal space (Fig. 2).

The following information was gathered and noted for analysis (type of the used flap for breast reconstruction, length of the flap pedicle, flap weight, flap surface area, size mismatch of IMP vessels with the selected flap pedicle, ischemia time of the flap, time of the

Figure 2



Intraoperative photographs showing the surgical steps during DIEP flap harvest and recipient site preparation: (a) Two perforators of deep inferior epigastric vessels are encountered superficial to anterior rectus sheath on left abdominal side. (b, c) DIEP flap is harvested with long pedicle and based on two perforators. (d) Motor nerves to rectus muscle is preserved to avoid weakness or hernia postoperatively. (e, f) Internal mammary perforator vessels are encountered deep in pectoralis major muscle in the second intercostal space. (g) Zone IV is discarded from the flap. (h) Upper part of the flap is de-epithelized for better flap inset. (i) Anastomosis of the flap pedicle to the recipient internal mammary vessels sparing the costal cartilage. DIEP, deep inferior epigastric perforator.

operation, and need to blood transfusion). The recommended postoperative anticoagulant treatment was used. Along with proper hydration and analgesia, low-molecular-weight heparin was administered to all patients as a preventative dosage for five days. The patients had been followed postoperative for 5–7 days for flap viability and to detect any early complications, such as vascular compromise, then discharged home with follow-up visits at interval of 1, 2, 3, and 6 months for detection of any late complications like fat necrosis.

Ethical approval

This research was performed at the Department of General Surgery, Ain Shams University Hospitals. Ethical Committee approval and written, informed consent were obtained from all participants.

Results

During a 25-month trial period that comprised 16 free flap breast reconstructions, four breast reconstructions out of 16 patients employed IMP arteries as recipients. The mean±SD age and BMI were 43.2±7.0 and 29.3 ±0.8, respectively. All the 16 (100%) patients received radiation therapy after mastectomy and presented for unilateral breast reconstruction. Free flap used was DIEP flap in 16 (100%) patients; 11 (68.8%) DIEP flaps were used for right breast reconstruction and five (31.3%) for left side in the remaining patients. The mean±SD harvested DIEP flap surface area (cm^2) and weight (g) were 310.5±34.6 and 679.6±29.8, respectively (Table 1).

IMP vessels were discovered during recipient site preparation in 14 (87.5%) individuals, but not in two (12.5%) patients. Overall, 64.3% of the discovered IMP vessels were identified in the third intercostal space (n=9) and 35.7% (n=5) in the second intercostal region. They were found deep inside the pectoralis major muscle in six (42.9%) patients and superficially in the subcutaneous plane in eight (57.1%) individuals. Moreover, 50.0% of the detected IMP vessels (seven patients) needed intramuscular dissection to gain more length. Only eight (57.1%) venae comitantes were seen associating the IMP arteries. A total of four (28.6%) IMP vessels showed a good blood flow after exposure and preparation, and therefore, they were used as recipient vessels. Blood flow of IMP vessels in 10 (71.4%) cases was not so adequate and suitable for anastomosis, so internal mammary vessels were used instead as recipients in 12 patients (Table 2).

Table 1 Demographic characteristics among the studied cases

Variables	Mean±SD	Range
Age (years)	43.2±7.0	30.0–54.0
BMI (kg/m^2)	29.0±0.8	27.5–29.9
	n (%)	
History of radiation	16 (100.0)	
Time of reconstruction		
Delayed	16 (100.0)	
Laterality		
Right	11 (68.8)	
Left	5 (31.3)	

Total=16.

The mean±SD diameters of the IMP vessels were 1.0 ±0.1 mm (range, 0.8–1.2 mm) and 1.4±0.4 mm (range, 0.9–2.1 mm) for the artery and vein, respectively. The mean±SD lengths of the dissected IMP vessels were 2.0±0.3 cm (range, 1.5–2.4 cm). The mean±SD diameters of DIEP arteries and veins were 2.2 ±0.3 mm (range, 1.7–2.7 mm) and 2.6±0.4 mm (range, 1.8–3.3 mm), respectively. We compared the diameters of IMP vessels with DIEP vessels, which showed size discrepancy. P value of IMP versus DIEP artery and vein was less than 0.001, which was significant statistically but it was clinically minimal and of no significance (Fig. 3).

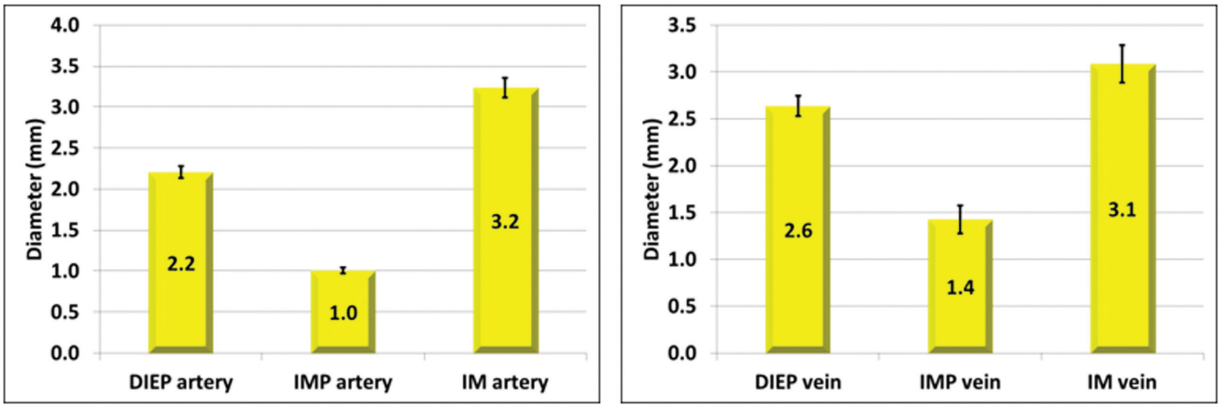
One (6.25%) early flap complication, represented by venous congestion on the first postoperative day, and one late flap complication, represented by flap fat necrosis after 6 months, were noted. The previous flap pedicle was anastomosed to internal mammary vessels. Owing to the compression over the veins created by the tight breast pocket, there was venous congestion, which necessitated an urgent re-exploration and repositioning of the flap. The flap was salvaged but experienced nonsignificant partial

Table 2 Characteristics of the detected internal mammary perforator among the studied cases

Variables	*n* (%)	
Site		
Second IC space	5 (35.7)	
Third IC space	9 (64.3)	
Relation to pectoralis major muscle		
Superficial	8 (57.1)	
Deep	6 (42.9)	
Need for pectoralis muscle dissection	7 (50.0)	
Venae comitantes	8 (57.1)	
Blood flow		
Adequate	4 (28.6)	
Not adequate	10 (71.4)	
	Mean±SD	Range
IMP length (cm)	2.0±0.3	1.5–2.4
Venae comitantes diameter (mm) (total=8)	1.4±0.4	0.9–2.1

Total=14. IC, intercostal; IMP, internal mammary perforator.

Figure 3



The mean diameters of DIEP, IMP, and IM arteries and veins among the studied patients. DIEP, deep inferior epigastric perforator; IM, internal mammary; IMP, internal mammary perforator.

flap loss. The latter, which accounts for 25.0% of the four flaps, was anastomosed to IMP vessels.

Hospital stay more than 1 week, venous congestion, need of flap revision, and partial flap loss were nonsignificantly less frequent in cases with IMP recipient vessels. Moreover, fat necrosis was nonsignificantly more frequent in cases with IMP recipient vessels. Time of recipient vessel preparation, time of anastomosis, ischemia time, and operation time were significantly shorter in cases with IMP recipient vessels. Blood transfusion was significantly less needed in cases with IMP recipient vessels, as shown in Table 3.

Table 3 Comparison according to recipient vessels in reconstruction regarding hospital stay and complications

Variables	IM (*N*=12) [*n* (%)]	IMP (*N*=4) [*n* (%)]	*P* value
Stay >1 week	1 (8.3)	0	0.999§
Need for blood transfusion	12 (100.0)	2 (50.0)	0.049*§
Venous congestion	1 (8.3)	0	0.999§
Need of flap revision	1 (8.3)	0	0.999§
Partial flap loss	1 (8.3)	0	0.999§
Fat necrosis	0	1 (25.0)	0.250§

IMP, internal mammary perforator. §Fisher's exact test. *Significant.

Discussion

One of the most significant and crucial factors in a successful microsurgical breast reconstruction is the choice of recipient vessels. With the transition from TD to internal mammary vessels, anastomosis to various blood vessels was documented in free flap breast reconstruction. On the subject of successfully obtaining a nice esthetic new breast, each of them has benefits and disadvantages of their own. To lessen recipient site morbidity, IMP arteries have advanced to be employed as recipients in several clinical investigations.

In our study, 87.5% of IMP were located in the second and third intercostal spaces. Moreover, in 12.5% (two out of 16 patients), IMP vessels were not found during dissection of the breast pocket owing to severe parasternal fibrosis and we did not perform more dissection upward on the mastectomy flaps to reach the first intercostal space as it is far away from the mastectomy scar where incision was done. Overall, 64.3% of IMP arteries were on the third intercostal space and 35.7% on the second intercostal space. It is possible to find and pinpoint the perforators in the subcutaneous, intramuscular, or submuscular plane. In our study, 42.9% of IMP arteries were intramuscular, and 57.1% were superficial to pectoralis major muscle in the subcutaneous plane. Halim and Alwi reported the useable IMPs were largely situated in the second and third intercostal regions in their prospective clinical investigation, in 86–100% of their cases. This result was reflected in their own series, where a total of 27 (85%) IMP arteries were used. Additionally, the IMP vessels in the first (3%) and fourth (12%) intercostal space were effectively used. Eight (25%) and 24 (75%) of the IMP arteries, respectively, were located intramuscularly [9]. Haywood and colleagues and Hamdi and colleagues reported that the second and third intercostal spaces have 100% of the IMP vessels. Similar to this, Munhoz and colleagues and Saint-Cyr and colleagues. discovered IMP branches in the subcutaneous tissue in the parasternal region in their retrospective studies. A total of 36 patients who underwent 40 free perforator flap breast reconstructions were clinically examined by Munhoz *et al.* [10], who found 29 (72.5%) of the IMP branches

were located in the subcutaneous tissue just above the pectoralis major muscle [11].

Free flap selection for breast reconstruction depends on many factors, including availability of tissues on donor site, surgeon experience, institution's setting, and size match with recipient vessels. In our study, we attempted using DIEP flap in all patients despite the size discrepancy with IMP vessels as it is considered the gold standard operation nowadays in microsurgical breast reconstruction. This is attributed to its merits of having long pedicle and reduction of the donor-site morbidities like hernia and abdominal muscle weakness [11] (Fig. 4). Depending on the size of recipient vessels, it is better to select a flap with suitable pedicle vessel diameter matching with each other. The IMP artery, according to Saint-Cyr *et al.* [11], is a better size match for the smaller SIEA than the internal mammary artery. As a result, they promoted the use of IMP recipient vessels for SIEA flap breast reconstruction. Additionally, the SIEA flap is favorable as it is entirely suprafascial, avoiding dissection via the anterior rectus sheath, rectus muscle dissection, and nerve damage. Despite having clear advantages, the flap's popularity has not increased over the DIEP flap owing to the decreased pedicle length and questionable vascular crossing the midline and the ipsilateral hemiabdomen is often supplied by the SIEA [12].

The amount of blood flow is the key consideration when selecting the perforator of the internal mammary vessel as a recipient vessel, and the diameter of the vessel can be a crucial indicator to verify the quantity of blood flow from the vessel [7]. In our investigation, sizes of the IMP, internal mammary, and DIEP arteries and veins were measured and compared. The mean±SD diameters of arterial and venous IMPs are 1.0±0.1 mm (range, 0.8–1.2 mm) and 1.4±0.4 mm (range 0.9–2.1 mm, respectively). The mean±SD diameters of internal mammary artery and vein are 3.2±0.4 mm (range, 2.6–4.0 mm) and 3.1±0.7 mm (range, 1.5–4.0 mm, respectively). However, the mean±SD diameters of the used DIEP flap pedicle are 2.2±0.3 mm (range, 1.7–2.7 mm) and 2.6±0.4 mm (range, 1.8–3.3 mm), for the arteries and the veins,

Figure 4

A case of DIEP free flap left-side breast reconstruction. Pictures are showing preoperative and postoperative follow-up of successful flap take and good contour of new breast in different positions. DIEP, deep inferior epigastric perforator.

respectively. This shows that IMP vessels are smaller than the internal mammary vessels. *P* value is less than 0.001 for the artery and vein, respectively. In comparison with each other, the difference between the diameter of the IMP and DIEP vessels is statistically significant, with *P* value less than 0.001. The donor vessel had a diameter that was double that of the recipient vessel. To facilitate the microvascular anastomosis and resolve their differences, we thus employed two approaches. We began by transecting the DIEP pedicle where it matched the diameter of the IMP vessel by dissecting the pedicle until a caliber match was attained, much as Hamdi and colleagues. The second approach uses two opposing stay sutures spaced 180 degrees apart and is known as the open-loop technique. The sutures were then clipped and knotted separately from the first loop to the final one as in the traditional interrupted suturing procedure. Four or five open-loop sutures were created constantly. The mean sizes of the IMP vessels described in earlier clinical investigations varied from 1.0 to 1.9 and 1.7 to 2.9 mm for the artery and vein, respectively. In the second intercostal space, IMP vessels with sizes comparable to those of the DIEP vessels were discovered by Guzzetti and Thione [13]. Park *et al.* [7] employed IMP arteries in the third intercostal space as recipients for the deep inferior epigastric vessels in their series of five patients with TRAM flaps. In four of their patients, the authors noted that the diameter of donor vessels ranged from half to twice that of the recipient vessels. To solve the issue, the authors employed the open-loop method. According to Munhoz *et al.* [10], vascular damage and diameter differences are reasons for not employing the IMP vessels in 40% of their perforator flaps, including the existence of a single artery and both of these factors. According to Hamdi *et al.* [8], the average arterial diameter was 1 mm and the average venous diameter was 1.7 mm (Table 4).

Prior research revealed that between 9 and 83% of IMP vessels were used as recipients in primary and delayed free flap breast reconstructions. Munhoz *et al.* [10] described a clinical series of 40 patients operated on by the same surgeon that included a 33% incidence of IMP recipient vessel usage. IMP recipient vessels were employed by Haywood *et al.* [14] in 39% of their clinical series of 54 consecutive cases by two surgeons. IMP recipient vessels were employed by Follmar *et al.* [15] in 23% of their clinical series of 100 consecutive cases by two surgeons as well. However, two surgeons employing IMP as recipient vessels in Asian patients achieved an 83% success rate, according to Halim and Alwi, and 64 patients were reported to have 27% of their IMP recipient vessels used, according to Saint-Cyre and colleagues. However, 9% of IMP recipient vessels were used, according to Hamdi and colleagues. Multiple surgeons worked on their series; therefore, it is probable that IMP vessels were not used in every procedure. They explained their comparatively lower IMP usage rate as being caused by European patients having lower average BMIs and, as a result, having smaller diameter IMP vessels, which reduced the rate of vessel use.

Our series is the first prospective study that, to our knowledge, uses IMP recipient vessels in delayed breast reconstruction after radiation therapy in overweight Egyptian women. In 25% of a single surgeon's 16 successive free DIEP flap breast reconstructions, IMP vessels were sufficient for use. They can be employed as recipient vessels in delayed cases of breast reconstruction despite the technical challenges involved in dealing with small-sized and thin-walled IMP vessels, which are primarily caused by damage from prior surgery or radiation therapy. In tiny intraoperative vessels that are smaller than 0.5 mm in size, the use of the IMP vessels as recipients is excluded if there are no veins or veins with very thin walls, as well

Table 4 Comparison of internal mammary perforator recipient vessel studies

Study details	Haywood *et al.* [14]	Hamdi *et al.* [8]	Munhoz *et al.* [10]	Saint-Cyr *et al.* [11]	Follmar *et al.* [15]	Halim and Alwi [9]	This study
Year published	2003	2004	2004	2007	2011	2014	2023
Number of cases	54	298	40	64	100	35	16
IMP as recipient, %	39	9	33	27	23	83	25
IMP in second or third ICS, %	100	100	86	94	NR	75	87.5
IMP in subcutaneous plane, %	NR	NR	100	NR	NR	75	57.1
Diameter of the IMP artery, mean, mm	NR	1.0	NR	1.9*	NR*	1.1	1.0
Diameter of the IMP vein, mean, mm	NR	1.7	NR	2.9	NR	2.2	1.4

ICS, intercostal space; IMP, internal mammary perforator; NR, not reported. *Arteries with diameter of less than 1.5 mm were excluded.

as if there is insufficient blood flow within. No IMP branch was discovered, and fibrous tissue was seen in the parasternal area in all nine patients in the late reconstruction group, according to Munhoz and colleagues. Follmar *et al.* [15] also stated that none of their 20 delayed reconstructions used IMP vessels. As recipient vessels, IMP vessels were used in nine (24%) delayed reconstructions, according to Saint-Cyr and colleagues. This demonstrates that there is a lot of consensus in the medical literature that in patients who have delayed breast reconstruction, the IMP arteries are sufficient for microvascular anastomosis to free lower abdominal flaps.

There was no discernible difference in the complication rates between the IMP and the internal mammary or TD when used as recipient vessels, according to Saint-Cyr *et al.* [11], Follmar *et al.* [15], and Halim and Alwi [9]. According to Saint-Cyr *et al.* [11], among the IMP recipient vessel cases, only one (3%) flap loss as a result of recurring arterial thrombosis was recorded. Additionally, Halim and Alwi [9] reported one (3% of the cases) flap complicated by venous congestion in IMP recipient vessels. In our study, we had one (25.0%) flap in between the IMP recipient vessel group that developed partial fat necrosis and needed debridement. On the internal mammary recipient vessel group, one (8.3%) flap developed early postoperative congestion owing to tight breast pocket and required emergency exploration. Therefore, the IMP and internal mammary recipient vessel cases did not substantially vary in the occurrences of flap loss and fat necrosis, and the postoperative flap complication rate is equivalent to those of previously published research, which reported rates ranging from 0 to 8%.

Although the IMP recipient vessels are one source of blood supply to mastectomy skin flaps, our research did not discover that cutting or ligating these vessels enhanced the risk of mastectomy skin flap necrosis. This finding is similar to that of the study by Saint-Cyr *et al.* [11]. When internal mammary recipient vessels are exposed and prepared as usual, IMP vessels are frequently tied off. This might explain why internal mammary recipient and IMP recipient patients have similar rates of mastectomy skin flap necrosis [11].

Axillary dissection is avoided, the internal mammary artery is preserved for use in future coronary revascularization, there is no need to remove costal cartilage or ribs, and positioning the microscope is made simple by the IMPs' advantages over both the internal mammary and thoracodorsal vessels. Unfortunately, in situations of delayed breast reconstruction, a good IMP is not usually visible; nevertheless, when occasionally a big IMP is seen along the medial border of the mastectomy defect with acceptable blood flow, use of the perforator can be considered. This also will minimize other reported complications of using IM vessels like pneumothorax [16], contour deformity, and intercostal neuralgia [17].

Conclusion

IMP vessels are a dependable choice as recipients in delayed free flap breast reconstruction in a chosen Egyptian population who had postmastectomy radiation therapy, despite their relatively small size, significant parasternal fibrosis, and damage from mastectomy or irradiation. When compared with internal mammary vessels, IMP vessels achieve low recipient site morbidity and are anatomically consistent while still being safe to use.

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Conflicts of interest

There are no conflicts of interest.

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