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Flow-through anterolateral thigh flap for simultaneous soft tissue and long vascular gap reconstruction in extremity injuries: Anatomical study and case report

Kanit Sananpanich[1], Yuan Kun Tu[2], Jirachart Kraisarin[1], Preecha Chalidapong[1]

[1] *Department of Orthopaedics, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand*
[2] *Department of Orthopaedics, E-DA Hospital, Kaohsiung Country, Taiwan*

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Summary[1] 47 dissections of cadaver thigh were studied to investigate pedicle configurations in the lateral descending branch of the lateral circumflex femoral arterial system, which can be used in harvesting a flow-through anterolateral thigh flap. The descending branch arose from the lateral circumflex femoral artery in 38 of the dissections, and the mean diameter at its origin was 3.0 mm (range, 2.2–4.0 mm). Skin peforators were of the solely musculocutaneous type in 37 dissections and were a combined septo-musculocutaneous type in 10 dissections. Pure septocutaneous perforator was not found in this study.

During the descending branch's journey to the distal part of the thigh, several branches went into the vastus lateralis and vastus intermedius muscles. The diameters were tapering and the mean terminal diameter was 1.3 mm (range 0.9–1.8 mm), which required intraoperative judgment for proper matching of diameter of the flow-through pedicle and the recipient artery. The mean total length of the descending branch from its origin to terminus was 30.3 cm (range 22.5–37.1 cm). In four dissections, the descending branch could not be used as a flow-through anterolateral thigh flap because the origin of the perforator arose from the transverse branch.

A flow-through anterolateral thigh flap has several advantages, including a large cutaneous area, acceptable donor-site morbidity, adjustable thickness, the ability to combine adjacent muscle or fascia lata and the possibility of simultaneous reconstruction of long arterial gap and soft-tissue defects. Four patients with severe injury and a vascular gap of longer than 10 cm in the extremities were used to confirm the usefulness of this application.

Introduction

Severe injury in the extremities usually causes deep defects and may be associated with major arterial damage, leading to poor perfusion of the distal part of those limbs. Flow-through flap seems to be the best choice in these situations as it can provide arterial reconstruction and soft-tissue coverage at the same stage. The utility of the flow-through flap is now well established, and its indications for use continue to grow [2].

[1] Abstracts in German, French, Spanish, Japanese and Russian are printed at the end of this supplement.

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The anterolateral thigh flap was first reported by Song et al [11] in 1984. Despite the variety of vascular pedicle character, the flap has gained popularity [15] because of its large cutaneous area, the long and large vascular pedicle, the acceptable donor-site morbidity, adjustable thickness and the ability to combine adjacent muscle or other skin flaps. Several authors have reported the clinical applications of flow-through anterolateral thigh flap [1, 8, 9] and consider the flap to be an ideal option for reconstructing soft-tissue defects and revascularising ischaemic extremities. However, it remains unclear whether the anterolateral thigh flap can safely be used to harvest as a flow-through type. Some types of vascular pedicle of anterolateral thigh flap cannot be used as a flow-through flap. In Kimata's classification [7], a descending branch of type 4, 5, 6 or 7 cannot be used as a flow-through flap, and neither can type II and IV in Shieh's classification [10]. Apparently, no studies have been published on the length of flow-through vascular pedicle and its tapering in size. This study aimed to investigate pedicle configurations in the lateral descending branch of lateral circumflex femoral arterial system, which can be used in harvesting a flow-through anterolateral thigh flap, and to present our 4-case experience in reconstructing with this type of flap.

Table 1: Parameters of flow-through anterolateral thigh pedicle

	Average	Range
Proximal diameter (mm)	3.0	2.2–4.0
Distal diameter (mm)	1.3	0.9–1.8
Total length of pedicle (cm)	30.3	22.5–37.1
Length from origin to skin flap (cm)	16.5	11.0–19.0
Thigh length (ASIS-Patella, cm)	41.3	33.5–46.5
% pedicle length to thigh	73.5	51.7–88.4

Anatomical study and results

47 dissections of the lateral circumflex femoral arterial system were carried out in 25 fresh cadavers (19 male, 6 female, 24 right and 23 left sides). The area to be dissected was approached through an anterior incision over the femoral artery just below the inguinal ligament. The origins and external diameters of the descending branch of lateral circumflex femoral artery were recorded. To facilitate dissection and determine the skin flap, the descending branch of lateral circumflex femoral artery was injected with 15 mL methylene blue dye. The stained methylene blue length and width on the skin was measured. The anterolateral thigh skin flap and its perforators were elevated and dissected toward the descending branch. Distal skin incision and dissection of descending branch were extended to the superior border of patella. The length of the descending branch and its terminal external diameter were measured and recorded. Detailed anatomical findings follow (Table 1 and 2 and Figure 1).

Table 2: Details and type of flow-through anterolateral thigh flap

	Details
Origin of the descending branch (Fig 1a)	– lateral circumflex femoral artery 38 dissections (81%) – profunda femoral artery 6 dissections (13%) – femoral artery 3 dissections (6%)
Origin of skin perforators (Fig 1b)	– descending branch 43 dissections (92%) – transverse branch 2 dissections (4%) – transverse and descending branch 2 dissections (4%)
Type of skin perforators	– musculocutaneous 37 dissections (79%) – septocutaneous and musculocutaneous 10 dissections (21%)
Origin of rectus femoris muscular branch (Fig 1c)	– descending branch 24 dissections (51%) – lateral circumflex femoral and descending branch 16 dissections (34%) – lateral circumflex femoral artery 7 dissections (15%)
Kimata's type	type 1: 37 (79%), Type 2: 5 (11%), Type 3: 1(2%), type 4: 2 (4%), Unable to classify: 2 (4%)
Shieh's type	type I: 32 (68%), Type II: 2 (4%), Unable to classify: 13 (28%)
Stained methylene blue colour on skin flap	– average length 14.1 cm (range, 10.4 to 19.9 cm) – average width 8.5 cm (range, 6.2 to 16.5 cm)

The descending branch arose from the lateral circumflex femoral artery in 38 dissections (Fig 1a), and the mean diameter at its origin was 3.0 mm (range, 2.2–4.0 mm). In 24 dissections, the rectus femoris muscular branch arose from proximal part of the descending branch (Figure 1c). Skin perforators were solely of the musculocutaneous type in 37 dissections and were combined septo-musculocutaneous type in 10 dissections. Pure septocutaneous perforators were not found in this study.

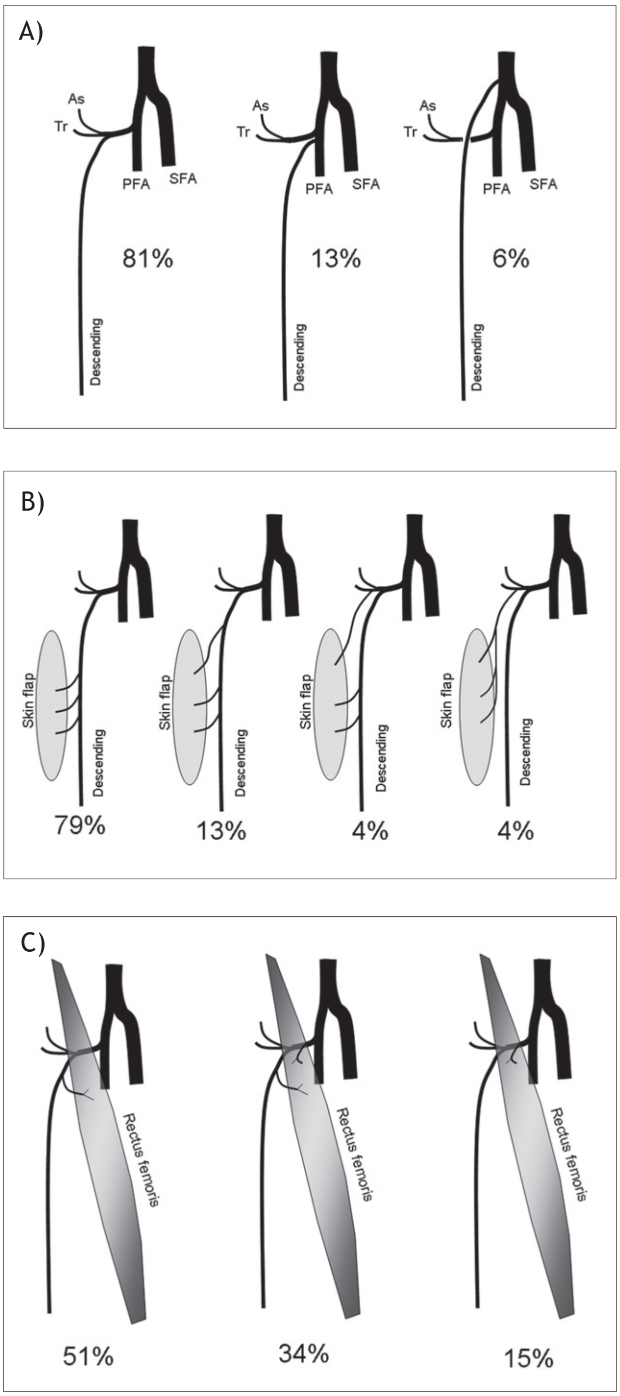

Figure 1. Schematic drawing of anterolateral thigh flap: a) origin of the descending branch, b) origin of skin perforator, and c) origin of rectus femoris muscular branch. As = Ascending branch; Tr = Transverse branch of lateral circumflex femoral artery; PFA = Profunda femoral artery; SFA = Superficial femoral artery.

Large septocutaneous perforators and superficial musculocutaneous perforators usually arise from the proximal part of the descending branch and run obliquely to the skin flap. The deep musculocutaneous perforators, which are small and cause difficulty during dissections, usually arise from distal part of the descending branch. In four dissections, perforators arose from the transverse branch of the lateral circumflex femoral artery (Figure 1b). The average number of perforators was three branches (range, 1–5).The mean distance from origin of the descending branch to skin flap was 16.5 cm (range, 11.0–19.0 cm). Methylene blue staining area on the skin had a mean length of 14.1 cm (range, 10.4–19.9 cm) and mean width of 8.5 cm (range, 6.2–16.5 cm). During the descending branch's journey to the distal part of the thigh, several branches went into the vastus lateralis and vastus intermedius muscles. The distal part was dissectible up to 5–10 cm above the patella. The diameters were tapering and the mean terminal diameter was 1.3 mm (range 0.9–1.8 mm). The mean total length of the descending branch from its origin to terminus was 30.3 cm (range 22.5–37.1 cm).

Case reports

Four flow-through anterolateral thigh flaps were used in four patients for reconstructing long vascular gap and soft-tissue defects (Table 3). Preoperative angiogram was done to confirm major vessel damage in every case. Sites of perforators were marked by handheld Doppler. The injured limb was first prepared to determine soft-tissue defect, length of recipient arterial gap, and diameter of proximal and distal stumps. Flap elevation was then performed through a longitudinal incision on the middle of the anterior thigh; the skin perforators of the lateral circumflex femoral vessels were identified. The descending branch was dissected toward the proximal and distal sides from the division of the perforator. Then, corresponding to the prepared defect, a flow through anterolateral thigh flap was designed on the anterior aspect of the thigh. Flap dimension was slightly larger than defect and slightly longer pedicle for interposition between both ends of injured artery. After the flap was transferred to the defect, the pedicle vessels were interposed into the vascular defect in the extremity. Finally, the donor defect was closed directly. All flaps survived in their entirety

Table 3: Patients' Summary. PTA = posterior tibial artery; RA = radial artery; UA = ulnar artery.

Case	Age/sex	Cause of injury	Lesion	Recipient artery	ALT flap
1	43/F	closed range shot-gun wound	left wrist	RA 16 cm	8 x 17 cm, skin
2	48/M	circular saw and infection	left wrist	RA 6 cm, UA 9 cm	7 x 12.5 cm, skin
3	20/M	electrical burn	right wrist	UA 12 cm	7 x 12 cm, skin
4	34/M	avulsion and infection	right leg	PTA 16 cm	9 x 20 cm, musculocutaneous

with successful arterial reconstruction. Details of the first and fourth cases follow.

Case 1

A 43-year-old woman sustained a close-range gun-shot injury of the left wrist that caused a large and deep defect of bone and soft tissue on the radial aspect of the wrist. She was treated with debridement and stabilised using a temporary external fixator (Figure 2a) and was transferred to our hospital 6 days after initial injury. She had lost median nerve sensation and could not move her thumb and fingers. Her hand had delayed capillary refill on radial digits. An arteriogram of the forearm showed a long radial artery gap (Figure 2b) with sluggish blood flow of radial digits from the ulnar artery.

Flow-through anterolateral thigh flap was performed on the day after her arrival. After debridement of the necrosed tissue, 1-bone forearm and wrist fusion was achieved by pin fixation. The radial

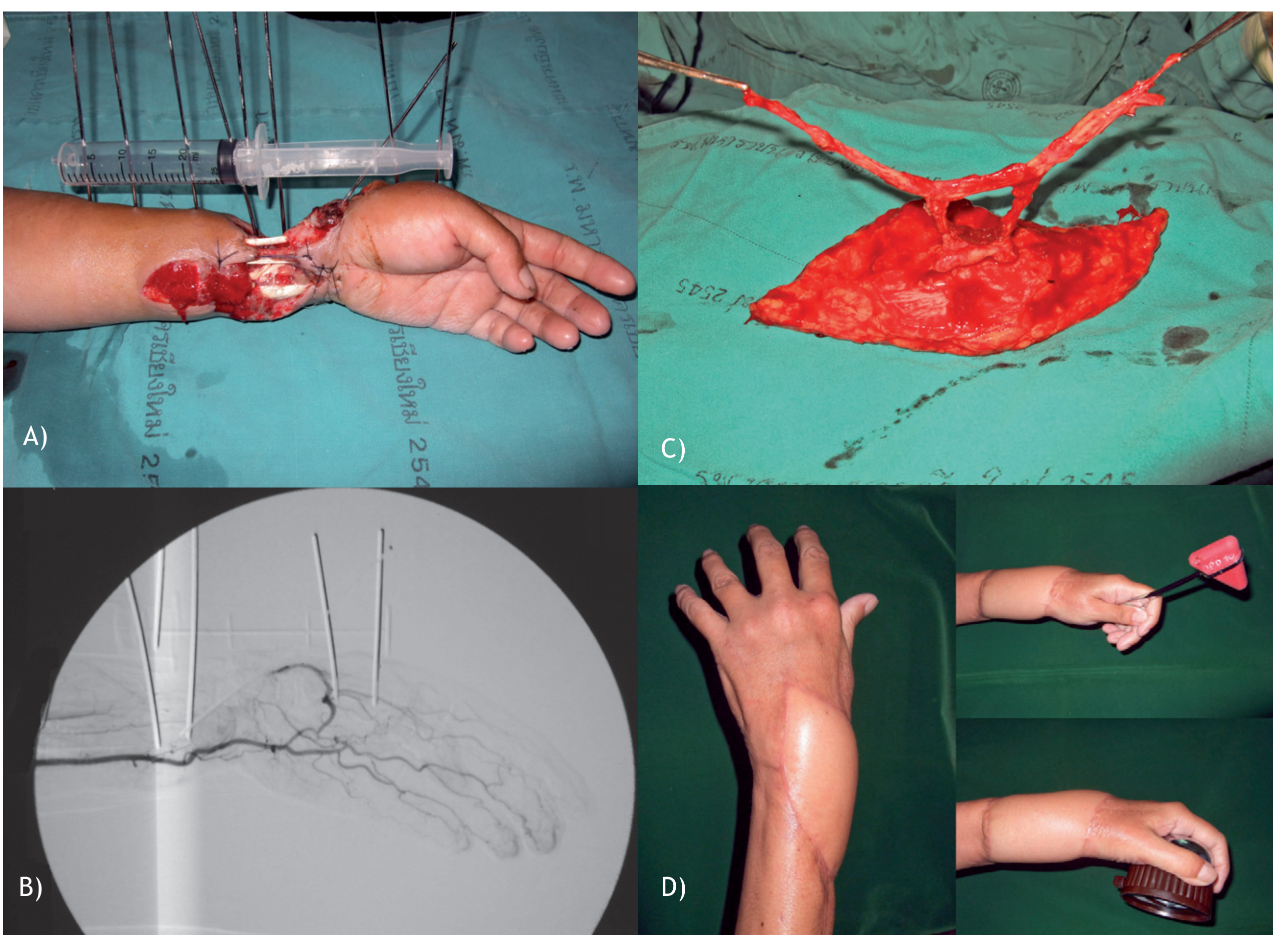

Figure 2. The patient in Case 1, 43-year-old woman. 2a) Large and deep defect on radial aspect of the wrist with temporary external fixator. 2b) An arteriogram of the forearm showed long radial artery gap with sluggish blood flow of radial digits from ulnar artery. 2c) Flow-through anterolateral thigh flap with its flow-through pedicle. 2d) Appearance and functional result after another tendon reconstruction surgery.

vessels were explored both proximally and distally. There was a 16 cm radial vessel gap across the wrist. An anterolateral thigh flap measuring 8 x 17 cm was obtained from the left thigh (Figure 2c), and transferred to the wrist defect. There were two large superficial musculocutaneous perforators from the proximal portion of the lateral descending branch of the lateral circumflex femoral system. The flap was thinned by fat removal under loupe magnification. The pedicle vessels and the descending branch were then interposed between both ends of radial vessels. The donor defect was primarily closed with direct suture.

The postoperative course was uneventful. The oedema and the delay refill of the radial digits disappeared after the reconstruction. Allen test and Doppler ultrasound confirmed patency of the radial artery. There was no flap necrosis or infection. The patient gained good function after another tendon reconstruction procedure four months later (Figure 2d).

Case 4

A 34-year-old man sustained a calf avulsion injury by falling from a roof onto his right leg (Figure 3a). He had lost sensation on the plantar aspect of the foot and was unable to perform plantar-flexion of the ankle and toes. An arteriogram of the leg showed occlusion of middle right posterior tibial artery and peroneal artery. A flow-through anterolateral thigh musculocutaneous free flap was created to reconstruct all soft-tissue structures within a single stage. The injured tibial nerve was repaired with a 3-fold sural nerve graft. The posterior tibial artery, with 16 cm gap, was repaired with an interposition pedicle of the flap. The calf muscle and Achilles tendon were repaired by vastus lateralis muscle and iliotibial band. The skin defect was replaced by cutaneous part of the flap (Figure 3b).

The postoperative course was uneventful. There was no flap necrosis or infection. 1 year after surgery, the patient was able stand on tip-toe with good power (Figure 3c). A spiral CT angiogram showed the interposition pedicle of the flow-through flap as a good substitute for the posterior tibial artery (Figure 3d).

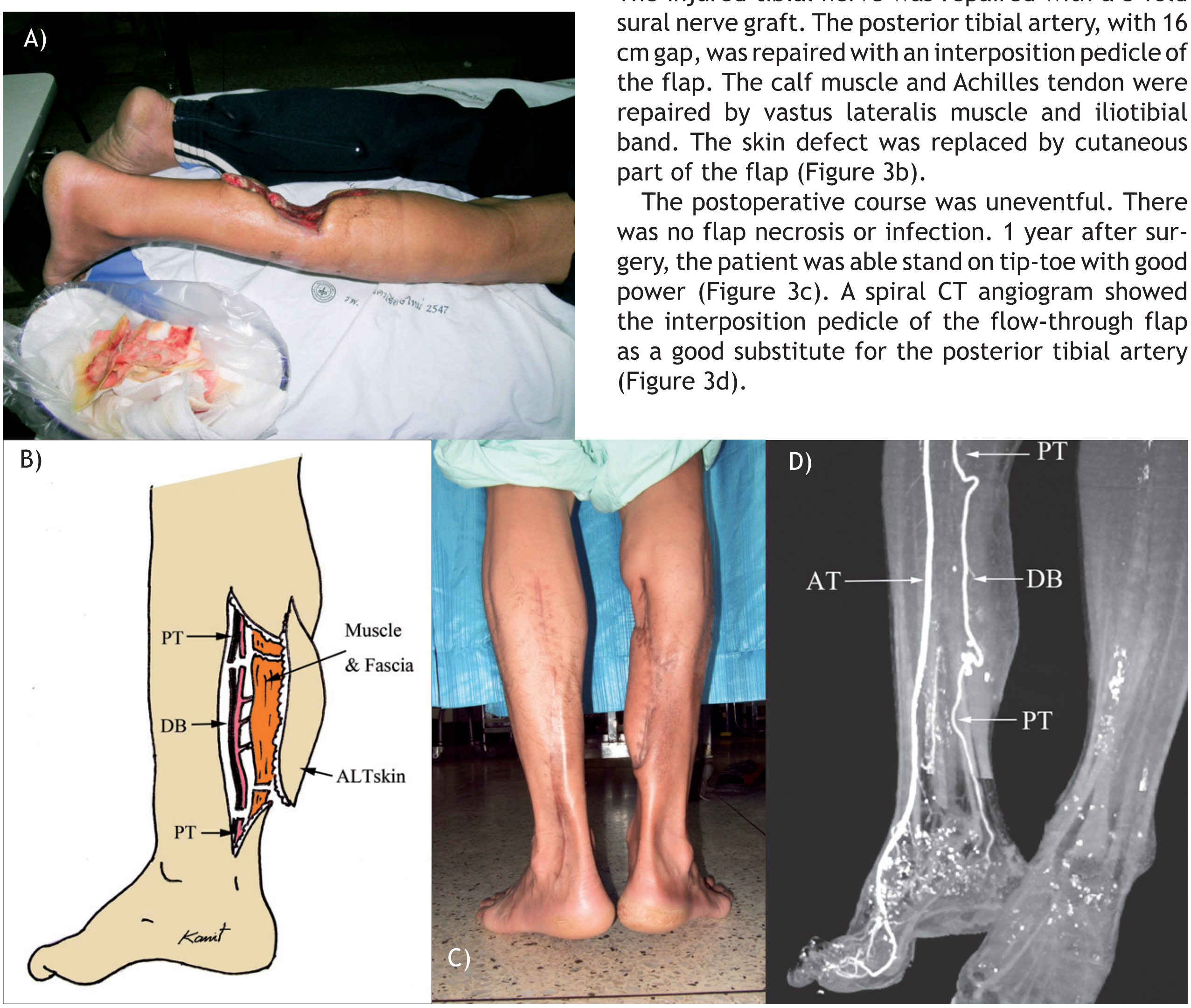

Figure 3. The patient in Case 4, 34-year-old man. 3a) Appearance of calf avulsion wound. 3b) Diagram of anterolateral thigh flow-through flap reconstruction. 3c) The patient could stand on tip of toe with good power 1 year after operation. 3d) Spiral CT angiogram showed interposition pedicle of the flow-through flap is a good substitute of posterior tibial artery. ALT skin = anterolateral thigh skin flap; AT = anterior tibial vessels; DB = descending branch pedicle of flow-through flap; PT = posterior tibial vessels.

Discussion

Flow-through flap seems to be the best choice in deep defects associated with major artery damage, because it can provide arterial reconstruction and soft-tissue coverage at the same stage. Without a flow-through flap, damaged extremities usually require second-stage operations, with vein grafts in the first stage and skin flaps or tissue transfers in the second stage. The utility of the flow-through flap is now well established, and its indications for use continue to grow [2]. The ideal interposition pedicle vessels for the flow-through flaps seem to be large-calibre, long trunk vessels with adequate septocutaneous perforators [4].

Since the early period of flow-through free flaps, the radial forearm has been one of the most popular donor sites [3, 4, 6, 12, 13] due to its long artery with septocutaneous perforators and simple elevation. However, a radial forearm flap has several drawbacks, including sacrifice of the radial artery, which is a major vessel of the forearm, skin-graft loss with tendon exposure, displeasing appearance of the skin-grafted donor site, in addition to which, a large flap size cannot be obtained. Various types of flow-through flaps from the subscapular arterial system are other good options due to the variety of tissue that can be combined in this flap such as skin flaps, muscle flaps, musculocutaneous flaps and osteocutaneous flaps [5].

However, an anterolateral thigh flap has a longer vascular pedicle [8]. The supine position during anterolateral thigh flap harvesting is another advantage compared to lateral decubitus position in flaps from subscapular arterial system. The anterolateral thigh flap has many advantages including its large cutaneous area, long and large vascular pedicle, acceptable donor-site morbidity, adjustable thickness and the possibility of combining adjacent muscle or other skin flap. One interesting clinical application of the anterolateral thigh flap is the flow-through type. Several authors consider this flap to be an ideal option for reconstructing soft-tissue defects and revascularising ischaemic extremities [1, 8, 9].

From our anatomical study, most anterolateral thigh flaps have blood supply from musculocutaneous perforators of the descending branch of the lateral circumflex femoral artery. After the perforator flap concept became well established, suitable perforators of the flap included not only the septocutaneous type but also musculocutaneous type. Therefore, flaps with musculocutaneous perforators from long vascular pedicle can also be good candidates for flow-through flaps.

All the cases reported here had an arterial defect longer than 10 cm, which was salvageable with a flow-through anterolateral thigh flap. The average length of flow-through anterolateral thigh pedicle in our anatomical study was 30.3 cm, which is long enough to bridge a long arterial defect in an injured extremity. However, the diameter of the distal pedicle tapers after branching to the vastus lateralis and vastus intermedius muscle, and this requires intraoperative judgment for proper matching of the diameter of the flow-through pedicle and the recipient artery.

Kimata et al [7] reported anatomical variations and technical problems of the anterolateral thigh flap from the clinical dissection of 74 cases. Eight anatomical types of pedicle were identified. In types 4, 5 and 6, the perforators arose directly from the trunk of the lateral circumflex femoral artery (5.7, 2.9 and 4.3%, respectively) which excluded using the descending branch as a flow-through pedicle. However, flow-through anterolateral thigh flap from these types can still be harvested by using the lateral circumflex femoral artery as the proximal anastomosis and the descending branch as the distal anastomosis, which is complicated. In type 7, perforators arose independently from the profunda femoris artery (1.4%), which cannot be used as a flow-through flap. Therefore, the descending branch could not be used as a flow-through flap in 14.3% of Kimata's subjects. Of our 47 dissections, two dissections were type 4 and two dissections could not be classified as any of Kimata's types as we found both septocutaneous perforators from the transverse branch (ie, type 4) and musculocutaneous perforators from descending branch (ie, type 1) in the same thigh. Therefore in 4 out of 47 dissections in our cadaver study, the descending branch could not be used as a flow-through anterolateral thigh flap.

Shieh et al [10] reported four different types of anterolateral thigh flap based on the direction and origin of perforators from clinical dissection. In our study, 13 out of 47 dissections could not be classified within Shieh's classification because we found combined septocutaneous and musculocutaneous perforators as well as combined vertical and horizontal direction in the same thigh.

The difference in our findings from previous reports may be caused by dye injection, which enhances visualisation of perforators and also our cadaver dissection technique, which differs from real clinical situations. During operations, surgeons have to concentrate on perforators of skin flap and dissection from distal to proximal. Therefore, other perforators may not be considered of interest or may be missed. For flow-through anterolateral thigh flaps in a real clinical situation, the descending branch should be explored thoroughly after perforator detection for matching proximal and distal anastomosis with flap inset distance. This requires careful intraoperative judgment and surgeon experience, especially in case of perforator that has a separate origin from the transverse branch, as we found in 4 out of 47 dissections. In such a situation, surgeon has to use the main trunk of the lateral circumflex femoral artery and include both transverse and descending branches to create flow through an anterolateral thigh flap, which is more complicated. To avoid this situation, Multi-Directional-Computer-Tomography (MDCT) with intravenous contrast media may be used to investigate type and origin of perforator before operation.

We found that the rectus femoris muscular branch arose from the very proximal part of the descending branch (24 dissections) or from lateral circumflex femoral artery (7 dissections) or both (16 dissections). This muscle can be used as a functional muscle transfer or as deep defect filling in the flow-through flap manner as described by Koshima et al [8]. Due to the proximity of branching, the lateral circumflex femoral artery usually has to be harvested. The relationship between the location of the skin defect, the muscle defect and both ends of the recipient vessels for anastomosis must be considered, especially in a flow-through flap. We still have no experience of including rectus femoris muscle in real flow-through clinical cases. For wide and deep defects with vascular injury at the same site, the vastus lateralis muscle is more convenient than rectus femoris. We used this composite flow-through anterolateral thigh flap to reconstruct the posterior tibial artery, calf muscle, Achilles tendon and skin defect in Case 4 with good results.

An anatomical study of 47 thighs of 25 cadavers may be too few to reach conclusions for every reconstruction case. There might be anatomical differences between and Asian patients and other groups [14]. Skin area measured from dye injection in this study seems to be smaller than reports from real clinical experience [8]. However, to the best of our knowledge, this is the first study of cadavers to focus on flow-through application of the descending branch and anterolateral thigh flap.

Conclusion

Of our 47 anatomical studies of cadavers, 43 descending branches were harvestable as flow-through anterolateral thigh flaps. Flow-through anterolateral thigh flap has several advantages, including large cutaneous area, acceptable donor-site morbidity, adjustable thickness, the possibility of combining adjacent muscle or fascia lata and the possibility of the simultaneous reconstruction of a long arterial gap and soft-tissue defect. Four patients with severe injury and long vascular gap in this report suggest that this is a useful application.

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Corresponding author:

Kanit Sananpanich, M.D.
Department of Orthopedics, Faculty of Medicine,
Chiang Mai University, Chiang Mai 50200, Thailand
Phone +66-53-945544
Fax +66-53-946442
email: ksananpa@mail.med.cmu.ac.th

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