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Pedicled perforator flaps in breast reconstruction: a new concept☆

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Summary *Introduction*. Pedicled perforator flaps have not been widely described for the breast. The aim of this study is to report our clinical experience with pedicled perforator flaps in breast reconstruction.

Material and methods. Between May 2000 and May 2003, pedicled perforator flaps were used in 31 patients. The indications were immediate partial breast reconstruction and thoracic reconstruction for carcinomatous mastitis or tumour recurrence. Perforators were identified by Doppler preoperatively. The Doppler-located thoracodorsal artery perforator (TDAP) or another perforator such as the intercostal artery perforator (ICAP) was looked for. If the perforators had good calibers, the flaps were then based solely on these perforators. If the perforators were tiny but pulsating, the TDAP flap was harvested as a muscle-sparing latissimus dorsi type I (MS-LD I) with a small piece of muscle (4×2 cm) included to protect the perforators. If the perforators were not-pulsating, a larger segment of the LD muscle was incorporated to include the maximum of perforators (MS-LD II flap). The nerve that innervates the rest of the LD muscle was always spared. If most of the LD was included in the flap, the flap was then classified as MS-LD III.

Results. The mean flap dimensions were 20×8 cm. Using this algorithm, the TDAP flap was harvested in 18 cases and the ICAP flap in three cases. In addition, there were 10 MS-LD flaps with a variable amount of muscle. In addition, one parascapular flap was dissected. A successful flap transfer was achieved in all but three patients, in whom limited partial necrosis occurred. Seroma was not encountered at the donor sites of the perforator flaps (0%) compared to four (40%) after a MS-LD flap.

Conclusion. Our results show that pedicled perforator flaps are additional options for breast surgery and that they may be used whenever an adequate perforator can be found. This technique is safe and reliable if the algorithm described is used when choosing a flap.

Perforator flaps are skin and fat flaps that are based on perforators arising from a deep vascular system through the underlying muscles or intermuscular septa. Harvesting the flap without sacrificing the muscle or the nerve is the essence of this

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technique, so reducing the donor site morbidity to the minimum. Although the thoracodorsal (TD) and the intercostal (IC) vessels provide many perforators to the region of the back, only the latissimus dorsi (LD) flap is used in breast surgery, leading to the sacrifice of the largest muscle in the body. Angrigiani et al.[1] first described the use of a cutaneous island of the latissimus dorsi flap without the muscle but based instead on one cutaneous perforator for lower extremity reconstructions. In our department, the thoracodorsal artery perforator (TDAP) flap is widely used as a free flap for large defects on extremities.[2,3] However, the use of TDAP flaps has not gained popularity because flap dissection was reported as tedious and the outcome as unpredictable.[4] Moreover, pedicled perforator flaps for breast surgery have not been reported in the literature. The pedicled TDAP flap was published in a few case-reports for shoulder and axillary defects.[4,5] This study reports our clinical experience with the use of pedicled perforator flaps for breast reconstruction.

Material and methods

Between May 2000 and May 2003, all patients who had partial breast or thoracic defects that required flap reconstruction were included in our surgical protocol. The purpose of the study was to investigate the reliability of a surgical algorithm in breast surgery using pedicled perforator flaps. The patients' characteristics and clinical indications for flap reconstruction are summarised in Table 1.

Flaps were classified as perforator flaps when they were harvested as thoracodorsal perforator (TDAP) or intercostal perforator (ICAP) flaps.

Muscle-sparing latissimus dorsi (MS-LD) flaps were classified as: (a) MS-LD I, in which a small piece of LD muscle (4×2 cm) was incorporated within the flap; (b) MS-LD II where a larger segment of up to 5 cm width designed along the anterior part of the LD muscle was incorporated; and finally (c) MS-LD III when most of the LD muscle was harvested. Fig. 1((A)–(F)) shows a schematic drawing of the blood supply to the flaps and different harvested flaps.

Anatomy

The blood supply to the LD muscle is well documented.[6] The TD vessels are the main pedicle of the LD muscle. After giving the serratus anterior (SA) branch, the TD vessels divide into two branches, the descending or vertical branch and the horizontal branch. These branches give numerous perforators to the skin. Anatomical studies on cadavers have shown that the vertical intramuscular branch provides two to three cutaneous perforators.[1,7] The proximal perforator pierces the muscle and enters the subcutaneous tissue approximately 8 cm below the posterior axillary fold and 2–3 cm posterior to the lateral border of the muscle. It is oriented obliquely from the deep to the superficial surface as a direct continuation of the TD artery itself. The second perforator originates 2–4 cm distal to the origin of the first perforator. The first and second perforators are found consistently in most people.[1,7] However, our clinical experience with the TDAP free flap showed that a direct perforator of TD arising around the anterior border of the LD muscle into the skin could be found in some cases. In other words, the perforator did not pierce the LD muscle, which made the dissection much easier and quicker.

An intercostal (IC) perforator can be found anterior to the LD border making the flap dissection possible without disturbing or sacrificing the TD vessels. These perforators pierce the serratus muscle and turn medially running above the LD muscle and are usually accompanied by a sensory branch to the skin of the back. The IC nerve

Table 1 The patients' characteristics, risk factors and clinical indications for flap reconstruction

No. 31 patients	Unilateral reconstruction	30 Patients
	Bilateral reconstruction	1 Patient
Average age		51 Years (31–74 years)
Indications	Partial breast reconstruction	28 Flaps
	Thoracic skin reconstruction	4 Flaps
Risk factors	Pre-op irradiation	2
	Post-op irradiation	24
	Neo adjuvant chemotherapy	5
	Adjuvant chemotherapy	15
	Smoking	5
	Diabetes mellitus	1

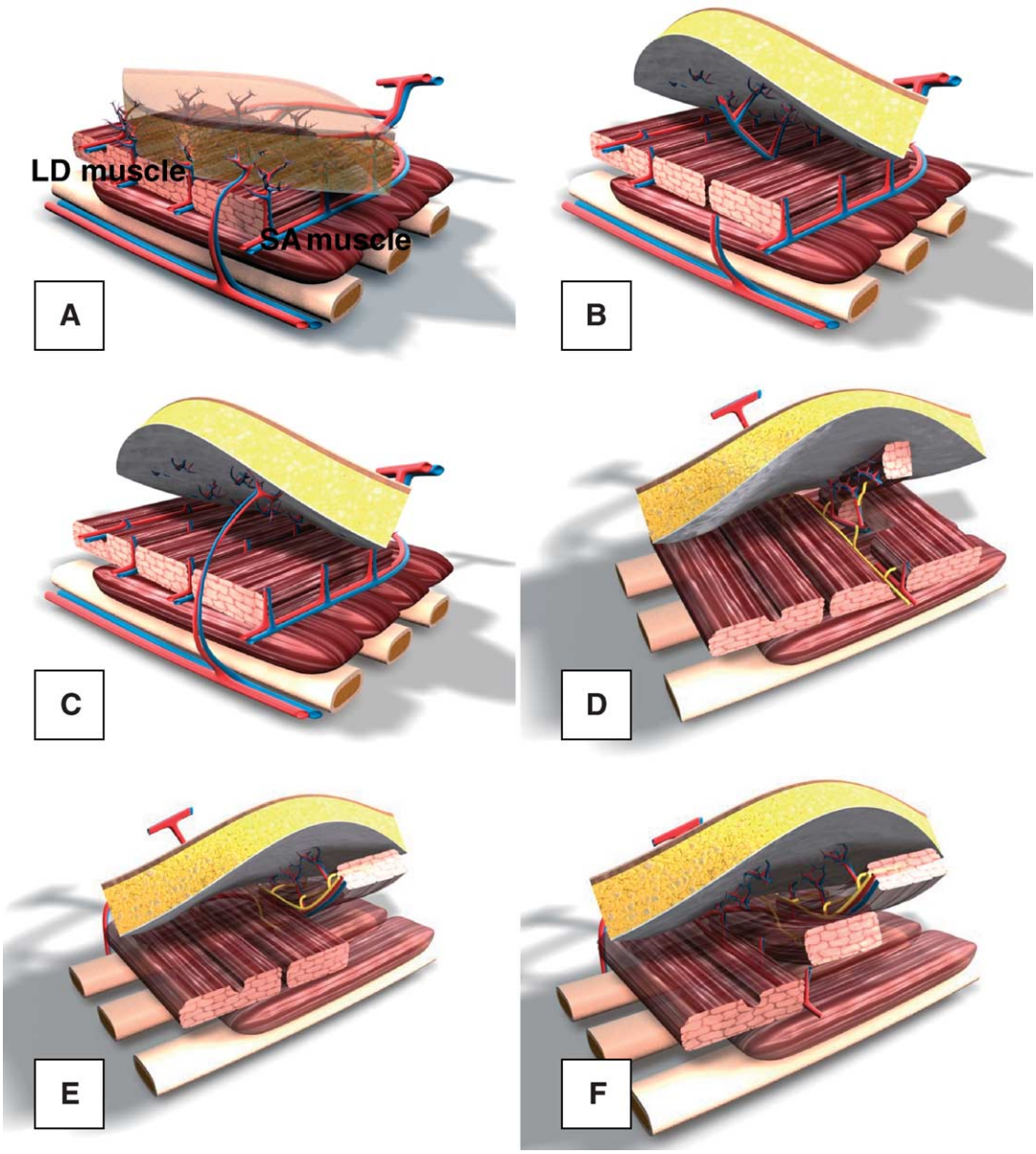


Figure 1 (A) The pedicle flap with different source blood supply by the TD, SA and IC branches. (B) A TDAP flap; (C) a ICAP flap; (D) a MS-LD I flap; (E) a MS-LD II flap and (F) a MS-LD III flap.

continues to enter the skin, usually with a perforator that arises through the LD muscle.

Preoperative assessment

The patient was marked the day before surgery. The breast size, tumour size and location as well as the estimated defect were considered. The excess of skin and fat of the back was determined by the pinch test. The patient was then asked to lie on her side as in the intra-operative position. The potential perforators were located by using a unidirectional Doppler whereupon the flap was designed to incorporate one or more of the localised perforators. The width of the flap was determined by the estimated defect and the requirement for primary donor site closure. The flap paddle was oriented parallel to the skin lines or as an extension to the axillary dissection's incision onto the shoulder. The island could also be horizontally designed according to the wishes of the patient. It was always extended over the anterior border of the LD muscle in order to include the pre-muscular perforators if they could be found. The incision of the tumour resection was planned together with the breast surgeon in order to provide the best access for the resection but also taking into account of aesthetic considerations.

Surgical technique

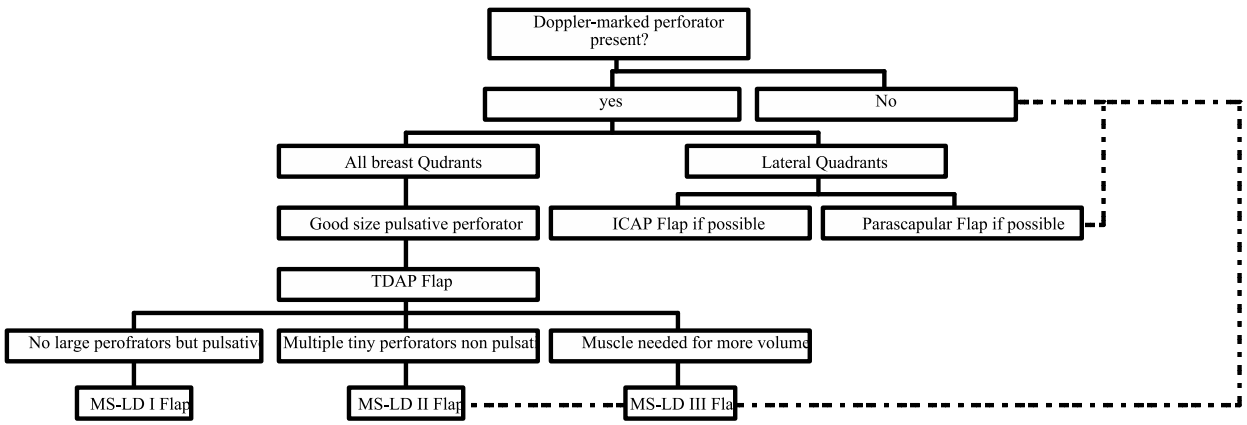
The patient is placed in a lateral position after the tumour resection. The arm is abducted 90° as for harvesting a classical LD flap. The skin and subcutaneous tissue are incised to the muscle's fascia. The dissection must be bevelled in order to include a maximum of fat. Flap elevation proceeds from distal to proximal and from medial to lateral at the level just above the LD muscle's fascia until the Doppler identified perforator or a good size perforator is found. The surgical algorithm used is described in Fig. 2.

The thoracodorsal artery perforator (TDAP) flap

A perforator originating from the descending branch is preferred as that makes the dissection easier since it is less involved with nerve branches, in addition, the vessel course is usually shorter within the muscle fibers. If two perforators are on the same line, both of them can be incorporated in the flap without cutting any muscle fibers. If the surgeon is satisfied with the caliber and the quality of the perforator, a complete dissection of the perforator can be done. Perforators must be pulsating and have good diameters to allow the decision to harvest a perforator flap (Fig. 3(A)). The anterior and superior part of the skin paddle should be left attached to the LD muscle. The muscle is split and the perforator is dissected cranially (Fig. 3(B)). All side branches are clipped or coagulated with a micro-bipolar. Nerve branches are dissected away from the vessels and they are preserved. The perforator, usually running in a loose areolar-fatty tissue is followed to the thoracodorsal pedicle. The TD vessels are dissected proximally until their origin from the subscapular vessels to provide a long pedicle, which is enough to reach distal breast defects. The serratus branch is divided when it hinders adequate length of the pedicle. Only when the dissection of the vessels is complete, can the skin paddle be raised from the LD muscle. The skin paddle is passed through the split LD muscle into the breast area under the skin bridge between the axilla and the thoracic regions (Fig. 3(C)). Extreme care should be taken at this point in order not to damage the perforator during the passage of the flap. In some cases, a perforator, arising from TD vessels and passing around the anterior border of the LD muscle into the skin, can be found and then preferably used.

The intercostal artery perforator (ICAP) flap

An intercostal perforator can also be encountered and dissected onto its origin from the intercostal bundle through the split serratus anterior muscle. However, an intercostal perforator flap is only indicated for lateral breast defects because of its short pedicle and cannot reach more medial defects (Fig. 4). An intercostal nerve can be included in the



Our surgical algorithm in choosing of pedicled flaps for breast:

TDAP= Thoracodorsal perforator, ICAP= Intercostal perforator, MS-LD=Muscle sparing-Latissimus Dorsi.

Figure 2 Our surgical algorithm in choosing of pedicled flaps for breast: TDAP, thoracodorsal perforator; ICAP, intercostal perforator, MS-LD, muscle sparing-latissimus dorsi.

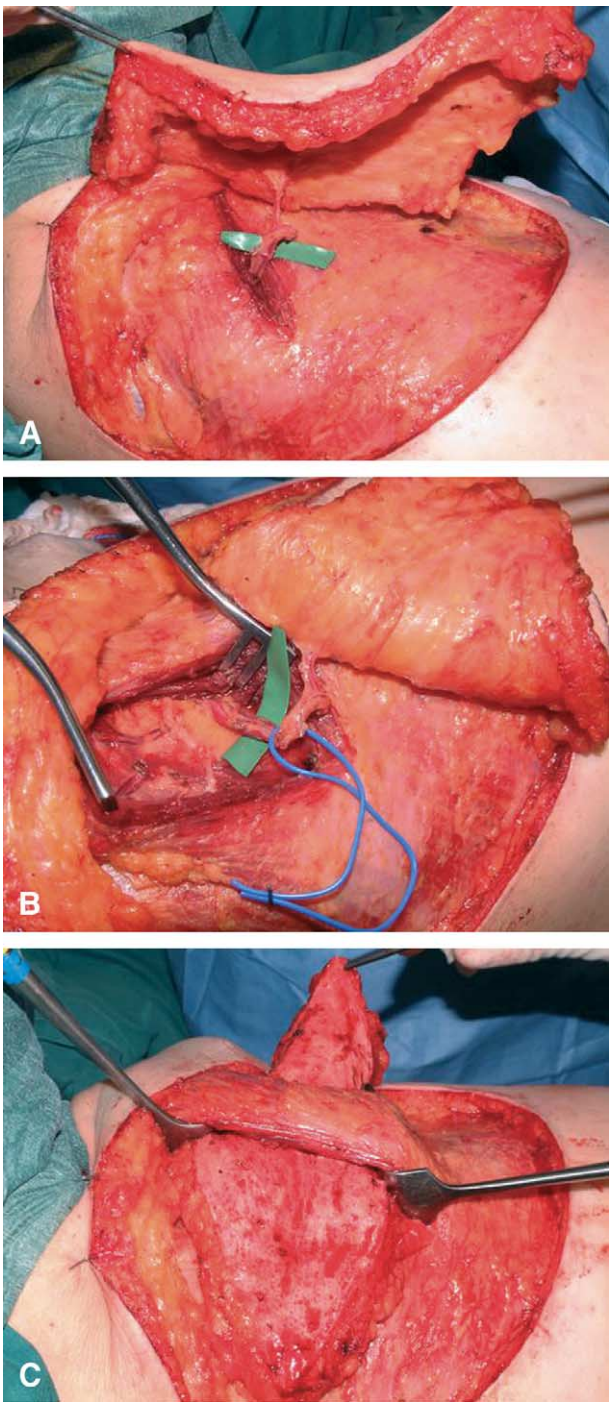


Figure 3 Shows the surgical technique of TDAP flap harvesting. (A) The perforator is dissected from the LD muscle. (B) The LD muscle is split and the perforator is dissected until the main pedicle. The TD nerve is preserved. (C) The TDAP flap was de-epithelialized and passed through the split LD muscle to the breast defect.

intercostal perforator flap, to make it a sensate flap. Dissecting the pedicle within the periosteum under the rib may make the pedicle longer but it has more technical difficulties with a potential risk of a pneumothorax.

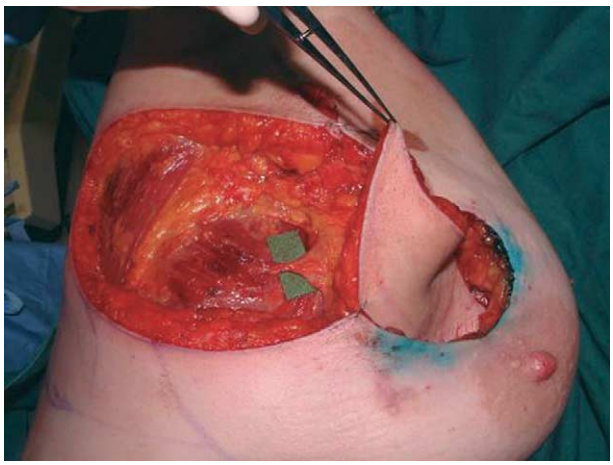


Figure 4 Shows an ICAP flap transposed for a lateral breast defect.

Muscle-sparing latissimus dorsi (MS-LD) flap

When tiny but pulsating, perforators are found, a muscle-sparing technique (MS-LD I) is used to harvest the flap with a 4×2 cm LD muscle piece. In this case, the perforators will be dissected within the split LD muscle but not from that muscular part which is included in the flap, so that the perforators are still attached to the LD segment. This requires direct visualisation of the perforators in order not to damage them during harvesting the muscular segment. Only a small nerve branch to muscle is sacrificed (Fig. 1(D)). The (MS-LD I) enables the surgeon a safer harvesting of the flap in these specific cases.

If the perforators are very tiny and nonpulsating, then the flap should be converted to (MS-LD II) flap in order to incorporate a maximum number of perforators within the flap. The nerve that innervates the rest of the LD muscle is always preserved (Fig. 1(E)). If most of the LD muscle is harvested, the flap is dissected as a MS-LD III flap (Fig. 1(F)).

The donor site is always closed primarily. Two drains are left under the skin. The patient is again placed into supine position and the flap is used to fill the defect in order to provide the best breast symmetry. The flap is partially or totally de-epithelialised depending on the nature of the defect (Figs. 5 and 6). The flap can also be folded into fit the defect. However, tension-free flap siting is mandatory in all cases to avoid rupture of the perforator. In the case of complete de-epithelialisation of the flap, a small skin paddle can be left at the recipient site for monitoring. This skin paddle is excised under local anesthetisia on the 5th post-operative day. All patients receive Nootropil® (Piracetam) 12 g/24 h IV for 5 days and as a solution 20% orally 25 cc q.i.d for another 5 days. This increases the viability of the distal portion of skin flaps due to an increase of the capillary blood flow.[8]

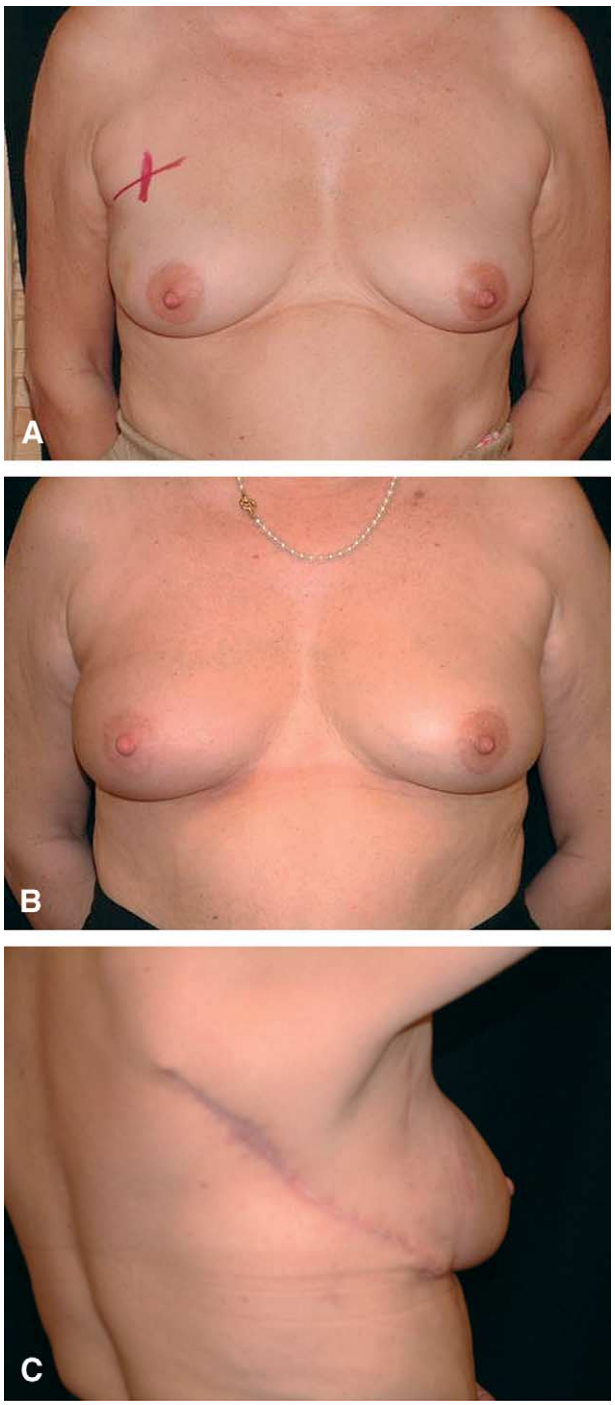


Figure 5 A patient who had a qudrantectomy for a breast cancer of the supero-lateral quadrant of the right breast reconstructed with a completely de-epithelialised TDAP based on one perforator as show in Fig. 3. (A) Pre-operative view, (B) the result of the partial breast reconstruction with good contour and breast symmetry and (c) the donor site.

Results

Thirty-one patients were operated on using the algorithm described above for pedicled flaps. One patient had bilateral TDAP flaps. The flaps' characteristics are summarised in Table 2. The average flap size was 20 × 8 cm (range of length 16–25 and width 6–10 cm). Perforator flaps were harvested in 21 cases (66%). These perforator flaps were based on one perforator in 13 cases and on two perforators in five cases. A small piece of LD was incorporated in the flap (MS-LD I) to protect the perforators in five cases (16%). In another three cases (9%), perforator flaps could not be harvested because suitable perforators could not be found. These flaps were dissected as (MS-LD II) flaps. In addition, one flap was converted into a LD musculocutaneous flap because of a technical error; and in another case the LD muscle was included to have more volume (SM-LD III). A parascapular flap was dissected for a lateral breast defect in one patient on finding a large descending branch of the circumflex vessels during flap dissection. The mean operative time was 2.5 h (range 1.5–3 h) depending on the dissection of the perforator but also on the shaping of the breast. Partial flap necrosis occurred in two cases of muscle sparing LD flap (one MS I and one MS II). Both necessitated a surgical debridement and direct closure. A small skin slough occurred in one TAP flap that healed spontaneously. Minor wound dehiscence in the donor site occurred in two patients (6%). Seroma formation in the donor site was encountered in three cases of converted TDAP to flaps but in no case of perforator flap (0 out 21 cases).

Discussion

Angrigiani[1] described harvesting the skin paddle of the traditional LD musculocutaneous flap based on a single perforator of the thoracodorsal artery without the LD muscle. In this technique, a flap with dimensions of up to 25 × 15 cm can be raised safely with a long pedicle because the dissected perforator increases the length of the TD pedicle by 3–5 cm.[1–4,7] The main advantage of the TDAP flap is the sparing of the LD muscle, which results in less donor site morbidity. The TDAP flap has not gained wide popularity compared to other perforator flaps for a variety of different reasons. Firstly, there are few adequate perforators on which the flap may be raised in contrast to other perforator flaps such as the deep inferior epigastric perforator (DIEP) flap.[1,4,7] Secondly, the distribution of these perforators has been investigated in only a few anatomical studies.[1,7] Consequently, the location and distribution of these perforators have not been adequately described.

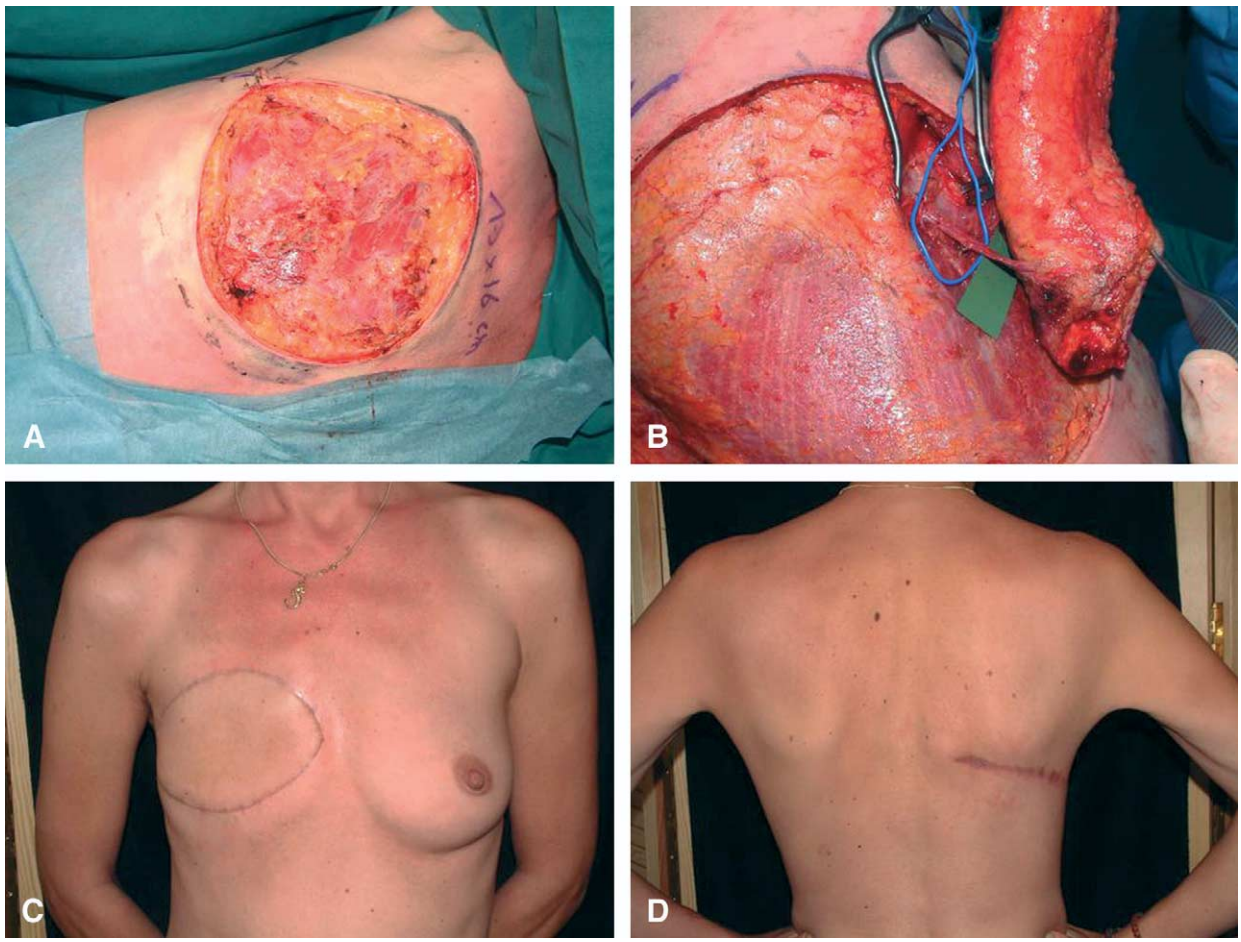


Figure 6 Shows a patient who had an extensive mastectomy for a large tumour. (A) Preoperative view, (B) a 20 × 10 cm TDAP flap was harvested based on one perforator, (C) the result of the thoracic reconstruction and (D) the donor site.

Using the Duplex to locate the perforators is not accurate enough because it is difficult to distinguish between the signal of a perforator and the main pedicle due to the relatively thin layer of the subcutaneous tissue.[9] Thirdly, the dissection of the perforators of the TDAP flap has been described as tedious because of the small diameter and their close relationship to the TD nerve branches.[4] Fourthly, venous drainage of the TDAP flap is described as poor and insufficient.[4] In addition, many surgeons will argue about the advantages of the TDAP flap over the parascapular flap since both flaps are almost on the same territory. Finally, there are no large well-designed studies that show a significant donor site morbidity after harvesting LD flap in order to justify the switch to a perforator flap which is much more technically demanding than harvesting the classical LD musculocutaneous flap.

This paper addresses some of these points using our current clinical experience and we have tried to make this technique more safe and reliable. We extended our experience with TDAP free flaps in

Table 2 The complications are summarized as related to different pedicled flaps

Type of flap	No. (%)	Partial necrosis of the flap	Seroma formation	Wound dehiscence at donor site
TDAP	18 (56)	1 (5.5%)	0 (0%)	1 (5.5%)
ICAP	3 (9.5)	0 (0%)	0 (0%)	0 (0%)
SM-LD I	5 (16)	0 (0%)	1 (20%)	1 (20%)
SM-LD II	3 (9.5)	1 (33%)	1 (33%)	0 (0%)
SM-LD III	2 (6)	1 (50%)	2 (50%)	0 (0%)
Parascapular	1 (3)	0 (0%)	0 (0%)	0 (0%)

trauma cases[2,3] to its use to breast surgery, as a pedicled flap. During, the last three years, every patient requiring quadrantectomy, which would have resulted in unacceptable aesthetic results or which would have led to a mastectomy was eligible for immediate partial breast reconstruction with a pedicled flap. In addition, we included patients who were candidates for thoracic reconstruction. The flap was always designed similarly to the traditional LD musculocutaneous flap. The Doppler examination was done with the patient lying in a lateral position, similar to that during surgery, with a 90° abducted arm. This facilitated the location of the perforator and seemed to improve the signal as reported also by Schwabbeger et al.[4] The accuracy of this method was up to 90% of the cases. The perforators were found to be based on the vertical branch of the thoracodorsal vessels in all cases within 5 cm from the anterior border of the LD muscle and between 7 and 10 cm from the posterior axillary line. This confirms findings of previous studies, which reported a dominant row of perforators extending along a line overlying the descending or vertical branch of thoracodorsal artery at 6–8 cm from the posterior axillary line close to the anterior border of the LD muscle.[1,7] Harvesting of the flap was easy and predictable when the correct perforator was chosen, the dissection done methodically, and with the right instruments. Microsurgical instruments and fine forceps were valuable in dissecting the perforator flaps. Perforator flaps could be harvested in two thirds of our patients when we used the suggested algorithm in choosing the blood supply to the flap. Raising the flap from medial to lateral and from distal to cranial allowed us to explore the Doppler-marked perforator. Every good perforator can be the pedicle of a perforator flap. The flaps we used have different advantages and disadvantages when compared to each other. Although, the dissection of a parascapular flap seems much easier than that of a perforator flap, the TDAP's pedicle is 4–5 cm longer. The parascapular flap has been used mainly for shoulder defects or axillary contractures and[10] it is only suitable to cover the lateral side of the breast. The parascapular flap cannot reach the other quadrants or the retro-areolar region because of the short pedicle. In addition, the pedicle of the TDAP flap has a vertical entrance to the subcutaneous tissue, which makes flap insetting and breast contouring easier. The parascapular flap must be designed more vertically and cranially on the back and this precludes the inclusion of the most fatty region of the back, which is usually located more distal.

Converting a perforator flap into a muscle sparing LD musculocutaneous flap should be performed, whenever the perforators are too small or nonpulsating. We had a partial necrosis in two flaps of converted perforator-to-LD flap because of a delayed decision to switch to the musculocutanous flap. Both patients were also smokers, and we could not locate any perforator with the Doppler preoperatively. This can be interpreted as an index of insufficient perforators and the flap should be harvested directly as a muscle-sparing LD flap.

Insufficient venous drainage, which leads to a total congested flap, was not observed in pedicled TDAP flaps in our current study. However, leeches were required in two of the converted TDAP to (SM-LD II) flaps and in two of the (MS-LD III) flaps in order to promote venous drainage in the distal part of the flap. Two of them were recovered completely and partial necrosis resulted in the other two. Venous congestion occurred in some of the free TDAP flaps. Most TDAP flaps turn red after harvesting, which means hypervascularisation more than venous congestion and they have a normal colour the following day. The orientation of the TDAP flap can influence the venous drainage but this is certainly not the only explanation. In a free TDAP flap, the skin paddle was always designed vertically along the anterior border of the LD muscle. In this series, pedicled TDAP flaps were mostly oriented parallel to skin lines with the tip towards the scapula angle within the related angiosome area, which is parallel to the ribs in this area as described by Taylor.[11] Additional studies are required to better understand the physiology of perforator flaps.

Harvesting a LD muscle induces the most common early complication at the donor site, which is seroma formation reported as high as 60–80% of cases.[12–15] None of our patients who had reconstruction with perforator flaps experienced this complication because of the elimination of dead space by the muscle conservation. The donor site morbidity after raising a TDAP flap is decreased to an absolute minimum since the LD muscle is intact with its motor innervation. However, it is hard to show a significant permanent functional defect of the shoulder after harvesting the latissimus dorsi muscle due to compensation by the other muscles around the shoulder.[12] Salmi et al.[14] did show that shoulder extension strength deteriorated permanently after part of the LD muscle had been removed despite minimal subjective morbidity. We still believe that the sacrifice of such a large muscle is not without any consequences. Prospective functional study is needed to confirm objectively the benefit of LD sparing.

The intercostal flap has been used as pedicled or free flaps.[16–18]. However, its use in breast surgery

has not been described yet. Its pedicle is 4–5 cm but it can be dissected within the intercostal muscles to obtain a longer pedicle.[18] This flap is of great value for lateral defects of the breast because it is very easy to raise and it can be transferred as a sensate flap. The anatomical description of these perforators is not clear. Nevertheless, those perforators can be found in front of the LD muscle and they can be dissected to include a skin flap that can be transferred as a transposition flap or turned 90 or 180°. It has a major advantage as it can be transferred as a sensate flap to the breast. The ICP flap is most suitable for defects in the lateral quadrants. Dissecting the intercostal vessels in the costal groove gives a longer pedicle resulting in more flap mobility to reach more distal defects in the breast but this dissection is quite difficult because of the adherent vessels to the periosteum and care must be taken to not damage the vessels.

The pedicled perforator flap is a new addition to breast surgery. Beside its functional benefit due to the minimal donor site morbidity, it gives advantages in flap shaping and consequently better aesthetic results and higher patient satisfaction. The algorithm described above is based on the perforator concept and allows the surgeon the freedom to select, tailor or compose the flap independent of the limited indications of conventional flaps.

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