Comprehensive Analysis of the Anterolateral Thigh Flap Vascular Anatomy

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Objective: The anterolateral thigh (ALT) flap has become a frequently used free flap for head and neck reconstruction. Widespread use has been based on literature of ALT flap thickness performed primarily in Asian populations. To our knowledge, to date there has not been a comprehensive analysis of the anthropomorphic parameters of this flap in the Western population, in which it is often much thicker, thereby potentially limiting its utility.

Methods: Computed tomographic angiograms of 106 patients were assessed, yielding 196 lower-extremity scans examined for volumetric characteristics and vascular anatomical variations.

Results: Perforator vessels were located in 88.8% of scans, and most commonly located were a hybrid musculoseptocutaneous vessel (52.3%) followed by septocutaneous (33.9%) and musculocutaneous (13.8%) vessels. The midpoint perforator was located within ±2% of the midpoint of the total thigh length in only 47% of legs. The proximal and distal perforators were located 52.7 and 58.6 mm from the midpoint, respectively. Subcutaneous fat thickness differed significantly by sex, with mean male and female thicknesses of 9.9 mm and 19.9 mm (P < .001), respectively. Thickness increased with increasing body mass index, especially in women.

Conclusion: This study used computed tomographic angiography to characterize the ALT flap vasculature and thickness, providing a degree of predictability to these 2 highly variable flap characteristics.

Most commonly used alternative and predecessor, the radial forearm free flap (RFFF), which is generally considered a thinner, more pliable flap but is associated with a higher donor site morbidity. Modifications of the ALT during harvest have been reported as a potential solution to the thickness of the ALT flap. Subcutaneous fat thinning as a 1-stage procedure has been described and used in an East Asian population to overcome this limitation. However, these techniques have not been reported extensively in a Western population. In fact, thinning the ALT flap during the primary reconstruction has been cautioned as increasing the risk for major complications by loss of flap viability. If not performed primarily, many flaps will need secondary debulking to achieve the desired functional result, thus potentially delaying maximal functional recovery.

The purpose of this study was to evaluate vascular anatomy and the volumetric nature of the subcutaneous tissue of the ALT flap in an American population using computed tomography angiography (CTA). These anthropomorphic data were used to characterize the variations and nuances of this flap in this population. In order to provide the head and neck reconstructive surgeon with meaningful data, these findings were then used to predict flap thickness by sex and body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) and demonstrate the use of an imaging modality to assist in characterization of the flap’s variable vascular anatomy.

**METHODS**

**STUDY POPULATION**

The CTA runoff images were studied in 106 patients who obtained this imaging for any indication. Patients were identified by searching the radiology dictation system for “CTA AORTA/FEM RUNOFF,” generating a random selection of studies from August 2006 through July 2009. All patients receiving a lower-extremity CTA during this time period were included, regardless of imaging study indication. Patients were excluded if scan quality rendered the scan uninterpretable or if a clinically significant disease process was present in the thigh (abscess, infection, tumor, amputation, vascular grafting or stent, and aneurysm). The Cleveland Clinic (Cleveland, Ohio) institutional review board approved this study.

Images of the right and left legs were obtained for each patient when available. Images thickness was either 1 or 3 mm and provided high-resolution images. For study inclusion, image extent had to include the area from the ASIS to the lateral patella. Therefore, a total of 196 legs were ultimately included in the study for analysis.

**IMAGING MEASUREMENTS**

Measurements were performed on Leonardo (Siemens, Malvern, Pennsylvania) postprocessing workstations using Siemens InSpace software (in the Dicom image format). A quad-pane view with the sagittal, coronal, and axial views was displayed. The sagittal pane was used to rotate the coronal axis and obtain thigh length, defined as the distance from the ASIS to the superolateral edge of the patella. To approximate the location of the dominant ALT perforator, the midpoint of the thigh length was determined and located. In the axial plane, images 10 cm adjacent to the midpoint were searched to identify a dominant midpoint perforator vessel and adjacent proximal and distal vessels that extended to the skin of the lateral thigh. In addition, the LCFA was traced inferiorty from its branching point off the profunda femoral artery. In this manner, any atypical vasculature was noted. Measurements of the intramuscular septum, thigh thickness, and vessel characteristics were obtained at the midpoint image and the image at which the perforator vessel was seen exiting the fascia lata. Images ranging from 10 cm superior to 10 cm inferior to the midpoint slice were then examined to locate adjacent perforators. If superior and inferior perforator vessels were visualized, similar thigh measurements were obtained at those points.

In order to standardize measures and distances between patients of all heights and, hence, thigh length, longitudinal distances were measured from the midpoint of each thigh and were divided by the determined thigh length (distance from the ASIS to the superolateral aspect of the patella). Therefore, longitudinal distances are expressed as a percentage of total thigh length from the midpoint (Figure 1). Negative measurements and percentages denote the distance proximal to the mid-

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**Figure 1.** Coronal view of perforator vessel. The midpoint of the thigh was calculated as halfway in-between the anterior superior iliac spine and the superolateral border of the patella (double-headed arrow). Measurements were calculated relative to the midpoint and adjusted for thigh length. A perforator vessel is seen close to the midpoint (arrow), and a proximal perforator is seen superior.
The perforator vessel was classified depending on its course as musculocutaneous, septocutaneous, or the hybrid musculoseptocutaneous. Although the configurations of vessel paths were numerous, musculoseptocutaneous perforators comprised the majority at 52.3%. This was followed by septocutaneous (33.9%) and musculocutaneous (13.8%) perforator courses (Figure 3). Therefore, 66.1% of cutaneous perforator vessels at some point of the vessel path traversed either the rectus femoris or vastus lateralis muscles.

Lower-extremity CTA scans from 98 patients (196 legs) were included by study criteria and assessed for analysis. Patient demographics are shown in Table 1. Male patients comprised 63% of the study population, with white individuals comprising 63% of the study population, with white individuals making up the majority at 74%. The mean (SD) BMI for the entire study population was 28.1 (6.4). Patients were evenly divided between BMI classifications of normal (<25), overweight (25-30), and obese (31-40).

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Because the descending branch of the LCFA travels laterally as it continues inferiorly beneath the vastus lateralis, we found a greater proportion of perforators distal to the midpoint to traverse through muscle (musculocutaneous or musculoseptocutaneous), whereas the proportion of septocutaneous perforators increases proximal to the midpoint (Figure 4). Perforators involving both the intermuscular septum and either the rectus femoris or vastus lateralis muscles (musculoseptocutaneous) were found throughout the distribution.

The midpoint perforator was found at the precise midpoint only 16.0% of the time, and, as shown in Figure 5, considerable variation in perforator location was found relative to the midpoint. However, 47.0% were found nearby within a surrounding distance of ±2% of the thigh length. The proximal and distal perforators were found surrounding the midpoint perforator in 65.8% and 60.7% of legs studied, respectively. Proximal and distal perforators were found at mean distances of 52.7 and 58.6 mm from the midline, respectively. Generally, the distribution of proximal perforators seems to exist closer to the midpoint compared with that of distal perforators (Figure 6).

Most vessels (73.6%) exited the fascia to enter the subcutaneous adipose tissues at the intermuscular septum. Of the remaining 24.4% of vessels that did not exit the fascia lata at the intermuscular septum, all exited through the vastus lateralis except in 1 leg. In this leg, the vessel exited 1 cm medial to the intermuscular septum through the rectus femoris. Most musculocutaneous vessels traversed the vastus lateralis and pierced the overlying fascia at a mean distance of 12.6 mm lateral to the septum, with 72% of these exiting the fascia 5 to 15 mm lateral to the intermuscular septum. Perforators were found 20 to 40 mm lateral to the septum in only 12% of musculocutaneous perforators (Figure 7).

The perforator vessel was seen to generally emerge from the LCFA system, but rarely was an aberrant vessel course to the lateral thigh observed. In 7 legs (4.0%), the vessel emerged from the superficial femoral artery and in 2 legs (1.1%) from the common femoral artery.

The mean flap thicknesses for males and females were 9.9 and 19.9 mm (P < .001), respectively. Flap thickness calculations were further divided by BMI and then by race (Table 3 and Figure 8). For BMIs of the normal (<25) and obese (31-40) categories, a statistically significant dif-
ference between males and females was found, and in the overweight (25-30) category, the sex difference was not significant ($P = .051$). There is a linear trend of increasing flap thickness with increasing BMI among males ($r^2 = 0.43$) and females ($r^2 = 0.37$). The sex difference in flap thickness was seen in both white and black races. Only 8 patients were Hispanic/Latino; therefore, these values may not be appropriately representative.

**COMMENT**

The ALT flap has become a workhorse flap for free tissue reconstruction in the head and neck. The relative ease of harvest and the minimal donor site morbidity has made this flap a popular option for complex defect reconstruction in the head and neck. The initial studies on the clinical relevance of this flap were performed in Asian populations, where large series were compiled with the flap being used for a wide array of reconstructions throughout the body. These studies have demonstrated numerous advantages of this flap, which include ability to perform a 2-team approach, sufficient pedicle length, appropriate match of arteriovenous vessel diameter for anastomosis, potential for sensory and motor reinnervation, flap pliability, ability to include multiple flap components (fascia, skin, and/or muscle), and, possibly most important, a minimal postoperative donor site morbidity.14-17

Extensive use of the ALT was initially precautionary in the Western population by perforator course variability and thickness of the flap.5 Unlike its alternative, the radial forearm flap, the ALT fasciocutaneous flap has 3-dimensional characteristics that are quite variable depending on the anthropomorphic characteristics of the patient. Our baseline understanding of flap characteristics has been extrapolated from the relatively thinner Asian population, which may not correlate well to a Western population. Also, previous studies have been almost exclusively based on cadaveric studies that can under estimate these parameters. Using in vivo radiological methods allows accurate assessment of perforator course and flap thickness. Therefore, we report a novel and comprehensive analysis of the LCFA and its relation to the ALT flap in an American population to help characterize the nature of this flap in this group and, in turn, hopefully better define its ideal use.
The relative thickness of this flap is, in general, greater than that of the RFFF, and we have explored preoperative patient characteristics that may be predictive of this thickness. Because females typically have a greater proportion of weight distributed in the thighs compared with males, our observations consistently revealed that the flap is significantly thicker in female populations. The flap is on average twice as thick in women than in men (19.9 mm vs 9.9 mm; \( P \leq 0.001 \)). The relevance of this can be illustrated in a clinical scenario. A hemiglossectomy defect in a female patient in the United States would arguably be best reconstructed with a thinner pliable RFFF. In a male patient, however, with a similar BMI, the ALT flap may be appropriate.

Beyond a significant sex relationship, an independent correlation to BMI is also evident in our data, as shown in Table 3. Female patients with BMI of 31 or greater will likely have flaps greater than 2.5 cm in thickness, causing the ALT flap to possibly not be an appropriate reconstructive means if a thin, pliable tissue is desired. Our flap thickness measurements were derived in a random selection of patients without head and neck cancer undergoing lower-extremity CTA imaging for any indication, and were very similar to those obtained in vivo by Yu in a population of patients with head and neck cancer. He demonstrated a 19.9-mm flap thickness in females, whereas males had a 12.9-mm flap thickness. This is in stark contrast to the mean flap thicknesses of 7.5 mm and 10.8 mm seen in males and females, respectively, in the Asian population, highlighting the importance of this study to characterize the ALT flap in the American population via an imaging modality.

While these observations do not preclude the use of this flap for any particular indication, surgeons should be aware of the range and predicted estimations of thickness in the planning and design of this flap. Ideally, the data presented herein may be used as a planning tool for surgeons to optimally choose (specific by sex, BMI, and race) the ideal patients and defects for use of the ALT flap. Therefore, this may predict those patients in whom harvest and inset may be difficult due to excessive flap bulkiness.

Thinning of the ALT free flap has been described, particularly among Asian population studies. Kimura et al have demonstrated the ability to successfully primarily...
debunk the subcutaneous fat to a total flap thickness of 3 to 4 mm in 31 cases. On the one hand, a carefully dissected area 2 cm in diameter circumferential to the perforator vessel was not debulked in order to protect the perforator vessel. In that series, the thinned ALT flap was used to reconstruct neck defects in 4 of the 31 described cases. On the other hand, Ross et al.21 warn against 1-stage thinning of the ALT flap at time of harvest. In 4 cases in which the ALT flap was thinned to reconstruct intraoral defects, the authors describe partial necrosis in 2 and complete necrosis in 1 flap, all of which were attributed to flap thinning. Similar to the study by Kimura et al.19 Ross et al.21 thinned the flap to 3 mm, leaving a 2-cm cuff around the perforator. Koshima et al.18 had partial necrosis in 1 of 4 thinned ALT flaps. Akureishi et al.12 further demonstrated by vascular dye perfusion of ALT flaps harvested from cadavers that thinned flaps showed reduced subdermal vascular plexus filling. Although the thinning of the ALT flap is controversial among free flap surgeons, generally a cuff of unaltered fatty tissue is left surrounding the perforator vessel. Therefore, despite an ability to thin the flap, the ALT thickness is an important consideration that should be assessed in preoperative planning, especially for defects requiring a thin, pliable reconstruction.

This comprehensive analysis of the ALT flap and its vascularity also led to a number of clinically relevant observations of its common vascular variations. Identifiable perforators (as small as 1 mm, based on radiological CTA sensitivity) are seen in 88.8% of patients. In 11.2%, the vessels are too small (likely multiple microscopic perforators) to observe. These patients would represent difficult flap harvests with a higher likelihood of failure. Kimata et al.26 in a series of 74 ALT flaps, found a significant proportion of our study population should therefore not be understated. This flap is routinely harvested without any prior angiographic workup, and yet in 11.2% of the cases, the vessels were too small to detect in high-resolution CTA imaging able to detect vessels of 1 mm diameter. A method to potentially obviate the need to locate appropriate perforators is to take a large section of vastus lateralis muscle to capture a “perforator field” akin to the harvest technique of the skin paddle in the pectoralis major flap. While this would likely preserve the blood supply to the skin paddle, it adds a considerable additional amount of bulk to a possibly already thick flap and places the perforator vessel in potential harm. Preoperative identification of these “problem” harvests could direct the surgeon to alternative reconstructive options.

Another potential concern is the point of origin of the perforator vessel as well as a relative range of its location. In several CTA scans, we found that the dominant perforator within the skin paddle of the traditional ALT flap was based on branches of the superficial (4.0%) or common femoral (1.1%) arteries. This finding is a cause for concern, and recognition of this important variant is critical to avoid a potential complication in the distal extremity, in which case harvest of the flap may lead to devastating limb loss, a rare but possibly underreported complication.22 In general, perforators originating in the rectus femoris 2 cm anterior to the septum did not arise from the LCFA system in our study of nearly 200 legs and should be avoided owing to possible compromise of the superficial or deep femoral arterial systems. This anteriorly located perforator likely represents a perforator vessel to the anteromedial thigh flap.

Our anatomical analysis of vessel course demonstrates that a greater proportion of vessels travels through a muscular component (66.1% vs 33.9%) than purely the septum as originally described by Song et al.1 Our rate of purely septocutaneous vessels is higher than that shown in recently published in situ and cadaveric studies that show a 12% to 13% rate of septocutaneous perforators.14,17 This may be attributed to a greater sensitivity of CTA to locate smaller vessels in vivo that may otherwise not be identified, especially in cadaveric studies. Also, since the descending branch of the LCFA typically traverses under the vastus lateralis in a diagonal fashion as it courses inferiorly, perforators distal to the thigh mid-point will more commonly have a muscular component to their course. If a relatively superiorly placed skin paddle is harvested, the likelihood of a septocutaneous perforator is much higher, as the original studies on the ALT flap may have observed.1,18 These factors may explain the apparent variations in the findings seen among studies that examine perforator course.

This study included any patient who obtained CTA imaging of the lower extremities, possibly to workup or follow peripheral vascular disease. We do not believe that the possibility of vascular disease in these patients adversely affected our study measures. The ability to potentially identify perforator vessels was adequate in all included scans because they were of high image quality. Patients with obvious vascular surgery or vascular stents in the lower extremity were not included because vascular anatomy and imaging quality may have been distorted. Because patients with cancer who require free flap reconstruction also often have risks factors for peripheral vascular disease, this may fundamentally be an ideally matched population in which to study free flap vascular anatomy. If there is a bias in this population, it favors patients with less peripheral vascular disease. Given this tendency, concerns about perforator availability are actually potentially more likely in a population of patients with cancer with additional vascular comorbidities.

Our comprehensive analysis of the LCFA has demonstrated a number of important vascular observations. We found a significant number of “hybrid” perforators that travel through both the septum and surrounding muscle, which we have termed musculoseptocutaneous perforator vessels. This is an important distinction for the free flap surgeon, because even though a vessel may appear to initially bear a septal course as it exits the overlying fascia, it may alter its path and proceed through muscle, warranting additional careful dissection. We noted that the muscular course was quite variable, with vessel extension into the muscle at varying degrees. Therefore, a blind cut through the muscle during harvest may in fact compromise flap blood flow in certain patients.21

The variability of the vascular anatomy identified through CTA analysis argues for its potential use as a standard preoperative assessment tool. Rozen et al23,24 have
recently made a similar recommendation and demonstrated preoperative imaging efficacy for ALT flap harvest. Imaging data are clearly useful in predicting flap thickness and perforator location and origin. However, the risk of radiation exposure from CTA must be weighed against the precise anatomical information gained by performing a high-resolution scan. Although the use of magnetic resonance angiography (MRA) to study ALT flap perforators has not been thoroughly examined, this technology may provide the necessary anatomical and perforator information without unnecessary radiation exposure. We routinely use MRA for preoperative evaluation of fibula osteocutaneous flaps. We hope that, even if preoperative imaging is not routinely undertaken, our data will provide surgeons a predictive tool based on BMI and other identified predictors to estimate the 3-dimensional characteristics of this flap and its likely vascular patterns, especially in the American population, which is in many ways quite different from its Asian counterparts on which preliminary studies were based.

In conclusion, we have established values of flap thickness by sex, race/ethnicity, and BMI to assist the surgeon in preoperative planning and flap choice. In addition, we have demonstrated the use of CTA to accurately describe flap perforator course and distribution, possibly creating a role for preoperative planning of flap harvest. The relative size and detail of this study (196 legs examined) will hopefully place a meaningful significance to the relative percentage of the flap variants we found and therefore help surgeons predict the potential perforator distributions and flap thickness based on our anthropomorphic data.

References: