The Anterolateral Thigh Perforator Flap for Reconstruction of Knee Defects

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Introduction: Large defects around the knee remain challenging reconstructive problems. We report our experience with the use of the anterolateral thigh perforator flap for various defects in this area, based on the anatomy seen intraoperatively.

Methods and Materials: Eight knee defects were reconstructed with the anterolateral thigh flap in accordance with our algorithm. Of them, 6 were performed as pedicled flaps and 2 as free flaps. For the pedicled flaps, 1 patient was reconstructed with an anterolateral thigh rotation flap, 3 patients with a directly transposed distally based anterolateral thigh flap, 2 patients with a "propeller" distally based anterolateral thigh flap. In the 2 patients reconstructed with the free anterolateral thigh flaps, the intramuscular part of the descending branch of the lateral circumflex femoral artery was used as the recipient vessel.

Results: Reconstruction was successfully performed in all patients. Defects limited to the patella and above can be covered by antegrade anterolateral thigh rotation flaps. For larger defects, the distally based flap is needed. This can be used in cases where the perforators arise from the descending branch of the lateral circumflex femoral artery, either as a direct advancement or propeller flaps. In cases where the perforators are not usable or arises from the oblique branch of the lateral circumflex femoral artery, reconstruction was completed as a free flap. In such instances, the distal descending branch provides a reliable recipient vessel.

Conclusion: The anterolateral thigh flap offers a versatile and reliable option for defects around the knee. Its use requires a certain degree of reconstructive flexibility as the anatomic variations of the flap may require the flap to be transferred as a free flap in some cases.

Key Words: distally based, reverse flow, complex, knee, defects, pedicled, propeller

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Large defects around the knee is a challenging reconstructive problem.[1] Although the gastrocnemius flap remains the workhorse flap for defects in this area for its reliability and ease of harvest,[2] its significant shortcoming remains the lack of sufficient tissue bulk in the distal part of the muscle and the size of defects than can be covered are essentially small defects located below the patella. Its use is also associated with significant knee stiffness.[3] The use of fasciocutaneous flaps is advantageous, as it avoids the sacrifice of precious regional muscles, provides durable coverage, and is easily re-elevated later if further work is needed on the underlying bone. There is, however, a paucity of local fasciocutaneous flaps of significant size that can be reliably used around the knee.[4–7]

The anterolateral thigh flap is currently a very popular soft-tissue flap.[8–12] The anterolateral thigh perforator flap has been successfully used in the groin, perineum, and buttock as a pedicled flap.[13,14] Its use in the knee region as a distally based flap is appealing for its low donor-site morbidity and the availability of large amount of tissues. Although the distally based anterolateral thigh flap has been reported,[15–18] concerns remain about the viability of this option in view of the significant anatomic variation with the vascular supply of the flap as well as the varying location of the dominant skin perforators. This article reports our experience on the use of the distally based anterolateral thigh flap for coverage of knee defects and highlights the relevant anatomic variations of the flap that impact its use in the knee as well as our approach to circumvent the anatomy in these situations.

METHODS AND MATERIALS

From January 2008 to April 2011, 8 patients with knee defects were reconstructed with the anterolateral thigh pedicled or free flap according to the algorithm as shown in Figure 1. The surgery was approached with a pedicled flap, with a view to convert to free anterolateral thigh flap as surgical consent. The perforators of the anterolateral flaps on both thighs were located by a hand-held Doppler. The wound is debrided, and the ipsilateral anterolateral thigh is explored; and depending on the anatomy, the design of the flap refined as needed. When feasible, a distally based anterolateral thigh flap is performed. If the anatomy is unfavorable for local transfer, the reconstruction is completed with the free anterolateral thigh flap, with the descending branch of the lateral circumflex femoral artery as the recipient vessel.

RESULTS

All flaps survived, and the reconstruction was successfully completed in a single stage with no need for additional flaps or skin grafts. Pedicled anterolateral thigh flap was performed in 6 patients, and free anterolateral thigh flap was performed in 2 patients (Fig. 2). For the pedicled flaps, 1 patient was reconstructed with an anterolateral thigh rotation flap, 3 patients with a directly transposed distally based anterolateral thigh flap, 2 patients with a "propeller" distally based anterolateral thigh flap. In the 2 patients reconstructed with the free anterolateral thigh flaps, the intramuscular part of the descending branch of the lateral circumflex femoral artery was used as the recipient vessel. The mean follow-up was 7 months (range, 2 months–3 years). In 1 patient, a 1-cm distal necrosis was managed by debridement and secondary suture with subsequent uneventful healing. Of the 5 distally based anterolateral thigh flaps, 2 developed transient mild venous congestion that resolved within 5 to 7 days. No augmentation of venous outflow was done in any of our cases.

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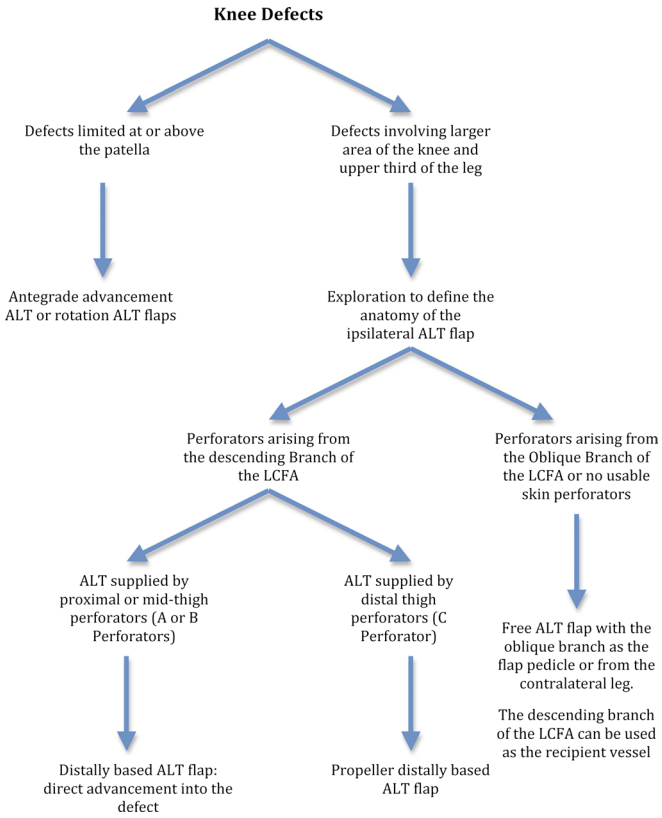

FIGURE 1. An algorithm for the use of the anterolateral thigh perforator flap for knee defects. ALT indicates anterolateral thigh flap; LCFA, lateral circumflex femoral artery.

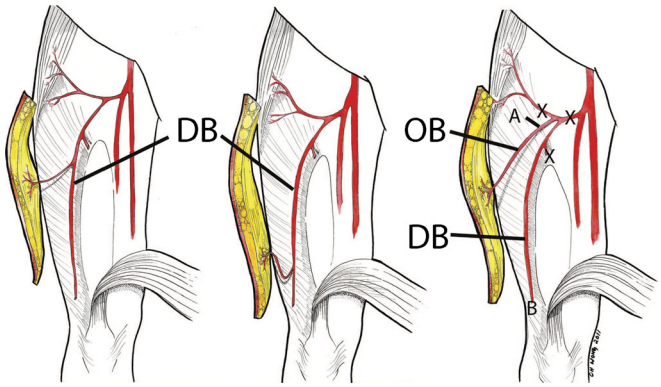

FIGURE 2. Operative plan based on intraoperative findings. Left, if the perforator arises from the midthigh, it can be dissected to the descending branch and the later traced distally. The distally based anterolateral thigh flap can then be transposed onto the knee. Middle, if the perforator is located in the distal thigh, the flap should be designed by including the proximal thigh skin, placing the perforator eccentrically in the distal thigh. The perforator is then traced to the descending branch, which is in turn mobilized as far distally down the thigh as possible. The flap is then twisted 180 degrees on its pedicle (propeller flap), and then advanced onto the knee. Right, when the flap is supplied by the oblique branch, harvesting the flap as a distally based flap would necessitate the division of transverse branch of the lateral circumflex femoral artery, the lateral circumflex femoral artery itself, and the branch to rectus femoris (main vascular supply to the rectus femoris) (Xs) as well as the multiple muscle branches from the oblique and descending branches supplying the vastus lateralis. This is ''too destructive'' as it causes extensive devascularization of the thigh musculature. We therefore recommend that when this anatomy is encountered, the reconstruction should be performed as free flap. The anterolateral thigh flap can be harvested based on the oblique branch (point A) and the distal descending branch (point B) used as the recipient vessel. DB indicates descending branch of the lateral circumflex femoral artery; OB, oblique branch of the lateral circumflex femoral artery.

Illustrative Cases

Case 1: Anterolateral Thigh Flap as a Rotation Flap

A 34-year-old man who had a road traffic accident suffered skin lost from the knee (Fig. 3A). As the defect was limited to the area above the patella, reconstruction with an anterolateral thigh rotation flap was planned. The perforators of the anterolateral flap were mobilized with the rotation flap to give the flap a more robust vascularity.[19] The wound successfully covered, and healing was uneventful (Fig. 3B). At 2-year follow-up, he was well with full range of knee motion.

Case 2: Distally Based Anterolateral Thigh Flap

A 71-year-old man with multiple comorbidities presented with a large defect over the knee. He had 2 previous total knee replacement surgeries, with the second attempt being complicated by septic arthritis and the soft-tissue necrosis (Fig. 4A). The wound was debrided, and tissue culture documented clearance of the infection. Coverage with a distally based anterolateral thigh flap was planned. Intraoperatively, a midthigh perforator arising from the descending branch was noted. This was ligated proximally, and the descending branch was mobilized distally to a distance of 10 cm cephalad to the upper border of the patella. The flap was then transposed into the defect (Fig. 4B). Postoperatively, he completed a 6-week course of antibiotics, and the flap healed uneventfully. Figure 4C shows his knee at 4-month follow-up.

Case 3: Propeller Distally Based Anterolateral Thigh Flap

A 47-year-old man sustained an open patella fracture and skin loss over the knee in a road traffic accident. This was treated with cerclage wiring, and reconstruction with a distally based anterolateral thigh flap was planned. Intraoperatively, the dominant perforator supplying the anterolateral thigh skin was located in the distal thigh (C perforator). This was traced to the descending branch, which was then ligated proximally and the pedicle traced distally to a distance of 9 cm from the upper edge of the patella. The pedicle length measured 12 cm. To harness the bulk of the flap which was located proximally to cover the defect, the flap was rotated 180 degrees on its pedicle and subsequently advance into the defect (Fig. 5A). Postoperatively, purulent discharge was noted from the drains. The wound was opened, and the patella was found to be necrotic. This was debrided, and the wound was subsequently secondarily closed after a week of negative pressure dressing. The flap survived completely, and the wounds healed with a prolonged course of antibiotics (Fig. 5B). Range of motion of the knee was good at 0 degree to 90 degrees at 6-month follow-up.

Case 4: Free Anterolateral Thigh Flap With the Ipsilateral Descending Branch of the Lateral Circumflex Femoral Artery as the Recipient Vessel

A 67-year-old man had a high-velocity road traffic accident and sustained an open patella fracture with skin necrosis (Fig. 6A). This was treated by debridement and cerclage wires of the patella. Reconstruction with an anterolateral thigh flap was planned. The ipsilateral thigh was explored, and the dominant perforator supplying the anterolateral skin was the distal knee (C) perforator. However, the perforator was bruised and not pulsating well as a result of the trauma, precluding its safe use. Accordingly, a free anterolateral thigh flap was harvested from the contralateral leg. The descending branch was traced intramuscularly to a distance of 12 cm from the upper edge of the patella (Fig. 6B). Microanastomoses were performed to the distal descending branch and its venae comitantes (1 artery and 1 vein) (Fig. 6C). Postoperative recovery was uneventful, and the flap survived completely (Fig. 6D). At 6-month follow-up, he had full range of motion in the affected knee.

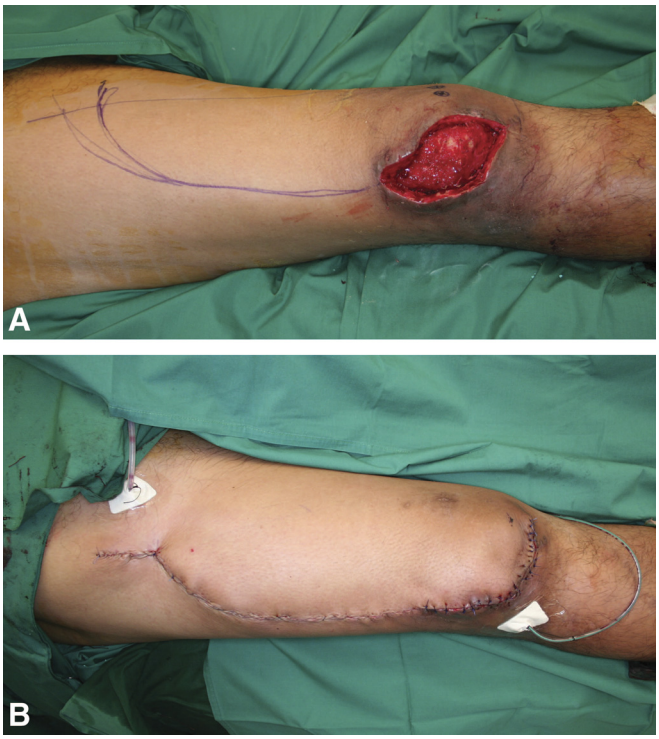

FIGURE 3. A, A defect involving the patella with the design of the anterolateral thigh rotation flap marked. B, The anterolateral thigh perforators were mobilized to its origin at the descending branch. This allowed the perforators to move with the rotation of the skin flap, providing a robust flap for coverage of the defect.

DISCUSSION

Based on the current understanding, the so-called "variations" in the vascular anatomy of the anterolateral thigh flap can simply be classified into (1) The variation in the course of the skin perforators of the flap; these can be musculocutaneous or septocutaneous and (2) Variation in the pedicle of the flap, which can either be the descending branch or oblique branch of the lateral circumflex femoral artery.[8,20] This knowledge has been instrumental in devising an algorithm that can reliably be used to resurface the knee with the anterolateral thigh flap. In considering the use of the distally based anterolateral thigh flap for the knee, the descending branch of the lateral circumflex femoral artery is always the preferred pedicle for the flap as consistently anastamose with the lateral superior geniculate artery or profunda femoris above the knee joint, which in turn reliably provides the retrograde inflow to supply the flap.[16] Therefore, when a choice exists, perforators arising from the descending branch should be selected.

In designing the skin island, the flap should be designed long in the longitudinal direction well into the proximal thigh, and the medial incision made initially to explore and define the vascular anatomy. The long initial incision gives the versatility needed to refine the skin flap design, in terms of the skin island size and dimensions, once the anatomy is defined. This gives the versatility of either advancing[16] or using it as a propeller-type flap[21] to cover the knee defect depending on the specific vascular anatomy of the flap encountered in each individual case.

Commonly, the dominant perforator supplying the anterolateral thigh skin arises from the descending branch of the lateral circumflex femoral artery.[10] This is favorable anatomy for the distally based anterolateral thigh flap. If this perforator is located at the midthigh (A or B perforators), it can be mobilized to its take-off from descending branch and the descending branch ligated proximal to this point. The descending branch can then be dissected distally by tracing it into the substance of the vastus lateralis muscle. Commonly, the pedicle can be safely mobilized to level about 10 cm cephalad to the superior edge of the patella, where the size of the artery and vein diminishes to <1 mm. This dissection, from the subfascial

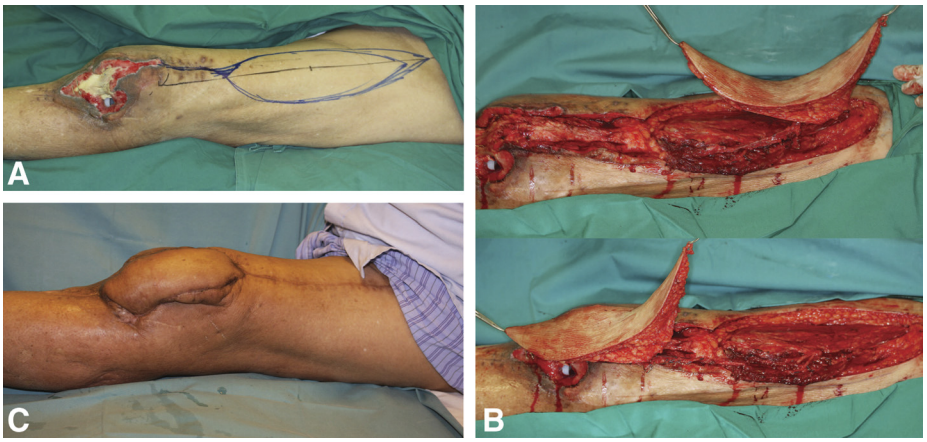

FIGURE 4. A, A knee defect with an exposed knee spacer. B, An anterolateral thigh flap supplied by a midthigh (B) perforator arising from the descending branch was raised. The pedicle of the distally based anterolateral thigh flap measured 18 cm and the flap can be transposed directly onto the large knee defect. C, Patient at 6-month follow-up.

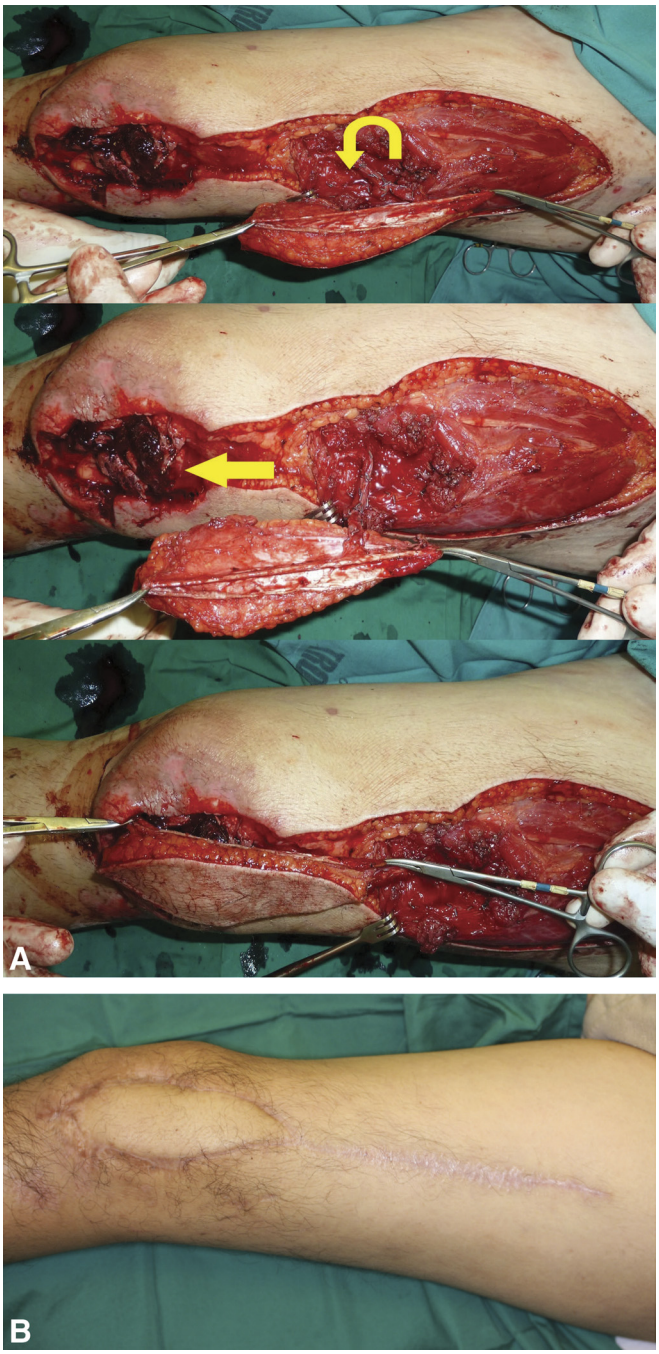

FIGURE 5. A, A large knee defect with coverage planned with a distally based anterolateral thigh flap. Intraoperatively, the largest perforator was the distal thigh (C) perforator. The flap was designed well into the proximal thigh and ''propellered'' on its pedicle before advancing into the defect. B, The patient at 1-year follow-up.

location of the dominant perforator to its origin of the descending branch and then distally down the course of the descending branch into the vastus lateralis will yield a pedicle length of 15 to 25 cm, allowing the distally based anterolateral thigh flap to advance into the knee area.[16]

In situation where the dominant perforator is located in the distal leg (C perforator), the length of the pedicle that can be harvested from the perforator to the descending branch and then subsequently distally down the course of the descending branch may be limited. In such cases, the amount of direct advancement that is achievable is limited. To increase the reach of the flap, one can harness the proximal thigh skin. This would place the perforator eccentrically in the distal part of the flap thus harvested. The flap can then be rotated 180 degrees on its pedicle and advanced into the defect (propeller flap).[21] It is safe to do this so long as the twist in the pedicle is distributed evenly over the course of the pedicle, and the pedicle is sufficiently long to allow for this even distribution (at least 3 cm).[22] It is crucial that the pedicle is placed under absolutely no tension from the flap advancement in propeller-advancement flaps.

In cases where the dominant perforator supplying the anterolateral thigh skin is supplied exclusively by the oblique branch of the lateral circumflex femoral artery[20] presents a unique anatomic conundrum, as the oblique branch is an end artery that terminates in the substance of the vastus lateralis muscle, with no retrograde inflow. Pan et al suggested that the oblique branch can be traced to its origin, commonly off the transverse or descending branch of the lateral circumflex femoral artery, and then dissecting down the descending branch toward the knee to procured the needed pedicle length to transpose onto the knee.[16] This approach causes extensive devascularization of the thigh muscles from ligation of the transverse branch (that supplies the tensor fascia lata), the branch to rectus femoris (the main supply to the rectus femoris), as well as the numerous muscle direct muscle branches from the oblique and descending branches that supplies the vastus lateralis.[23,24] Hence, we agree with Lin et al that performing the reconstruction as a free flap is the most sensible option in this situation.[24]

Finding a reliable recipient vessel for free tissue transfer around the knee joint is challenging.[25,26] We have found that the descending branch can be dissected intramuscularly to a distance of about 8 to 12 cm from the upper edge of the patella. Its size at this level is about 1 mm. The pedicle is also well protected by the vastus lateralis in cases of associated knee trauma. We have found that it is reliable and easy to use as the recipient vessels because of its relatively superficial location, longitudinal orientation along the axis of the leg, and its location on the lateral aspect of the thigh. An added advantage, as part of the overall algorithm with the use of the anterolateral thigh flap for knee defects, is off course no additional incisions are necessary. It is now our preferred recipient vessel for free flaps around the knee.[25–27] As noted, for knee defects, it is necessary to use the intramuscular part of the descending branch where it is closer to the defect. To expose the vessel, it is simply unroofed to define its course, taking care to preserve all the muscle branches that supplies the vastus lateralis. This minimizes devascularization of the vastus lateralis muscle, especially if the oblique branch has already been harvested. Only about 1 to 2 cm of the artery and vena comitantes at the site where the microanastomoses are to be performed are skeletonized. Mobilizing the descending branch formally (by ligating all muscle branches) in an attempt to gain more ''length'' is time-consuming and may, in fact, be counter productive. The mobilized vessel tends to retract, is more susceptible to compression and vessel spasm, and inevitably causes more devascularization of the thigh musculature.

The issue of venous congestion of the flaps remains a justified concern, particularly so with the distally based flaps.[28] The long saphenous vein is assessable from the wound by dissecting in the subcutaneous plane medially, and this can be traced distally down to the knee, ligated, and transposed into the lateral aspect of the thigh. This vein can reliably be used for additional venous outflow, either to relieve venous congestion in distally based anterolateral thigh

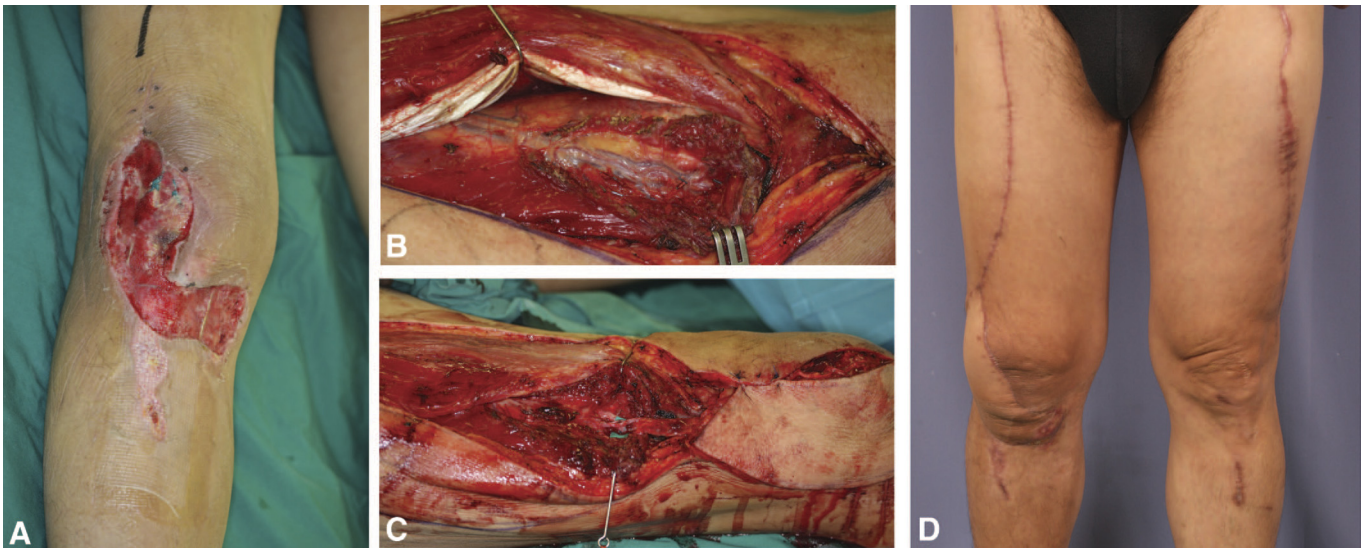

FIGURE 6. A, A large knee defect with exposed wires. B, The intramuscular portion of the descending branch of the lateral circumflex was exposed by ''inroofing'' the vastus lateralis muscle covering it to a distance of 10 cm above the superior edge of the patella. This was used as the recipient vessel. C, A contralateral anterolateral thigh flap based on the descending branch was harvested as microanastomoses performed to the ipsilateral intramuscular portion of the descending branch. D, The defect was successfully covered.

flap for provision of antegrade venous drainage[29] or as a second recipient vein for free flaps. However, we have not found this to be necessary in any of our cases.

Several technical points with regards to the distally based (a retrograde flow flap) anterolateral thigh flap should be noted. These are low flow flaps, and one can note that despite adequate circulation, the pedicle itself do not pulsate well (as with "conventional" antegrade flow flap). These "low-flow" pedicle are susceptible to compression, and it is important to be cautious when advancing the flap into the defect and be mindful to keep the pedicle absolutely tension free.[30] To facilitate this, we have found it beneficial to cut a trough in the part of the vastus lateralis muscle that is causing the pedicle to tent when the flap has been transposed, providing a more direct path for the pedicle to sit. While the arterial inflow is by a retrograde flow, venous drainage is by reverse flow. Clinically, significant flap congestion was not seen in our series, and venous outflow was generally adequate, even when the flap was used as a propeller flap with a 180 degrees twist to the pedicle. Transient, mild congestion immediately after inset is seen on several occasions, which resolved within a few days with no adverse sequelae on the flap survival. The postulated mechanisms that enable reverse flow include "crossover" flow via bypass channels connecting the paired venae comitantes.[30,31] To maximally preserve this potential, the pedicle should be harvested en bloc along its entire length, with the artery and vena comitantes as a single bundle, preserving the communicating branches between the vena comitantes, and avoid unnecessarily skeletonizing the veins.

CONCLUSION

The anterolateral thigh flap offers a degree of versatility that is unparallel by other available local options for defects around the knee. Its use, however, mandates a certain degree of creative flexibility in terms of varying the pattern of tissue transfer (direct advancement vs. propeller flaps), skin paddle design, and more importantly an ever-readiness (both on part of the surgeon as well as the patient) to convert to a free flap reconstruction depending on the anatomy that presents intraoperatively. In free flaps, the distal part descending branch of the lateral circumflex femoral artery near the knee joint presents a robust recipient vessel for knee defects and is readily accessible when needed. With this approach, one can reliably reconstruct a variety of knee defects with the anterolateral thigh flap.

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