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Bipedicled DIEAP flaps for reconstruction of limb soft tissue defects in male patients[☆]



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KEYWORDS

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Summary *Background:* Extensive soft tissue deficiencies involving the limbs can be difficult to reconstruct and may require more than one microsurgical flap transfer to cover the defect. This can be particularly challenging in male patients, where the sacrifice of a donor muscle could result in considerable comorbidity. This paper describes the use of the bipedicled deep inferior epigastric artery perforator (DIEAP) flap to perform a one-stage reconstruction of extensive soft tissue defects in male patients.

Methods: By using preoperative multidetector computed tomographic (MDCT) angiography, the dominant perforators of the abdominal wall were identified and the bipedicled DIEAP flap was used for a one-stage reconstruction of complicated tissue loss in 12 male patients. In seven of these flaps, a microsurgical anastomosis between the two epigastric pedicles of the DIEAP flap was carried out. The feasibility of the procedure, clinical outcome, and possible associated comorbidities were evaluated.

Results: Successful large tissue reconstructions were performed using all four traditional zones of the DIEAP flap, with dimensions of flaps ranging from 20 × 8 to 50 × 17 cm. Venous congestion was seen to develop in two flaps, one of which was salvaged by performing an additional venous anastomosis, but the other flap failed to survive. Apart from this, complications were minimal.

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Conclusions: Soft tissue coverage of extensive wounds in male patients without sacrificing muscle flaps can be challenging. This extended utilization of the entire DIEAP flap has helped us to address this issue.

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Introduction

Extensive tissue loss in the extremities often requires reconstruction with free flaps due to the exposure of underlying neurovascular structures, bone, tendon, or joints.¹ Moreover, substantial tissue loss results in contour deformities that need to be restored. Extremity reconstruction can be challenging, as the donor tissue should not be too bulky to avoid functional impairment or aesthetically unpleasant results. Wound coverage can be achieved with local or regional flaps, such as the latissimus dorsi flap for upper limb defects. However, this is often not feasible considering the extent and complexity of the trauma. Tissue loss in the extremity is often axially orientated due to avulsion and shearing forces, and the reflex of withdrawing the extremity from the source of injury aggravates the degloving trauma. The resulting type of injury requires coverage with relatively long flaps. In these cases, free microsurgical tissue transfer is the primary option to meet the reconstructive needs. This usually involves free muscle transfer, but the sacrifice of muscle compartments can result in additional morbidity.^{2,3} Whereas some have recommended muscle flaps for Gustilo IIIb fractures,^{4,5} fasciocutaneous flaps have been equally promoted by others.^{6,7} Perforator flaps, such as the thoracodorsal artery perforator (TDAP) flap⁸ or the anterolateral thigh (ALT) flap,⁹ have been used to avoid the donor-site morbidity associated with muscle flaps. The dimensions of these flaps are limited and this has resulted in the use of multiple perforator flaps in our practice as reported in the past.¹⁰ The amount of tissue that can be harvested safely to cover primarily an extremity defect will often determine a successful outcome. In particular, large circumferential defects or axial tissue deficiencies involving joint regions should be covered with one long, reliable flap. The deep inferior epigastric artery perforator (DIEAP) flap is a large perforator flap and is our standard choice in autologous breast reconstruction. In male patients, the abdomen is often less attractive due to a limited amount of donor tissue, particularly in lean patients. When the flap is vascularized through one pedicle, the most contralateral area of the flap is often underperfused, which reduces the length of the flap that can be utilized.¹¹ We have addressed this by successfully using the entire area of the DIEAP flap by vascularizing it by both inferior epigastric pedicles to achieve successful reconstruction of extensive soft tissue deficiencies in the limbs.

Surgical anatomy

The perforator vessels arising from the deep inferior and superior epigastric system predominantly perfuse the abdominal wall. Additional blood supply comes from the superficial inferior epigastric, superficial external pudendal, intercostal, and the superficial and deep circumflex iliac vessels.¹² The deep inferior epigastric artery (DIEA) has different branching patterns. This was originally described as Type 1 (single trunk), Type 2 (two trunks), and Type 3 (three trunks).¹³ Computed tomographic angiography (CTA) imaging has shown that there are two additional branching patterns: Type 0 with an absent DIEA and Type 4 with the DIEA dividing into four trunks.¹⁴ Although different branching patterns exist, 91% of the cases show Type 1 and Type 2 patterns.¹⁴ The anterior abdominal wall had originally been described to comprise of four zones, while others have questioned this classification.^{11,15} However, the most distal contralateral zone is usually underperfused, reducing the area of the flap that can be used.

Surgical technique

Preoperative vascular mapping of the abdominal wall is performed with CT angiography and the surgery is planned depending on the perforators and branching pattern visualized.¹⁶ The surgical technique is the same as that of the standard harvest of the DIEAP flap for breast reconstruction. Unless there is a need to include more than one perforator vessel, we tend to base each side of the flap on a single dominant perforator, which is dissected through its course, to the DIE vessels and further proximally up to their origin from the external iliac artery. A long pedicle is useful in limb trauma to facilitate microsurgical anastomosis outside the zone of trauma. When dissection of the perforator reaches the main DIE vessels, a long stump of the other branched-out trunk is dissected. The perforator vessels are similarly identified on the contralateral side and dissected, with the DIE vessels dissected proximally beyond its division, but dissection need not be done up to its origin. Instead, it is sufficient to dissect out the DIE vessels to a level where the caliber of the vessels matches that of the ipsilateral branched stump of the DIE vessels and the vessels are long enough to reach the contralateral side. Although we have performed extra flap anastomosis of both the DIE vessels into separate recipient vessels in the past, we now prefer to perform intraflap anastomosis first and

then anastomose a single DIE vessel pedicle to the recipient vessels. The harvested flap is moved to a sterile side table and microsurgical anastomosis is carried out between the DIE vessels on the contralateral side with the branched stump of the pedicle DIE vessels. The flap is then transferred to the limb wound, and microsurgical anastomosis is carried out between the pedicle DIE vessels and the recipient limb vessels.

Clinical cases

Case 1

As a result of a road traffic accident, a 23-year-old patient sustained a Gustilo IIIb fracture of his ulna ([Figure 1](#)). Following bony fixation, the soft tissue defect was reconstructed with a bipediced DIEAP flap. A 20 × 8-cm flap was harvested based on one perforator on the left side and two on the right side with the flap perfused by the left DIEA. An intraflap anastomosis was carried out between the right DIE vessels and the lateral branch of the left DIE vessels ([Figure 2](#)). The flap was then transferred to the defect and the left DIE pedicle vessels were anastomosed end to side into the radial vessels, with a good reconstructive outcome ([Figure 3](#)).



Figure 1 Extensive soft tissue loss over left elbow and forearm, with exposed fractures of the ulna.

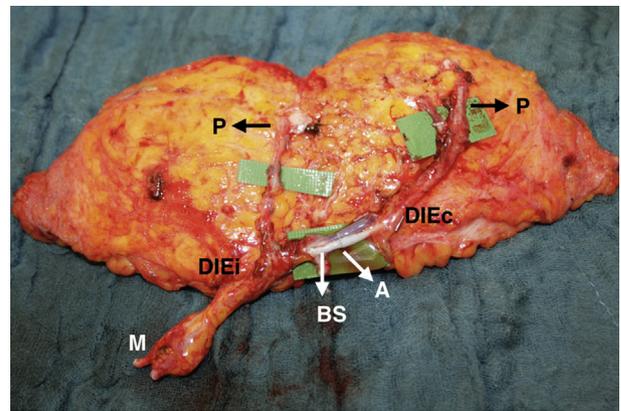


Figure 2 Intraflap anastomosis (A) was carried out between the DIE vessels of the contralateral right side (DIEc) with lateral branch (branched stump: BS) of the ipsilateral left pedicle DIE vessels (DIEi; M: main pedicle; P: perforator).

Case 2

A 27-year-old patient was involved in a road traffic accident and had sustained an extensive burn injury to his right leg.



Figure 3 Following adequate debridement of the wound, the defect was resurfaced with the bipediced DIEAP flap with an acceptable clinical outcome.

As a result, almost two-thirds of the length of his tibia was left devoid of soft tissue cover. A 37 × 8-cm bipedicled DIEAP flap was harvested based on one set of perforator vessels on the left and two sets of perforator vessels on the right, with the left DIE vessels as the pedicle. An intraflap anastomosis was performed between the right DIE vessels and the lateral branch of the left pedicle DIE vessels. The flap was transferred to the leg and the pedicle anastomosed end to end to the anterior tibial vessels (Figure 4a). There was partial necrosis in the proximal end of the flap, which was debrided, and the wound bed was resurfaced with a skin graft (Figure 4b).

Case 3

A 54-year-old patient had been treated for an unknown osseous lesion 35 years ago with resection and post-operative radiation therapy. The etiology could not be retrieved from his medical files but the adjuvant treatment therapy resulted in an unstable callus formation with a “floating” upper leg complicated by chronic osteomyelitis (Figure 5). As a result, he had been wearing a supportive prosthetic device since then. An extensive resection of the unstable bone tissue was performed, and the bones were externally stabilized with the application of an Ilizarov device (Figure 6). The chronic wound was excised extensively and the resultant circumferential defect was covered with a bipedicled DIEAP flap (Figure 7). This resulted in a successful reconstruction, with a good functional outcome, for the patient (Figure 8).



Figure 5 Radionecrosis of femur, resulting in chronic osteomyelitis.

Results

We used the bipedicled DIEAP flap to reconstruct large extremity defects in 12 male patients. Five flaps were bipedicled DIEAPs, where the two DIE vessel pedicles were anastomosed independently into two sets of recipient vessels. The other reconstructions were performed with an intraflap anastomosis as described in our surgical technique. The mean age of our patients was 35 years (17–72 years), with most of our patients being involved in labor-intensive jobs (Table 1). Although the etiology of the soft tissue defect was burns in two patients and radionecrosis of the femur in two patients, the most common indication for



Figure 4 (A) Extensive burn injury of the right lower limb, resulting in soft tissue loss and exposure of two-thirds of the tibia. A 37 × 8-cm DIEAP flap was raised based on one set of medial perforator vessels on the left and two sets of medial perforator vessels on the right side of the flap. An intraflap anastomosis was carried out between the right DIE vessels and the lateral branch of the left pedicle DIE vessels. The bipedicled DIEAP flap was transferred to the leg and the pedicle vessels were anastomosed end to end to the anterior tibial vessels. (B) This resulted in a satisfactory reconstructive outcome on follow-up at 6 months.



Figure 6 Unstable bone resected, extensive debridement carried out, and bones stabilized with an Ilizarov device. Recipient vessels were retrieved more proximally away from the zone of injury. The long pedicle of the DIEAP flap provides the opportunity to perform an anastomosis with the recipient vessels in the upper leg outside the zone of injury.

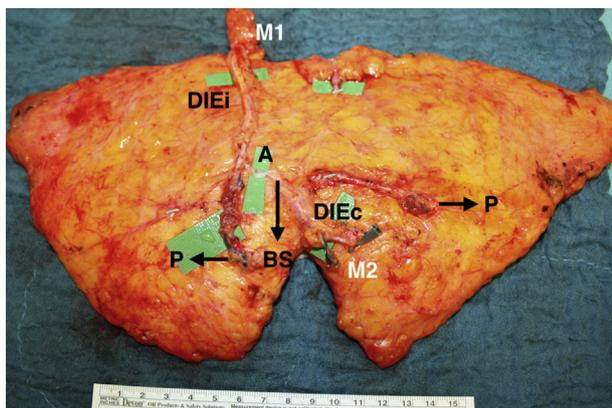


Figure 7 A 25 × 12 cm DIEAP flap was harvested. Both pedicles (M1 and M2) were included in the flap and anastomosed separately in two recipient sites. The distal branched stump (BS) of the left pedicle (DIEc) was additionally anastomosed (A) to a branch of the right epigastric pedicle (DIEi; P: perforator).



Figure 8 Clinical outcome at 1 year and after additional debulking of the flap.

soft tissue cover in our cases was the presence of Gustilo IIIb fractures. The site involved was predominantly the lower leg with extension of the defect into the adjacent areas. The flaps were based on various combinations of number of perforator vessels, but the majority of them were perfused by one set of dominant perforator vessels on each side of the flap (Table 2). An additional pedicle from the superficial epigastric artery was used in one of the cases. In the seven flaps with an intraflap anastomosis, the lateral branch was more commonly used to anastomose into the contralateral DIEA pedicle. In our series of cases, two flaps developed partial necrosis and another dehiscid at one end after the inset of the flap. Venous revision was required in two flaps, one of which did not survive. In the case of successful salvage, venous revision was performed to deal with venous congestion in the most distal contralateral part by performing an additional anastomosis of the contralateral superficial epigastric vein (SEV) to an additional recipient vein in the limb. One of the flaps was bulky around the ankle area and secondary liposuction was carried out to enable the patient to wear footwear. Bulging of the abdominal wall or hernia and seroma or infection were not observed in these patients.

Table 1 Overview of the 12 patients with description of the trauma.

Patient	Age	Occupation	Site	Nature of wound
1	40	Farmer	Thigh	Radionecrosis of femur
2	44	Manual laborer	Upper leg	Bilateral below-knee traumatic amputations
3	23	Farmer	Elbow	Fracture ulna with elbow joint exposed
4	27	Construction worker	Lower leg	Burns exposing the tibia
5	17	Student	Upper leg/ Knee	Tibial plateau fracture with exposed knee joint
6	22	Office job	Distal tibia/ ankle	Compound fracture dislocation of ankle
7	31	Construction worker	Lower leg	Compound fracture tibia with both anterior and posterior tibial vessels severed
8	53	Farmer	Lower leg	Burns with exposed tibia
9	72	Retired	Lower leg	Degloved leg with compound fracture tibia and fibula
10	25	Manual laborer	Lower leg/ forefoot	Chopart amputation of forefoot
11	40	Warehouse worker	Lower leg	Degloved leg with compound fracture tibia and fibula
12	54	Office worker	Thigh	Radionecrosis of femur

Table 2 Overview of the different flap designs and encountered complications.

Patient	Number of perforators used	Flap anastomoses	Area of flap	Complications
1	One on each side	Intraflap; Left DIE vessels anastomosed to lateral branch of Right DIE vessels	28 × 13 cm	Extravenous anastomosis done with superficial epigastric vein to relieve congestion in zone 4
2	Two on each side	Intraflap: Right DIE vessels anastomosed into medial branch of left DIE vessels	30 × 13 cm	–
3	One on left side and two on right side	Intraflap: Right DIE vessels anastomosed into lateral branch of left DIE vessels	20 × 8 cm	–
4	One on left side and two on right side	Intraflap: Right DIE vessels anastomosed into lateral branch of right DIE vessels	37 × 8 cm	Partial necrosis of the flap. Residual defect was resurfaced with a skin graft
5	One on each side	Intraflap: Left DIE vessels anastomosed into medial branch of left DIE vessels	25 × 11 cm	Extra venous anastomosis done with the other vena comitantes to relieve venous congestion; however, flap failed to survive
6	One on each side	Intraflap: Contralateral DIE vessels anastomosed to lateral branch of ipsilateral DIE vessels	Not recorded	Small area of necrosis. Debrided and directly closed
7	One on one side and two on the other side	Extraflap; both pedicles anastomosed end to end, as a flow through anastomosis, to anterior, and posterior tibial vessels	50 × 17 cm	Wound dehiscence, secondary closure done
8	One on each side	Extraflap: both pedicles anastomosed end to end with recipient vessels	Not recorded	Patient died after 6 weeks due to MOF
9	One on each side	Extraflap: both pedicles anastomosed end to end with the recipient vessels	Not recorded	–
10	One on one side and two on the other side	Extraflap: Both pedicle DIE vessels anastomosed end to end with recipient vessels	Not recorded	Bulky, secondary liposuction done
11	One on each side + superficial epigastric perforator	Extraflap; both DIE vessels and one superficial epigastric pedicle was anastomosed end to end with recipient vessels	Not recorded	Partial necrosis, local advancement flap done
12	One on each side	Intraflap: Right DIE vessels anastomosed into lateral branch of left DIE vessels	25 × 12 cm	–

Discussion

Since its introduction,^{17–19} the DIEAP flap has revolutionized autologous breast reconstruction. However, when the DIEAP flap is based on a single pedicle, the most contralateral part is not well perfused and needs to be discarded,^{11,15} reducing the effective area of the flap that can be used. When large-volume breast reconstruction is required, the entire area of the flap needs to be utilized, which has been effectively achieved with the bipedicled DIEAP flap.^{20,21} Similarly, it is useful to bipedicle the DIEAP flap in the presence of a midline abdominal scar.^{22–24} The bipedicled DIEAP flap has also found a place in reconstructions elsewhere.²⁵ Considering its large surface area and associated low comorbidity, we have been using the bipedicled DIEAP flap to cover large soft tissue defects in the limbs. Muscle flaps have been commonly used in the past to resurface extensive soft tissue defects, but the sacrifice of muscle compartments can lead to increased donor-site morbidity. Most of the patients presented in this series were involved in labor-intensive jobs. Perforator flaps have known advantages in reducing donor-site morbidity. A bilateral DIEAP flap dissection is more

extensive, and it has been reported previously that bilateral flap harvest results in increased hernia and bulge formation.²⁶ However, this has not been the case in our experience, as none of the patients in this series developed these complications. Venous revision had to be performed in two cases. One patient presented with congestion of the distal contralateral part of the flap, which was salvaged with an additional venous anastomosis to the contralateral SEV. We have stated in the past that circulation in this area is often compromised due to venous congestion, rather than lack of arterial inflow.²⁷ In our practice, we tend to observe the most distal contralateral region of the DIEAP flap for signs of congestion after we have anastomosed the main DIE pedicle vessels. If congestion is present, we electively anastomose the contralateral SEV into an independent recipient vein in the limb. In the other patient, venous revision of the main pedicle was performed for complete flap congestion. Unfortunately, the flap failed due to suboptimal recipient conditions. Reconstruction had to be carried out mostly in the presence of extensive physiological and anatomical disruption of the tissues, which can often result in a poor outcome. Perforator flaps also provide stable cutaneous coverage compared with a

skin-grafted muscle flap, which in turn results in a better reconstructive result. They also tend to be thinner and provide a better contour match. In some cases, the DIEAP flap can be thick and the flap should be thinned down before transfer. It has been shown on CT angiography that the perforator vessels perfusing the skin and subcutaneous tissues tend to branch out superficial to Scarpa's fascia.²⁸ Hence, debulking of the flap can be safely performed deep to Scarpa's fascia. If satisfactory debulking cannot be performed initially, then liposuction may need to be carried out at a later stage. Various options of performing intraflap anastomosis have been described in the past. The caudal end of the DIE vessels on the contralateral side can be anastomosed end to end to the cranial end of the pedicle DIE vessels on the ipsilateral side, the caudal end of the contralateral DIE vessels can be anastomosed end to end to the side branch of the pedicle DIE vessels, one of the vena comitantes of the contralateral side can be anastomosed end to end with one vena comitantes of the pedicle DIE vessels, and the contralateral DIEA can be anastomosed end to side with the pedicle DIEA.²⁴ The cranial end of the pedicle DIE vessels has also been anastomosed to the contralateral paraumbilical perforator vessels.²⁹ We prefer to anastomose the contralateral DIE vessels to the branch of the ipsilateral pedicle DIE vessels. We have found that vessel dissection is easier and it provides a long pedicle length for a tension-free anastomosis. In addition, the main pedicle DIE vessels are long and allow for a microsurgical anastomosis to be carried out outside the zone of trauma. A bipediced DIEAP flap provides the equivalent of two or three other perforator flaps, but leaves behind a single donor scar. Various imaging techniques such as the handheld Doppler, color Doppler ultrasound, CT angiography, and magnetic resonance angiography are available to help assess the vascular architecture of the DIEAP flap.³⁰ We have found CT angiography to be an invaluable tool in our preoperative planning of the procedure, making the procedure safe and swift.³¹ A recent study by Wong et al. has provided greater insight on the perfusion in these zones.³² With the help of CT angiography, it has been shown that the medial row perforator vessels perfuse the central area of the flap better than the peripheral zones. However, lateral row perforators perfuse the ipsilateral part of the flap better than the contralateral part. Moreover, perfusion to the contralateral peripheral part of the DIEAP flap was found to be very poor with a lateral row perforator vessel, as would be expected. It has been advocated in the past that the DIEAP flap should be based on using the single largest perforator.³³ Accordingly, we have based our flaps on the largest perforator on each side. This has, however, resulted in the use of either medial or lateral row perforator vessels, and the lateral branch of DIE vessels has been used for anastomosis to the contralateral DIE pedicle vessels more commonly than the medial branch. As lateral row perforator vessels perfuse zone 3 better, we should perhaps base each side of our flap on the lateral row vessels, thus maximizing perfusion to the lateral corners of the flap. The medial branch can then be used for the intraflap anastomosis, which will also help prevent rotation of the pedicle DIE vessels. This can only be done in the presence of good-caliber perforator vessels from the lateral row.

Conclusion

Extending the area of the conventional DIEAP flap by bipedicling, it has helped us to convert the conventional DIEAP flap into a large versatile flap that can be used in the reconstruction of extensive soft tissue deficiencies of the limbs, leading to a good contour match and minimal donor-site morbidity.

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None of the authors have any financial interests to disclose.

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