The Versatility of the Anterolateral Thigh Flap

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Summary: In the last two decades, the anterolateral thigh flap has emerged as one of the most popular reconstructive options for multiple body sites. Based on a perforator flap harvest concept, the flap encompasses the advantages of versatility, pliability, and potential for composite tissue replacement. Although numerous anatomical variations exist, these are well-described, and flap safety remains uncompromised if certain anatomical boundaries are respected. Careful preoperative planning and identification of perforators remain the cornerstone of successful flap harvest. Once perforators are identified, variations in skin paddle design allow for multiple skin paddle configurations, central or eccentric orientations, and custom-made flaps tailored to fit almost any defect. A suprafascial dissection allows for “ultra-thin” flaps ideal for folding, tubing, or packing purposes. The versatility of the lateral circumflex femoral artery branches can be exploited to include muscle, iliac bone, tendon, fascia, or nerve in extended designs. The anterolateral thigh flap is currently the frontline choice for head and neck reconstruction, including intraoral, mandibular-maxillary, tongue, and facial defects, and is gaining popularity in abdominal and pelvis reconstruction. It can also be used as a pedicled flap in phallus or perineum reconstruction. More recently, the flap has proved to be extremely useful in skin resurfacing and even functional reconstruction in traumatic wounds. This review summarizes the anatomy, planning, flap harvest, donor morbidity, and clinical applications of the anterolateral thigh flap. An algorithm is proposed that facilitates a clear, problem-based approach for the use of this versatile reconstructive option. (Plast. Reconstr. Surg. 124: 395e, 2009.)

The anterolateral thigh flap was introduced in Asia and has gained international popularity because of a recent shift toward perforator flaps. Advances in the past century that have made perforator free flaps possible include the pioneering anatomical works of Manchot1 and Salmon,2 improvements in operative microscopy, and refinements in surgical techniques. Song et al. first described the anterolateral thigh flap in 19843; since then, it has evolved as one of the most versatile perforator flaps.

The versatility of the anterolateral thigh flap hinges on the ability to harvest multiple tissue components in various combinations; the reliable size and position of the perforators supplying the large skin paddle; and the long, wide-caliber pedic-ple. Anterolateral thigh flap harvest is convenient because it does not require patient repositioning and can be performed simultaneously using a two-team approach. The anterolateral thigh donor site is concealed easily, as it can be closed primarily and does not violate a functional motor unit and thus results in minimal morbidity. However, it can be quite unappealing if it required a split-thickness skin graft, especial in younger or female patients.

ANATOMY

The anterolateral thigh flap incorporates the anterior and lateral thigh skin on a longitudinal axis from the anterior superior iliac spine to the superolateral margin of the patella. The skin and underlying musculature are largely supplied by branches of the lateral circumflex femoral artery, which arises from the profunda femoris (75 percent) or directly from the femoral artery (25 percent).4 The lateral circumflex femoral artery

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courses laterally deep to the rectus femoris and sartorius before dividing into ascending, transverse, and descending branches. Usually the anterolateral thigh flap is based on perforators from the descending branch of the lateral circumflex femoral artery (75 percent); however, in a significant minority, the perforators are derived from the transverse branch (25 percent) (Fig. 1).\(^4\)

Although originally described as a free cutaneous flap based on a septocutaneous vessel, in fact, only 12 to 18 percent of anterolateral thigh flaps are septocutaneous.\(^5\) In over 80 percent of cases, the blood supply to the cutaneous flap is through musculocutaneous perforators traversing the vastus lateralis. Very rarely, there may be no suitable perforators on which to base a fasciocutaneous anterolateral thigh flap,\(^5,6\) in which case the flap may be raised using the underlying vastus lateralis muscle as a carrier, extended medially as a “free-style” free flap\(^8\) or laterally as a tensor fascia lata flap; or the contralateral thigh is explored because vascular asymmetry is the rule.\(^9\)

The lateral circumflex femoral artery pedicle length ranges from 8 to 12 cm, with a proximal vessel diameter greater than 2 mm and two accompanying veins.\(^10\) Cutaneous sensation is supplied by the lateral femoral cutaneous nerve of the thigh (L2-L3), which divides into anterior and posterior branches; the larger anterior branch passes downward to supply the anterolateral thigh cutaneous territory. Motor innervation is by means of the femoral nerve (L2-L4), which travels with the descending branch of the lateral femoral circumflex artery and should be preserved during intramuscular perforator dissection, because one perforator can nourish a large skin territory.

**DEFINITION**

The anterolateral thigh flap may be defined by its vascular supply as either musculocutaneous or septocutaneous. The distinction is significant because the “true” perforator flap relies on intricate dissection of the musculocutaneous perforator passing through the vastus lateralis muscle.\(^11\) A septocutaneous flap is based on shorter, more direct vessels penetrating the septum between the rectus femoris and the vastus lateralis.

Alternatively, the anterolateral thigh flap may be defined by its tissue components: skin, fat, fascia, tendon, muscle, or nerve. The anterolateral thigh flap may be raised as a compound myocutaneous flap with simple en bloc elevation of the overlying skin, or the skin paddle may be dissected free of the underlying muscle based on the perforators.\(^12\) Multiple tissues may be harvested on individual perforators and dissected separately but based on the same source vessel\(^13\); alternatively, a double-paddled flap may be raised\(^13\) or multiple anterolateral thigh flaps harvested from a single thigh.\(^15\) Although the anterolateral thigh flap was originally developed as a free flap, it may also be raised as a proximally pedicled flap for perineal or abdominal reconstruction\(^16,17\) or as a distally based pedicled flap with reverse flow for knee abnormalities or to optimize amputation stumps.\(^16,18\)

**PLANNING AND DESIGN**

The anterolateral thigh flap is marked with the patient supine. The longitudinal axis of the flap based on a line joining the anterior superior iliac spine and superolateral patella approximates the underlying intermuscular septum between the vas-

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**Fig. 1.** The anterolateral thigh flap vascular supply. The source vessel is usually the descending branch of the lateral femoral circumflex artery (LCFA) and provides multiple perforators to the skin of the anterolateral thigh. The main branch to the rectus femoris (RF) is proximally based and can be preserved in most cases, unless a very long pedicle is required. ASIS, anterior superior iliac spine; PFA, profunda femoral artery; VL, vastus lateralis.
tus lateralis and the rectus femoris and also, in part, the surface marking of the lateral femoral cutaneous nerve of the thigh.

The majority of perforators are located within a circle with a 3-cm radius bisecting the midpoint of the longitudinal axis and can be located using a 5- to 8-MHz hand-held Doppler probe. The required skin paddle is centered on the selected perforator(s), typically as an ellipse 8 to 10 cm wide and 20 to 25 cm long. However, designs based on a geometrical template of the defect that includes the pedicle direction may be preferred (Fig. 2).

In emergency cases where an anterolateral thigh flap had not been anticipated, an anterolateral thigh flap can be marked empirically and the medial edge raised to allow visual confirmation of suitable perforator(s). The perforator is then dissected retrogradely through the tissues to the source vessel as a “free-style” free flap.

**FLAP HARVEST**

The medial border is incised down to or through fascia, depending on the preferred plane of dissection, and the flap elevated laterally until the perforators supplying the skin paddle are identified. Intramuscular dissection of the selected perforator(s) proceeds in a retrograde fashion to connect with the source vessel in the intermuscular septum. If the source vessel is the transverse branch of the lateral circumflex femoral artery, this may entail a longer intramuscular dissection. Septocutaneous perforators are more likely to be located proximally and follow a direct route to the source vessel; this permits rapid, straightforward dissection of the anterolateral thigh flap. Musculocutaneous perforators may take a more circuitous route, requiring 2 to 6 cm of meticulous dissection from the surrounding muscle. Precise hemostasis is mandatory for successful intramuscular dissection because a blood-stained field serves to make perforator identification challenging.

The motor nerve to the quadriceps runs superolaterally with the main pedicle and is preserved during intramuscular perforator dissection. If the motor nerve runs between multiple perforators, the motor nerve can be preserved, and the components of anterolateral thigh flap are divided based on separate perforators and raised as a chimeric-style flap. The other alternative is to preserve the motor nerve and harvest another free or distant flap.

**APPLICATIONS**

The versatility of the anterolateral thigh flap is attested to by the extensive spectrum of defects to which it can be applied. An algorithm outlining the different anterolateral thigh flap types suitable for various defects is outlined (Fig. 3).

Thin flaps with a large surface area are ideal for resurfacing or for draping over three-dimensional or mobile structures. Such “ultrathin” anterolateral thigh flaps are also suitable for defects

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**Fig. 2.** Design of the anterolateral thigh flap cutaneous paddle. (Above) An ellipse is the standard design and results in a straight-line scar with good cosmesis and minimal tension. Flap widths greater than 8 cm require skin grafting. (Center) A rhomboid design is an excellent alternative to the elliptical design and results in a Z-plasty type scar rather than a straight line. (Below) A pentagon is an efficient way of raising sufficient skin for total or near-total tongue reconstructions. The tip is ideal for inset into deeper areas such as the trigone.
where a contour deformity would be undesirable cosmetically (face) or functionally (dorsum of foot/ankle/hand). The anterolateral thigh flap is pliable enough to be folded, tubed, or packed into cavities, and the ease with which it is harvested makes it an excellent first-line emergency flap.

Myocutaneous anterolateral thigh flaps may be raised with skin and muscle intact or with the tissue components separated on individual perforators for more flexible insetting of the flap. They are ideal for obliterating dead space or for providing bulk to reconstruct complex three-dimensional defects.20

Recently, bulky adipofasciocutaneous anterolateral thigh flaps have been developed for selected use in breast reconstruction. Supplementary tissues such as iliac bone, tendon, fascia, or nerve may be reconstituted using suitable tissues raised in an “extended” anterolateral thigh flap based on the lateral circumflex femoral artery system.21 The anterolateral thigh perforator flap may be divided to provide multiple tissue paddles,15 two smaller sized anterolateral thigh flaps raised from one thigh15 or multiple flaps raised based on the lateral circumflex femoral artery14,21 to fill multiple defects using only one vascular anastomosis.

**Head and Neck Reconstruction**

**Intraoral**

The radial forearm flap is ideal for reconstructing thin, small defects such as those of the nose, palate, upper, and lower lips. An anterolateral thigh flap is sometimes difficult to harvest if the width is less than 4 cm. The anterolateral thigh flap has superseded the radial forearm flap for head and neck reconstruction in the Asian population because the defects are usually large (Fig. 4).7 The thin, relatively hairless anterolateral thigh fasciocutaneous flap is ideal for resurfacing intraoral defects and can be folded to cover internal and external surfaces (Fig. 5) and through-and-through defects (Fig. 6). An anterolateral thigh flap raised with two skin paddles based on widely separated perforators allows for eccentrically aligned tissue defects to be reconstructed with a single flap and a single anastomosis (Fig. 7).

Larger anterolateral thigh flaps may be raised and the excess cutaneous portion deepithelialized and buried to minimize contour deformities or fill dead space.22 The ability to base different tissue components on individual perforators in an anterolateral thigh flap allows for maximal flexibility in flap inset of often very complex head and neck cases (Fig. 8).23,24

**Mandible**

Extensive composite mandibular defects are increasingly reconstructed with combined bone and soft-tissue flaps to reconstitute the missing tissues and combat the effects of radiotherapy.23,26 The current practice is to use a fibula osteoseptocutaneous flap in combination with an anterolateral thigh flap for complex composite tissue defects with segmental

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**Fig. 3. Algorithm outlining anterolateral thigh flap type suitable for reconstructing various defects and tissue deficits. SF, suprafascial; FC, fasciocutaneous; LCFN, lateral cutaneous femoral nerve; MC, musculocutaneous; ALT, anterolateral thigh.**
mandibulectomy. The two-flap approach uses the anterolateral thigh flap for external resurfacing and/or soft-tissue reconstitution.

Both flaps can be harvested from a single limb simultaneous with recipient-site preparation in a multidisciplinary surgical approach. If there is a paucity of local recipient vessels following recurrence or radiotherapy, the anterolateral thigh flap can be used to “piggyback” a second flap or as a flow-through flap.

Maxilla

Maxillary defects are often complex three-dimensional entities with the need for multiple tissue components. The anterolateral thigh flap provides bulk to reconstitute the soft-tissue deficit, and deepithelialized flap or fascia can be used to fill dead space/sinus or to separate compartments.

Fig. 4. Fasciocutaneous anterolateral thigh flap (thin, long flap with a large cutaneous paddle). This flap is ideal for draping over structures or resurfacing shallow defects. It is also suitable for filling cavities and sinuses or improving contour with partial deepithelialization.

Fig. 5. Musculocutaneous anterolateral thigh flap is folded over the commissure to provide internal and external skin coverage.

Fig. 6. A through-and-through defect of the left cheek. (Above) A musculocutaneous anterolateral thigh flap has been used for full-thickness reconstruction and provision of internal coverage. (Below) External skin coverage provided by the same anterolateral thigh flap.
Partial glossectomy is ideally reconstructed using a large, relatively pliable fasciocutaneous anterolateral thigh flap that can be molded to the contours of the tongue (Fig. 9). The thinness of the fasciocutaneous anterolateral thigh flap maintains movement of the residual tongue, thereby optimizing speech and swallowing. Total or near total glossectomy requires muscle bulk. In such cases, the anterolateral thigh myocutaneous flap has proved an ideal flap. Furthermore, a sensate neotongue has been described by coapting the lateral cutaneous femoral nerve to the lingual nerve.28

**Tongue**

Pharyngoesophagus

The fasciocutaneous anterolateral thigh flap is rapidly gaining preeminence over the free jejunal flap in pharyngoesophageal reconstruction. A wide anterolateral thigh flap may be harvested to fabricate a long, wide-bore tube with relative ri-
gidity because of the dermal component of the anterolateral thigh compared against the lamina propria of the jejunum. The harvesting of additional fascia facilitates three-layered closure of the neotube, resulting in a safer, watertight closure that reduces postoperative complications such as stricture, leakage, and fistula formation. Recent studies have demonstrated superior functional outcomes using the anterolateral thigh flap, including more intelligible speech, fewer postoperative complications, shorter hospital stay, and lower costs.

Craniofacial

The anterolateral thigh flap has been used successfully in skull base surgery, cranioplasty, and scalp reconstruction. The fasciocutaneous flap is particularly useful in cranioplasty reconstruction when radiation therapy is anticipated, as it undergoes less soft-tissue contracture than a muscle flap. The harvest of additional fascia with the anterolateral thigh flap produces a vascularized fascial flap for coverage of exposed dura mater. The anterolateral thigh flap drapes and conforms to the convex contours of the skull and can be used in the forehead or temporal scalp to improve contour.

The versatile anterolateral thigh flap can be used most elegantly to harvest additional fascia lata for use as a static sling or additional neural tissue (lateral cutaneous femoral nerve) for interposition nerve grafting. Three branches of the lateral cutaneous femoral nerve were used successfully to reconstruct facial nerve branches following excision of a facial tumor. Sensorineural anterolateral thigh flaps have successfully achieved sensate resurfacing of facial defects.

Facial Contour

Fasciocutaneous anterolateral thigh flaps are ideal for the correction of hemifacial microsomia, because they are of sufficient size to correct the whole deformity, thin enough to be buried under facial skin flaps, and provide fascia for gliding of overlying tissues. The successful use of buried fasciocutaneous anterolateral thigh flaps has also been reported in other cases with adversely affected facial contour.

Trunk

Breast

In patients with low body mass index and insufficient abdominal tissue who do not wish to sacrifice gluteal contour and want to avoid implants, the adipofascial anterolateral thigh flap has been used successfully for breast reconstruction (Fig. 10). Initially, moderate weight adipofascial anterolateral thigh flaps were raised; how-
ever, in larger patients, larger flaps have been reported. Use of an adipose anterolateral thigh flap for breast reconstruction is limited but may have some benefit in patients with compromised pulmonary function, in whom abdominal flaps should be avoided.

**Abdomen and Pelvis**

Proximally pedicled anterolateral thigh flaps have been used to reconstruct defects of the lower abdomen, perineum, greater trochanter, and gluteal and ischial tuberosity. Large full-thickness abdominal wall defects have been repaired successfully using large anterolateral thigh flaps with additional vascularized fascia lata.

**Phallus and Perineum**

Initially, the anterolateral thigh fasciocutaneous flap was used as a secondary option in patients with failed phallus reconstruction or for complex perineal reconstructions. One-stage innervated proximal islanded anterolateral thigh fasciocutaneous flaps have been reported for successful phallus reconstruction, and sensate free fasciocutaneous anterolateral thigh flaps have been developed for use in gender reassignment surgery. The anterolateral thigh flap offers a considerably more discrete donor scar than that of the radial forearm flap. The pedicled anterolateral thigh fasciocutaneous flap is also useful in complex perineal reconstruction because it is relatively tolerant to fecal contamination and maceration.

**Trauma**

**Lower Limb**

The goals of reconstruction of the traumatically injured leg include limb salvage, preservation of function, and optimization of aesthetics. Traumatic wounds have variable soft-tissue requirements, and the anterolateral thigh flap offers a “warehouse” of donor tissues, a long vascular pedicle, and the ability to confine all surgery to the injured leg. Malleolar wounds require thin coverage to facilitate footwear; whereas deeper wounds or osteomyelitis requires bulk for obliteration of dead space. The anterolateral thigh flap offers sufficient area of skin plus the ability to tailor additional muscle (Fig. 11).

Another advantage of using the anterolateral thigh flap for lower limb trauma is the potential to use epidural anesthesia for patients unfit for general anesthesia. Fasciocutaneous flaps have been shown to have some advantages over muscle flaps, especially with regard to secondary surgery. In addition, the anterolateral thigh flap does not sacrifice an entire motor unit, which may be vital in trauma cases. Applications include using a myocutaneous anterolateral thigh flap to bank and carry avulsed plantar heel tissue, amputation stump revision and length preservation, and immediate reconstruction of the Achilles tendon with vascularized fascia lata. A flow-through flap designed on a short vascular pedicle preserves arterial flow in a single vessel limb or those with peripheral vascular disease. Distally pedicled reverse-flow anterolateral thigh flaps have been used successfully to repair soft-tissue defects of the ipsilateral knee.

**Upper Limb**

Soft-tissue loss can be reconstructed and exposed tendons wrapped in additional fascial component to permit effective gliding in cases of severe bursitis. Functional reconstruction of elbow flexion and extension following degloving injury and concomitant biceps and triceps tendon injuries has been achieved using a free anterolateral thigh flap and fascial extension.

**Burn Injury**

Burns are most likely to require extensive resurfacing for reconstruction of vital structures and restoration of function. Release of often disabling contractures results in considerable tissue deficit and may require microvascular tissue transfer. The anterolateral thigh fasciocutaneous flap offers a large cutaneous skin paddle, and bilateral anterolateral thigh flaps have been used to salvage the severely burned leg. There are also case reports of the previously burned anterolateral thigh skin being used for microvascular transfer.

Tissue expansion was developed to increase the skin available from the anterolateral thigh. Tissue expanders are inserted subcutaneously lateral to the perforators and expanded over the course of several months. The increased skin allows for harvest of even larger anterolateral thigh flaps and facilitates closure of the donor site.

**Anterolateral Thigh Flap Modifications**

Harvesting two separate anterolateral thigh flaps from a single thigh allows reconstruction of bilateral buccal defects in a single operation with a single donor site. Each cutaneous flap is designed around two widely separated perforators and is a simple but elegant method of minimizing donor-site morbidity.

The thickness of a cutaneous flap is determined by its dermal component: the radial forearm flap has an average dermal thickness of 2 mm, whereas that of the anterolateral thigh is approx-
Fig. 11. Anterolateral thigh flap in lower limb reconstruction. (Above, left) Large-surface-area, thin anterolateral thigh flap. (Above, right) Anterolateral thigh flap inset to achieve excellent contour on the anterior surface of the leg. (Below, left) Gustilo grade IIIb open fracture with loss of cortex of tibia; antibiotic beads are visible inferiorly. (Below, right) Large-surface-area, thin anterolateral thigh flap raised with additional vastus lateralis muscle to obliterate the dead space.
An ultrathin anterolateral thigh flap may be raised in a suprafascial plane; such cutaneous flaps are dependent on the perforator supply to the subdermal plexus and exclude the rich blood supply of the deep fascial plexus. Alternatively, the anterolateral thigh flap may be thinned to a dermal thickness of 3 to 4 mm. Primary thinning, in which the flap is thinned before ligation of the pedicle, can be performed under microscope guidance, but the area where the pedicle enters the flap must be safeguarded. The thinned flap is nourished exclusively by the subdermal vascular network derived from the perforator pedicle. Despite the proven reliability of thinned flaps, the procedure has proven controversial, with reports of partial or total flap loss following primary thinning.

DONOR SITE

Primary closure of the donor site results in minimal pain or paresthesia, acceptable scar cosmesis, good thigh contour, and rapid mobilization (Fig. 12). Patients may report transient numbness in the distribution of the lateral femoral cutaneous nerve but rarely report any discernible weakness. Objective assessment has demonstrated a 10 to 30 percent reduction in strength of knee extension and tethering of the underlying muscle has been described with the use of skin grafts. Techniques for donor-site closure include skin grafting, the use of preexpanded donor tissue, V-Y flap closure, lateral rectangular advancement flaps, local groin flaps, and fascial imbrications that facilitate primary skin closure in flaps wider than 8 cm without increasing the risk of compartment syndrome. There have been reports of donor-site complications, including wound infection, dehiscence, bulging, and herniation of the thigh, seroma, paresthesia, and scar cosmesis. Partial rectus femoris necrosis has been reported following ligation of the anterolateral thigh source vessel proximal to the branch to the rectus femoris and has been seen in one case in the senior author’s (M.H.C.) experience. For cosmesis, the donor-site scar can be concealed if it is less than 8 cm wide. However, the scar is usually not acceptable for younger or female patients if skin grafting is required for donor-site closure.

ASSIMILATION OF THE ANTEROLATERAL FLAP

Anterolateral thigh flap selection is based largely on clinical parameters such as color, tissue quality, laxity, thickness, and hairiness of the anterolateral thigh skin. Minimal preoperative investigations are necessary, and predictable flap harvest can be achieved by proceeding only after suitable perforators have been located. Any initial reluctance to accept the anterolateral thigh flap had been based on the perceived difficulties of “perforator” flap surgery and recognized variations in flap vascularity. With time and experience, perforator flaps in general and the anterolateral thigh flap in particular have become widely accepted.

CONCLUSIONS

The anterolateral thigh flap is one of the most versatile and useful perforator flaps for multidimensional reconstructions at all body sites. It has become the main workhorse flap for head and neck reconstruction, with increasing utility in limb, trunk, and perineal reconstruction. The anterolateral thigh flap is indicated for reconstruction of a diverse range of defects of various surface areas and depths; it can be used as an ultrathin flap for resurfacing, rolled up for filling in dead space, or taken with muscle to obliterate spaces or provide bulk. The anterolateral thigh flap has been
used in trauma salvage as a flow-through flap, as a tissue carrier, and to piggyback additional flaps. The flap can be raised pedicled (proximally or distally) or free, suprafascial or subfascial, further thinned, or harvested with muscle or additional tissue components. Despite the pendulum effect to which new techniques are prey, the anterolateral thigh flap has proved robust and versatile enough to fulfill a wide variety of reconstructive requirements.

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