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Breast

A Systematic Review and Meta-analysis of Clinical Outcomes in Autologous Breast Reconstruction Using Internal Mammary Artery Perforators as Recipient Vessels

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Background: Recipient vessel selection is vital for successful autologous free-flap breast reconstruction. Internal mammary artery perforators have gained interest as a recipient vessel option. However, previous studies on their microsurgical safety and efficacy are limited and inconsistent. Thus, we conducted a systematic review and meta-analysis to assess the safety and effectiveness of using internal mammary artery perforators as recipient vessels in breast reconstruction.

Methods: The protocol has been previously published in PROSPERO (CRD42020190020). The PubMed, Scopus, Web of Science, and PROSPERO databases were searched. Two independent reviewers evaluated the articles for inclusion in the study. Study quality was assessed using the Newcastle-Ottawa Scale and the MINORS instrument (Methodological Index for Non-Randomized Studies).

Results: Of the 361 articles screened, 13 studies were included (313 patients with 318 flaps; 223 unilateral, 31 bilateral, mean average age 51.2 and mean BMI 27.8±1.9). The mean overall success rate was 99.8%, the pooled surgical success rate was 100% [95% confidence interval (CI): 97%–100%], and the overall rate of complications was 11% (95% CI: 7%–18%). The most common complication was vascular-related to microanastomoses, with an incidence of 5% (95% CI: 2%–10%). The fat necrosis rate was 3% (95% CI: 2%–6%).

Conclusions: This study verified that internal mammary artery perforator vessels are reliable in breast reconstruction, with a high success rate and a relatively low complication rate. Moreover, in selected microsurgical breast reconstruction patients, internal mammary artery perforators may be the primary recipient vessel choice over the internal mammary artery or thoracodorsal vessels. *(Plast Reconstr Surg Glob Open 2023; 11:e4969; doi: 10.1097/GOX.0000000000004969; Published online 17 May 2023.)*

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INTRODUCTION

In recent studies, using internal mammary artery perforators (IMAPs) as recipient vessels has reduced global morbidity while preserving the benefits of internal mammary artery (IMA) vessels. IMAPs can be considered an alternative recipient vessel to replace the thoracodorsal (TD) and IMA vessels eventually.[1] In 1999, Blondeel reported the first successful free flap transfer to IMAPs, while Hamdi et al described their experience using IMAPs with 3.3% of arterial thrombosis and no donor-site morbidity.[2] Similar studies reported the use of IMAPs between

Disclosure statements are at the end of this article, following the correspondence information.

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5.5% and 39% for breast reconstruction.[3] In a retrospective study of 686 abdominal free flaps, Saint-Cyr et al found IMAPs were used in 27%, with a complication rate similar to IMA vessels.[4]

Clinical factors and the surgeon's expertise usually determine IMAP use. The most limiting factor for this choice is caliber size, which ranges from 0.85 to 1.9 mm, located in the second and third intercostal (IC) spaces in nearly 94%–100% of cases.[2,5,6] IMAPs originate from the IMA, perforate the pectoralis major muscle, and overlie the fascia.[7] Division of the deep inferior epigastric artery (DIEA) pedicle to match the IMAP vessel diameter, the use of a mechanical coupler device for arterial microanastomosis, and using the superficial inferior epigastric artery flap (SIEA) or the superior gluteal artery perforator (SGAP) flap for better vessel match can overcome size discrepancy.[4,6,8] Other drawbacks include less reliable anatomical location, thinner and weaker walls, surgical exposure, technical difficulties, delayed reconstruction, and radiotherapy.[1,2–4,6,8]

Rationale

The data on microsurgical safety and efficacy of IMAPs as recipient vessel flaps in autologous breast reconstruction are scarce and heterogeneous. Thus, a systematic review and meta-analysis of microsurgical efficiency are needed.

Objectives

This study will (1) determine the overall success rate, (2) determine overall complication rates, and (3) compare subgroups for complications, with the use of IMAPs as recipient vessels for breast reconstruction.

METHODS

Protocol and Registration

The review utilized the University of York's Center for Reviews and Dissemination International Prospective Register of Systematic Reviews (PROSPERO) to reduce bias (registry CRD42020190020).

Eligibility Criteria

Articles had to meet the following criteria: (a) clinical studies; (b) consecutive cases; (c) IMAPs were selected as a recipient vessel; (d) autologous breast reconstruction after breast cancer; (e) perioperative clinical data; and (f) more than two cases. The study excluded (a) review articles, abstracts, or letters; (b) ambiguous results; (c) animal or simulation studies; (e) inaccessible articles; (f) studies with no outcome measures; and (g) other vessels that were not IMAPs.

Information Sources

An electronic database search was performed on March 3, 2020; these searches were updated on June 3, 2020: PubMed, Scopus, Web of Science and PROSPERO (Jan 2000–Jun 2020). The databases were reported by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.[9]

Takeaways

Question: What is the efficacy and safety of internal mammary artery perforators as recipient vessels in autologous breast reconstruction?

Findings: This systematic review and meta-analysis verified that internal mammary artery perforator vessels are reliable in breast reconstruction, with a high success rate and relatively low complication rate.

Meaning: Internal mammary artery perforators may be the primary recipient vessel choice over the internal mammary artery or thoracodorsal vessels using autologous tissue for breast reconstruction.

Search and Study Selection

The search strategy was developed for MEDLINE and adapted to other databases. (**See graph, Supplemental Digital Content 1,** which displays the search strategy. **http://links.lww.com/PRSGO/C536**.)

Data Items and Collection Process

Two reviewers (O.F. and G.C.) analyzed and extracted data using an Excel (v.16.36; Microsoft Corp., Redmond, USA) spreadsheet. Disagreements were resolved by consensus between the two reviewers (O.F. and G.C.) or by a third reviewer (M.G.). The following data were extracted and collected: general information, demographics, and perioperative outcomes. The first and corresponding authors were contacted via email if missing data were found.

Risk of Bias in Individual Studies and Across Studies

The NOS was used to evaluate nonrandomized studies.[10] The selected observational studies were also assessed for bias using the MINORS scale.[11] The included studies were rated using the Oxford Center for Evidence-Based Medicine Levels of Evidence.[12]

Statistical Analysis

We considered a qualitative synthesis of the results whenever two or more studies were quantitative (meta-analysis) and worthy of analysis. Data on the flap failure rate, flap success, and the number of complications were collected and pooled. The RStudio Team (v.1.3; Rstudio, Boston, Mass.) was used for the statistical analysis. Study results are shown with event incidence rate (event number ratio to patient number) and 95% confidence interval (CI) proportions. Statistical heterogeneity among the included samples was determined using I and Q statistics. The variability percentage across studies was measured. $I^2 > 50\%$ or $P < 0.05$ was considered heterogeneous. In all analyses, random effects were used to cover the variation between and within studies. To determine the complication rates and related CIs, meta-command (meta-analysis of single proportions) was used. The forest plot then described the cumulative results, and a funnel plot was used to look for evidence of publication bias.

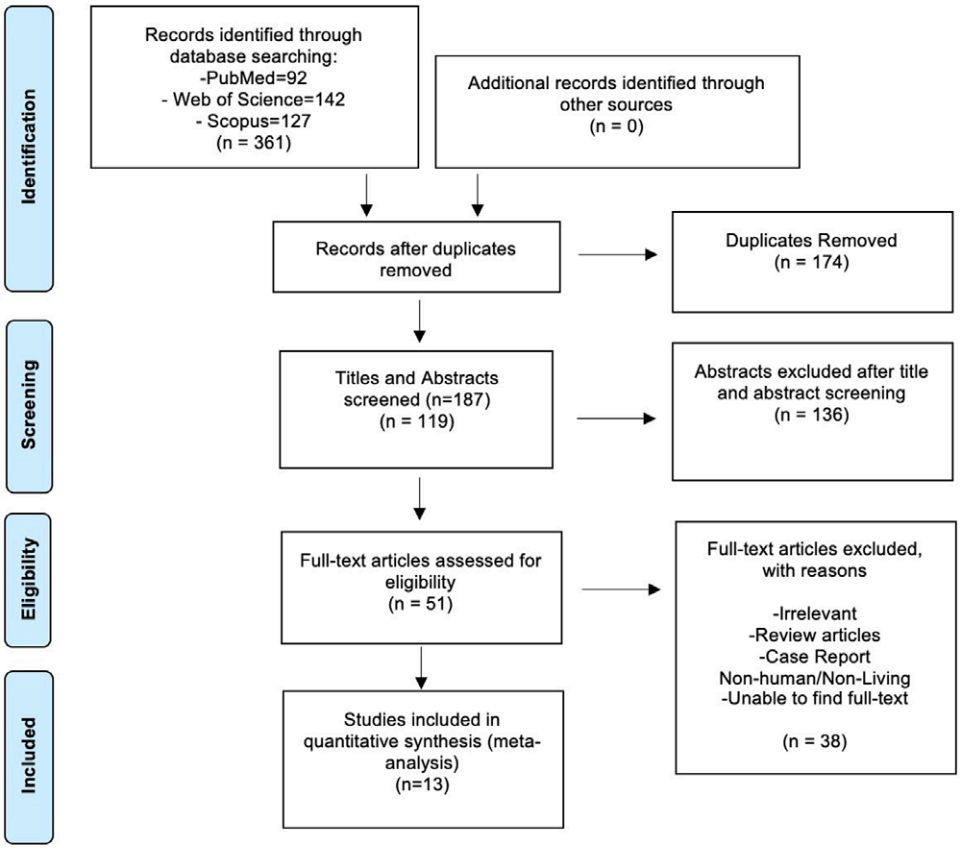

Fig. 1. PRISMA flow diagram illustrating the study selection process.

RESULTS

Study Selection

The PRISMA flow diagram summarized the review (Fig. 1). A total of 361 articles were found, including 92 from PubMed, 142 from Web of Science, and 127 from Scopus. After duplicate removal, 187 remained (174 eliminated), and this number was reduced to 51 articles after title and abstract screening. Thirteen articles were selected for a full review.

OVERVIEW OF INCLUDED STUDIES

Of the 13 studies, 12 were retrospective, and one was prospective. From 2003 to 2017, medical institutions worldwide conducted studies, including two from Brazil, two from the United Kingdom, three from the United States of America, and one from Belgium, South Korea, Germany, Malaysia, and India (Table 1).

STUDY CHARACTERISTICS

Demographics

Thirteen studies comprising 313 patients and 318 flaps were included in this systematic review. Of these flaps, 223 (70.1%) were unilateral; 31 (9.7%), bilateral; 210 (66%), immediate; and 58 (18.2%), delayed. The mean average age of the patients was 51.2±5.1 years, with a mean BMI of 27.8±1.9; two (0.63%) were active smokers, and 41 (12.9%) had previous radiotherapy and mastectomy (Table 2).

Flap Types, Mean Operative Time, and Mean Follow-up

Of the 318 flaps, the type of free flap was reported for 249 (76.1%). These were deep inferior epigastric artery perforator (DIEP), 163 (65.4%); free transverse rectus abdominis (TRAM) flaps, four (1.6%); free muscle-sparing TRAM flap, 12 (4.8%); transverse myocutaneous gracilis/transverse upper gracilis (TMG/TUG) flaps, 52 (20.8%); SIEA flap, 17 (6.8%); and superior gluteal artery perforator (SGAP) flap, one (0.4%). The mean operative time was 7 hours 10 minutes, and the mean follow-up was 21±15.9 months. (**See graph, Supplemental Digital Content 2,** which displays the summarized flap types, mean operative times, and follow-ups of the different studies. **http://links.lww.com/PRSGO/C537**.)

Anatomical and Operative Findings

Within the 318 free flaps anastomosed to IMAPs as a recipient vessel, the mean arterial diameter was 1.4±0.3mm, and mean venous diameter, 2.1±0.5mm. The location of the IMAP vessels was reported in 87 cases. The second IC was the most frequently used in 50 patients (57.5%), third IC in 32 (36.8%), fourth IC

Table 1. Summary of the Characteristics of the Studies

Number	Study	Year	Location	Title	Methods	N	Flaps	Level of Evidence	MINORS	NOS
1	Haywood et al	2003	United Kingdom	Autologous free tissue breast reconstruction using the internal mammary perforators as recipient's vessels	Retrospective	21	21	IV	4	5
2	Park et al	2003	South Korea	Use of internal mammary vessel perforator as a recipient vessel for free TRAM breast reconstruction	Retrospective	4	4	IV	10	6
3	Mendoca Munhoz et al	2004	Brazil	Perforator flap breast reconstruction using internal mammary perforator branches as a recipient site: an anatomical and clinical analysis	Retrospective	13	13	IV	4	5
4	Hamdi et al	2004	Belgium	Algorithm in choosing recipient vessels for perforator free flap in breast reconstruction: the role of the internal mammary perforators	Retrospective	30	30	IV	9	6
5	Saint-Cyr et al	2007	USA	Internal mammary perforator recipient vessels for breast reconstruction using free TRAM, DIEP, and SIEA flaps	Retrospective	35	38	IV	6	5
6	Rad et al	2008	USA	Free DIEP and SIEA breast reconstruction to internal mammary intercostal perforating vessels with arterial microanastomosis using a mechanical coupling device	Retrospective	9	9	IV	9	6
7	Follmar et al	2011	USA	Internal mammary intercostal perforators instead of the true internal mammary vessels as the recipient vessels for breast reconstruction	Retrospective	23	23	IV	10	6
8	Mendoca Munhoz et al	2011	Brazil	Superficial inferior epigastric artery (SIEA) free flap using perforator vessels as a recipient site: clinical implications in autologous breast reconstruction	Retrospective	5	5	IV	8	6
9	Fansa et al	2013	Germany	Computed tomographic angiography imaging and clinical implications of internal mammary artery perforator vessels as recipient vessels in autologous breast reconstruction	Retrospective	13	13	IV	6	5
10	Halim et al	2014	Malaysia	Internal mammary perforators as recipient vessels for deep inferior epigastric perforator and muscle-sparing free transverse rectus abdominis musculocutaneous flap breast reconstruction in an Asian population	Prospective	29	29	III	8	5
11	Vollbach et al	2016	Germany	An appraisal of IMAPs as recipient vessels in microvascular breast reconstruction—an analysis of 515 consecutive cases	Retrospective	112	112	IV	6	5
12	Saour et al	2017	United Kingdom	Microsurgical refinements with the use of internal mammary (IM) perforators as recipient vessels in transverse upper gracilis (TUG) autologous breast reconstruction Samer	Retrospective	12	14	IV	5	5
13	Kanoi et al	2017	India	Computed tomography angiographic study of internal mammary perforators and their use as recipient vessels for free tissue transfer in breast reconstruction	Retrospective	7	7	IV	5	5

Table 2. Demographics

	Study	N	Flaps	Unilateral	Bilateral	Immediate	Delayed	Mean Age (range)	Mean BMI (range)	Active Smokers	Obese	Other Comorbidities
1	Haywood et al	21	21	NR	NR	10	11	NR	NR	NR	NR	NR
2	Park et al	4	4	4	0	4	NR	40.5	NR	NR	NR	NR
3	Mendoca Munhoz, et al	13	13	NR	NR	NR	NR	58.05±6.5	26.67	NR	NR	NR
4	Hamdi et al	30	30	NR	NR	NR	NR	NR	NR	NR	NR	NR
5	Saint-Cyr et al	35	38	24	14	29	9	49.9 (42-64)	29.4 (24.2-37.5)	NR	NR	NR
6	Rad et al	9	9	5	4	7	2	51.2±9.2 (43-60)	27.2±4.5 (25.7-38.9)	NR	NR	2 – Preoperative radiotherapy
7	Follmar et al	23	23	22	1	20	3	50±7	28±6	2	NR	NR
8	Mendoca Munhoz	5	5	5	0	5	0	54±5 (46-61)	NR	NR	NR	NR
9	Fansa et al	13	13	13	0	13	0	52.5	NR	NR	NR	NR
10	Halim et al	29	29	29	0	26	3	NR	NR	NR	NR	NR
11	Vollbach et al	112	112	101	11	82	30	NR	NR	NR	NR	39 – Preoperative radiotherapy
12	Saour et al	12	14	13	1	14*	0	53.25 (45-65)	NR	NR	NR	NR
13	Kanoi et al	7	7	7	0	NR	NR	NR	NR	NR	NR	NR
Total		313	318	223	31	210	58	51.2±5.1	27.8±1.2	2	NR	41 – Preoperative radiotherapy

BMI= body mass index, NR=Not registered data or data not available.

in three (3.4%), and first IC in two (2.3%). (**See graph, Supplemental Digital Content 3,** which displays the summarized anatomic and operative findings of the different studies. **http://links.lww.com/PRSGO/C538**).

META-ANALYSIS OF STUDIES

FREE Flap Outcomes

All 13 studies evaluated the flap loss incidence, ranging from 0% to 0.3%, using the IMAP vessels. The overall success rate was 99.8%. (**See graph, Supplemental Digital Content 4,** which displays the free flap outcomes. **http://links.lww.com/PRSGO/C539**.) In Figure 2, it is demonstrated that the pooled free flap success rate was 100% (95% CI: 98%–100%). This confirmed the efficacy and safety of this surgical approach to some extent. Literature heterogeneity testing showed $I^2 = 0\%$ and $P = 1.00$, indicating homogeneity in the diverse literature.

Overall Complications

Complications were reported in 10 of the 13 studies. Among the 10 studies reporting complications, the pooled complication rate was 11% (95% CI: 7%–18%) (Fig. 3). Literature heterogeneity testing showed $I^2 = 51\%$ and $P = 0.04$, indicating moderate heterogeneity and statistical significance in the diverse literature.

Flap Vascular Complications

Seven studies reported vascular complications: 11 were venous (3.5%); four, arterial (1.3%); and one (0.3%), a flap pedicle avulsion. In Figure 4, the flap vascular complication rate was 5% (95% CI, 2%–10%). Literature heterogeneity testing showed $I^2 = 43\%$ and $P = 0.33$, indicating moderate heterogeneity and no statistical significance in the diverse literature.

Recipient Site Complications and Fat Necrosis

Seven studies reported recipient site complications. There were seven (2.2%) skin necrosis, one breast hematoma (0.3%), and fat necrosis in 11 (3.5%). In Figure 5, it was demonstrated that there was a pooled fat necrosis rate of 11% (95% CI: 7%–19%). The heterogeneity test indicated I^2=0% and $P = 0.98$, which showed no heterogeneity and no statistically significant differences among the studies.

Donor Site and Other Complications

One study reported one (0.3%) abdominal seroma. Other complications were one thermal burn and two tender venous couplers **(Supplemental Digital Content 4, http://links.lww.com/PRSGO/C539**).

Subgroup Analysis

Unilateral versus Bilateral Breast Reconstruction with the Use of IMAPs

The fixed effects pooled risk ratio (RR) of the five studies was 0.66 (95% CI: 0.08–5.19), indicating a lack of difference between the laterality of either unilateral or bilateral breast reconstruction concerning flap loss (Fig. 6). The statistical heterogeneity value was ($P = 0.07$; I^2 58.0%).

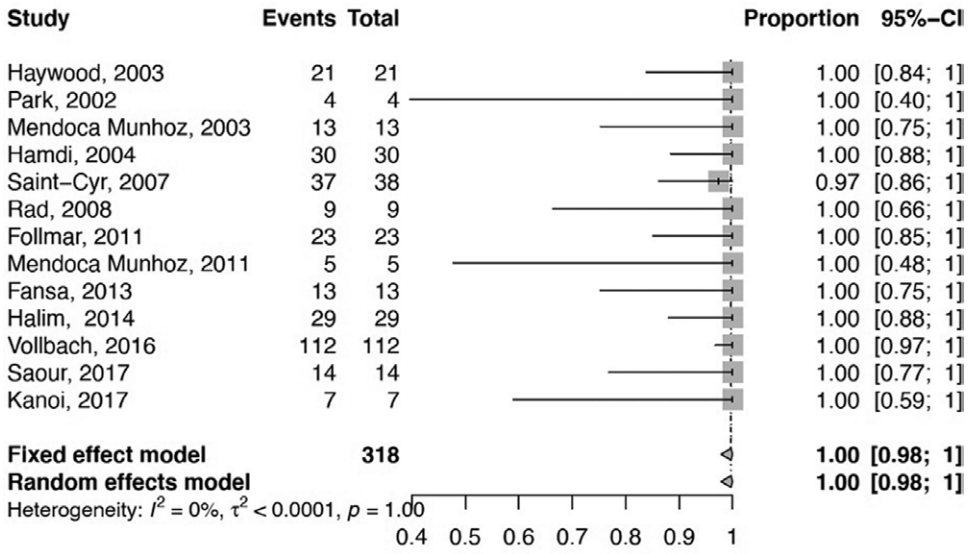

Fig. 2. Forest plot of pooled surgical flap success rate.

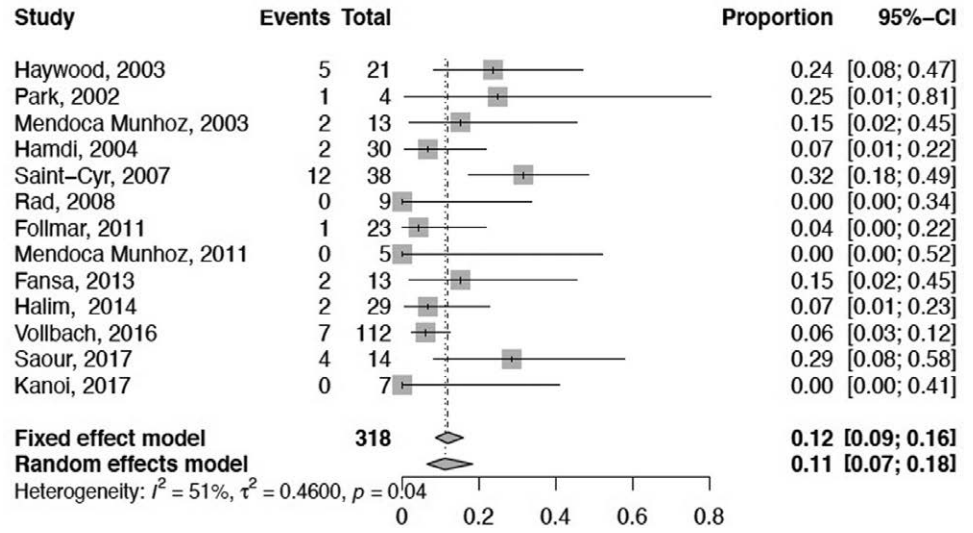

Fig. 3. Forest plot of pooled complication rate after surgery.

Immediate versus Delayed Reconstruction with the Use of IMAPs

The fixed effects pooled risk ratio (RR) of the six studies was 0.89 (95% CI: 0.17–4.70), indicating no difference between the immediate or delayed reconstruction timing in terms of flap loss (Fig. 7). The statistical heterogeneity value was (P = 0.14; I^2 42.0%).

QUALITY ASSESSMENT AND RISK OF BIAS WITHIN STUDIES

The study design and levels of evidence are summarized in Table 1. Twelve studies were retrospective case series with a level of evidence of four, and one was a retrospective cohort with a level of evidence of three. The NOS score ranged from 5–6. Their quality was good, with a mean score of 5.4±0.5 (Table 3). The MINORS mean score was 6.9±2.17 (Table 4). A funnel plot of complications after IMAP recipient selection for breast reconstruction is shown in Figure 8. From a general view of the image, the distribution of each study in the triangle was relatively symmetrical.

DISCUSSION

Following the main results according to the included literature, the microsurgical outcomes of IMAPs in breast reconstruction can be summarized as follows:

(1) The IMAPs have relatively consistent anatomy, located mainly in the second intercostal space. This was described by an anatomical study in 31 fresh cadavers, coining the term dominant IMAPs, and later reiterated by other cadaveric studies.[13–15] It should be noted that

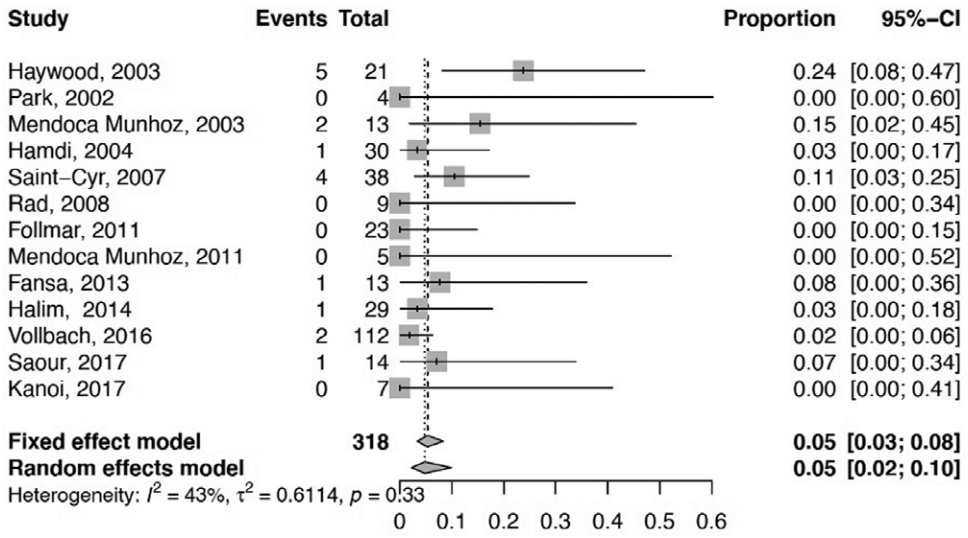

Fig. 4. Forest plot of pooled total flap vascular complication rate after surgery.

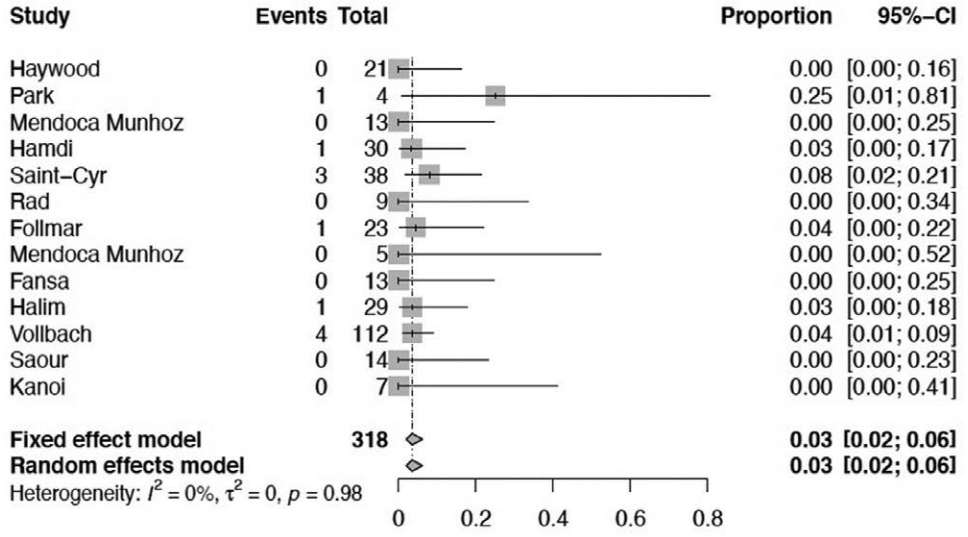

Fig. 5. Forest plot of pooled total fat necrosis rate after surgery.

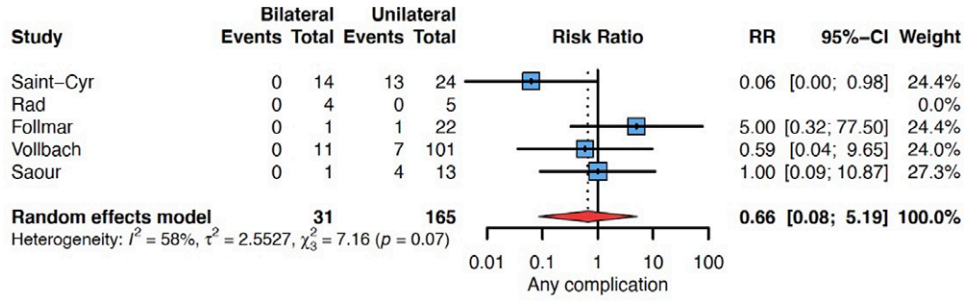

Fig. 6. Forest plot depicting the pooled risk ratio (RR) of any complication of bilateral and unilateral breast reconstruction with IMAPs as recipient vessels.

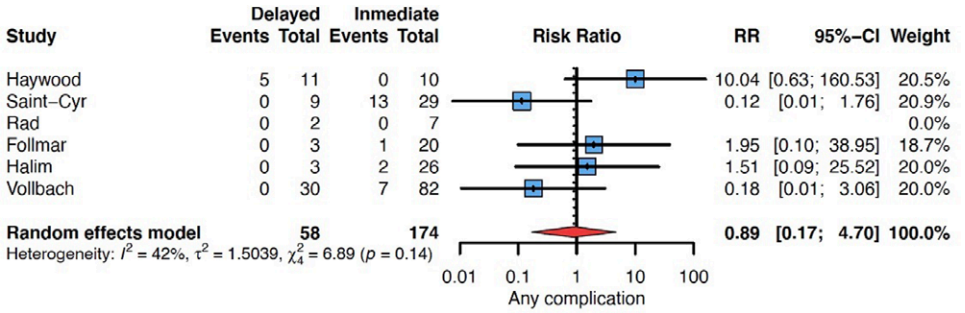

Fig. 7. Forest plot depicting the pooled risk ratio (RR) of any complication of delayed and immediate breast reconstruction with IMAPs as recipient vessels.

Table 3. Assessment of Risk of Bias Using the NOS for Cohort Studies

		Selection				Comparability		Outcome			Total Quality Score
	Year	Representativeness of Exposed Cohort	Selection of Non-exposed Cohort	Ascertainment of Exposure	Outcome Not Present at Start of Study	Comparability on Main Factor	Comparability on Other Risk Factors	Assessment of Outcome	Long Enough Follow-up Median >1 year	Loss to Follow-up Rate	
Haywood et al.	2003										5
Park et al	2003										6
Mendoca Munhoz et al	2004										5
Hamdi et al	2004										6
Saint-Cyr et al	2007										5
Rad et al	2008										6
Follmar et al	2011										6
Mendoca Munhoz et al	2011										6
Fansa et al	2013										5
Halim et al	2014										5
Vollbach et al	2016										5
Saour et al	2017										5
Kanoi et al	2017										5

The NOS uses a star system to assess the quality of a study, based on selection and outcomes; the quality of the study is rated as low (0–3 stars), medium (4–6 stars), or high (7–9 stars). Scoring with color red indicates 0 stars; yellow, data not available or not applicable; and green, 1 star.

Rozen et al demonstrated in their study that IMAPs had a caliber size greater than 1 mm (mean 1.27 mm, range 0.3–2.5 mm) within the second and third intercostal space at a rate of 91%, comparable to other smaller studies.[6,7,16] Similar findings were observed in various clinical studies, in which IMAPs emerged from these regions at 86%–100%. However, some studies have reported perforators arising from the first or fourth intercostal spaces in a few cases.[3,5,7] Although there is considerable variation in the use of IMAPs, clinical evidence supports a growing trend in the last decade, ranging from 9% in early studies to 83% in recent years.[2,4,6,8,17,18]

Table 4. Assessment of Risk of Bias Using the MINORS Scale for Cohort Studies

MINORS Score Author	Year	1	2	3	4	5	6	7	8	Total
Haywood et al	2003									4
Park et al	2003									10
Mendoca Munhoz et al	2004									4
Hamdi et al	2004									9
Saint-Cyr et al	2007									6
Rad et al	2008									10
Follmar et al	2011									10
Mendoca Munhoz et al	2011									8
Fansa et al	2013									6
Halim et al	2014									8
Vollbach et al	2016									6
Saour et al	2017									5
Kanoi et al	2017									5

Items 1–8 represent: 1, a clearly stated aim; 2, inclusion of consecutive patients; 3, prospective collection of data; 4, endpoints appropriate to the aim of the study; 5, unbiased assessment of the study endpoint; 6, follow-up period appropriate to the aim of the study; and 7, loss to follow-up less than 5%; 8, prospective calculation of the study size. An item scored 0 means not mentioned, 1 means reported but inadequate, and 2 means reported and adequate. The total score was 16 for self-controlled studies. Scoring with color red indicates 0 points; yellow, 1 point; and green, 2 points.

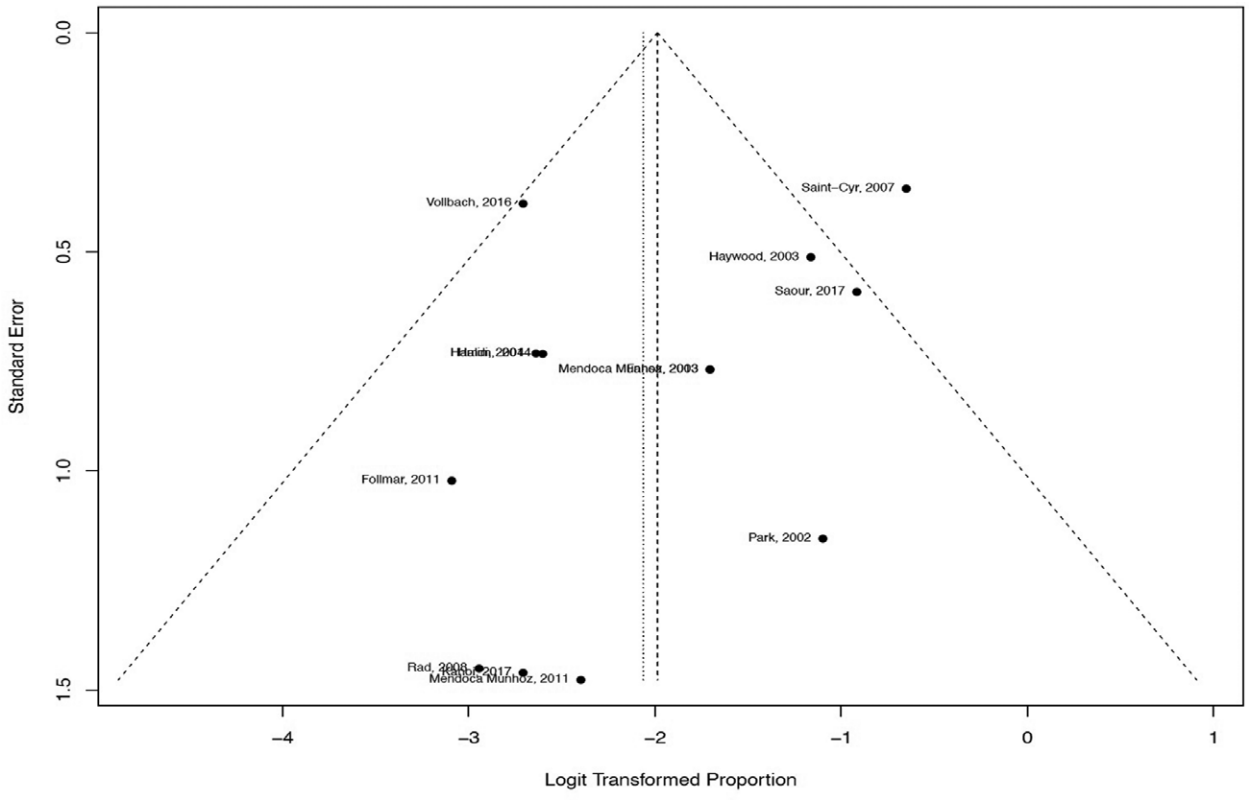

Fig. 8. Funnel plot of complications with the use of IMAPs as recipient vessels.

(2) IMAPs provide adequate vessel size for anastomosis. The mean IMAP diameter size for the artery and vein diameter found in the different studies ranges from 1.0 to 1.9 mm and 1.4 to 2.9 mm, respectively. It is considerably smaller on the left side than the contralateral right side and donor pedicle.[19] A size difference between the donor vessel and the thin vein wall may present significant surgical problems for many microsurgeons. Some studies have reported only performing anastomoses to IMAPs greater than 1.5 mm.[4,8] However, Hamdi et al effectively used vessels of 0.5 mm or larger by transecting the DIEP pedicle until it matched the diameter of the IMAP vessel. In the case of an SGAP, the pedicle was dissected until the size match was reached.[2] While the difference in vein size is well handled using the anastomotic coupler system, the method of proceeding with arteries is different.[20] Rad et al successfully performed arterial and venous anastomoses using an anastomotic coupler device with no further postoperative complications.[21] Donor arteries were 1.5–2.0 times larger in diameter than recipient IMAPs vessels,[22] and no statistically significant difference was reported in the average arterial diameter of donor vessels and recipient IMAPs.[17] Saour et al described various techniques to overcome arterial mismatch when (1) the mismatch diameter was 1:1.5 by gently dilating the smaller vessel, and (2) the mismatch diameter was 1:2 by using a modified version of the Harashina fish mouth technique or by utilizing an area of branching or bifurcation of the IMAPs.[23,24] Although a significant drawback of the size of the IMAPs on the left side, which is somewhat smaller than the contralateral right side and donor pedicle, adequate anastomoses can be performed between IMAPs and deep inferior epigastric artery branches or perforators, the latter ones with a more suitable size match.[2,5,16,18]

(3) IMAPs provide a safe anatomical dissection, low complication rate, and satisfactory aesthetic outcome. Up to 75% of these IMAP vessels are usually identified in the superficial subcutaneous plane, and nearly 25% run through the intramuscular or submuscular plane.[4,17] Thus, extensive muscular dissection or rib excision is unnecessary. This speeds up surgical anatomical dissection and vessel preparation for the recipient. These superficial perforators are less affected by respiratory movement than the IMA vessels, making microvascular anastomosis and microscope placement easier.[1,4,21] The use of IMAPs prevents the harmful effects of utilizing either the TD or IMA vessels by (1) avoiding axillary dissection, preventing the arm restriction, and sparing TD vessels by providing an LD pedicled flap if needed[25]; (2) sparing the IMA for coronary artery bypass graft use; and (3) avoiding pneumothorax, chronic intercostal neuralgia, and chest wall abnormalities.[26] It has been reported that 5%–14% of patients show this type of contour deformities, characterized by a visible depression on the medial chest wall.[27] Finally, inserting any flap into any of the IMAP locations provides medial fulness to improve satisfactory aesthetic results.[8,23]

Summary of Main Results Based on Our Statistical Results

IMAPs were broadly and efficiently selected in this systematic review. Meta-analysis showed no difference in flap success rate or complications across studies. The rationale included three statements: high success rate, low complication rate, and no difference in reconstruction time (immediate versus delayed) or unilaterality versus bilaterality.

First, the combined surgical success rate was 99% (95% CI: 97%–100%) and 0.3% total flap loss, which is homogeneous among the compared studies and comparable to other recipient vessels. A systematic review and meta-analysis comparing the surgical outcomes of the TD and IMA vessels reported a rate of flap loss of 0%–7% and 0%–5.5%, respectively, with a pooled risk ratio of 1.18, indicating no difference in terms of flap loss.[28] This high success rate with IMAPs suggests that the availability of IMAPs as a recipient vessel was adequately dissected, and a skilled surgeon performed the microvascular technique. In addition, a systematic review and meta-analysis by Escandon et al showed a 96.6% flap success rate and a 5.9% loss of flap when performing supermicrosurgical techniques (the dissection and anastomosis of vessels smaller than 0.8 mm in diameter), demonstrating the high reliability of small caliber vessel anastomotic safety.[29]

Second, the overall pooled complication rate was 11% (95% CI, 7%–18%) (Fig. 3). Microanastomotic complications (5%) and fat necrosis (3%) were the most common. This result was almost equal to seven studies that reported complications with 5%–12% IMA vessels and TD vessels, 3.4%–12%.[28] In addition, Saint-Cyr et al and Follmar et al found no difference between IMAPs and IMA or TD recipient vessels.[4,8] Only one case was found in which fat necrosis was linked to prior radiotherapy.[3]

Third, when performing a subgroup analysis of IMAPs in unilateral versus bilateral breast reconstructions, the fixed effects pooled RR was 0.66 (95% CI: 0.08–5.19) (Fig. 6). A similar pattern of results was obtained when comparing immediate versus delayed use of IMAPs with a fixed pooled RR of 0. 89 (95% CI: 0.17–4.70), a low risk of outcome (Fig. 7). Thus, there was no difference between the use of either group of flaps. Given the statistical analysis, the heterogeneities of pooled flap success rate and fat necrosis were low (I^2 <50%). Significant heterogeneity was found in the pooled general and flap vascular complication rates. Heterogeneity prevails among retrospective studies owing to variability in comorbidities, surgeon expertise, different techniques, and nonrandomized studies. A random-effects model was used to reduce the effect of the heterogeneity of the pooled results. Due to the limitations in the available data, further analysis to determine the origin of heterogeneity was challenging.

Selected Cases for IMAPs and Proposal of a Systematic, Algorithmic Approach

IMAPs have advantages in selected scenarios. For this reason, this study proposes three scenarios in which IMAP recipient vessels may offer the best option and proposes an algorithmic approach. First, IMAPs provide an adequate recipient vessel for groin flaps. In this reported study, up to 30% of all the free flaps performed were non-DIEA flaps. The most common was the TMG/TUG flap, with 52 (20.8%) cases, followed by the SIEA with 17 (6.8%) and

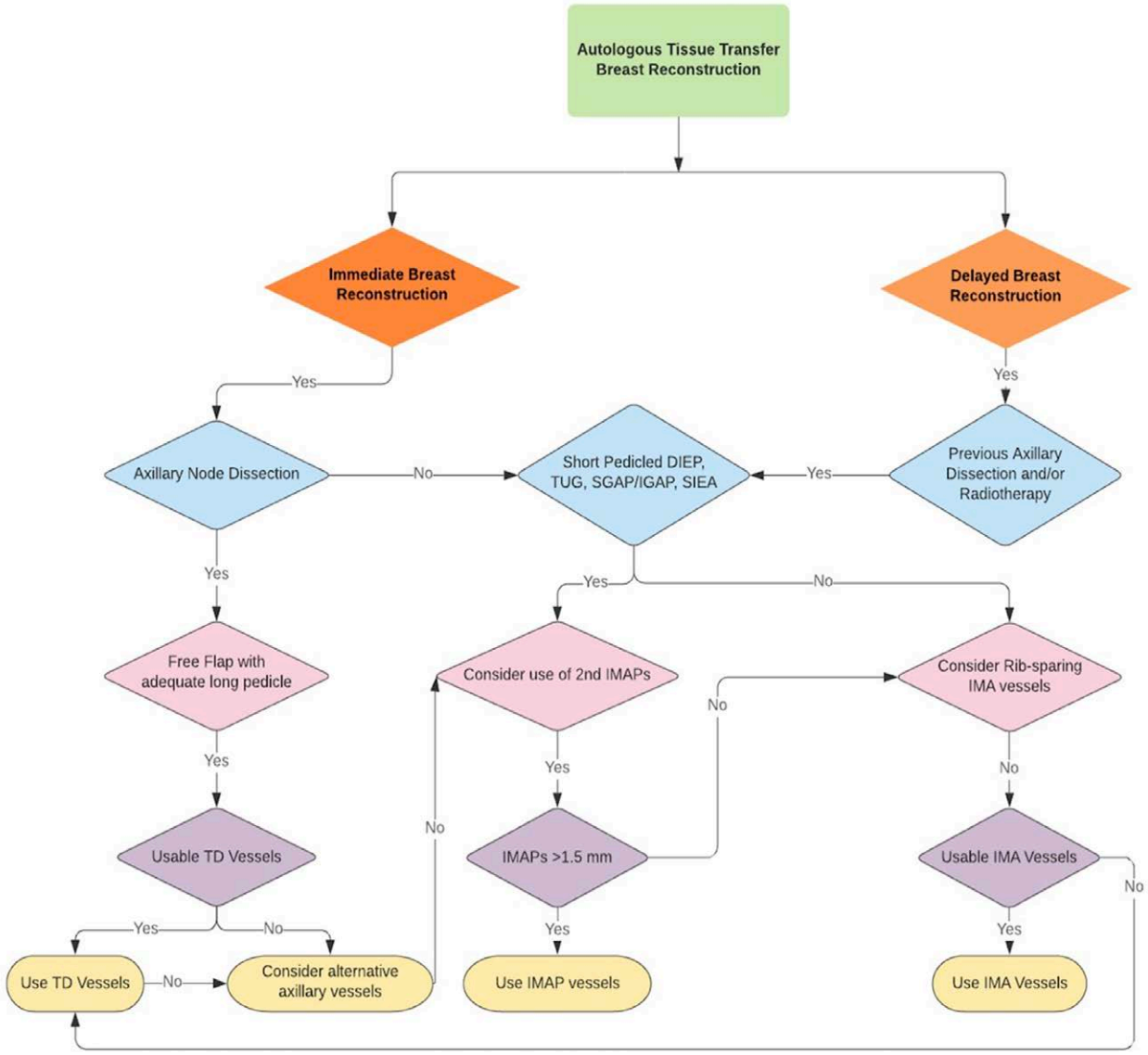

Fig. 9. Algorithm for choosing recipient vessels in autologous tissue transfer reconstruction based on IMAP selection.

the SGAP with one (0.4%). Two studies reported the use of TMG/TUG or SIEA flaps with no flap loss or minor complications.[23,30] Second, some studies reported the effective use of IMAPs for gluteal flaps. However, no specific flap success or complication rate has been documented.[2,6,18] It is important to point out that IMAPs offer an excellent vessel match to short-length vascular pedicles, such as the SIEA, TMG/TUG, or SGAP/inferior gluteal artery perforator (IGAP) flaps. Third, even though vessel size discrepancy is a common problem when anastomosing a DIEP flap to an IMAP recipient vessel, this review showed that the DIEP flap was used in 65.4%. Thus far, evidence supports that good microsurgical skills and experience can solve vessel size mismatches. Still, the surgeon must know how to troubleshoot anatomical problems like short vessels that could bend or twist and thin vessel walls, and always have the IMA ready as a lifeboat. In addition, supported by the collected data and literature review, which described three algorithms[2,8,31] on the selective use of IMAPs, a newly suggested decision-making algorithm[32] based on the timing of breast reconstruction, axillary dissection/radiotherapy, type of free flap, IMAP availability, and recipient vessel size is proposed in Figure 9. In delayed breast reconstruction, several factors, including scarring, radiotherapy, and lymph node dissection, may limit the recipient vessel options.

Limitations of Review

This study had several limitations, including a few studies with small sample sizes. The quality of the trials was low, with only one prospective study. Like any meta-analysis, reporting bias and unpublished data affected the results. Clinical variability may have occurred in the selected patient population and the authors' definitions of outcomes and complications. As in most systematic reviews, the number of cumulative studies varies widely, and non-English articles were excluded.

Learning Points for Future Development

Some common shortcomings were observed during the review. Few studies provided appropriate clinical data that may affect surgical outcomes, such as length of time to flap raising, detailed description of the location and size of IMAPs, total operative time, and two-team management. It is worth mentioning that complications were not classified through tools, such as the Clavien-Dindo classification[33,34] or the ACS-NSQIP system,[35] to help predict surgical outcomes. Therefore, this study did not conduct a meta-regression analysis of the potential risk factors. In addition, patient-reported outcome measures for breast reconstruction, such as the BREAST-Q, which is essential for evaluating comprehensive outcomes of IMAPs, were absent in these studies. These poor points should be covered by future larger cohort samples, randomized design, and multicentre research with standardized parameters and endpoints, which is beyond the scope of this study.

CONCLUSIONS

IMAPs have been used extensively in breast reconstruction. IMAP vessels are safe and reliable in breast reconstruction, with a high success outcome and low complication rate. This systematic review can serve as a blueprint for microsurgeons to choose the best patient alternative. Moreover, in selected cases, such as SIEA, SGAP/IGAP, TUG/TMG flaps, and short-pedicled DIEP flaps, IMAPs may be the primary recipient vessel choice over IMA or TD vessels.

Successful outcomes require preoperative preparation and an experienced surgical team. However, multicenter studies with larger samples and standardized reports of perioperative parameters and clinical outcomes are needed to substantiate the findings of this study and for further evaluation.

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DISCLOSURE

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