CLINICAL REVIEW

David W. Eisele, MD, *Section Editor*

ANTEROLATERAL THIGH FLAP

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Abstract: The anterolateral thigh (ALT) flap is a versatile soft tissue flap. It can be harvested as a fasciocutaneous or myocutaneous flap. Vascularized fascia can be included or the pedicle may be harvested as a flow-through flap. The flap can also be harvested incorporating multiple skin islands or as a chimeric flap incorporating separate skin and muscle components. When a large flap is needed, the entire lateral thigh can be harvested by combining the ALT with either the tensor fascia lata or the anteromedial thigh flap as a conjoined flap. Morbidity is remarkably minimal despite the availability of such generous amounts of tissue. The purported difficulty with the use of this flap is because of the anatomical variations that may render this flap unreliable. This paper clarifies the vascular anatomy of the flap and elaborates an approach to flap harvest that can be used to reliably harvest the flap in spite of the anomalies that may be encountered. © 2009 Wiley Periodicals, Inc. *Head Neck* **32:** 529–540, 2010

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The anterolateral thigh (ALT) flap was first described by Song et al[1] in 1984 as a flap based on septocutaneous vessels running in between the rectus femoris and vastus lateralis muscles. However, it was soon noted that septocutaneous vessels were present only in a minority of cases. The majority of the vessels supplying the flap are musculocutaneous perforators traversing the vastus lateralis muscle.[2–4] Intramuscular dissection was considered unsafe and ill-advised in 1984. Koshima et al,[2] in his early series, noted that this flap was unusable in 5 of 13 cases because of absent septocutaneous vessels. The flap thus gained a reputation of being unusable in a significant proportion of patients. With the development and maturation of perforator flaps, the technique of intramuscular perforator dissection gradually became widely used. The ALT perforator flap quickly gained prominence and was regarded as exemplary of perforator flaps.[5–8] Wei et al[9,10] was instrumental in popularizing its use and considered it an ideal soft tissue flap. With greater collective experience, the initial difficulties with this flap were gradually surmounted and its advantages appreciated more and more. Despite this, its adoption remains cautious because of the so-called anatomic variations of its vascular anatomy for

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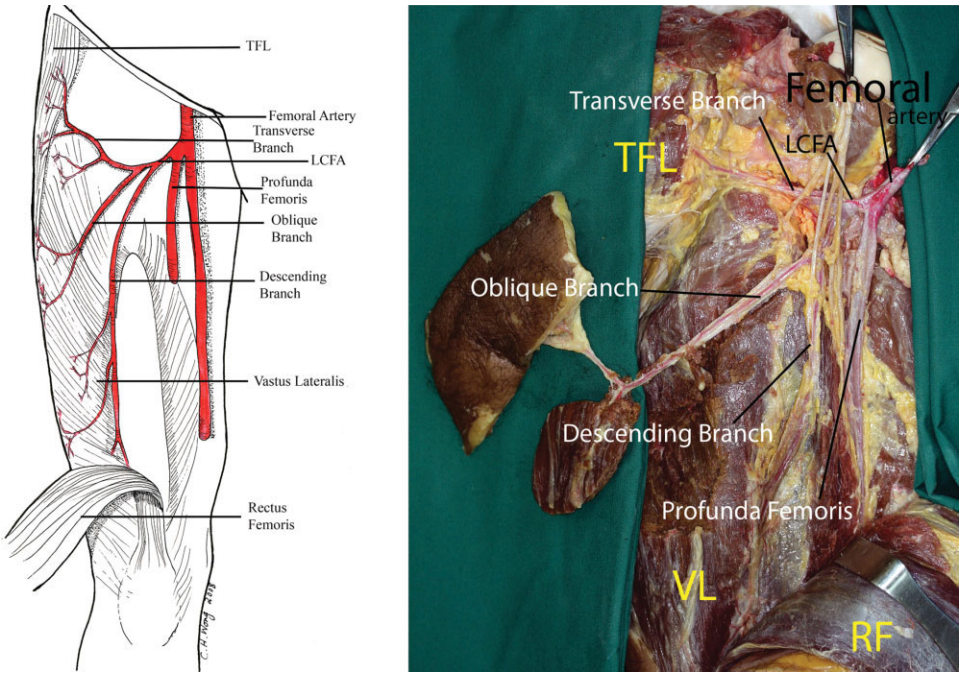

FIGURE 1. (**Right**) Schematic illustration of the oblique branch of the lateral circumflex femoral artery. When present, the oblique branch is located between the transverse branch and the descending branch. (**Left**) Cadaveric specimen demonstrating the oblique branch. Note that in this specimen the oblique branch was almost of equal diameter as the descending branch and that it originated from the later. TFL, tensor fascia lata; LCFA, lateral circumflex femoral artery; VL, vastus lateralis; RF, rectus femoris. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

which this flap is notorious. To harness its full potential, an in-depth understanding of its vascular anatomy is a prerequisite. This paper aims to clarify its vascular anatomy and highlight relevant anatomical variations that impact flap harvest. Techniques to deal with such variations that enabled us to reliably harvest the anterolateral thigh flap in spite of such variations are also described herein.

SURGICAL ANATOMY OF THE ANTEROLATERAL THIGH FLAP

The lateral circumflex femoral artery is the first branch of the profunda femoris. It in turn gives off the descending and transverse branches. The anterolateral thigh flap is usually harvested based on the descending branch of the lateral circumflex femoral artery. The descending branch traverses in the intermuscular septum between the rectus femoris and vastus lateralis muscles for a variable distance before entering the substance of the vastus lateralis muscle.[9] Proximally, near its take off from the lateral circumflex femoral artery, it gives off a large branch to the rectus femoris muscle. This is the dominant pedicle of the rectus femoris muscle and should be preserved when possible.[11] The descending branch usually consists of 1 artery and 2 veins. The vessel diameter is more than 2 mm and the pedicle length is between 8 and 16 cm.[9] In additional to the descending and transverse branches, 34% of patients have an extra vessel in the anterolateral thigh in the plane between the rectus femoris and vastus lateralis muscles. Known as the oblique branch of the lateral circumflex femoral artery, it can be reliably used as the pedicle of the anterolateral thigh flap when necessary (Figure 1).[12] The skin of the anterolateral thigh may be supplied by either septocutaneous vessels or musculocutaneous perforators.[9]

ANATOMICAL VARIATIONS

The anatomical variations encountered with the anterolateral thigh flap can simply be classified into 2 types: (1) variation in the course of the vessels supplying the skin,[9,13] and (2) variation of the vascular pedicle of the flap.[5,12,14] The former has been quite clearly detailed in the literature, whereas the latter is much less appreciated.[2,3,4,9,13] Regardless, once these 2 aspects of the anatomy of the flap are thoroughly understood, you can overcome the anatomic uncertainties and reliably harvest the flap

every time. The only instance when the surgeon needs to abandon the harvest is when there is an absence of sizable perforators in the lateral thigh. This is fortunately a very rare occurrence (about 1%).[12]

The skin vessels that supply the skin can either be musculocutaneous perforators or septocutaneous vessels. In a review by Wei et al[9] of 672 anterolateral thigh flaps, the vessels that supply the anterolateral thigh skin was noted to be musculocutaneous in 87% of cases and septocutaneous in 13%. A flap based on septocutaneous vessels is easily harvested, but this occurs in only a minority of cases. Musculocutaneous perforators can be safely mobilized by meticulous intramuscular dissection and have been demonstrated to be equally reliable.[5–9] As such, these variations in the course of the skin vessels do not affect the reliability of the flap.

A lesser-known and somewhat poorly described anatomy pertains to the pedicle of the flap itself. It was didactically stated that the pedicle of the flap is the descending branch of the lateral circumflex femoral artery.[1–9] However, this is not always the case. Several authors have noted that in a significant proportion of patients, the skin of the anterolateral thigh is supplied by a source other than the descending branch. In Kimata et al's[14] analysis of 74 consecutive patients, this anomalous situation was noted in 16% of the patients. Shieh et al[5] noted an even higher incidence of 32%. These reports in the literature have contributed to the confusion and contradictions surrounding the anterolateral thigh flap. On 1 hand, the pedicle is said to be the descending branch of the lateral circumflex femoral artery. On the other hand, the perforator supplying the skin can arise from a source other than the descending branch in a significant proportion of patients. This 'alternative' pedicle to the anterolateral thigh flap, however, remains poorly defined.

In a prospective analysis of 89 consecutive flaps, Wong et al[12] noted the presence of a previously unnamed vascular branch in the lateral thigh in 34% of patients. It was named the oblique branch of the lateral circumflex femoral artery for its locality between the transverse and the descending branches. When present, the oblique branch variably takes over the blood supply of the vastus lateralis muscle and the anterolateral thigh skin. The origin of the oblique branch itself is variable. It may originate from the descending branch (36%), transverse branch (52%) or lateral circumflex femoral artery (6%). Rarely it may even arise directly from the profunda femoris (3%) or femoral artery (3%). It was also demonstrated that the oblique branch can reliably be used as the pedicle of either an anterolateral thigh perforator or myocutaneous flaps. Of the 89 cases, 14% were raised with the oblique branch as the flap pedicle, leaving the descending branch in-situ. When present, the oblique branch is very sizable consisting of an artery and usually 2 veins. The pedicle of the anterolateral thigh flap can thus be either the descending or oblique branches.

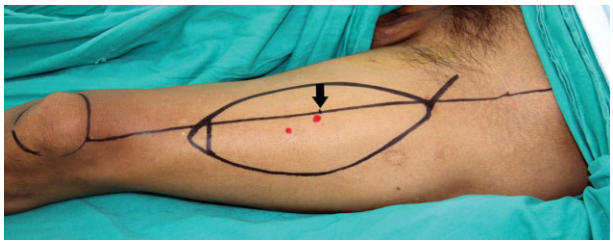

FIGURE 2. Skin markings for the anterolateral thigh flap. Arrow indicates the midline, and red dots mark the location of skin vessels as detected by the handheld Doppler. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

SURGICAL TECHNIQUE FOR HARVESTING ANTEROLATERAL THIGH PERFORATOR FLAP

Skin Markings. A line joining the anterior superior iliac spine and the upper outer border of the patella is drawn (Figure 2). This line corresponds to the intermuscular septum between the rectus femoris and the vastus lateralis muscles. Skin vessels supplying the anterolateral thigh flap are usually located along this line or slightly lateral. The midpoint of this line is then marked. As described by Yu et al,[15,16] the skin vessels supplying the flap tend to be located in the vicinity of the midpoint. Additional perforators are located 5 to 10 cm proximal and distal to the midpoint perforator. Vessels sited at these locations are designated from proximal to distal as vessels A, B, and C, respectively. While not invariably present at each location, this system of naming the clusters of skin vessels gives a useful guide for vessel localization. A handheld Doppler (Super Dopplex II, model number MD2/SD2; Huntleigh Diagnostics, South Glamorgan, Wales, United Kingdom) is then used to locate the skin vessels in the anterolateral aspect of the thigh. The required size of the skin flap is then marked incorporating these vessels.

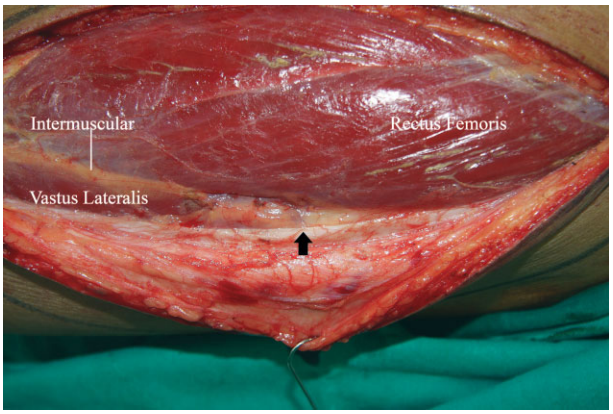

FIGURE 3. The flap is elevated to the intermuscular septum. The vessels to be used to nourish the flap are located in the septum or lateral to it (arrow). The rectus femoris can be distinguished from the vastus lateralis by observing the muscle fiber orientation. This pattern is clearest in the distal part of the dissection. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Flap Elevation. The medial incision is made first. The flap may be elevated suprafascially or subfascially. The flap can be elevated expediently off the rectus femoris muscle. It is important to accurately identify the rectus femoris early in the dissection as vessels coming through the rectus femoris can be safely ligated whereas those traversing within the intermuscular septum or arising through the vastus lateralis muscle must be preserved because these supply the flap. This may be difficult in muscular individuals or in patients with thick subcutaneous tissue. The easiest way of doing this is by carefully observing the orientation of the muscle fibers. The rectus femoris is a bipennate muscle with fibers of the lateral half of the muscle running from the superomedial to the inferolateral direction. The fibers of the vastus lateralis muscle in contrast run in a superolateral to inferomedial direction. This pattern is most distinct in the distal thigh. Also, the subcutaneous tissue tends to be thinner and the septum more distinct in the distal thigh. The rectus femoris can also be distinguished from the vastus lateralis by observing the way in which the muscles contract when directly stimulated by the electrocautery. The rectus femoris has greater excursion and contracts with a predominantly superior vector. The vastus lateralis, in contrast, has a more superolateral vector of excursion. Once identified, the surgeon can safely elevate the flap to the intermuscular septum (Figure 3).

The septum is then explored. The vessels supplying the skin are either septocutaneous vessels or musculocutaneous perforators and commonly lie within this septum. Care should therefore be taken when dissecting here to identify and preserve these vessels. Selected vessels to be included with the flap must be sizable (>0.5 mm) and pulsating well. Once the vessels have been located, the next step is to open the intermuscular septum. The rectus femoris is retracted superiorly with skin hooks and the septum cut with cautery from distal to proximal. The tendinous posterior surface of the rectus femoris is the safest plane of dissection and should be followed when opening this space. In the vicinity of the skin vessels, small branches may supply the rectus muscle and these should be secured with hemoclips and divided. Once the rectus femoris is separated from the vastus lateralis, the descending branch of the lateral circumflex femoral artery will come into view (Figure 4). If an oblique branch is present, it can usually be seen at this point as a vessel lying laterally to the descending branch.

If the vessel supplying the flap is a septocutaneous vessel, this is simply mobilized and flap harvest can be expediently completed. For musculocutaneous perforators, intramuscular dissection is needed for mobilization. Dissection starts with the unroofing of the muscle covering the perforator. This should be performed in the perivascular loose areola tissue around the perforator. Dissecting scissors are inserted into this plane and the muscle above it gently tented up. The assistant can then cut the muscle with a sharp-tip electrocautery. This is done in short segments of about 0.5 to 1 cm following the

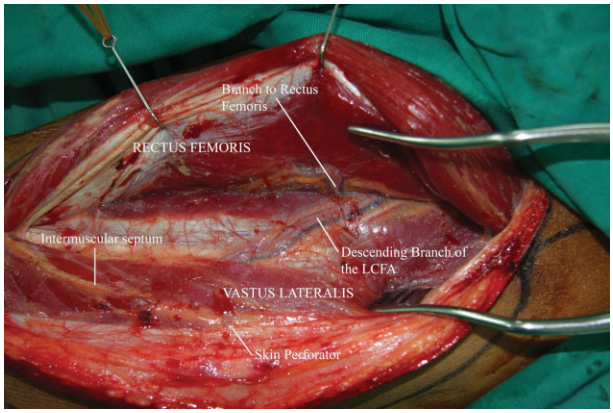

FIGURE 4. Once the septum is opened, the descending branch of the lateral circumflex femoral artery comes into view. LCFA, lateral circumflex femoral artery. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

course of the perforators. The perforator can thus be traced from the point it pierces the deep fascia to the point it joins the main pedicle. The perforator is then separated from the muscles on its sides. Multiple small vessels can be seen arising from the perforator supplying the muscle. These must be secured with hemoclips or with bipolar cautery (Figure 5). Once traced to the descending branch, the fascia layer covering the pedicle is cut. The descending branch distal to the point at which the perforator joins the pedicle can be ligated and divided. The flap can then be completely islanded. The flap is lifted gently off its bed, presenting the inferior surface of the perforator to the surgeon. The surgeon lifts the flap gently off its bed with his nondominant hand while the assistant retracts the muscle laterally and inferiorly with skin-hooks. This clearly presents the posterior aspect of the perforator. The remaining muscle attaching to the perforator can then be cut. Small branches supplying the muscle are ligated and cut. The flap should be lifted with sufficient traction to present the perforator for dissection. Intermittently, the perforator is relaxed to allow for perfusion. The vessels are intermittently irrigated with relaxants (such as papaverine or lignocaine) to prevent vasospasm. This dissection technique of lifting the flap to provide retraction on the perforator significantly expedites the dissection. Gentle handling is crucial. Overzealous traction on the perforator may induce vasospasm that in some cases may be irreversible. Mobilizing in this manner completes the flap harvest (Figure 6). The pedicle is mobilized proximally and harvested at a point just distal to the branch to the rectus femoris, which is the main vessel supplying the latter. If pedicle length is insufficient, this branch can be ligated to increase the pedicle length up to the point at which the lateral circumflex femoral artery arises from the profunda femoris. An additional length of 3 to 4 cm can be procured with this maneuver. However, devascularization of the rectus femoris muscle occurs and this carries with it a small risk of rectus femoris necrosis.[6] The pedicle usually comprises 1 artery with 2 vena comitantes. The artery and the veins should be separated for a distance of at least 2 cm to facilitate microanastomosis at the recipient site. Once the recipient site is ready, the flap can be divided. The artery should be distinguished from the veins either by tagging it with a hemoclip or marking it with ink. The donor site can usually be closed primarily in flaps of less than 8 cm wide. Donor sites for wider flaps needs to be skin grafted. Drains are not routinely necessary.

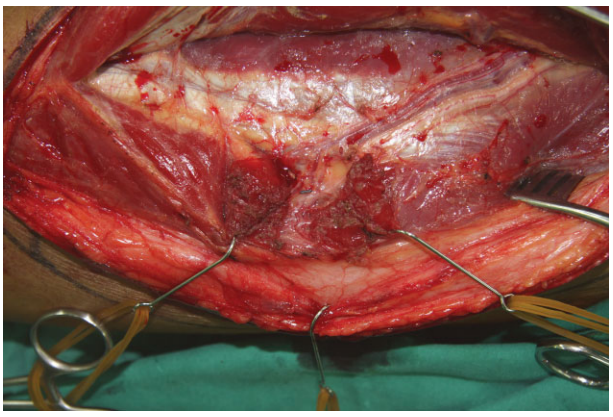

FIGURE 5. The musculocutaneous perforator is unroofed from the subfascial level to its origin at the descending branch. Muscle branches running medially and laterally are ligated and divided. The descending branch distal to the origin of the perforator is ligated and the pedicle mobilized. The main motor nerve to the vastus lateralis muscle should be preserved in perforator flaps. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

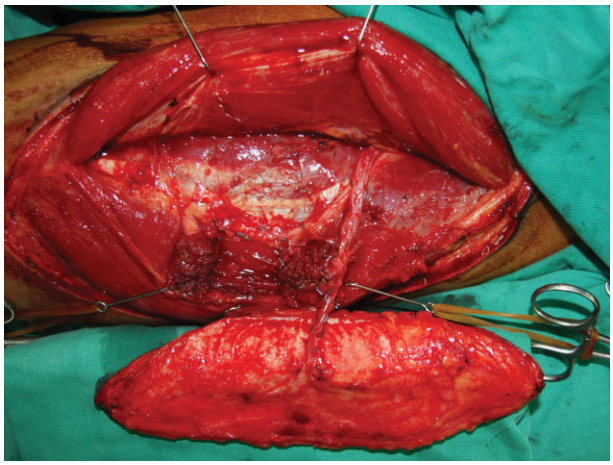

FIGURE 6. The skin paddle is then completely islanded and perforator mobilization completed by gently lifting the flap, and presenting the inferior surface of the perforator and pedicle for dissection. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Clinical Significance of the Oblique Branch in the Harvest of the ALT perforator Flap. Occasionally the vessels supplying the anterolateral thigh originate from the oblique branch of the lateral circumflex femoral artery (Figure 7). In such a situation, the oblique branch can reliably and

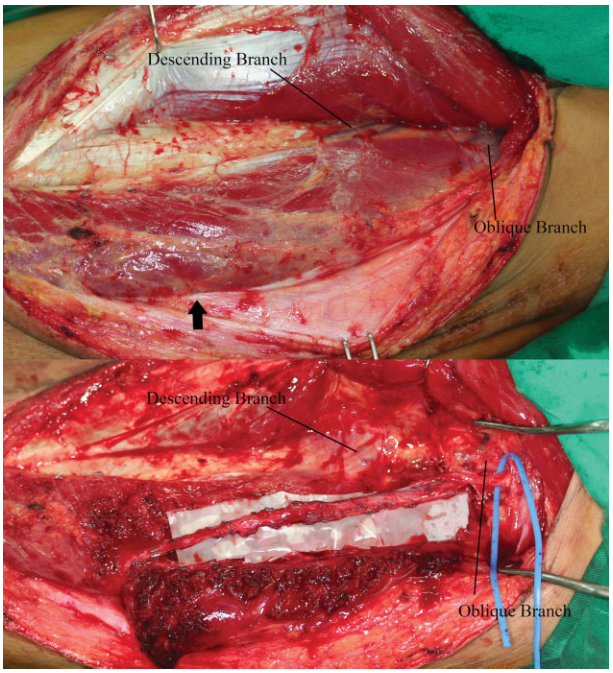

FIGURE 7. (**Above**) In this case, the anterolateral thigh was supplied by a single perforator (arrow). The descending and oblique branches were noted upon opening the intermuscular septum. (**Below**) The perforator was noted to originate from the oblique branch. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

safely be used as the flap pedicle (Figure 8). However, it should be noted that the oblique branch is usually a little smaller (mean diameter, 1–1.5 mm) and shorter than the descending branch (mean pedicle length, 12 cm).[12] Appropriately sized recipient vessels should, therefore, be selected. If a longer and larger caliber pedicle is needed, the surgeon can trace the vessel proximally to include higher order branches such as the descending, transverse, or even taking the lateral circumflex femoral artery, as necessary.[12]

Modified Technique of Harvesting the Anterolateral Thigh Myocutaneous Flap. The harvest of the anterolateral thigh myocutaneous flap has been described previously. The conventional method of harvesting the flap is easy and expedient.[9] However, occasionally this approach results in a muscle component that is healthy while the skin component is nonviable. This has been attributed to poorly defined "anatomical variations" that preclude the harvest of myocutaneous flaps in certain patients. The exact anatomic explanation for this occurrence has hitherto not been documented. Based on current understanding of the vascular anatomy of the anterolateral thigh, failure of the skin component of the flap can now be pinpointed to the (unrecognized) presence of the oblique branch of the lateral circumflex femoral artery in those patients.[17] In most patients, the descending branch supplies both the vastus lateralis muscle and the anterolateral thigh skin through myocutaneous or septocutaneous vessels. However, in cases in which an oblique branch is present, it may be the dominant supply of the anterolateral thigh skin. Harvesting the flap in the conventional method would result in division of the oblique branch when the vastus lateralis muscle is cut proximally. Failure to include the oblique branch would then result in a nonviable skin.

A slight modification in the approach to anterolateral thigh myocutaneous flap harvest is proposed to safeguard against such anatomical variation.[17] The medial incision is made and the flap is elevated to the intermuscular septum. The skin vessels to be included with the flap are

FIGURE 8. A perforator flap was harvested based on the oblique branch of the lateral circumflex femoral artery. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

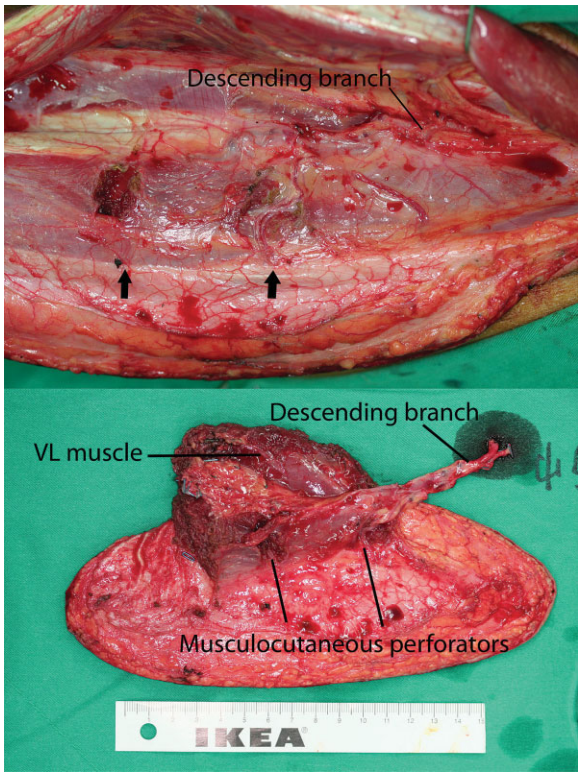

FIGURE 9. (**Above**) In harvesting an anterolateral thigh myocutaneous flap, the vessels supplying the skin are unroofed to determine its origins (arrows). (**Below**) Once this is known, a myocutaneous flap can be confidently harvested by inclusion of skin and transecting the vastus lateralis muscle proximal and distal to these perforators. This is the most reliable approach to harvesting the myocutaneous flaps as the exact vascular pattern is known prior to committing to the flap harvest. VL, vastus lateralis. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

then selected and the intermuscular septum opened. The descending branch and the oblique branch (if present) can usually be seen. The perforator supplying the skin is then traced to its origin by unroofing the muscle over the musculocutaneous perforators. Septal vessels are also followed to its origin. Unroofing of musculocutaneous perforators is safe, minimally devascularizes the muscle, and can be done quickly with minimal bleeding. This is because the branches from the perforator supplying the vastus lateralis muscle usually run medially, laterally, and posteriorly. Very few of them run anteriorly.[18] Once the anatomy is defined, 3 scenarios are possible. First, skin and muscle are supplied by the descending branch (Figure 9). This is the most common situation and the flap harvest can be completed in the usual manner, taking a segment of the vastus lateralis muscle with a skin island. Second, the skin is supplied by the descending and oblique branches. In this situation, as long as there is at least 1 sizable skin vessel originating from the descending branch, it is the preferred pedicle as it is usually larger and longer. The oblique branch contribution can be cut and the flap harvest completed in the usual manner (Figures 10 and 11). Third, the skin is supplied exclusively by vessels arising from the oblique branch. In such situations, the oblique branch can usually be used as the pedicle of the myocutaneous flap, leaving the descending branch in situ (Figures 12 and 13). Rarely, if a large piece of the vastus lateralis muscle is needed, both the descending branch and the oblique branch may have to be included to adequately nourish the flap (Figure 14). In such a situation, in the majority of the cases, the descending branch and oblique branch converge at the lateral circumflex femoral artery (types 1

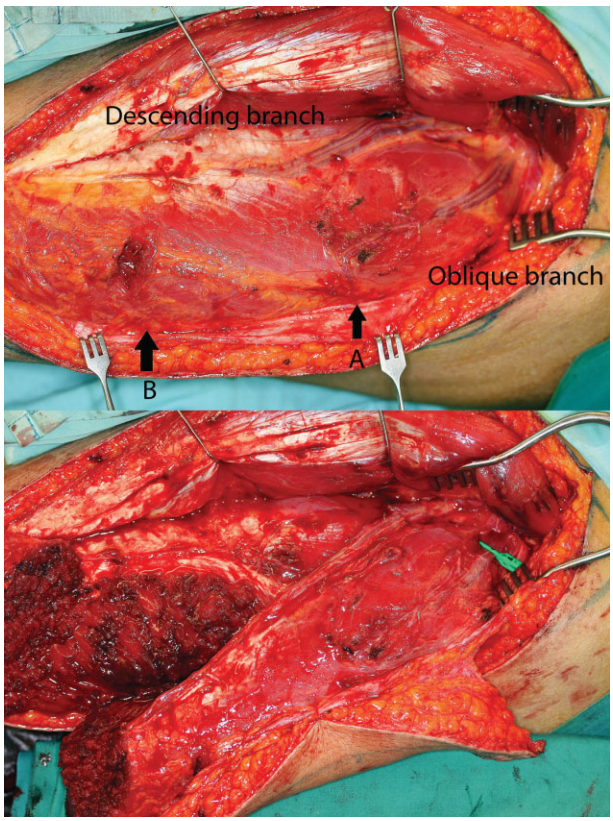

FIGURE 10. (**Above**) In this situation, 2 equally large perforators supply the anterolateral thigh (arrows). One originates from the descending branch (B) and the other from the oblique branch (A). (**Below**) When a choice exists, the descending branch is usually preferred as it is usually larger and longer. A vascular clamp is placed on the oblique branch to confirm skin viability prior to dividing it. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

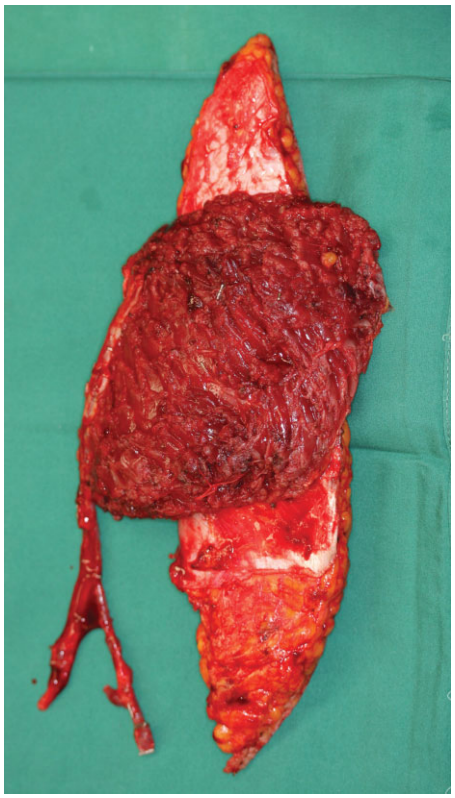

FIGURE 11. Anterolateral thigh myocutaneous flap harvested based on the descending branch. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

and 2, 88%) and the flap can be harvested as a single pedicled flap. Rarely (types 3, 4, and 5, 12%) they are divergent and join the profunda femoris separately. Two sets of microsurgical anastomoses are then necessary.[12] It should be noted, however, that the need to harvest the flap based on both the descending and oblique branches is a rare occurrence. In our prospective series of 89 cases, we had to do this in only 1 case (1%).[12] In most cases, either the descending branch or the oblique branch alone was sufficient to supply the flap, whether we were harvesting a fasciocutaneous or myocutaneous flap.

DISCUSSION

Wei et al[19–21] pioneered the concept of harvesting flaps in a "free-style" manner. With this approach, a cutaneous vessel is localized with a handheld Doppler and a flap is designed around it. The vessel is then mobilized by retograde dissection until a sufficient pedicle length and caliber is procured. The actual pedicle of the flap is not important and may indeed be irrele-

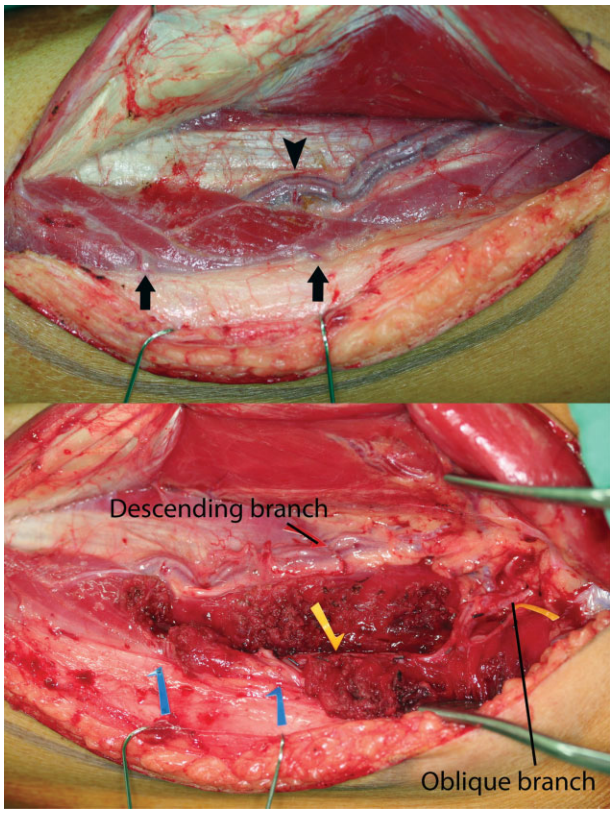

FIGURE 12. (**Above**) A seemingly straightforward and favorable situation for the harvest of an ALT myocutaneous flap. Two perforators (arrows) apparently arising from the descending branch of the lateral circumflex femoral artery (arrow head) located just a short distance away. However, harvesting the flap in the conventional method would have resulted in a nonviable skin component in this case. (**Below**) Unroofing demonstrated that the 2 perforators originated from the oblique branch with no vascular connection to the descending branch. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

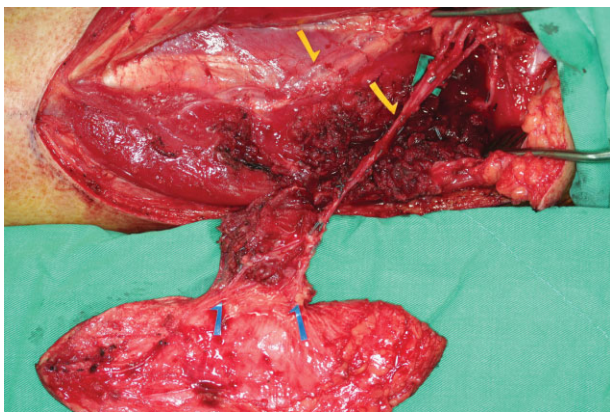

FIGURE 13. The flap harvested based on the oblique branch. The artery was 1.5 mm, and 2 veins were both 2 mm. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

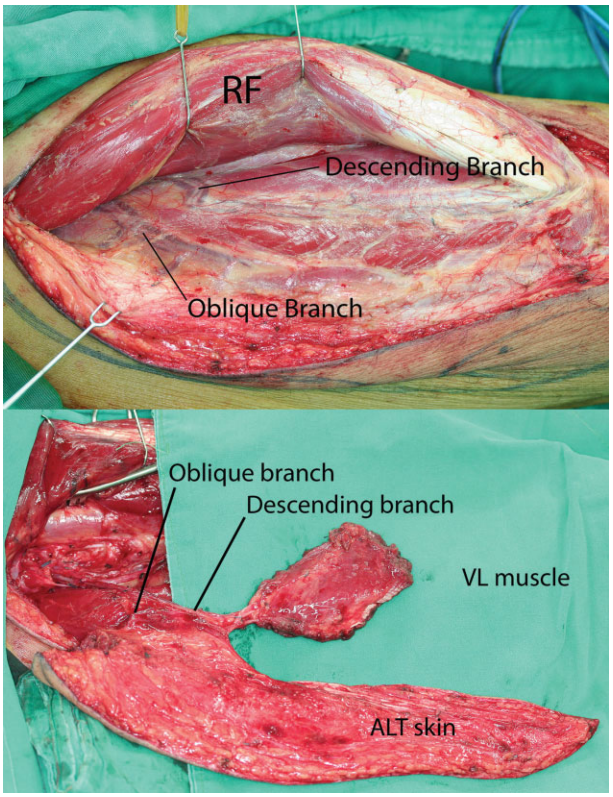

FIGURE 14. (**Top**) In this case, the skin of the anterolateral thigh was supplied by a large oblique branch and the vastus lateralis muscle by the descending branch. (**Bottom**) The flap harvested as a chimeric flap including both the oblique and descending branch. RF, rectus femoris; VL, vastus lateralis. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

vant as long as the pedicle is adequate for safe microsurgical anastomoses. In the past, it was didactically stated that the descending branch of the lateral circumflex femoral artery is the pedicle of the anterolateral thigh flap. When the perforators are noted to originate from a source other than the descending branch, flap harvest may be abandoned. Conversely, if the descending branch was blindly harvested as the flap pedicle of the myocutaneous flap regardless of the potentially anomalous anatomy, partial or even complete necrosis particularly of the skin component resulted. Adopting a "free-style" approach to the harvest of the anterolateral thigh flap, the surgeon should retrogradely trace all skin vessels and use whatever pedicle the vessels originate from. Two potential pedicles exist for the anterolateral thigh flap: either the descending or the oblique branches.[12] In rare instances, both may need to be harvested. The descending branch is, however, the preferred vessel because it is usually longer and larger caliber. With the free-style approach, the anterolateral thigh flap of various configurations can be successfully harvested in most patients.

The versatility of the anterolateral thigh is unparalleled[22–31]; no other donor site provides such a large amount of soft tissue – skin, muscle and fascia – with so little donor morbidity. In our practice, it is the workhorse soft tissue flap and has largely replaced the radial forearm flap, which was the most common soft tissue flap used prior to the rise of the anterolateral thigh flap. It can be harvested as a cutaneous, fasciocutaneous, and myocutaneous flaps.[9] When a thin flap is needed, it can be thinned to about 5 mm by excision of subcutaneous tissue.[25] It can be harvested as a muscle flap (vastus lateralis muscle flap) based on the descending branch of the lateral circumflex femoral artery.[29,30] The flap can be sensate by inclusion of the lateral femoral cutaneous nerve.[9] It can be harvested with multiple skin islands (Figure 15) or as 2 separate free flaps from a single donor site.[32] A large piece of vascularized fascia lata can be included with the flap for tendon reconstruction (eg, patella tendon or the tendo Archilles). For segmental defects of blood vessels, the descending branch can be harvested and anastomoses performed in a flow-through manner for reconstitution of distal flow.[22,24] For complex 3-dimensional defects, a chimeric type flap can be readily harvested. A functional muscle can also be harvested by inclusion of the vastus lateralis or rectus femoris muscle with its motor

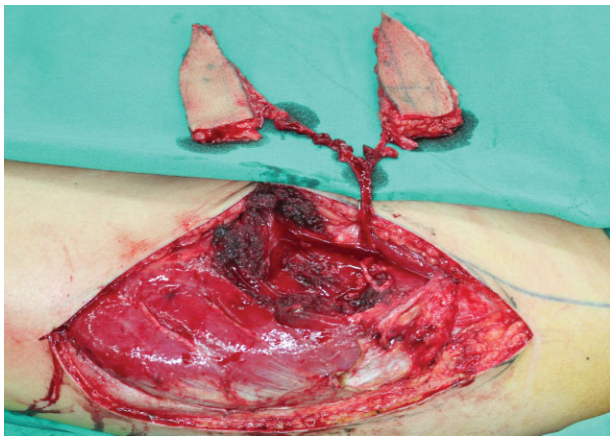

FIGURE 15. Anterolateral thigh perforator flap with 2 separate skin islands. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

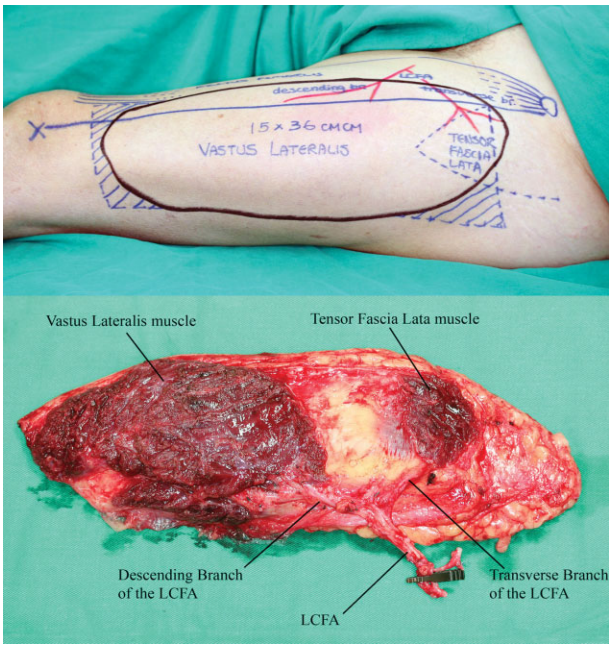

FIGURE 16. A conjoint anterolateral thigh and tensor fascia lata flap incorporating most of the lateral thigh skin. LCFA, lateral circumflex femoral artery. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

nerves.[22,31] For massive defects, the entire lateral thigh can be harvested by combining the anterolateral thigh and the tensor fascia lata flaps as a conjoined flap (Figure 16).[33] The anterolateral thigh flap can also be harvested conjoined with the anteromedial thigh flap. Free grafts of nerve (lateral femoral cutaneous nerve), fascia (fascia lata), and vein (long saphenous vein) can also be directly accessed from the donor site without the need for additional incisions. The only limitation of this flap is that it is unable to reliably provide bone. When a bone flap is needed, the fibula osteoseptocutaneous flap is our choice flap. With large complex defects with both bone and soft tissue loss for which double free flaps are needed, we have found the combination of anterolateral thigh and fibula osteoseptocutaneous flaps ideal.[34–36]

The only other donor site of comparable versatility is the dorsal thoracic territory based on the subscapular system.[37–39] This system allows the harvest of skin, muscle, myocutaneous, and bone in various combinations. The major advantage that the anterolateral thigh flap has over the dorsal thoracic territory flaps is the patient positioning during the harvest. The latter is usually harvested in the prone or lateral decubitus position and, therefore, usually requires intraoperative repositioning for head and neck cases. This significantly prolongs the surgery. The anterolateral thigh, in contrast, allows simultaneous flap harvest by a 2-team approach. It is also in a much more accessible location and allows the surgeon to be seated comfortably during most of the procedure. Donor site morbidity tends to be slightly greater when the subscapular system is used and includes shoulder stiffness and high rates of seroma, particularly if the latissimus dorsi muscle is harvested.[38]

The skin vessels supplying the flap have been designated perforators A, B, and C by Yu et al.[15,16] This is a useful guide for locating the skin vessels preoperatively with the handheld Doppler. It should also be noted that vessels at each of these locations tend to have certain characteristics. The A location is the most common site for septocutaneous vessel. The oblique branch (when present) more commonly supplies this location as well. The B vessel is usually a musculocutaneous perforator with a short, direct and superficial intramuscular course to the pedicle. Mobilization is therefore easier and quicker. The C perforator is almost always musculocutaneous and usually located more laterally on the vastus lateralis muscle. It usually has a tortuous intramuscular course running caudally and

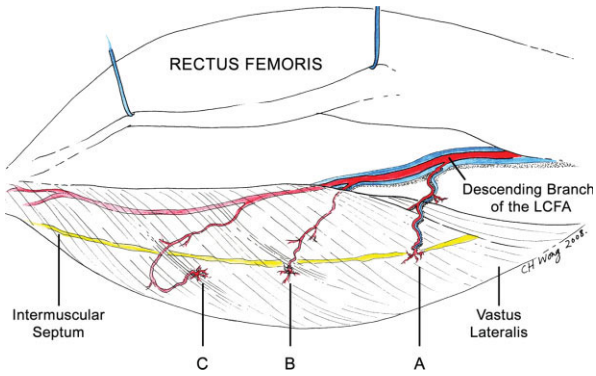

FIGURE 17. This diagram illustrates the general characteristics of vessels at the A, B, and C locations. 'A' vessels have the highest possibility of being septocutaneous. It may also be musculocutaneous with a short intramuscular course. The oblique branch, when present preferentially, supply vessels in this area. 'B' vessels are usually musculocutaneous with a characteristically short and direct intramuscular course to its pedicle. It runs in a relatively superficial location within the muscle. 'C' vessels are almost always musculocutaneous perforators. It is located more laterally and characteristically has a long, tortuous course within the muscle. LCFA, lateral circumflex femoral artery. [Color figure can be viewed in the online issue, which is available at www.interscience. wiley.com.]

posteriorly before turning cephalad and anteriorly to join the pedicle. Mobilization requires long intramuscular dissection and is, therefore, arduous and time-consuming. They are, however, reliable and reward the surgeon with a very long pedicle up to 20 cm (Figure 17).

CONCLUSION

The anterolateral thigh flap is a flap of unsurpassed versatility. No other donor site in the body offers such large amount of tissue with such minimal donor morbidity.[40,41] With the current understanding of the vascular anatomy of this flap as elucidated in this article, the anterolateral thigh flap can reliably and safely be harvested in most patients.

REFERENCES

1. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. Br J Plast Surg 1984;37:149–159.
2. Koshima I, Fukuda H, Utunomiya R, Soeda S. The anterolateral thigh flap; variations in its vascular pedicle. Br J Plast Surg 1989;42:260–262.
3. Koshima I, Fukuda H, Yamamoto H, Moriguchi T, Soeda S, Ohta S. Free anterolateral thigh flaps for reconstruction of head and neck defects. Plast Reconstr Surg 1993;92:421–428; discussion 429–430.
4. Zhou G, Qiao Q, Chen GY, Ling YC, Swift R. Clinical experience and surgical anatomy of 32 free anterolateral thigh flap transplantations. Br J Plast Surg 1991;44:91–96.
5. Shieh SJ, Chiu HY, Yu JC, Pan SC, Tsai ST, Shen CL. Free anterolateral thigh flap for reconstruction of head and neck defects following cancer ablation. Plast Reconstr Surg 2000;105:2349–2357; discussion 2358–2360.
6. Koshima I. Free anterolateral thigh flap for reconstruction of head and neck defects following cancer ablation. Plast Reconstr Surg 2000;105:2358–2357; discussion 2358–2360.
7. Kuo YR, Yeh MC, Shih HS, Chen CC, Lin PY, Chiang YC, Jeng SF. Versatility of the anterolateral thigh flap with vascularized fascia lata for reconstruction of complex soft-tissue defects: clinical experience and functional assessment of the donor site. Plast Reconstr Surg 2009;124:171–180.
8. Luo S, Raffoul W, Luo J, et al. Anterolateral thigh flap: a review of 168 cases. Microsurgery. 1999;19:232.
9. Wei FC, Jain V, Celik N, Chen HC, Chuang DC, Lin CH. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. Plast Reconstr Surg 2002;109:2219–2226; discussion 2227–2230.
10. Lutz BS, Wei FC. Microsurgical workhorse flaps in head and neck reconstruction. Clin Plast Surg 2005;32:421–430, vii.
11. Mathes S, Nahai F. Reconstructive surgery; principles, anatomy and technique. Vol 2. QMP, St Louis. 1233–1246.
12. Wong CH, Wei FC, Fu B, Chen YA, Lin JY. Alternative vascular pedicle of the anterolateral thigh flap: the oblique branch of the lateral circumflex femoral artery. Plast Reconstr Surg 2009;123:571–577.
13. Kawai K, Imanishi N, Nakajima H, Aiso S, Kakibuchi M, Hosokawa K. Vascular anatomy of the anterolateral thigh flap. Plast Reconstr Surg 2004;114:1108–1117.
14. Kimata Y, Uchiyama K, Ebihara S, Nakatsuka T, Harii K. Anatomic variations and technical problems of the anterolateral thigh flap: a report of 74 cases. Plast Reconstr Surg 1998;102:1517–1523.
15. Yu P. Characteristics of the anterolateral thigh flap in a Western population and its application in head and neck reconstruction. Head Neck 2004;26:759–769.
16. Yu P, Youssef A. Efficacy of the handheld Doppler in preoperative identification of the cutaneous perforators in the anterolateral thigh flap. Plast Reconstr Surg 2006; 118:928–933; discussion 934–935.
17. Wong CH, Kao HK, Fu B, Lin JY. A cautionary point in the harvest of the anterolateral thigh myocutaneous flap. Ann Plast Surg 2009;62:637–639.
18. Kimata Y, Uchiyama K, Ebihara S, et al. Versatility of the free anterolateral thigh flap for reconstruction of head and neck defects. Arch Otolaryngol Head Neck Surg 1997;123:1325–1331.
19. Wei FC, Mardini S. Free-style free flaps. Plast Reconstr Surg 2004;114:910–916.
20. Mardini S, Tsai FC, Wei FC. The thigh as a model for free style free flaps. Clin Plast Surg. 2003;30:473–480.
21. Chang CC, Wong CH, Wei FC. Free-style free flap. Injury 2008;39 Suppl 3:S57–61.
22. Lin CH, Wei FC, Lin YT, Yeh JT, Rodriguez Ede J, Chen CT. Lateral circumflex femoral artery system: warehouse for functional composite free-tissue reconstruction of the lower leg. J Trauma 2006;60:1032–1036.
23. Koshima I, Hosoda S, Inagawa K, Urushibara K, Moriguchi T. Free combined anterolateral thigh flap and vascularized fibula for wide, through-and-through oromandibular defects. J Reconstr Microsurg 1998;14: 529–534.
24. Ao M, Nagase Y, Mae O, Namba Y. Reconstruction of posttraumatic defects of the foot by flow-through anterolateral or anteromedial thigh flaps with preservation of posterior tibial vessels. Ann Plast Surg 1997;38: 598–603.
25. Kimura N, Satoh K. Consideration of a thin flap as an entity and clinical applications of the thin anterolateral thigh flap. Plast Reconstr Surg 1996;97:985–992.
26. Sasaki K, Nozaki M, Nakazawa H, Kikuchi Y, Huang T. Reconstruction of a large abdominal wall defect using combined free tensor fasciae latae musculocutaneous flap and anterolateral thigh flap. Plast Reconstr Surg 1998;102:2244–2252.
27. Koshima I, Yamamoto H, Hosoda M, Moriguchi T, Orita Y, Nagayama H. Free combined composite flaps using the lateral circumflex femoral system for repair of massive defects of the head and neck regions: an introduction to the chimeric flap principle. Plast Reconstr Surg 1993;92:411–420.
28. Pribaz JJ, Orgill DP, Epstein MD, Sampson CE, Hergrueter CA. Anterolateral thigh free flap. Ann Plast Surg 1995;34:585–592.
29. Wolff KD, Grandmann A. The free vastus lateralis flap: an anatomic study with case reports. Plast Reconstr Surg 1992;89:469–475; discussion 476–477.
30. Spyriounis PK, Lutz BS. Versatility of the free vastus lateralis muscle flap. J Trauma 2008;64:1100–1105.
31. Lin CH, Lin YT, Yeh JT, Chen CT. Free functioning muscle transfer for lower extremity posttraumatic composite structure and functional defect. Plast Reconstr Surg 2007;119:2118–2126.
32. Huang JJ, Wallace C, Lin JY, et al. Two small flaps from one anterolateral thigh donor site for bilateral buccal mucosa reconstruction after release of submucous fibrosis and/or contracture. J Plast Reconstr Aesthet Surg 2009 Apr 7. [Epub ahead of print].
33. Wong CH, Lin CH, Fu B, Fang JF. Reconstruction of complex abdominal wall defects with free flaps:

indications and clinical outcome. Plast Reconstr Surg in press.
34. Demirkan F, Wei FC, Chen HC, Chen IH, Hau SP, Liau CT. Microsurgical reconstruction in recurrent oral cancer: use of a second free flap in the same patient. Plast Reconstr Surg 1999;103:829–838.
35. Wei FC, Yazar S, Lin CH, Cheng MH, Tsao CK, Chiang YC. Double free flaps in head and neck reconstruction. Clin Plast Surg 2005;32:303–308, v.
36. Jeng SF, Kuo YR, Wei FC, Su CY, Chien CY. Reconstruction of extensive composite mandibular defects with large lip involvement by using double free flaps and fascia lata grafts for oral sphincters. Plast Reconstr Surg 2005;115:1830–1836.
37. Wei FC, Jain V, Celik N, Chen HC, Chuang DC, Lin CH. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. Plast Reconstr Surg 2002;109:2219–2226; discussion 2227–2230.
38. Germann G, Bickert B, Steinau HU, Wagner H, Sauerbier M. Versatility and reliability of combined flaps of the subscapular system. Plast Reconstr Surg 1999;103:1386–1399.
39. Aviv JE, Urken ML, Vickery C, Weinberg H, Buchbinder D, Biller HF. The combined latissimus dorsi-scapular free flap in head and neck reconstruction. Arch Otolaryngol Head Neck Surg 1991;117:1242–1250.
40. Kuo YR, Jeng SF, Kuo MH, et al. Free anterolateral thigh flap for extremity reconstruction: clinical experience and functional assessment of donor site. Plast Reconstr Surg 2001;107:1766–1771.
41. Kimata Y, Uchiyama K, Ebihara S, et al. Anterolateral thigh flap donor-site complications and morbidity. Plast Reconstr Surg 2000;106:584–589.