Soft tissue reconstruction with the superior gluteal artery perforator flap

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Perforator flaps are one of the most recent developments in reconstructive microsurgery. In the last few years they have revolutionized our opinions on flap harvesting. Perforator flaps are harvested from the same donor sites as the conventional myocutaneous flaps, but the goal is to harvest only a (sensory) skin and fat paddle. The underlying muscle that usually was harvested, completely or partially, with the skin and subcutaneous fat, with the thought that the muscle would protect the vascular pedicle, is split longitudinally in the direction of the muscle fibers. One or several transmuscular perforating vessels that provide blood flow to the subdermal plexus of the skin island are dissected from between the muscle fibers until larger axial vessels are reached. The perforator itself can be cut before entering the axial vessels if an anastomosis to small recipient vessels is preferred; generally, the main vessels are followed and cut further on to increase vessel diameter, pedicle length, and flexibility during shaping. By meticulous dissection, the motor nerves and the collateral blood circulation of the remaining muscle are carefully preserved so that the muscle’s function is not affected.

The superior gluteal artery perforator (SGAP) flap is the descendant of the traditional gluteus maximus myocutaneous flap [1]. The latter flap, based either on the superior or inferior gluteal artery, did not gain much popularity because of its drawbacks. Surgical exposure of the donor vessels is difficult, the vascular pedicle is short, and the flap dissection is difficult and may result in injury to the adjacent sciatic nerve. Pain and paresthesias following exposure of the sciatic nerve after flap harvesting are disturbing complications. Partial resection of the gluteus maximus muscle can eventually result in weakness of muscle function in abduction and extension of the thigh, depending on the level of activities of the patient.

Koshima et al [2] first described the pedicled SGAP flap for the use in pressure sore treatment. The flap was based on multiple perforators, including the parasacral perforators, which allowed only a limited transposition maneuver. Allen and Tucker [3] reported the use of the free SGAP flap in breast reconstruction. Shortly thereafter, our group reported on the use of the pedicled SGAP for sacral pressure sores [4]. This time, the flap was isolated on one single perforator which allowed a combination of transposition and rotation, and provided a much longer range of flap movement. In 1999, the sensory innervation of the flap was described and the advantages of the use of the flap as an alternative in breast reconstruction was reconfirmed [5,6].

Based on a single perforator, it is possible to raise skin flaps of up to 30 cm by 13 cm with a pedicle length of 6 cm to 10.5 cm, and leave behind an anatomically and functionally intact muscle [4,6]. Flap dimensions are limited by the possibility of primary closure of the donor site, rather than by vascularization of the flap.

This article describes the indications for which we have been using the SGAP flap, the surgical technique to harvest the flap, the advantages, and disadvantages.
Flap harvesting: surgical technique

The relatively constant anatomy of the superior gluteal artery and the small number of perforators that cross the fascia perpendicularly, make it easy to preoperatively identify the location of the perforators by unidirectional Doppler flowmetry. Preoperatively, the location where the superior gluteal artery exits the suprapiriform foramen is marked on the skin at the proximal one third of a line that connects the posterior superior iliac spine and the apex of the greater trochanter. The position of the piriform muscle is located by connecting the middle of a line between the posterior superior iliac spine and the coccyx with the superior edge of the greater trochanter of the femur (Fig. 1A). The main perforators are localized by unidirectional Doppler flowmetry in an area above the piriform muscle, laterodistally to the exit point of the superior gluteal artery and parallel to the first line.

A fusiform skin island is drawn over the perforators (Fig. 1B). In the treatment of pressure sores, triangular-shaped flaps can sometimes be used combined with V-Y advancement and closure.

The axis of the skin island can be positioned in any direction over the identified perforators but will be strongly influenced by skin tension during donor site closure. This means that for larger flaps, a horizontal or slightly oblique (from medio-caudal to laterocranial) position is preferred (see Fig. 1B). This allows easy closure, even with a certain amount of lifting of the buttock and without too much residual contour deformity. Specifically, in breast reconstruction, the slightly more horizontal-oblique positioning of the flap will provide a scar that can be completely hidden by normal underwear.

Harvesting is performed with the patient in either the lateral decubitus or prone position, depending on the indication. Harvesting of the flap starts laterocranially. After incising the skin and the analog of Scarpa’s fascia at this part of the body, the nervi cluni superiores can be identified at the superior edge of the flap, above the muscle fascia. If these nerves are large enough to be identified and dissected, they can be included in the flap. The number, course, and branching of these nerves are variable, and, in general, the more distally the flap is harvested, the greater the chance that the nerves have split into undetectable small side branches. Nevertheless, in cases where the nerve can be isolated, it can be dissected more cranially on top of the deep fascia, often accompanied by a small blood vessel. Above the crista iliaca, the sensory nerve pierces the deep fascia. The origin of these nerves is the posterior rami of the intercostal nerves from T12 to L2 [6].

Undermining of the flap and the search for the perforator starts at the most laterocranial part of the flap. At this point, the gluteus medius muscle should not be mistaken for the gluteus maximus muscle. The gluteus medius muscle can be discerned by the more vertical orientation of its fibers. After the superior border of the gluteus maximus muscle is reached, dissection proceeds above the muscle fascia parallel to the direction of the gluteus maximus muscle fibers. When the dissection approaches the area where the perforator pierces through the fascia, previously marked by the preoperative Doppler, the muscle fascia is incised and the dissection continues on top of the muscle. The individual perimysia that run parallel with the muscle fibers and connect with the overlying fascia are transected one by one.

After a suitable perforator is encountered (the more lateral the perforator, the longer the pedicle), muscle fibers around it are split longitudinally to expose the perforator (Fig. 2A). Wide exposure and a bloodless dissection are two extremely important points in the dissection of any type of perforator flap; this is also true for the dissection of the SGAP flap. The muscle fibers of the gluteus maximus need to be split longitudinally, along the epimysium that embraces the perforating vessels, from the sacrum down to the distal tendinous part of the muscle just above the trochanter. This wide exposure permits easy dissection of the perforator and avoids working in a small hole with poor visibility. The muscle is split all the way down to its anterior surface. In the more anterior part, small motor branches are often observed that easily can be preserved because they are some distance from the perforator itself. After opening the muscle, the perforator can be seen running within the epimysium. The epimysium is cut at both sides parallel to the perforator, and all of the side branches are ligated carefully (Fig. 2B). Attention must also be paid to the small side branches on the backside of the perforator. Lifting the perforator with a vessel loop is helpful. Alternatively, the entire flap can be flipped laterally to obtain good exposure of the perforator from a medial point of view.

The dissection continues down to the anterior fascia of the gluteus maximus muscle. This is a strong, and often thick, distinctive structure through which the vessels perforate. If the size and length of the perforators are acceptable at this point, the vessels can be cut if a free flap is harvested. More often, larger or longer vessels are preferred and dissection has to be continued below the anterior fascia. This fascia is opened, once again paying attention to wide exposure of this area (Fig. 2C). Soon, many large side branches will be encountered that come from all directions. After clearing off the loose fat tissue around these
Fig. 1. (A) Markings of the anatomical landmarks and localization of the perforators. The dotted lines delineate the area where main perforators of the superior gluteal artery (SGA) can be expected. PIS, posterior iliac spine; TROCH, trochanter; X, location of a major perforator. (B) Positioning of the skin paddle in case of a free SGAP breast reconstruction.
vessels, the main gluteal vessels are exposed. A decision has to be made about where to cut the vessels (in case of a free flap). Two points influence this. First, depending on the size of the recipient vessels, comparable vessel diameters will try to be obtained. Second, a segment of artery and vein without any side branches over a distance of 4 mm to 5 mm is identified to facilitate later microanastomoses.

In the case of a pedicled flap, it must be decided if dissecting the area in front of the anterior fascia will add significantly more mobility to the flap. The plexus of side branches is often close to the apertura piriformis; ligating these branches only will devascularize the area even more, which precludes the use of a gluteus maximus muscle flap in a later phase.

Donor site closure is started by undermining of the skin edges. Primarily, the distal skin flap is undermined to achieve a limited buttock lift. Undermining over the crista iliaca and trochanter is avoided, if possible, because this will interrupt important periostium-to-skin attachments and increase the risk of postoperative seroma formation. Deep sutures are placed on the superficial Scarpa-like fascia and skin closure is performed by a layer of resorbable subdermal stitches and 2-octyl cyanoacrylate (Dermabond, Ethicon Inc, New Brunswick, NJ) skin adhesive.

Indications

Breast reconstruction

Earlier, we described the free SGAP flap as a valuable second choice for autologous breast recon-

Fig. 2. Intraoperative view after (A) splitting the muscle along the epimysium, (B) incising the epimysium parallel to the perforator (arrow), and (C) opening the fascia anterior to the gluteus maximus muscle (arrow).
Fig. 2 (continued).
struction after the deep inferior epigastric perforator (DIEP) flap [6]. The SGAP flap can be used for total or partial breast reconstruction (Fig. 3) and is indicated in patients who have an asthenic body habitus or excessive abdominal scarring. An increasing number of patients present for breast reconstruction or autologous breast augmentation following liposuction of the abdomen or abdominoplasty. Patients who have a family history of breast cancer should carefully consider having these procedures at the abdominal wall, because this will eliminate an important option for breast reconstruction.

Although a single subcostal or midline scar is not a contraindication for DIEP flap harvesting, multiple abdominal scars following intra-abdominal surgery might pose such a risk for postoperative wound complications that one needs to resort to the SGAP flap. If a DIEP flap has already been harvested for previous breast cancer or after DIEP flap failure, the SGAP flap is a valuable alternative.

Currently, we will design the flap in a more horizontal position. Additionally, we will add a small fish tail at the medial tip of the flap to avoid dog-ear formation in the median gluteal crease (see Fig. 1B). Flaps are also designed to be longer, so that the breast can be shaped in the form of a hammock, with care taken to reconstruct the anterior axillary fold and the full width of the inframammary crease and breast. During flap harvesting, the patient is positioned in lateral decubitus with the arm of the affected side free.

Fig. 3. (A) Pre- and (B,C) postoperative images of a 51-year-old woman who underwent a secondary autologous breast reconstruction with a free SGAP flap following right subtotal mastectomy for invasive breast cancer.
Fig. 4. (A) Pre-, (B,C) intra-, and (D) postoperative images of 32-year-old man with a large sacral pressure sore that was treated with debridement and single stage closure with a pedicled SGAP flap.
and the upper body twisted back 60° to allow a simultaneous two-team approach to the donor and recipient sites.

The axillary vessels should not be used for SGAP breast reconstruction. Pedicle length is often insufficient and the establishment of the sentinel biopsy technique avoids exposure and dissection of axilla and thoracodorsal vessels. The preferred recipient vessels for the SGAP flap are either the perforators of the internal mammary vessels at the second or third intercostal space (perforator-to-perforator flap) or the internal mammary vessels themselves at the third or fourth costochondral junction. Perforators can be looked for either between skin and pectoralis muscle or between the rib cage and the pectoralis muscle.

After vessel microanastomosis, the patient is placed in the dorsal decubitus position and sat up to perform adequate shaping and achieve acceptable symmetry. Operating time ranges between 4 and 6 hours.

Dorsal pelvic area: sacrum

As a pedicled flap, the SGAP flap is an excellent tool to cover large sacral and gluteal defects [2,4]. The ischium can also be reached because of the long pedicle and the wide range of the flap, but the inferior gluteal artery perforator is probably a better choice to cover defects in that region [7]. The SGAP flap is particularly suited to reconstruct large sacral midline defects in one stage, especially in the nonplegic patient. Although a pedicled fasciocutaneous flap is the first choice for smaller defects, the SGAP flap is a step between these flaps and the myocutaneous flaps of that region. Because the SGAP flap preserves the vascularization to the gluteus maximus muscle, it eliminates less options than a myocutaneous flap and preserves the opportunity for later reconstructions with muscle or other flaps, if a recurrence should occur (Fig. 4).

The pedicled SGAP flap for sacral pressure sores is a good learning model for surgeons who have limited experience with perforator flaps. If this is the case, a conservative approach to the flap can be chosen. The upper border of the flap should be designed as a sector of an imaginary rotation flap, in which the flap could be reconverted if a dissection error is made during harvesting, or if no suitable perforator is encountered during the dissection. This provides the technique with an additional safety factor. The superior border of the flap is incised first, without beveling, through skin, subcutaneous tissue, and fascia to the muscle. From there, the flap is detached from the muscle, until the chosen perforator is encountered. Dissection of the perforator is similar
to that described earlier. After one has obtained certainty of the patency of the nourishing vessels, the lower border can be incised and the flap can be transferred. By dissecting the nourishing vessel through the muscle, a considerable pedicle length is gained; this gives the flap its superior mobility. In most cases, the length of the pedicle allows the use of healthy skin from a distant, untraumatized zone.

One single perforator is sufficient to vascularize the entire flap, because the angiosomes in this part of the body are relatively large. A single blood vessel pedicle also provides more liberty in shaping and a wider range of motion. The donor site is always closed primarily. Operating time ranges between 2 and 3 hours.

**Dorsal lower trunk**

Wounds at the dorsal lower trunk or lumbar area can be caused by acute trauma, have a congenital origin (ie, myelomeningocele), or be a consequence of chronic internal (exposed osteosynthesis material) or external pressure (pressure sores). Deep defects with exposure of vital structures over and around the lumbar spine have always been troublesome to cover. Most frequently, local fasciocutaneous flaps or the pedicled turn-over latissimus dorsi muscle flap were used. Because of the poor vascularization of those flaps, partial flap necrosis and wound healing problems were observed at the point where the flap was needed the most. Free flap surgery in this area is particularly difficult, because of the absence of decent-sized recipient vessels.

Currently, the extended SGAP provides a more reliable solution. The conventional design of the skin island, as described earlier, can be extended more laterally or laterodistally to increase the length of the axis of the flap. The dissection is identical to the SGAP for sacral pressure sores, but the flap is now rotated counterclockwise. By maximally splitting the gluteus maximus muscle cranially, an important cranial displacement can be added, which provides coverage up to L1-T12 [8].

**Proximal lower extremity reconstruction**

Because of the thickness of the subcutaneous layer of the SGAP flap, even in thin patients, this flap is not suited for reconstruction of the head and neck, upper extremity, or distal lower extremity. In exceptional cases in the area of the upper leg, the SGAP can be used to fill deep defects and to fill dead space. Indications are limited, however, and if the defect cannot be covered in a pedicled fashion, then the flap needs to be transferred as a free flap.

**Discussion**

The work of Taylor and Daniel [9] was a milestone in the development of new flaps that are used in reconstructive (micro-)surgery. Their main goal was to develop new donor sites for tissue transfer by thoroughly studying and documenting the vascular anatomy of the entire human body. Consequently, it was their intention to harvest skin flaps on the septo- and musculocutaneous perforators that they had identified. It was concluded, nevertheless, that harvesting of these flaps would probably be safer if the septum, fascia, or muscle that surrounds the perforating vessels was harvested with the overlying subcutaneous fat and skin island. Because clinical microsurgery was still in its pioneer phase, the lack of sophisticated microsurgical instruments and optical devices probably influenced that decision. The microsurgical anastomosis of larger, well-known vessels was considered to be safer than performing anastomoses of small perforating vessels. Their work was crucial in the development of perforator flaps.

Basically, there was no reason to sacrifice the muscle through which the perforating vessels traversed, other than the fear that the vessel would be damaged during dissection or that the muscle had a protective role to play on the perforating vessels. Over the last decades, several reconstructive surgeons believed that resecting a part or the entire muscle could not always be compensated for by the action of its neighboring agonists. This led to the development of more muscle-sparing techniques in an attempt to preserve as much of the muscle function as possible. Probably the most popular example is the evolution of the pedicled transverse rectus abdominis myocutaneous (TRAM) flap into the free TRAM flap, and, later, into the muscle-sparing TRAM flap. It was only logical to go one step further and reduce the amount of muscle resection so that the muscle would be split in the direction of its muscle fibers, the perforating vessels would be dissected from between these muscle fibers, and all muscle would be left in place.

This important step was first taken in a clinical case by Koshima and Soeda [10] when they used the “thin paraumbilical” perforator flap to reconstruct a tongue and groin defect. A second article on the same subject was published by Koshima et al [11] in 1992. The first reports of the use of the DIEP flap for breast reconstruction were by Allen and Treece [12] and our group [13]. Despite the initial positive results, there was considerable skepticism concerning the technique. In 1994, Cormack and Lamberty [14] regarded the technique “as more a demonstration of technical skill than a significant advance in flap construction.”
The question if the muscle that was spared would be functional was well founded.

Although in 1995 Allen and Tucker [3] reported the use of the SGAP flap in breast reconstruction and Angrigiani et al [15] reported the first thoracodorsal artery perforator (TAP) flap, no scientific study had demonstrated the advantage of sparing the muscle on muscle function. The prospective study by our group in 1997 [16] clearly demonstrated that saving the rectus abdominis muscle reduced the donor site morbidity to an absolute minimum. Although no prospective donor morbidity studies have been performed on other donor sites, it is logical that more muscle function will be preserved if the muscle is left intact.

Preserving the muscle function relies on respecting the vascularization by collateral blood vessels, and more importantly, preserving the continuity of the motor nerve branches that pass through the plane of dissection. If the motor nerves of the donor site muscle are cut during splitting or lifting of the muscle, the donor morbidity will be comparable to that of a muscle-sparing myocutaneous flap.

The advantages of using an SGAP flap for the indications mentioned earlier are: (1) the abundance of adipose tissue in the gluteal area, even in thin patients; (2) a better intraoperative exposure and a longer vascular pedicle compared with its myocutaneous predecessor; (3) a well-hidden scar; (4) excellent projection of the reconstructed breast compared with the DIEP and TRAM flap; and (5) the preservation of the integrity of the gluteus maximus muscle. The donor morbidity is the lowest that can be offered to the patient today. Including a sensate branch of the nervi clunii superiores can provide better quality and quantity of sensation to the flap [5,6]. Leaving the muscle intact avoids exposure of any nerves or bony eminences. Absence of a muscle cuff around the vascular pedicle also avoids postoperative atrophy and aids in modeling the flap, especially in breast reconstruction. Not resecting any muscle also results decreased postoperative pain and thus, a swifter rehabilitation. This leads to a shorter hospital stay, and, therefore, reduced costs. By harvesting skin and fat from the superior part of the buttock, it is possible to minimize any contour deformities and position the final scar within the bikini line. Finally, the preservation of the viability and function of the muscle at the donor site makes the rare case of total flap loss less dramatic, because only skin and subcutaneous fat are lost.

In the case of a pedicled flap, the tissues used in the SGAP flap come from a distance from the ulcus or wound, and, as such, they are less inflamed, less edematous, and less prone to dehiscence. The length of the pedicle gives the flap an impressive mobility and allows for easy tissue transposition without tension. The inset of the flap is always tension-free and the donor defect can always be closed primarily.

The firmer consistency of gluteal fat makes it more difficult to mold the flap, especially for breast reconstruction. Additional minor secondary corrections might be necessary to obtain the desired shape. The skin paddle that is included is often smaller than a TRAM or DIEP flap and should be considered in the preoperative planning. Although the contour deformity is considerably less than with the myocutaneous flaps, unilateral harvesting may necessitate a secondary correction of the contralateral side.

In our early experience with treating sacral pressure sores, there was a tendency for seroma formation underneath the flaps. This was reduced by harvesting the flap in a suprafascial plane instead of below the gluteus maximus muscle fascia.

In general, the steep learning curve is the main disadvantage of perforator flaps. Nevertheless, the technique of dissecting perforating vessels is not more difficult or tedious than other microsurgical procedures. To the contrary, if specific surgical acts and retraction are applied and adapted microsurgical instruments and optical devices are used, the dissection can be safe because the vessels are always under direct visual control. Perforator flap dissection is often more about patience than about skills. Wide exposure of the surgical field and bloodless dissection are key to complication-free surgery. Perfecting this new style of dissecting can be time consuming, especially during the early cases, and will add a considerable amount of operating time. After the surgeon is familiar with the technique, the operative time for a perforator flap procedure may be comparable or even less than for a myocutaneous flap. International courses on perforator flaps are organized yearly to teach the concepts to interested surgeons.

The clinical experience and the favorable results with perforator flaps in several centers in Europe, Asia, and the United States have shown that this technique is new, but sufficiently reliable, to be used in daily clinical practice and is reproducible by other colleagues. The combination of the advantages that were discussed earlier, and the fact that all intrinsic advantages of each myocutaneous flap is preserved, make perforator flaps even more attractive. Although no scientific data are available on the physiology of blood flow in perforator flaps, the clinical experience [5,6,17–19] has proven that the blood flow through one perforator is almost always sufficient to vascularize a large overlying skin island. The design of that skin island may nevertheless be a little different than
that of its myocutaneous predecessor. Skin islands must be centered on top of the perforator or following the direction of the main branches of the perforator within the flap, as if it would be an axial pattern flap. A larger amount of partial- or fat necrosis may be encountered if the conventional design is applied [20].

**Summary**

The development of the perforator flap technique revolutionized the practice of soft tissue transfer. The main goal of this technique is muscle sparing at the donor site for function and strength. Meanwhile, this concept is being widely applied for reconstruction of tissues throughout the entire body. Perforator flaps are the ultimate upgrade of the well-known myocutaneous flaps. Theoretically, any myocutaneous flap can be harvested as a perforator flap if skin resurfacing is needed.

Although the DIEP flap, the anterolateral thigh flap, and the TAP flap are probably more frequently used for breast, trunk, and upper and lower limb reconstruction, as well as head and neck reconstruction, the SGAP flap takes its own position in the large group of perforator flaps and has its own specific indications.

**References**


