

Utility of Preoperative Positron Emission Tomography (PET) in Localizing Perforator Vessels of Anterolateral Thigh Free Flap

Alexandra McMillan¹, Sameer A. Alvi^{2,3}, Zaid Al-Qurayshi¹, Zachary Fleishacker¹, Nitin A. Pagedar^{1,4}, Marisa R. Buchakjian^{1,4*}

¹Department of Otolaryngology, University of Iowa Hospitals and Clinics, Iowa City, IA, USA

²Division of Otolaryngology-Head & Neck Surgery, North Shore University Health System, Evanston, IL, USA

³Pritzker School of Medicine, The University of Chicago, Chicago, IL, USA

⁴Holden Comprehensive Cancer Center, University of Iowa, Iowa City, IA, USA

Email: *Marisa-buchakjian@uiowa.edu

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Abstract

Objectives: The anterolateral thigh (ALT) flap is often considered the workhorse in soft tissue reconstruction of head and neck defects secondary to trauma, infection, or tumor resection. Despite its many advantages, ALT flaps have been criticized due to variability in vasculature, which may result in inadequate or non-existent perforators. This retrospective study aims to investigate the utility and validity of positron emission tomography (PET) scan to identify the location and characteristics of perforators to the ALT flap. **Methods:** We performed a 10-year retrospective review of ALT flaps at our institution to identify patients with preoperative PET scans available for analysis. Three reviewers (attending physician, fellow, and resident) were asked to identify the number, location, and characteristics (myocutaneous versus septocutaneous) of ALT perforators on imaging, and reviewer agreement was assessed. Results were then compared to available operative data. **Results:** One hundred twenty-one patients were identified who underwent ALT free flap surgery. Thirty-eight preoperative PET scans were identified for review. At least one perforator was identified in 92.1% of scans. Agreement percentages regarding the number of perforators ranged from 53% - 61% whereas agreement regarding the location of a single perforator ranged from 79% - 90%. However, reviewers did not agree regarding the type of perforator, with agreement ranging from 34% - 53%. Poor agreement was observed when compared to intraoperative data, with the number of perforators ranging from 26% - 34% and the type of perforator 11% - 24%. These findings are likely due to insufficient data available in operative reports. **Conclusion:** Al-

though initial studies suggest that PET scan shows promising evidence to support the capacity to preoperatively identify ALT perforators, future prospective studies are warranted to fully validate these findings.

Keywords

Anterolateral Thigh Flaps, Positron Emission Tomography, Head and Neck Defects, Perforator Mapping

1. Introduction

The anterolateral thigh (ALT) flap is often considered the workhorse in soft tissue reconstruction of head and neck defects secondary to trauma, infection, or tumor resection [1]. First described by Song *et al.* in 1984 [2], this versatile fasciocutaneous or musculocutaneous flap is raised as a perforator-based free flap with a long and sizeable pedicle [3] [4]. The pedicle typically originates from the descending branch of the lateral circumflex femoral artery (LCFA) but may originate from the transverse, lateral, or ascending branches of the LCFA, as well as the common and deep femoral arteries [3]. The pedicle of the ALT flap is oriented along the axis of the septum between the vastus lateralis and the rectus femoris muscles, and distal perforators to the overlying fascia can travel as septocutaneous perforators (13%) or through the vastus lateralis muscle as musculocutaneous perforators (87%) [5] [6].

Although the ALT flap usually contains at least one major perforator [1,6], identifying the location of the perforator can be a major obstacle for appropriate flap harvesting, notably in patients with a high body mass index (BMI) [4]. Studies estimate that in about 0.89% - 11.4% of patients, ALT free flaps are nonviable due to small or nonexistent skin perforators, likely due to variability in pedicle anatomy [4] [7] [8] [9]. Initial flap design with localization of the perforator preoperatively can be predicted with anatomic landmarks. The ABC method, described by Lin *et al.*, [10] involves marking a straight line extending from the anterior superior iliac spine (ASIS) to the superolateral border of the patella (the AP line). The midpoint of the line is marked and doppler examination within a 3-cm radius around the midpoint is used to identify perforator B. Once a signal is obtained, perforators A and C are examined within a 3-cm radius either 5 cm proximal or distal to the perforator B, respectively. In fact, perforators can often be mapped out with the use of a handheld acoustic doppler in the majority of cases [4]. An acoustic doppler in the hands of a skilled operator can detect vessels with a diameter of approximately 0.2 mm with a sensitivity of 100% [4] [10]. However, a vessel other than the perforator can be detected with this method, leading to discrepancies between identified and actual perforators [4].

Preoperative identification of suitable perforators and determination of perforator characteristics has been shown to facilitate pre- and intra-operative

planning. For example, in a prospective study of 16 patients who underwent preoperative computed tomography angiography (CTA) mapping for ALT flap reconstruction [11], CTA influenced surgeons to modify the reconstructive surgery in 37.5% of cases. Preoperative imaging can be used to identify cases in which ALT flap perforator dissection may be difficult, allowing for consideration of alternative flap designs preoperatively. Additionally, they may aid in the identification of optimal thigh laterality to obtain ideal perforators. For example, imaging may suggest the presence of a superiorly based perforator on one side that could necessitate moving the planned skin paddle superiorly and thus shortening the flap pedicle. Similarly, preoperative imaging with CTA in flaps for breast reconstruction has demonstrated decreased operative times, complications, and donor site morbidity [12]. Several tools have been described to improve preoperative confidence in perforators to the ALT free flap including CTA, magnetic resonance angiography (MRA), and color duplex ultrasound [3] [4] [10] [13]. CTA with contrast has most commonly been applied to map ALT perforators and enable three-dimensional visualization of the vessels [3] [4] [14]. This is the preferred imaging modality in ALT perforator identification because it can show vessel origin, length, and perforator type. Imaging modalities such as CTA are ideal in that they can be obtained quickly and provide important anatomical information such as vascular variation as well as measure the depth of the perforator [4] [14]. In addition, because imaging is typically obtained preoperatively, it does not delay the operation. Despite these benefits, there are additional healthcare costs and radiation exposure associated with the use of the CTA, which is not a standard diagnostic scan used during patient workup for soft tissue reconstruction in head and neck surgery [15].

Positron emission tomography (PET) scan images may circumvent the need for additional imaging for preoperative perforator mapping of ALT flaps as they are often obtained preoperatively for head and neck cancer staging [16] [17] [18] [19]. The use of PET scans would then eliminate the additional cost and radiation exposure associated with acquiring CTA for the sole purpose of perforator mapping. No prior studies have investigated the utility and validity of using PET scans in assessing perforators of the ALT. Therefore, the primary aim of this study was to perform a retrospective analysis of our institutional ALT flaps to investigate the efficacy of preoperative PET scans to identify the location and characteristics of ALT flap perforators.

2. Methods

A retrospective review of all patients who underwent ALT flap surgery at our institution over a 10-year period (9/1/2011-1/1/2021) was conducted in accordance with Institutional Review Board approval and the Declaration of Helsinki. One hundred twenty-one patients were identified, and 43 patients were found to have undergone ALT flap reconstruction with preoperative PET scan images available. Five scans were excluded due to poor image quality, and 38 scans were reviewed in this report, the majority of which were mid-thigh scans.

All scans were reviewed by three study members which included a head and neck attending physician, head and neck fellow, and otolaryngology resident (equal weight given to each member). The number, type (myocutaneous versus septocutaneous), and location of perforators were assessed by each reviewer and percent agreement was compared. Fused axial PET images obtained from a variety of hospitals with slice width ranging from 2.00 - 3.73 mm were evaluated on the clinical PACS system (**Figure 1**). The location of perforators was recorded as image cut and position (in millimeters) according to the PET scan metrics. Radiographic data regarding the type and number of identified perforators was then compared to operative findings. Demographic data including patient age, sex, body mass index, and tumor type were collected (**Table 1**). Statistical analysis with R, version 4.2.3 was performed to calculate reviewer agreement regarding the presence of perforators on PET scans and the type of perforators present compared to intraoperative data. Statistical analysis regarding reviewer agreement of perforator location was analyzed using the equation $\text{agreements} / (\text{agreements} + \text{disagreements}) \times 100\%$.

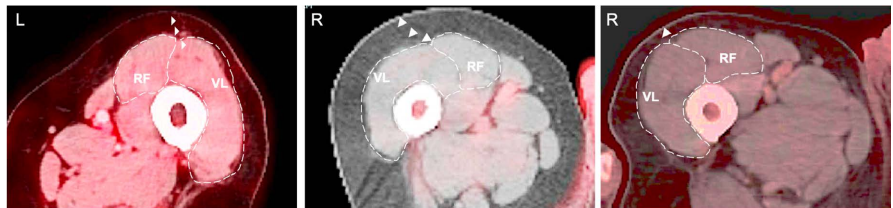


Figure 1. Identification of an anterior lateral thigh (ALT) perforator on preoperative position emission tomography (PET) scan in 3 patients, perforator denoted by white arrowheads. VL = vastus lateralis; RF = rectus femoris.

3. Results

3.1. Patient Characteristics

The average age of patients included in this study was 63.3 ± 12.0 (mean \pm standard deviation; **Table 1**). There were 10 female (26.3%) and 28 male (73.7%) patients. The average BMI was 23.1 ± 5.0 . Thirty-five patients presented with squamous cell carcinoma (92.11%) and one each (2.63%) with basal cell carcinoma, esthesioneuroblastoma, and carcinoma ex pleomorphic adenoma.

Table 1. Patient demographics.

Patient Characteristics	Total
Age, mean (SD) years	63.3 (12.0)
Sex	
F	10 (26.3%)
M	28 (73.7%)
BMI, mean (SD)	23.1 (5.0)

Continued

Cancer type (%)	
Squamous cell carcinoma (SCC)	92.1%
Basal cell carcinoma (BCC)	2.6%
Esthesioneuroblastoma	2.6%
Carcinoma ex pleomorphic adenoma	2.6%
Mean # of perforators identified (%)	
1 perforator	77.7%
2 perforators	19.0%
3 perforators	1.0%
Type of perforator identified (%)	
Reviewer#1	
Myocutaneous	46.2%
Septocutaneous	53.8%
Reviewer#2	
Myocutaneous	26.5%
Septocutaneous	73.5%
Reviewer#3	
Myocutaneous	28.6%
Septocutaneous	71.4%

3.2. Radiographic Information

Approximately 92.1% (35/38) of PET scans had at least one perforator identified by a reviewer. One perforator was identified in 77.7% of scans, 2 perforators in 19.0% of scans, and 3 perforators in 1.0% of scans based on average reviewer assessment. Of the perforators identified, Reviewer #1 identified 46.2% described as myocutaneous and 53.8% as septocutaneous (**Table 1**) whereas Reviewers # 2 and 3 identified 26.5% and 28.6%, respectively, as myocutaneous and 73.5% and 71.4%, respectively, as septocutaneous.

3.3. Reviewer Agreement Regarding Radiographic Information

The agreement percentage regarding the number of perforators per scan, regardless of location, ranged from 53% - 61% (**Table 2**). However, the rater agreement regarding the type of perforator (myocutaneous versus septocutaneous) showed poor agreement (34% - 53%) when taking into account the total of identified perforator types (**Table 2**). The percentage agreement in the location of perforators on PET scans was compared between the three reviewers to de-

termine to what extent reviewers identified the same perforator on imaging. The percentage agreement between raters who identified a single perforator based on location on PET imaging ranged from 79% - 90% (**Table 2**).

Table 2. Percentage agreement regarding the number of perforators, type of perforators (myocutaneous vs septocutaneous), and location on PET imaging.

Percentage agreement regarding the number of perforators	
Reviewer #1 vs #2	61.0%
Reviewer #1 vs #3	53.0%
Reviewer #2 vs #3	55.0%
Percentage agreement regarding the type of perforator (myocutaneous vs septocutaneous)	
Reviewer #1 vs #2	34.0%
Reviewer #1 vs #3	37.0%
Reviewer #2 vs #3	53.0%
Percentage agreement regarding perforator location on PET scan	
Reviewer #1 vs #2	89.0%
Reviewer #1 vs #3	79.0%
Reviewer #2 vs #3	90.0%

3.4. Reviewer Agreement Compared to Operative Findings

Next, the agreement between radiographic data and available data on intraoperative reports was assessed. The percentage agreement regarding the number of perforators identified on PET scan per reviewer compared to findings on intraoperative report revealed low agreement, ranging from 26% - 32% (**Table 3**). Similarly, the type of perforators identified showed poor agreement, ranging from 11% - 24%.

Table 3. Percentage agreement between reviewer identified number and type of perforator on PET scan compared to intraoperative findings.

	Probability of agreeing regarding the number of perforators	Probability of agreeing regarding the type of perforator
Reviewer #1	34.0%	24.0%
Reviewer #2	26.0%	11.0%
Reviewer #3	32.0%	18.0%

4. Discussion

The ALT flap is a popular flap in head and neck reconstruction, with multiple advantages including minimal donor site morbidity, a large skin paddle, and a

long vascular pedicle with good caliber which can facilitate vessel anastomosis [4] [20]. However, the main disadvantage of the ALT flap is the variability in vasculature [4], which may result in inadequate or non-existent perforators or the need to change the design of the flap during the harvest. Although salvage options exist if an ALT flap is raised without adequate perforator identification, preoperative knowledge and confirmation of the perforator anatomy can expand reconstructive options and may guide the surgeon on site selection. Here, a retrospective review was performed to identify patients who underwent ALT flap reconstruction with available preoperative PET scans to investigate the efficacy of this imaging modality for identifying the location and characteristics of skin perforators to the ALT flap.

Although PET scans are often readily available for cancer staging, no prior studies have investigated the efficacy of the PET scan in assessing perforators of the ALT flap or other reconstructive flaps. Early identification of an inadequate ALT perforator can allow the surgeon to expand options for reconstruction. Likewise, the identification of multiple perforators may give confidence in designing two perforator or chimeric flaps. Our results reveal that 92.1% of PET scans had a perforator identified by a reviewer. Likewise, good agreement regarding the identification of a perforator based on location (79% - 90%) was observed, suggesting the promise of this imaging modality to identify ALT perforators. The noted interrater variability, notably regarding perforator type, suggests that training and skill may be a confounding variable given that a resident, fellow, and attending participated in the study. Additionally, poor agreement was achieved when comparing imaging findings with intraoperative findings as it was difficult to get a complete match in perforator number or characteristic due to limited data available in the operative reports.

This study has several limitations as this was a retrospective, imaging-based study. As noted, there was limited data available in operative reports given the retrospective nature of this study. The majority of reports only describe the perforators off of which the flap was ultimately designed, making correlation between imaging and operative findings difficult. Moreover, the majority of PET scans were mid-thigh scans which likely resulted in missing more distal perforators. A variety of PET scans from outside hospitals were assessed with differing quality of images and slice width ranging from 2.00 - 3.73 mm, resulting in the possibility of missing smaller perforators ~2.00 mm.

In summary, PET scans can potentially provide additional information that is often readily available when used in conjunction with anatomic landmarks and doppler to identify ALT perforator number and location. Although initial findings show modest agreement among raters identifying the location of perforators on PET scans, additional skill and training in the identification of perforations along with prospective studies to correlate surgical findings with PET findings are warranted. Additionally, future studies may investigate the impact of imaging on clinical outcomes, including surgical time and flap success.

Therefore, although further studies are planned, the current study raises the possible potential use and advantages of a cancer staging PET scan to identify the location of an ALT perforator. This may enable perforator mapping for reconstructive surgical planning with readily available PET scans.

5. Conclusion

The anterolateral thigh free flap will continue to be a workhorse soft tissue flap for head and neck reconstruction. In a small minority of patients, the skin paddle cannot be harvested as a free flap, and a contingency plan should be discussed with the patient preoperatively. Multiple salvage options exist, and these options are best discussed preoperatively based on anticipated patient-specific anatomic vasculature. Early identification of an inadequate ALT perforator can allow the surgeon to expand options for reconstruction. Retrospective analysis of perforator location on PET scans obtained preoperatively showed 92.1% of PET scans had at least one perforator identified by a reviewer and 79% - 90% agreement between 3 reviewers regarding the location of a single perforator which shows the feasibility of this concept. Additional skill and training regarding perforator identification on PET scans is warranted. Moreover, prospective studies are necessary to assess the accuracy of perforator location and characteristics identified on imaging compared to intraoperative findings and correlate this knowledge with the impact on clinical decision making.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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