Review Article

The propeller thoracodorsal artery perforator flap—designs for breast reconstruction and perspectives

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Abstract: The propeller thoracodorsal artery perforator flap (pTDAP) is a further development and simpler version of the classic TDAP pioneered by Angrigiani C in 1995. The pTDAP can be used for immediate and delayed breast reconstruction in combination with an implant, fat grafting or in combination with other perforator flaps as an alternative to the latissimus dorsi flap. The pTDAP breast reconstruction can be performed and designed in several different ways regarding: (I) flap design, (II) axilla design and (III) breast design. The aim of this paper is to describe and illustrate different pTDAP designs and perspectives. We present the indications for use of the propeller TDAP in delayed as well as immediate breast reconstruction. The TDAP can be harvested from the back in various ways, horizontal and two different oblique techniques, upwards and downwards angled. The flap can be raised as an extended flap to include as much subcutaneous fat adjacent to the skin island as possible, either in the entire length of the flap or as the "Saturn"-design. The location of the dominant perforator(s) is predictable in most cases, but variations due occur and flap harvest can preferably be targeted by color Doppler ultrasonography for perforator identification. The propeller flap pedicle can be tunneled or left visible below/in the axilla. The flap can be augmented by an expander/direct to implant technique or combined with fat grafting or other perforator flaps, an internal mammary perforator flap from the contralateral breast, a superior epigastric artery perforator (SEAP) flap or with a free TDAP as stacked flaps. The pTDAP can and should be designed, targeted and adapted to the individual patient when used for breast reconstruction. This entails the flap size and shape in the back, the choice and use of perforators, the design and rotation in the axilla and the breast reconstruction when using the flap for augmentation, shaping and draping using expanders, implants, fat grafting or in combined with other flaps.

Keywords: Thoracodorsal artery perforator flap (TDAP); propeller flap; breast reconstruction; perforator

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The latissimus dorsi flap without muscle or the thoracodorsal artery perforator (TDAP) flap was introduced by Angrigiani in 1995 (1). This was the first time the TDAP flap was used for breast reconstruction. The TDAP in one variant from a range of TDAP flaps: (I) the extended lattisimus dorsi flap (ELD), (II) the latissimus dorsi flap (LD), (III) the muscle sparing latissimus dorsi flap (MSLD), (IV) the propeller thoracodorsal artery perforator flap (pTDAP) and (V) the classic thoracodorsal artery perforator flap (cTDAP). The different indications for use of these flaps in breast reconstruction have recently been described as well as the different designs of these flaps (2). The pTDAP itself can be designed in many different ways, the location, orientation and size and outline of the skin island. The rotation/

tranposition of the pedicle as well as ways to use the flap for shaping, draping and augmentation in the recipient site can also be designed in multitude of different ways. The pTDAP is often used instead of the LD flap for breast reconstruction to leave the upper body's largest muscle intact and to avoid the possible morbidity of the shoulder and arm associated with the use of the LD muscle (3,4). The indications for using the pTDAP flap for breast reconstruction is similar to the indications for using the LD flap (2,5). The flaps can be used for both immediate and delayed breast reconstructions and often in women who previously had radiation therapy to the chest, where the damaged unpliable skin and subcutis can be replaced by the more pliable flap tissue, which enables a better cosmetic and functional result in the long run (6). The aim of this paper is to describe and illustrate different pTDAP flap designs for breast reconstruction and the perspectives.

Indication for breast reconstruction

Delayed breast reconstruction

The pTDAP is used to add extra tissue to enable the breast reconstruction and often in combination with an implant. The skin and subcutis or the remainders of the mastectomy flap in the anterior part of the thorax is raised as a musculocutaneous flap with the pectoralis major muscle. In a few cases, where the subcutis is particularly thick or if the radiation damage to the muscle is severe, the flap can be raised as a cutaneous flap without muscle (6-8). The two flaps are combined to shape and drape the reconstruction.

Immediate breast reconstruction

In women who previously have had radiation therapy in combination with a lumpectomy, the skin of the lower quadrants is often removed after the mastectomy or as part of the mastectomy specimen. The aim is to replace the tissue damaged by radiation therapy by the pliable tissue of the pTDAP (6). It sometime seems odd to excise skin and tissue which at a first glance seems unaffected by radiation, but there is a substantial risk of capsular contracture in cases, where the damaged breast skin in not replaced by pliable skin. The alternative to the pTDAP in these cases is multiple fat graftings of the radiated mastectomy flaps, however in many cases it is only a matter of time before the contractures calls for a flap solution.

The pTDAP can also be used for partial breast reconstruction or salvage of reconstructed breasts (6).

Designs

Overall, there are three steps to designing a breast using a pTDAP flap: (I) flap design, (II) axilla design and (III) breast design. The designs are described below.

Flap design

In unilateral cases the flap is raised with the patient in the lateral position. The flap can be raised simultaneously with dissection of the axilla and recipient site (7,9). In bilateral cases, the recipient site is prepared first with the patient in the supine position. The patient is then turned to the prone position to raise the flaps and subsequently turned once again to the supine position for the breast reconstruction (10).

The skin island for the TDAP flap is harvested from the back and can be designed in many different ways. The base of the skin island is marked above and around the perforator(s). The flap can be designed in various ways and in different angles, however, there are three main designs: (I) horizontal (H), (II) oblique upwards (OU) and (III) oblique downwards (OD) (9,11-14), *Figure 1A*.

The scars of the first two options, H and OU can be hidden under clothing, whereas the third option leaves a scar in the lower part of the back, which can be difficult to hide. The flaps of the H and OU designs have to be rotated 180° or more to the recipient site, whereas the OD design only needs to be rotated in angle of 120–135° (9,11,12,15). Thus, the pedicles of the H and OU designs needs to be dissected more thoroughly and often all the way through the muscle to enable relocation of the flap from the donor site to the recipient site (9,12,15). The flap length of the oblique flap designs, the OU and the OD, can be up to 35 cm long compared to 25 cm of the H design (11). However, this also means that the distal part of the OU/OD flaps can only be used if the blood supply is reliable, when tested by fluorescence using indocyanine green or similar techniques (16). The distal 5 cm of the tip of the flap often has to be removed due to insufficient perfusion (2). The size of the flap, thickness, width and length, depends on the size and proportions of the individual patient. In skinny patients, the flap width can usually only be 6–7 cm compared to 10–11 cm in larger patients. The lengths of the flaps may variate from 18 cm up to almost 40 cm in large patients (7). The thickness and amount of subcutaneous tissue to be harvested varies a lot depending on BMI and the looseness of the skin. The

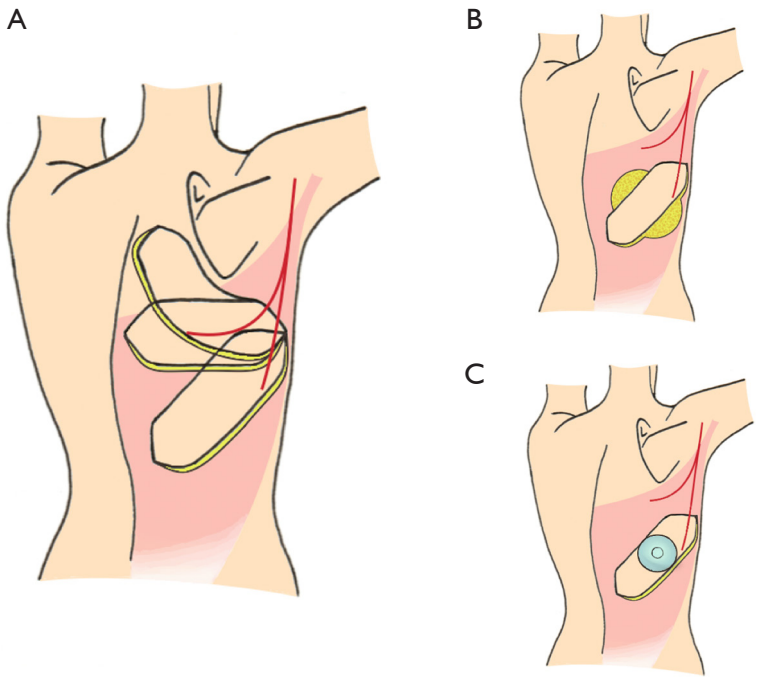

Figure 1 Designs of the pTDAP in the back. (A) The three main designs of the pTDAP flaps. (B) The extended Saturn design. (C) Expander placed under the pTDAP for preexpansion. pTDAP, propeller thoracodorsal artery perforator flap.

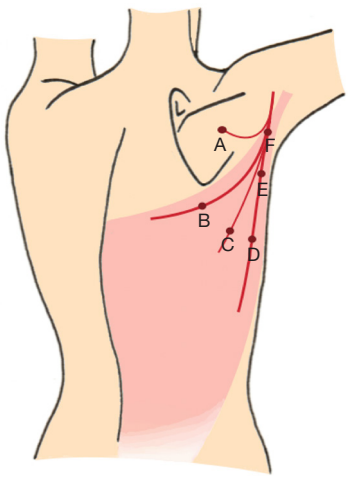

Figure 2 Location of TDA perforators. Perforators E and D are usually the dominant perforators. TDA, thoracodorsal artery.

largest flaps can be harvested in massive weight loss patients, where the tissue is often very loose and the perforators are relatively sizable compared to patients who have not lost weight. The flaps can be harvested as extended flaps including as much of the subcutaneous tissue under and adjacent to the skin island as possible (6,17,18). This can be designed in different ways, however in many patients the location of the subcutaneous fatty tissue allows for a "Saturn" design of the flap as illustrated in *Figure 1B*. The harvest of the subcutaneous tissue is often limited by the fascia of Scarpae, which should preferably be saved for closure of the donor site. Maybe this limitation can be overcome by pre-expansion, *Figure 1C*.

Raising the flap from the tip towards the base can be recommended using a scalpel in combination with bipolar cautery or a monopolar cautery. The skin is incised and bevelled outwards in the subcutis to add additional subcutaneous tissue to the flap volume if possible and necessary (7-9,14). The flap can be raised with or without the muscle fascia. The thickness of the muscle fascia variates and is often very thin almost as an epimysium. The argument for leaving the fascia intact is allegedly less seroma formation, however, regardless of the design there is no need for drains in the donor site as there is hardly any seroma formation (7). The advantage of raising the flap with the fascia is that it can be used to drape the implant when performing the reconstruction. The first three quarters of the flap can be raised very quickly until a close proximity to the perforators is reached (*Figure 2*), unless

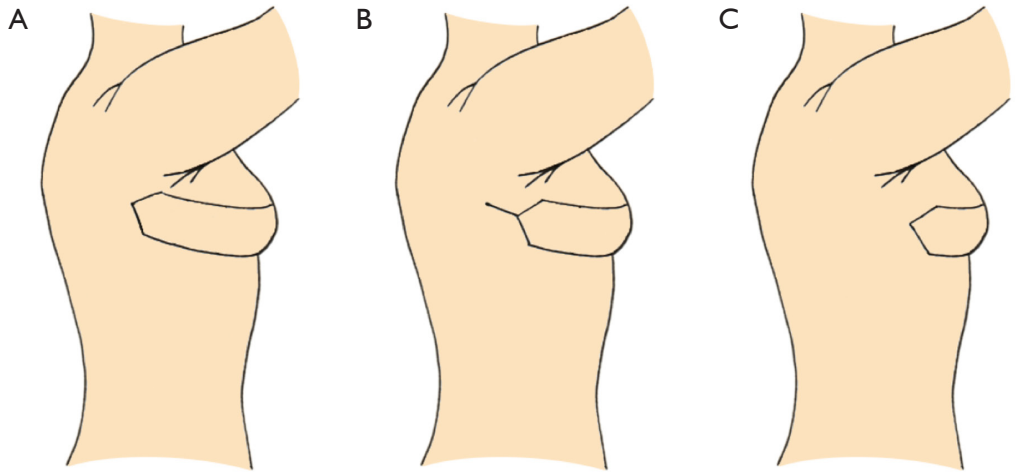

Figure 3 Axilla designs. (A) Simple rotation and base of flap visible. (B) VY design. (C) Base of flap tunneled.

preoperative color Doppler ultrasound has revealed a sizable perforator outside the usual location (A, B, C in *Figure 2*). In the majority of cases the dominant perforator(s) will be located close to the anterior border of the latissimus dorsi muscle (E in *Figure 2*). However, the location and the size of the perforator variate and preoperative color Doppler ultrasound is recommended for identification of the perforators (6,10,19,20). In the majority of cases there are one to two sizeable perforators located at the most prominating anterior part of the LD muscle, approximately 8–12 cm from the top of the axilla and 3–5 cm from the anterior border of the LD muscle (7,9) (D, E in *Figure 2*). The dominant perforator(s) can be located more distal along the descending or the horizontal branches of the TDA. Sometimes the dominant perforator can be placed in unexpected locations due to scars, which has redirected the original blod flow to the skin (2) (A, B, C in *Figure 2*). In these cases, the CDU is a very good tool for a targeted approach (19). Once in a while there are no obvious dominant perforator and three or more smaller perforators have to be included in the flap pedicle (21).

The flap area can be expanded in the back using an expander (*Figure 1C*), which has not been described for breast reconstruction, but for coverage of severe scarring in the cervicofacial regions (22). However, this could also be an option for breast reconstruction in patients with damaged or very thin skin in the recipient site.

The donor site is closed in three layers using absorbable sutures adapting the fascia of scarpae, the deep dermis and the subcutis. No drains are needed (7).

Axilla design

The pedicle of the pTDAP can be placed and designed in different ways depending on the location of the perforators.

(I) In patients where the perforator(s) is located 5–7 cm or more behind the anterior edge of the LD muscle and if the skin in the axilla is tight it is often advantageous to incise the skin between the flap and the recipient site and simply place the base of the flap in the gap to release the tight skin in the axilla and to ensure unaffected blood perfusion through the flap (10) (*Figure 3A*). Another reason for this approach is that the base of the flap can sometimes be quite bulky and difficult to cover by the axillary skin. The procedure not only releases the tight axillary skin, but also makes the donor site closure easier simply by providing more skin for the axilla and adjacent area, which can be somewhat tight when harvesting a big flap from the back.

(II) In cases where the perforator(s) perforates the muscle 3–4 cm behind the anterior edge of the LD muscle, the base of the pTDAP flap above the perforators can be deepithelialized and covered by the adjacent axillary skin (8,14). Often the skin is incised all the way from the flap to the recipient site and subsequently, when you know how much tissue is at hand the posterior base of the flap can be covered by the adjacent axillary skin in a VY manner (*Figure 3B*).

(III) When the perforator(s) is located anterior to or close the anterior edge of the LD muscle, the

pTDAP can be tunneled under the axillary skin to the recipient site (*Figure 3C*). The tunneled base of the TDAP flap can be used to replace the missing tissue in the axilla of women who had an axillary lymph node dissection (7,14). The added tissue often leaves a satisfying cosmetic as well as functional result as the scar tissue following the axillary procedure is removed and released as part of the procedure. This often enables better movement of the shoulder and arm as perceived by the patient.

The axillary skin and base of the TDAP flap will loosen over time and in approximately 50% of cases a lateral liposuction, shape and drape procedure is needed to debulk and tighten the tissue lateral to the reconstructed breast (6,7).

Breast design

The patient is placed in the supine position for breast reconstruction. In delayed breast reconstructions, the pTDAP flap can be placed where the scar was placed following mastectomy. However, the scar is often placed quite cranially and when the relatively thick pTDAP flap is placed in the middle of the breast reconstruction with a thin tissue layer bordering both sides of the flap, this often leaves a rather abrupt transition from the mastectomy flaps to the pTDAP flap simply due to the differences in flap thickness (8,14). This can successfully be corrected by several additional fat grafting procedures (23).

However, the pTDAP flap can also be placed in the neo-inframammary crease, where it is much easier to make a smooth transition for pTDAP flap to mastectomy flap (7,10,18). The mastectomy flap is raised as a musculocutaneous flap with the major pectoralis muscle, which makes the thickness of the flap similar to the pTDAP and the extended subcutis of the pTDAP flap can be used to shape a smoother transition between the flaps (7). In cases where the mastectomy scar is placed in the lower part of the chest, the skin between the neo-inframammary crease and the mastectomy scar can be removed to avoid a third scar. However, when the scar is placed more cranially, the skin is needed for the breast reconstruction leaving three scars, the mastectomy scar, the cranial pTDAP scar and the caudal pTDAP/neo-inframammary crease scar. The latter procedure enables the best possibility for shaping and draping the reconstructed breast and eventually the best cosmetic result despite the additional third scar. There is a risk of insufficient blood supply to the mastectomy skin below the mastectomy scar. In a few cases, we have had to remove this skin in a secondary procedure.

Shaping and augmentation of the pTDAP breast reconstruction

Direct to implant

In many cases the pTDAP flap can be immediately combined with a permanent implant for breast reconstruction (8,9,24). The implant can be placed and supported in the desired location by use of a biologic or a synthetic mesh (8). In some cases, the extended fascia around the pTDAP flap can be used to support the implant and in those cases a mesh is not needed.

Expander to implant

In the last couple of years, we have increasingly used expanders for pTDAP reconstruction (10) (*Figure 4A*). One reason for this is that we are using the pTDAP for breast reconstruction in patients with lower BMIs, where an expander seems to be the safer option to ensure sufficient blood supply. Another reason is that the expansion enables a sufficient and sizable cavity for a correct sized permanent implant (9,14,24,25). The majority of pTDAP reconstructions are, however, still reconstructed by a direct to implant technique using a permanent implant (*Figure 4B*).

Expander-fat

When a patient wishes a breast reconstruction with a pTDAP in combination with fat grafting, the fat augmentation can preferably be combined with an expansion using an expander for preshaping the breast prior to fat grafting (23,26). In the subsequent procedures the water volume of the expander is deflated simultaneously with fat grafting of a similar amount of fat replacing the water volume in the expander with fat injected into the tissue surrounding the expander. This enables better shaping of the reconstruction and also there seems be a better take of the transplantation fat as the loose preexpanded tissue seems more susceptible to the injected fat.

Internal mammary artery perforators (IMAP)

The implants alone, in combination with fat grafting or fat grafting alone has been the mainstay for augmenting

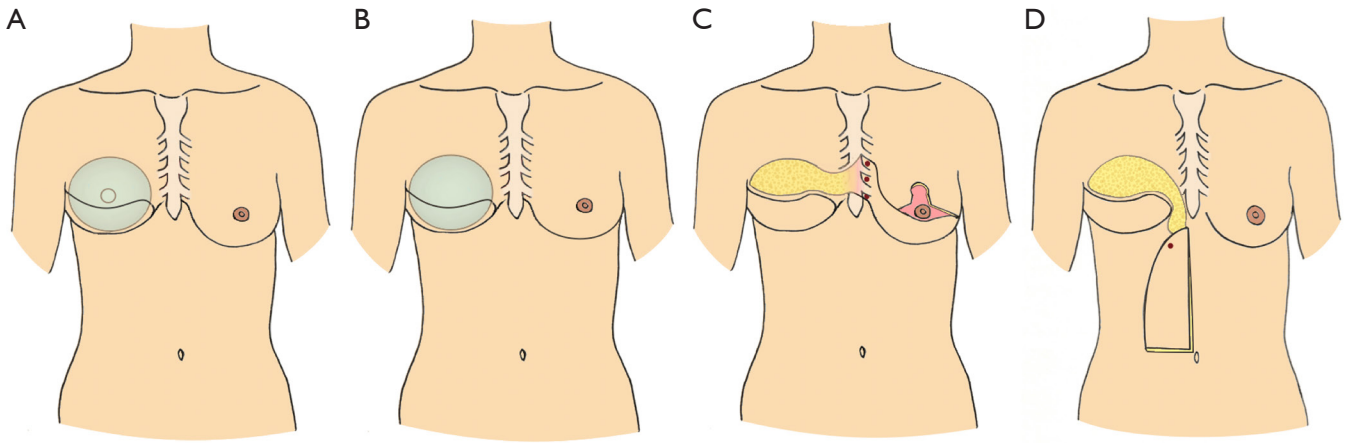

Figure 4 Design of the breast reconstruction. (A) Expander placed under flap. (B) Permanent implant placed under flap. (C) pTDAP flap combined with IMAP flap from the opposite breast. (D) pTDAP flap combined with SEAP flap from the abdomen. pTDAP, propeller thoracodorsal artery perforator flap; IMAP, internal mammary artery perforator; SEAP, superior epigastric artery perforator.

the breasts reconstructed with pTDAP flaps. However, there are other novel options, which can also be used. The pTDAP can be combined with other flaps for augmentation and added volume.

In unilateral breast reconstructions, where the patient has a large contralateral breast, which needs to be reduced, the deepithelialised skin and subcutis can be utilized as a flip over flap based on IMAPs (*Figure 4C*). This is only possible if a sizable perforator(s) can be identified in intercostal spaces of the caudal part of the sternum. Preoperative imaging, MRI, CDU and preferably a combination of these two imaging modalities is mandatory for preoperative identification of the perforators, which enables a targeted reconstructive procedure (19,20). When raising the IMAP flap consisting of skin and subcutaneous fat, the plastic surgeon has to be experienced in finding the correct dissection plane between the glandular tissue and the subcutaneous tissue (27). The procedure is not intended to be a breast-sharing technique, but rather to use a cutaneous flap for augmentation in order to avoid transposition of glandular tissue from one breast to the other. The flap perfusion needs to be examined by indocyanine green to ensure sufficient blood flow in the distal part of the IMAP flap prior to tunneling of the flap to the recipient site (16). The flap can be placed and used for augmentation of the cranial part of the breast reconstruction and the shaping of the flap can be supported by a reabsorbable mesh. The combined pTDAP/IMAP flaps can be augmented further by fat grafting in subsequent procedure(s) along with the lateral correction of the pTDAP pedicle (7,23). A total of 3–4 fat graftings should be anticipated, when using this approach. The bulkiness of the pedicles of both the TDAP and IMAP flaps needs to be corrected by liposuction in one of these subsequent procedures to finalize and shape the reconstruction and areas adjacent to the reconstruction.

Superior epigastric artery perforator (SEAP)

In patients with abundant loose abdominal subcutaneous tissue, who are candidates for a vertical abdominoplasty, the vertical SEAP flap can be used to augment the breast reconstruction in combination with pTDAP flap (*Figure 4D*). The location and size of the SEAP perforator has to be confirmed by CDU prior to surgery for a targeted procedure (19,20). The length of the flap goes from a couple of centimetres above the xiphoid process to 3–5 cm cranial to the umbilicus and the width from the midline and laterally based on a pinch test using the usual markup for a vertical abdominoplasty. The perfusion has to be checked by ICG prior to tunneling of the flap to the recipient site (16). The combined TDAP/SEAP flaps needs to be augmented by fat grafting, shaped and corrected in the same manner as the TDAP/IMAP flaps (6,7,23).

Free TDAP

The pTDAP can also be combined with a free TDAP as stacked flaps breast reconstruction (2).

Perspectives

We expect that the use of the pTDAP in combination with expanders, implants and fat for breast reconstruction will increase in the years to come. We also expect to see an increase in the use of combined flaps from the thorax, pTDAP, IMAP and SEAP, for breast reconstruction in a selected group of patients. Preexpansion of the pTDAP in the back prior to breast reconstruction is also an obvious possibility in selected cases.

Conclusions

The pTDAP can and should be designed, targeted and adapted to the individual patient when used for breast reconstruction. This entails the flap size and shape in the back, the choice and use of perforators, the design and rotation in the axilla and the breast reconstruction when using the flap for augmentation, shaping and draping using expanders, implants, fat grafting or in combined with other flaps.

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