



The deep inferior epigastric artery perforator flap: a narrative review on its various uses in non-breast reconstruction

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Background and Objective: The deep inferior epigastric artery perforator (DIEP) flap was first described by Koshima and Soeda in 1989 and is now well-established as the gold standard in breast reconstruction. Lately, this issue has been explored in the context of head and neck reconstruction, highlighting growing interest in the use of the DIEP flap beyond breast reconstruction, but its usage in other anatomical regions appears elusive. Nevertheless, DIEP flap reconstruction may be a viable choice for complex, three-dimensional head and neck deformities while upholding the criteria of minimal donor site morbidity, according to a recent review. To determine whether the DIEP flap may be used successfully in other types of reconstruction, we conducted a review on the use, applications, and outcomes of the DIEP flap in non-breast reconstruction. This is, as far as we are aware, the first comprehensive analysis of all applications of the DIEP flap other than for breast reconstruction.

Methods: A literature review was performed using PubMed to include all relevant articles in English or French published up to February 2022. Keywords included “DIEP flap” and “deep inferior epigastric perforator flap”.

Key Contents and Findings: A total of 1,299 articles were identified with 105 on the use of the DIEP flap in non-breast reconstruction. This suggests increasing recognition of the DIEP flap as a feasible option for reconstruction of most anatomical regions, especially in lower limb and head and neck reconstruction, followed by gynecological reconstruction. The DIEP flap was also utilized in the reconstruction of upper limb, thigh and hip defects. Less commonly, it has been used for penoscrotal, groin, sternal, buttock and abdomen reconstruction.

Conclusions: The scientific body of evidence showed the robustness and versatility of the DIEP flap in non-breast reconstruction, with its relative pros and cons at different anatomical regions.

Keywords: Deep inferior epigastric artery perforator flap (DIEP flap); reconstruction; free flaps; pedicled flaps

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Introduction

Free tissue transfers have revolutionized the reconstruction of soft tissue defects. Since Hartrampf first described the transverse rectus abdominis muscle (TRAM) flap in 1982, the abdomen has been recognized as an invaluable source of autologous donor tissue (1). In 1989, Koshima and Soeda (2) published the first case of inferior epigastric skin flaps without the rectus abdominis muscle and subsequently, described the paraumbilical perforator variation. This came to be known as the deep inferior epigastric artery perforator (DIEP) flap, which was then popularized by Allen and Treece in 1994 (3). It has since become the gold standard in autologous breast reconstruction (4). Indeed, it is considered to be the most reliable flap for this type of reconstruction, even in the elderly population (5), with published flap failure rates ranging from less than 1 to 4 percent (6). With further progress, the goal of DIEP breast reconstruction has evolved from flap success to minimizing complications and maximizing aesthetic outcomes and operative efficiency. Despite the DIEP flap's well-established usage in breast reconstruction, its application in the reconstruction of other body areas remains uncommon and is not usually a first-choice option in other reconstructive settings. Mayo-Yáñez *et al.* (7) have published a systematic evaluation on the use, applications, and outcomes of the DIEP flap in the head and neck region, which reflects growing interest in such non-breast applications. Their review found that the DIEP flap could be an alternative for treating complex, three-dimensional head and neck abnormalities while maintaining low donor site morbidity. They also examined the DIEP flap's advantages and disadvantages.

Therefore, we examined the usage of the DIEP free flap for all non-breast reconstructions to provide a more comprehensive report. In this context, we analyzed the benefits and drawbacks of the DIEP flap in comparison to alternative flaps, depending on the target body region. We present the following article in accordance to the Narrative Review reporting checklist (available at <https://atm.amegroups.com/article/view/10.21037/atm-22-2623/rc>).

Methods

The authors first conducted a comprehensive literature search for articles published up to February 2022 using PubMed. We used the following key words: "DIEP flap" OR "deep inferior epigastric perforator flap". We then expanded these terms to include the corresponding Medical

Subject Headings and Emtree subject headings. The search terminology is listed in *Table 1* (search strategy summary). A total of 1,692 articles were identified. After removing duplicates, two reviewers (CG and ECT) separately screened the individual articles by reviewing the titles and abstracts to eliminate those unrelated to the current study. The same two reviewers then reviewed the full text of the remaining articles based on our inclusion and exclusion criteria: we included articles that (I) were in English or French and (II) where the DIEP flap was defined as an inferior epigastric artery skin flap without rectus abdominis muscle, used as a free flap or pedicled on the muscle perforators and the proximal deep inferior epigastric artery. Articles on breast reconstruction, and those that did not have the full-text available were excluded. Reference lists in the remaining articles were screened manually to identify potentially relevant studies that were not found during the initial search. Overall, 1,692 articles were identified, of which 105 fulfilled the inclusion criteria for this review.

The authors then conducted a second search with the same key words AND "breast" and found 1,129 articles.

Results

DIEP flap in breast reconstruction versus DIEP in non-breast reconstruction

Firstly, the literature search on DIEP flap for breast reconstruction retrieved 1,129 articles. These articles were compared with the 105 articles detailing the use of the DIEP flap for other anatomical areas of reconstruction.

Figure 1 showed that the vast majority (92%) of the current literature was on the use of the DIEP flap for breast reconstruction.

Figure 2 categorized the different anatomical regions for usage of the DIEP flap for non-breast reconstruction based on the available literature. When an article presented cases on several anatomical sites, it was counted for separately in each region. The most frequent anatomical regions were the head and neck region with 28 articles (21%) and the lower limb with 26 articles (19%). This was followed by its use in gynecological reconstruction (21 articles, 16%), the upper limb (17 articles, 13%), and the thigh and hip (12 articles, 9%). Ten articles quoted its use in penoscrotal reconstruction (7%) and 8 detailed its use in groin reconstruction (6%). The remaining articles described its use in the reconstruction of sternal wounds (6 articles), buttocks, or the abdomen (6 articles).

Table 1 The search strategy summary

Items	Specification
Date of search	01/28/2022
Databases and other sources searched	PubMed
Search terms used	“DIEP flap”[mh] OR “deep inferior epigastric perforator flap”[mh] OR “deep inferior epigastric artery perforator flap” OR “DIEP flap”[tiab] OR “deep inferior epigastric perforator flap”[tiab] OR “DIEP”[tiab] OR “DIEP reconstruction”[tiab]
Timeframe	1982–2022
Inclusion and exclusion criteria	Inclusion criteria: all study types on humans about DIEP flap in the setting of non-breast related reconstruction (defined as an inferior epigastric artery skin flap without rectus abdominis muscle, used as a free flap or pedicled on the muscle perforators and the proximal inferior deep epigastric artery) Exclusion criteria: articles on breast reconstruction, articles in languages other than English or French
Selection process	Two reviewers separately screened the studies by reviewing the titles and abstracts, followed by the full text

DIEP, deep inferior epigastric perforator.

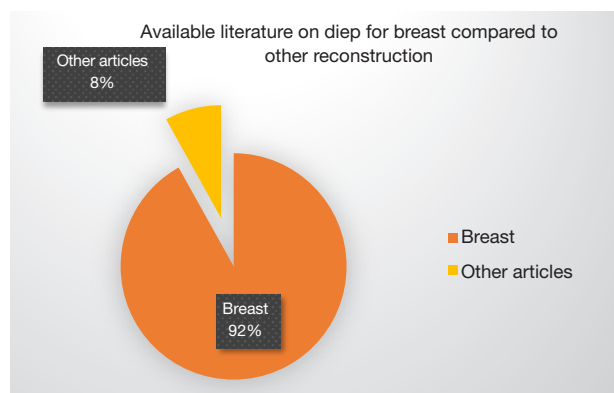


Figure 1 Available literature on DIEP flap for breast reconstruction compared to other anatomical areas. Only 105 articles were on the use of the DIEP flap in non-breast reconstruction (8%) compared to 1,129 articles on its use in breast reconstruction (92%). DIEP, deep inferior epigastric perforator.

Lower limb

Twenty seven articles were on the use of the DIEP flap in lower limb reconstruction. Most were case series (16 articles, 135 patients) (8-23) and case reports (7 articles, 7 patients) (24-30). There were also four retrospective reviews (112 patients) (31-34).

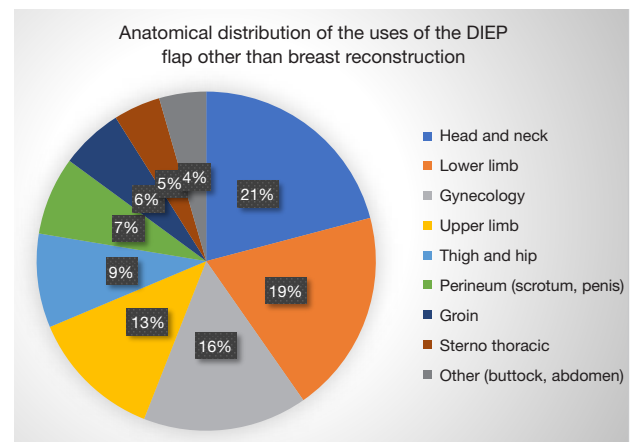


Figure 2 Anatomical distribution of the use of the DIEP flap in non-breast reconstruction. The most common anatomical regions were the head and neck region (28 articles, 21%) and the lower limb with 26 articles (19%). This is followed by its use in gynecological reconstruction (21 articles, 16%), the upper limb (17 articles, 13%), and the thigh and hip (12 articles, 9%). Ten articles proposed its use in penoscrotal reconstruction (7%) and 8 articles were on its use in the groin region (6%). The remaining articles detailed its use in the reconstruction of sternal wounds (6 articles), buttocks, or the abdomen (6 articles). If an article discussed several cases of reconstruction in different anatomical areas, it is individually counted for in each area. DIEP, deep inferior epigastric perforator.

Table 2 Reported advantages and disadvantages of the DIEP flap in lower limb reconstruction

Pros	Cons
Large flap and long pedicle	Thick and bulky flap (especially in pediatric patients)
Avoids sacrificing major vessels of the lower limb: preservation of the lateral circumflex femoral artery as compared to ALT	Unightly donor site scar on the anterior torso compared to ALT and CSAP flaps for foot and ankle reconstructions
Superficial and deep venous drainage system, useful to prevent venous congestion	Higher rates of complication [in pediatric patients, foot and ankle (31)]: longer harvest and operative time, higher operative blood loss and incidence of flap necrosis
Lower tissue expansion risks of the abdomen, if necessary, as compared to limb flaps	
Presence of multiple perforators = versatile design and several skin paddles	
A single operative position for donor site harvest and inset, unlike latissimus dorsi or radial forearm, scapular and parascapular flaps	
Added advantages of abdominoplasty, when designed as a horizontal DIEP flap	

In large lower limb defects, the DIEP flap is an alternative to the anterolateral thigh, thoracodorsal artery perforator, and gluteal artery perforator flaps. It is especially useful to obviate the needs to turn the patient intra-operatively, thus shortens the operative time. It also avoids sacrificing the vessels in the lower extremities, which is particularly advantageous for patients with vascular pathologies. DIEP, deep inferior epigastric perforator; ALT, anterolateral thigh flap; CSAP, circumflex scapular artery perforator flap.

Microsurgical reconstruction of the lower extremity is associated with a greater risk of flap failure than anywhere else in the body. This is because of suboptimal vascularity in the distal part of the lower limb and the continuous weight-bearing forces (32). Nevertheless, microsurgical advances are such that muscle flaps are no longer the only reconstructive option (35,36). Of the included articles, the reported total flap failure rate was up to 13% and partial flap necrosis up to 20%, mostly attributed to venous outflow issues (8-22).

The use of the DIEP flap in lower limb reconstruction has been reported in the context of trauma (11,18,19,21,23,30) and burns (18,23), oncology (18,33), aesthetics (27), infection (23,28), venous ulcers (19) and diabetes (9,17). Interestingly, such use is not limited to adults with good outcomes (13,15,23,26,31,34) but also reported in the pediatric population. Indeed, it has been noted that the relative size of the pedicle vessels in children are larger than that in adults (23). We reported in *Table 2* the advantages and disadvantages of the DIEP flap in lower limb reconstruction.

The extended, bipediced DIEP flap is one of—if not the—largest flap in the human body

The extended bilateral DIEP flap is commonly harvested

(20,21,26,27) to maximize the length of the flap. According to Mahajan *et al.* (20), a bipediced DIEP flap provides the equivalent of two or three perforator flaps with a single donor site scar. Ou *et al.* showed that it can be particularly useful in cases of extensive soft tissue loss such as in treating circumferential wounds (14). Yoshimatsu *et al.* (29) presented a case in which a 72-cm long DIEP free flap was successfully harvested with extra flap microvascular anastomoses for reconstruction of a lower leg with no suitable recipient vessels around the injury zone, and still achieved primary closure of the donor site. This very long flap allowed them to avoid using cross-leg free flaps, vein grafts, arteriovenous loops and their potential complications.

The DIEP flap can provide sufficient and well-vascularized tissue which is especially useful in patients with diabetes (9) and other vascular pathologies. Indeed, it avoids sacrificing major vessels such as the lateral circumflex femoral system which provides important collateral blood supply to ischemic extremities.

To further increase the available tissue size, pre-expansion of DIEP flaps has also been described (18,26,27). Melnikov *et al.* (27) described the use of a prefabricated bilateral DIEP flap in the reconstruction of a large tissues defect (50×25 cm²) after the excision of a giant pigmented

nevus in the lower limb, with satisfactory results. In another case, Grinsell *et al.* (26) chose a pre-expanded DIEP flap over a pre-expanded anterolateral thigh (ALT) flap because the use of tissue expansion in the abdominal region has a lower risk of complications compared to the lower extremity (such as pre-expanded ALTs) (37).

The vascular anatomy of the abdomen is especially useful in the setting of the lower limb for venous drainage

Venous drainage issues often complicate lower limb reconstruction (38). Due to the unique vascular anatomy of the legs, it is important to account for venous congestion by positioning the flap appropriately to achieve a through-flow of venous blood. In this regard, abdominal tissue has inherent advantages when it comes to flap mobilization due to its relatively constant anatomy, an excess of tissue available for transfer, and a rich venous drainage system (superficial and deep) (27). Distal perfusion of the DIEP flap could be augmented by supercharging and superdraining via the superficial circumflex iliac artery (SCIA) system if needed (24).

The DIEP flap design can be versatile

The horizontal DIEP flap is the most commonly used design in breast reconstruction because it offers the secondary advantage of an abdominoplasty which can improve the patient's body habitus. In lower limb reconstruction, this advantage has been highlighted by Hallock *et al.* (22), where three female patients chose the DIEP flap solely for this reason, while fully understanding the potential need for later flap revision to optimize the appearance and function of the flap at the recipient site. Other skin paddle designs have been described in the literature. These include the oblique (16,18) and vertical designs (12,19). The oblique design is similar to the deep inferior epigastric artery with inferior rectus abdominis flap as originally described by Taylor in 1984 (39), with the added advantage of minimizing donor site morbidity by preserving the rectus muscle. On the other hand, in the case of the vertical design, the operating time may be shorter compared to the classical transverse technique as it eliminates the need for a more extensive dissection. It also avoids unnecessary sacrifice of the contralateral flap (19). Nevertheless, the vertical/oblique donor site scar is not as aesthetically acceptable. In addition, the existence of multiple perforators allows a large flap to be raised (via intra-flap anastomoses of perforators from each abdominal

side), while allowing surgeons to use ipsilateral perforators to harvest multiple skin paddles. Luo *et al.* (15) described a "kiss design" DIEP flap with two skin paddles, each on a different perforator, that can be rotated or translated to create various shapes and achieve good aesthetic and functional results.

The DIEP flap among other flaps for thigh and lower limb reconstruction

A retrospective review of 563 flaps by Abdelfattah *et al.* (32) showed that among the different flaps used for lower limb reconstruction, the DIEP flap not only provides the largest size ($836.2 \pm 210.3 \text{ cm}^2$) and the longest pedicle ($11.7 \pm 1.4 \text{ cm}$) but is also the thickest ($11.1 \pm 3.9 \text{ mm}$). The ALT flap is a very popular free flap option for lower limb reconstruction. It can be raised from the contralateral limb without any need for intra-operative repositioning and can be taken as a thin flap (or thinned primarily after raising) to provide an acceptable profile in reconstructing soft tissue defects around the foot and ankle. Other commonly used fasciocutaneous free flap options include those from the radial forearm (for smaller defects), scapular and parascapular region (40).

A study by Cao *et al.* (31) compared the ALT perforator flap to the DIEP flap in pediatric patients. Their study showed that an ALT perforator flap may yield better results than a DIEP flap in terms of short- and long-term complications, scarring, and morpho-functional outcomes for pediatric patients undergoing reconstruction of foot and ankle defects. They showed that the ALT group have a significantly lower operative blood loss than the DIEP group and a lower flap necrosis rate (5.3% *vs.* 24.4%). In long-term follow-up, the ALT group showed a lower late complication rate and a better cosmetic and functional outcome than the DIEP group ($P < 0.05$). Another article from the same authors (19) compared the DIEP flap to the circumflex scapular artery perforator (CSAP) flap for foot and ankle reconstruction of moderate-sized defects in pediatric patients. They concluded that the CSAP flap has a shorter operating and flap harvest time, lower fat hyperplasia rate, and better long-term cosmetic outcomes than the DIEP flap. They noticed that most DIEP flaps gained various degrees of bulkiness as patients grew and gain weight, despite the immediate smooth contour post-operatively.

Our study however, did not find any article comparing the CSAP flap to the DIEP flap in adult patients. When it comes to lower limb reconstruction, preservation of

the femoral system provides an advantage. Other free flap options such as the latissimus dorsi perforator flap or scapular flap do preserve this femoral system as opposed to the ALT but they cannot be raised in the supine position, unlike the DIEP flap that has these two advantages (17). Besides that, the scapular flap uses skin of the back that is somewhat thick for foot coverage and does not match skin texture on the dorsum of the foot (21).

Hip and thigh reconstruction

There were eight articles on thigh reconstruction using the DIEP flap, five of which were isolated case reports (41-44); the remaining three were case series (5 patients) (45-47).

All were reconstruction cases after sarcoma resection (41-45,48). All authors used the DIEP flap in pedicled fashion (41,43,47-49) except Bota *et al.* (42), who described raising an abdominoplasty-like paddle and transferred it as a free flap. Scaglioni *et al.* (41) reported a case of a pedicled, split, extended vertical DIEP flap for reconstruction of the medial thigh compartment after sarcoma resection. In his report, the cranial part of the flap was de-epithelialized and used as an adipo-dermal thigh flap to fill the dead space, while the caudal part was used for skin closure. Fernández Garrido *et al.* (43) described a turbocharged bi-pedicled DIEP flap for reconstruction of the thigh without recipient vessels and coverage of a femoropopliteal bypass.

In a more recent literature review, Kotick (50) proposed the pedicled ALT perforator flap as the gold standard for reconstruction of the groin and complex, upper medial thigh defects. Among the pedicled perforator flaps employed in this area, the DIEP flap was not a common choice (41). However, it should be noted that an ideal flap for the reconstruction of soft tissue defects after radiotherapy at these anatomical regions should provide robust, non-irradiated tissue for the coverage of important structures such as blood vessels, nerves, and bone. The pedicled DIEP flap could thus be a good candidate that fulfills these criteria.

In hip reconstruction, three articles described the use of the pedicled DIEP flap (19,51) following trauma, infected hip prosthesis and for aesthetic reasons.

Upper limb

The main objectives in soft tissue reconstruction of the upper extremity are to restore function, with emphasis on avoiding prolonged immobilization that can cause joint

stiffness, tendon adhesion, scar contractures, and ultimately, loss of function. There are some local flap options available, such as pedicled flaps based on the radial and ulnar arteries, which have their limitations when it comes to resurfacing larger defects. In addition, the use of local flaps could further compromise blood flow to an already injured upper extremity (52).

We found 17 articles describing the use of the DIEP flap in upper extremity reconstruction. Most of these were clinical series (9 articles) (10,13,15,18,36,53-56) and case reports (5 articles) (28,57-60). There were two retrospective reviews (52,61) (4 patients) comparing the use of the DIEP flap in upper limb reconstruction with other flap options such as the ALT, SCIA, superficial inferior epigastric artery (SIEA) and thoracodorsal perforator flaps. There was also a prospective study (18 patients) looking at consecutive DIEP flaps in the reconstruction of burns or scar contracture wounds of the upper extremity (61). The DIEP flap has been used in the context of trauma (11,18-21,23,29,30,54-56,59,61) and burns (55,57,58,60). Other uses are in cases of meningococcal (55) and mucormycosis (28) infections.

Most of the articles discussed the use of the DIEP flap in adult patients, with only two articles (5 patients, mean age =8 years) discussing the use of the DIEP flap in pediatric patients (14,23). We reported in *Table 3* the advantages and disadvantages of the DIEP flap in upper limb reconstruction.

The DIEP flap design can be versatile

All articles described the use of the DIEP flap as a free flap, except three articles where it was used as pedicled flap. The pedicled DIEP flaps were used for elbow (56) and hand (60) reconstruction in two stages. There was also an article that described islanding of the DIEP flap to close the donor site after harvesting a superficial inferior epigastric artery flap for hand defect resurfacing (58).

For the upper extremity, the skin paddle design could be transverse, vertical or oblique. The flap could be harvested either above or below the level of the umbilicus (55). A trefoil-shaped flap was also described by Chew *et al.* (57) to reconstruct a right hand defect. The flap was raised from the left lower hemi-abdomen (17 cm × 13 cm) to resurface soft tissue defects at the volar aspect of the first webspace, the whole dorsal metacarpal area while the third part of the flap was sited at the dorsum of the first webspace.

Pre-expanded DIEP flaps were also used by Shang *et al.* (60) to resurface one or both sides of the hand after

Table 3 Reported advantages and disadvantages of the DIEP flap in upper limb reconstruction

Pros	Cons
Well-concealed donor site, when used as a horizontal DIEP flap	Thick flap, not very suited for the hand: may require revision procedures such as liposuction or primary thinning with prior insertion of a silastic sheet
Sensate tissues	Risk of bulk gain significant body weight gain may translate to increased flap bulk on the upper extremity
Avoids sacrificing major vessels of the upper limb: preservation of arteries providing inflow to the distal extremity, especially useful in traumatic wound	
If the patient is in a supine position, no operative position change is required, potential for a concurrent two-team approach	
Versatile flap design	

Due to its bulk and thickness, the DIEP flap is not commonly chosen for upper extremity reconstruction; however, it should be considered for large, proximal upper arm defects. In most cases involving reconstruction of the upper extremity, the ALT flap is a superior alternative. DIEP, deep inferior epigastric perforator flap; ALT, anterolateral thigh flap.

burn contracture excision. Simultaneous reconstruction of the thumb and first webspace using a DIEP flap has been reported in five cases by Li *et al.* (54). This is achieved by combining a free second toe transfer and a DIEP flap, where both arterial pedicles were anastomosed to the same recipient artery. A further case described the use of a laparoscopically-assisted, chimeric, peritoneal DIEP flap to provide coverage of exposed tendons in the hand and lower limb (10).

The DIEP flap amongst other flaps for upper limb reconstruction: better in large proximal upper arm defects than in the hand?

A review by Wang *et al.* (61) compared the ALT, SCIA, deep inferior epigastric perforator, superficial inferior epigastric artery, and flow-through flaps for upper extremity defects. The authors highlighted the fact that these flaps share several qualities: a well-concealed donor site, preservation of major arteries responsible for providing inflow to the distal extremity, and the potential for a concurrent two-team approach. These flaps also have the potential to be sensate, which is particularly important in the hand. According to the authors, the DIEP flap could be a feasible option for large, proximal upper arm defects. The bulkiness of these free flaps may require additional revision procedures such as liposuction to improve the contour. However, significant weight gain could lead to a subsequent increase in flap bulk on the upper extremity. For distal upper limb defects such as on the dorsum of the hand and wrist, the thin SCIA, groin or ALT flaps are preferred.

A separate paper by Hamdi *et al.* echoed the notion but advocates that the DIEP flap could be used for the reconstruction of dorsal hand defects by immediate flap thinning to obtain a better contour (55). This could be a viable option if other flap options such as the thoracodorsal artery perforator (TDAP) flap are unavailable (62). Chen *et al.* (53) reviewed four cases on the use of the DIEP flap for reconstruction of the thumb and first webspace, palm, dorsum of the hand, wrist, and forearm defects, comparing it to other free flaps such as the ALT and thoracodorsal perforator flaps. They concluded that DIEP flaps are generally at least 5 mm thick—more than other flap options. The authors thus suggested primary thinning with prior insertion of a silastic sheet at the lateral border of the rectus abdominis muscle one week prior to flap elevation, or defatting of the flap. Nevertheless, the authors acknowledged that while the DIEP flap may be more suitable for proximal upper limb defects, the ALT flap is otherwise a superior option in most cases of upper extremity reconstruction.

Head and neck

Immediate reconstruction of head and neck defects after oncological resection is now considered the gold standard of care. Reconstruction with vascularized tissue transfer minimizes postoperative complications by eliminating communication between the neck defect and the oral cavity by filling the dead space.

A systematic review on the use of the DIEP flap in head

Table 4 Reported advantages and disadvantages of the DIEP flap in head and neck reconstruction

Pros	Cons
Provide adequate bulk for orbital and maxillary regions and radiation-induced soft tissue atrophy Sufficient width for the coverage of skull and exposed brain	Too bulky for intra-oral defects
Versatile flap design: oblique or vertical as the most frequently used design, “accordion” (tongue), peanut-shaped design (post maxillectomy), multiple lobes, and de-epithelialization for nasal lining or the palate	

The DIEP flap is most frequently used to reconstruct glossectomy defects, followed by the orbit and maxilla. The DIEP flap is a viable option for laryngopharyngeal reconstruction, although the ALT and radial forearm free flaps continue to be the most frequently used techniques for reconstructing these defects. DIEP, deep inferior epigastric perforator flap; ALT, anterolateral thigh flap.

and neck reconstruction was recently published by Mayo-Yáñez *et al.* (7) in 2020. They reviewed 31 articles with 185 flaps and reported a 95% flap survival rate. In concordance with our findings in the current study, the authors agreed that the DIEP flap is the gold standard in breast reconstruction, but its use remains anecdotal in the head and neck. Their methodology and inclusion criteria are similar to our findings—of 31 articles included, 20 (64.52%) were case series, 9 (29.03%) case reports and 2 (6.45%) were preclinical studies. In the current study, we excluded three of the articles (cadaveric, preclinical and porcine) that were used in their review.

The most frequent sites of reconstruction were the tongue (30.51%) (63-72) and maxillary region (26.27%) (46,73,74). Several designs have been described, but most followed that described by Koshima (2), or with slight modifications according to the flap shape required. The preferred flap design was oblique or vertical based on the ipsilateral side, in the peri-umbilical region. This orientation of the DIEP flap provides a longer pedicle than the transverse orientation with the advantage of increased thickness, which is often a better fit for head and neck reconstruction (67,68,75). The abdominoplasty-like transverse design is also proposed in some of the articles (18,76,77) although some variations exist. Yano *et al.* (65) described a DIEP flap that has three lobes and a single perforator. Adding a shallow incision on the surface between the second and third lobe helps in creating a crease for three-dimensional spatial flap in-setting. This design could also be used to separate the DIEP flap into several smaller “islands”, similar to that previously used by Koshima *et al.* (63) with their “accordion” modification (66,78). Wisecarver *et al.* (79), proposed a four-lobe DIEP flap with flow-through intra-flap anastomosis. Miyamoto *et al.* (48) suggested a vertical peanut-shaped design for post-maxillectomy defects where the cephalic part of the

skin paddle was used for nasal lining or the palate while the rest of the flap was de-epithelized for volume restoration to achieve a better facial contour. Other articles reported burying of the de-epithelized flap (80,81). The concept of tissue expansion prior to raising the DIEP flap has also been described by some of the papers to increase the final size of the raised flap (18,76,82,83).

In summary, the relatively constant vascular anatomy of the DIEP flap with its high flap survival rate and relatively low donor site morbidity makes it a great option for reconstructing complex head and neck defects (62). It is a feasible option in laryngopharyngeal reconstruction, although the ALT and radial forearm free (RFAF) flap remain the most common options for reconstructing these defects (63,64). The DIEP flap provides adequate bulk for reconstructing the orbital and maxillary regions, in addition to providing vascularized tissues that are sufficiently wide to provide coverage to the skull and exposed brain tissues if necessary.

We reported the advantages and disadvantages of the DIEP flap in head and neck reconstruction in *Table 4*.

Genito-crural reconstructions

Vaginal reconstruction

Vaginal reconstruction is usually performed for congenital vaginal agenesis, post-oncological resection, and in gender reassignment. Vaginal defects post-oncological resection is often challenging due to the need for adjuvant chemotherapy and radiotherapy. It requires careful planning to minimize the risk of delayed wound healing which could be detrimental. The primary goals of vaginal reconstruction are to improve the patients’ quality of life, return of sexual function and minimize the risk of developing empty pelvis syndrome (84).

Our literature review found 13 articles on vaginal reconstruction, consisting of four case series (84-87), two

Table 5 Reported advantages and disadvantages of the DIEP flap in vaginal reconstruction

Pros	Cons
Long pedicle: can be used as a pedicled flap with no microvascular anastomosis required	Can be too bulky and subsequent thinning of flap may be required
Offers sufficient volume for large defects following pelvic exenteration	Technically more challenging (compared to VRAM, Singapore, gracilis)
Muscle preservation (compared to VRAM and gracilis)	No spontaneous mucus production (compared to rectosigmoid vaginoplasty)
Hairless (compared to the Singapore flap)	Insensate DIEP flap might not be ideal for reconstruction in the case of vaginal agenesis
Odorless (compared to skin grafts)	

The DIEP flap is safe, dependable, and provides sufficient volume for large pelvic defects while reducing morbidity at the donor site. It could become the preferred flap following pelvic exenteration. Due to the inability to achieve a normal sexual life in young patients, its routine use in congenital agenesis is questionable. In cases of pelvic exenteration, it may be necessary to perform primary thinning. DIEP, deep inferior epigastric perforator flap; VRAM, vertical rectus abdominis myocutaneous flap.

Table 6 Reported advantages and disadvantages of the DIEP flap in vaginal reconstruction

Pros	Cons
Long pedicle: can be used as a pedicled flap with no microvascular anastomosis required	High vulvar carcinoma recurrence: not an optimal choice for first-line surgeries for small defects
Robustness and reliability of its vascular pedicle, especially if radiotherapy is required	
No extensive thinning is required for vulvar reconstruction (compared to vaginal and scrotal reconstruction)	
No intraoperative repositioning of the patient	

Lotus petal flaps can be used to repair external vulvar defects without vaginal involvement, whereas the DIEP flap is useful for extensive vulvar defects involving the distal third of the vagina or the anus. DIEP, deep inferior epigastric perforator flap.

single case reports (88,89), three technical notes (90-92), two experimental studies (87,93), a review (94) and a letter to editor (95).

The first description of a pedicled DIEP flap for vaginal reconstruction was described in 2006 (96) for reconstruction of the external genitalia in a case of congenital vaginal agenesis. It has been described in a few other cases of congenital agenesis since (86,87,94,97). Apart from these unusual cases, this flap was used mostly in the context of oncological reconstruction (85-87,90,93,97) after primary resection (85) or in cases of recurrence (94). We reported in *Table 5* the advantages and disadvantages of the DIEP flap in vaginal reconstruction. The advantages and disadvantages of the DIEP flap in vaginal reconstruction were reported in *Table 6*.

The pedicled DIEP flap is safe in vaginal reconstruction

The relative long length of the pedicle renders the DIEP flap a feasible and robust pedicled option for vaginal

reconstruction. This obviates the need for microvascular anastomosis, as in the case of free flap. For perineal reconstruction, Fang *et al.* described the use of the DIEP flap as a pedicled island flap (87), thus reducing the risks inherent to free tissues transfer, such as anastomotic thrombosis.

Interestingly, loss of the pedicled DIEP flap has not been reported for vaginal reconstruction after pelvic exenteration, likely due to the relatively small number of cases and appropriate patient selection (85). In a study comparing the DIEP to the TRAM flap by Qiu *et al.* (93), 40 patients underwent vaginal reconstruction, 21 with TRAM flaps and seven with DIEP flaps: all DIEP flaps survived while three TRAM flaps were lost because of total necrosis, and another five developed partial flap necrosis.

The DIEP flap can form an effective neo vagina

The design of its skin paddle is versatile and follows the

principles of propeller flaps. The orientation can be oblique (9,87,90) or vertical (85,86,88,89,91-93), depending on the availability of excess tissue for a neovagina. It is then folded onto itself and fashioned in a spiral orientation, with the epithelial surface as the inner lining of the neovagina.

The pedicled DIEP flap could be too bulky for vaginal reconstruction (86). For this reason, several articles have proposed thinning of the flap as part of the primary procedure (87,97). The authors concluded that the DIEP flap can provide a reliable and adequate soft tissue paddle for perineal reconstruction and that it can be thinned without damaging the tissues inferior to the superficial epigastric vein. This thinning allows the creation of a wider neovagina, while giving a more natural perineal appearance (87).

The DIEP flap could be the preferred flap after pelvic exenteration

Three types of pedicled flaps have been used frequently in vaginal reconstruction: the Singapore or pudendal thigh flap, the vertical rectus abdominis myocutaneous (VRAM) flap, and the gracilis flap. Of these, the most frequently used reconstruction technique is the muscle-sparing VRAM flap, which is generally easier to perform than DIEP reconstruction but has a higher incidence of abdominal wall complications. A 21% incidence of incisional hernias was reported with the VRAM as compared to less than 3% with the DIEP flap (93).

More recently, there has been a shift towards using the DIEP flap for circumferential vaginal reconstruction after pelvic exenteration compared to the VRAM (85,88,93). Similarly, the gracilis flap can achieve satisfactory results in perineal reconstruction, with the main disadvantage being that of sacrificing a functioning muscle. In addition, according to Wang *et al.* (86), the DIEP flap has the added advantage of being hairless (compared to the Singapore flap), odorless (skin paddle forming the neovagina), less contracture and stenosis, and provides reliable harvest due to its constant anatomy.

The DIEP flap addresses volume defects associated with pelvic tissue losses while protecting visceral and vascular structures. It also reduces the incidence of wound infections and fistula formation in irradiated areas (90). Nevertheless, its routine use in congenital agenesis is more debatable. Indeed, for some authors, the use of an insensate DIEP flap for vaginoplasty in congenital vaginal agenesis is unacceptable due to its inability to achieve a normal sex life in young patients (95). Some authors argue that this flap should be strictly limited to cases of vaginal reconstruction post oncological resection, or in extensive trauma;

otherwise, rectosigmoid vaginoplasty is preferred.

Vulvar reconstruction

Our literature review found nine articles on vulvar reconstruction, consisting of four single case reports (98-101), three case series (87,102,103), a retrospective study (104) and a short communication with a video describing a surgical technique (105).

Vulvar defects following oncological resection are usually closed primarily by the gynecologist. Nevertheless, in cases of larger defects and irradiated vulvar tissues, reconstruction is usually achieved with musculocutaneous flaps, often bilateral. In addition, recurrence of vulvar carcinomas remains a difficult issue with up to 50% of women requiring a second surgical intervention within the first 14 months of diagnosis (106), and a 5-year recurrence rate of up to 33% (107,108). Secondary reconstruction becomes even more challenging when locoregional flaps have already been used or if the patient has had adjuvant radiotherapy.

Flap design and thinning

For vulvar reconstruction, a vertically oriented DIEP flap has been described by a few authors (99,100). On the other hand, a bilateral, transverse pedicled DIEP flap was used for extended vulvar reconstruction (98,101). Cheng *et al.* (102) described splitting and thinning of a transversely oriented DIEP flap to help with contouring and optimizing aesthetic outcomes. Santanelli *et al.* (100) described using the umbilicus for reconstruction of the distal urethra. The convexity of the mons pubis and vulva can be satisfactorily recreated simply and safely by thinning the adipose tissue beneath Scarpa's fascia. This does not require the same extensive thinning compared to cases of vaginal and scrotal reconstruction. This anatomical region also has a relative paucity of linking vessels so removal of this tissue is unlikely to affect flap perfusion (102).

The DIEP flap is a useful tool in extensive vulvar reconstruction

The ideal flap for vulvar reconstruction has the characteristics of providing a large volume of well-vascularized tissue of matching tissue thickness. It should provide restoration of both function and sensation, as well as a normal appearance and an inconspicuous donor site scar with minimal donor-site morbidity (102).

Negosanti *et al.* (103) proposed a reconstructive algorithm based on the topography of the external vulvar defect. According to the proposed algorithm, all external vulvar defects without any vaginal involvement can be repaired with lotus petal flaps. In cases of wider resection,

Table 7 Reported advantages and disadvantages of the DIEP flap in penoscrotal reconstruction

Pros	Cons
Long pedicle: can be used as a pedicled flap with no microvascular anastomosis required	Too bulky for penoscrotal reconstruction
Early ambulation (compared to skin grafting)	

It seems unlikely that DIEP will be widely used for penoscrotal reconstruction. DIEP, deep inferior epigastric perforator flap.

including other pelvic organs, the algorithm suggests the use of the DIEP flap for reconstructive purposes. Similarly, other authors (100) have also suggested limiting the use of the DIEP flap to cases with extensive vulvar defects, where the distal third of the vagina or the anus are involved.

Advantages of the DIEP flap include the robustness and reliability of its vascular pedicle, even after radiotherapy; its ability to provide a skin island with plenty of subcutaneous tissue that can be tailored to fill in dead space, and it does not involve an intra-operative change of patient position. It can be harvested transversely or vertically, and in cases with a previous midline laparotomy, without additional donor site scars. The donor site can also be closed primarily (103). Furthermore, in comparison to flaps raised from the thigh and other musculocutaneous options, the DIEP flap enables early post-operative mobilization and can reduce the length of hospital stay (100).

Penoscrotal and groin reconstruction

Penoscrotal

Our literature search returned five cases series (87,109-112) on penile reconstruction, after circumcision complications and penile amputation (109,111), for false hermaphroditism (109) (matching chromosomal and gonadal tissue sex, but mismatching external genitalia) and cases of penoscrotal Paget's disease (87,112). For scrotal reconstruction, five articles were included: there were two case series (47,112), a commentary (113), and two case reports on reconstruction after Fournier's gangrene (114,115). One of the cases required coverage of a soft tissue defect measuring 36 cm × 18 cm involving the testes, both sides of the groin, the left medial thigh, and perianal skin. This was successfully reconstructed using a left DIEP and bilateral ALT flaps (115).

The main goal of penile reconstruction is to achieve a watertight urethra with sufficient penile stiffness, and to provide a sensate penis for normal sexual function.

Ye *et al.* found that the neopenis tends to become tactile and erogenous six months after penile reconstruction (109). The intercostal nerves commonly found running alongside

the perforating vessels of deep inferior epigastric vessels, if preserved, could provide sensate skin (116). In all cases of penile reconstruction, the DIEP flap was harvested as a pedicled flap with either a low abdominal skin paddle and additional costal cartilage graft (109), or a vertical skin paddle with (110) or without cartilage graft (87,111). Immediate flap ischaemia and flap loss was reported in one case, likely due to the pedicle having undue tension (111). The contralateral DIEP was then used without further complications. In the two cases reported by Ye *et al.* (109), one patient reported full sensation along the entire length of the neophallus, while the other reported partial sensory recovery of a 2-cm area near the pedicle at 1-year follow-up. A fistula occurred in one case that was then resected and redone at six months (109). No meatal stenosis was reported in these cases. Even though the flap was usually thinned primarily, several authors (87,113) still reported that the DIEP flap remains too bulky for penoscrotal reconstruction. Nevertheless, this disadvantage could be acceptable among elderly patients, considering the advantages of early ambulation provided by the pedicled DIEP flap as compared to skin grafting (112,113). We reported in *Table 7* the advantages and disadvantages of the DIEP flap in penoscrotal reconstruction.

Groin reconstruction

We included seven articles on the DIEP flap for groin reconstruction. Kotick *et al.* (50) reported a case of groin scar contracture following a pedicled DIEP flap. Three out of their 105 reviewed cases used the DIEP flap for groin reconstruction (112,117,118) in lymphatic malformation, burn scar contracture release and coverage after resection of a Paget's carcinoma. The authors found that in most cases, a pedicled flap was used, with the ALT flap being the most common. Our literature review found four other case reports or case series (47,48,117,119). All cases utilized the DIEP flap in pedicled fashion.

Scaglioni *et al.* (119) reported a case of total groin defect reconstruction with a lymphatic flow-through, pedicled DIEP flap using its superficial veins for lymphovenous anastomosis with good outcomes. This article suggests that the lymphatic

flow- through DIEP flap might be a new solution in cases requiring both dead space obliteration and lymphatic drainage restoration in regions such as the groin due to its proximity to the inguinal lymph nodes where seroma, lymphocele, and lymphedema are often unavoidable complications.

Other reconstructions

Buttock reconstruction

Our literature review found two case reports on buttock reconstruction, one of which used the DIEP flap as a pedicled flap (120), while the other used it as a free flap (121). Both articles reported satisfactory results suggesting that the DIEP flap could be used for reconstruction of large buttock defects.

Abdominal reconstruction

We included four articles (111,122-124) on abdominal reconstruction with the DIEP flap where it was used as a pedicled flap. In these articles, the authors proposed that the long and robust vascular pedicle of the DIEP flap is ideal for its use in islanded, local advancement or 'propeller' rotation to adjacent abdominal wall defects. These cases used the DIEP flap for oncological reconstruction except a case by Monsivais *et al.* (123), where the flap was pre-expanded for burn resurfacing.

Sterno-thoracic reconstruction

Six articles on sterno-thoracic reconstructions were included. Three free DIEP flaps were used by Angrigiani *et al.* (125) to treat restricted chest wall expansion secondary to burn contracture. Several cases have been reported where the DIEP flap was used for the protection of underlying critical structures, such as the heart and lungs. Manley *et al.* (126) reported a case of a de-epithelized free DIEP flap for filling of dead space after resection of postpneumectomy empyema. In another case reported by Inatomi *et al.*, a bilobed pedicled DIEP flap was used (127) to prevent intestinal prolapse through an omental flap after heart transplantation. Sharma *et al.* (128). also used a bilateral pedicled DIEP flap in a case of chondrosarcoma of the sternum requiring wide local excision of the full thickness of the chest wall. A bilobed DIEP flap, extended with a superficial circumflex iliac artery perforator (SCIP) flap was used to reconstruct the soft tissue defect following resection of a refractory ulcer on the torso, was reported by Yoshimatsu *et al.* (33). Finally, Miyamoto *et al.* (48) reported

a case of free DIEP reconstruction for an anterior chest wall defect after dermatofibrosarcoma excision.

Discussion

In the late 1970s and early 1980s, musculocutaneous flaps were popularized for pedicled flap reconstruction of large soft tissue defects. The success of musculocutaneous flaps is often attributed to the robust blood supply to the muscle and its usefulness in providing bulk for volume defect (129).

When first described in 1994, the use of the free DIEP flap for breast reconstruction was considered new and unconventional. However, over time, the DIEP flap has become the gold standard in autologous breast reconstruction (130). The abdominal region is a robust donor site for free tissue transfers, offering relatively large skin and soft tissues for reconstructive use. Partial necrosis of the flap is always an existing risk, especially for longer flaps, and is mostly attributed to venous outflow issues but can be prevented by supercharging and superdraining via the SCIA system if needed. The laxity of abdominal skin also minimizes the risks of donor site morbidity and it can almost always be closed primarily. It has been used successfully in a variety of anatomical regions, especially for larger defects but not only, and the authors believe that its use in regions other than the breast could become more common thanks to the numerous advantages associated with this flap.

Most of the reports were case reports and the small number of reports could introduce publication bias, presenting only successful cases of reconstruction with the DIEP flap. In many case series, the various types of DIEP flaps were reported but not explained in detail. As previously reported in a head and neck review by Mayo-Yáñez *et al.* (7), the workgroup with the largest number of publications on the use of DIEP flap is Koshima's (2,25,63,64). It is also worth noting that non-breast reconstruction using the DIEP flap is not a common technique employed by most reconstructive surgeons. Those who publish the different reports are usually from the same working groups [Yano *et al.* (65,66), Zhang *et al.* (67,75,104) or Kostakoğlu *et al.* (18,76)].

It is also interesting to note that the versatility of DIEP flap for use in non-breast reconstruction was first proposed as early as 1999 by Classen (47) but has only gained some traction in the past decade. We hope that this review will provide a useful summary of the pros and cons of the DIEP

flap in non-breast reconstruction and raise awareness amongst our colleagues, in the hope of benefiting our future patients.

Conclusions

The DIEP flap can be used as a pedicled flap in the reconstruction of pelvic, ischial, perineal and thigh regions up to the lower third or as a free flap when needed. It is a good option for reconstruction of the ventral part of the body, especially when the patient is supine. The DIEP flap is also useful when the reconstruction does not require a particularly thin flap, although some authors have suggested that it can be safely thinned primarily or in secondary procedures. The DIEP flap's size can be increased as necessary by utilizing pre-expansion. The feasibility and safety of doing so has been previously demonstrated. Furthermore, its reliable vascular anatomy and long pedicle make it particularly useful when no reliable vascular recipient is available adjacent to the defect such as in trauma or post-radiation cases. Its versatile skin paddle designs can address a variety of defect sizes and contours specific to different anatomical regions. From the traditional horizontal, abdominoplasty-like paddle to an oblique design and a vertical, customized skin paddle, possibilities with the DIEP flap are limitless. Additionally, by incorporating multiple perforators, it allows the creation of different skin paddles that can be rotated or tailor-matched to specific defect shapes and sizes.

As was the case when it was first introduced and considered anecdotal, we believe that the use of the DIEP flap in reconstruction of other regions will gradually become more accepted and mainstream. Hence, Plastic Surgeons should familiarize themselves with this flap as it will most likely become an indispensable reconstructive tool in future beyond breast reconstruction. This is particularly applicable to the reconstruction of large, proximal upper and lower limb defects. With regard to head and neck defects, it provides adequate bulk for volume defects of the orbit and maxilla, besides providing protection for the skull or exposed brain tissues. For genital reconstructions, the DIEP flap is safe and effective in vaginal reconstruction and useful in extensive external vulvar defects when the vagina is also involved. We do not believe however, that the DIEP flap should be used for penoscrotal reconstruction due to the flap being bulky, even after primary thinning. It may be considered acceptable for elderly patients with more emphasis on functional rather than aesthetic outcomes as it

allows for early ambulation when compared to resurfacing with skin grafts.

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Footnote

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