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Original Article

Gender Disparities and Ultrasonographic Evaluation of Anatomic Features of Anterolateral Thigh Flap (ALT) in Individuals with Diverse BMI: A Retrospective Clinical Study ^{☆,☆☆}

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ABSTRACT

Background: The anterolateral thigh (ALT) flap plays a crucial role in reconstructive surgeries, providing versatile and reliable soft-tissue coverage. Flap thickness is a critical determinant of tissue volume and quality. Vascular factors, including the vascular diameter of the perforators and the length of the vascular pedicle, significantly influence flap viability and postrepair outcomes. To enhance preoperative assessment, this study integrated gender and body mass index (BMI) to analyze the anatomical characteristics of ALT flaps.

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Methods: This study used somatic penetrating ultrasonography to examine bilateral ALT flaps in patients. This study analyzed the relationship between gender and ALT flap thickness, vascular diameter of the perforators, and vascular pedicle length. Chi-square test was used to assess variations in age and gender. Multiple t-tests compared flap thickness, vascular diameter, and pedicle length between men and women in different BMI groups.

Results: A total of 158 patients were included in this study from January 2018 to December 2022. In BMI < 24 and BMI ≥ 24.0 groups, males had lower ALT flap thickness than females ($p < 0.0001$ in each subgroup). Similarly, the vascular diameter of the perforators followed the same trend, with females having larger vascular diameters than males in BMI < 24 and BMI ≥ 24.0 groups. In terms of vascular pedicle length, males had longer pedicle length than females in both BMI < 24 and BMI ≥ 24.0 groups ($p < 0.05$ in each subgroup).

Conclusions: Females demonstrate greater ALT flap thickness and larger vascular diameter of the perforators than males, whereas males have a longer length of the vascular pedicle.

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Introduction

The anterolateral thigh (ALT) flap is widely recognized for its versatility and reliability in reconstructive procedures, offering effective soft-tissue coverage in various anatomical regions.^{1–5} The anatomic characteristics of the ALT flap hold a significant influence over the success of intraoperative and postoperative flap repairs.^{6,7} Among these characteristics, the flap thickness stands out as a critical factor with a direct impact on the volume and quality of transferred tissue.¹ Moreover, the vascular factors affecting flap viability, including the vascular diameter of the perforators and the length of the vascular pedicle, play a pivotal role in determining the success or failure of flap preparation and postrepair outcomes.^{8,9} Any instances of intraoperative vascular injury and subsequent vascular distortion or compression within this vascular network can give rise to a potential vascular crisis.¹⁰ Therefore, a thorough understanding of the anatomical characteristics of the ALT flap can prevent complications and ensure the viability and success of flap reconstruction.

Previous research has established a robust correlation between body mass index (BMI), a widely utilized measure for assessing obesity, and the characteristics of the ALT flap.¹¹ However, this association only allows for a preliminary preoperative assessment of ALT flap thickness in patients with varying BMIs and does not enable personalized prediction of an individual patient's ALT flap composite. In the authors' clinical practice, we have observed that the anatomical variances in ALT flap preparation between patients of different genders significantly influence the intraoperative assessment of the flap by surgeons. In this study, we utilized ultrasonography as a noninvasive examination method and verified that gender has a significant impact on ALT flap thickness, vascular diameter of the perforators, and length of the vascular pedicle in patients with different BMIs.

Patients and Methods

This retrospective clinical study included patients who were enrolled at the Ninth People's Hospital, Shanghai Jiaotong University School of Medicine, and imaging data were collected by the Department of Ultrasound. To ensure consistent measurement standards, two skilled clinicians and imaging

physicians processed the imaging data in this study. The Medical Ethics Committee of the Ninth People's Hospital of Shanghai Jiaotong University School of Medicine approved this clinical study (SH9H-2021-T19-2). Because this study involved the retrospective collection of patients' medical history data, it will be conducted only after obtaining approval from the Medical Ethics Committee through an Application for Informed Consent Waiver. The subjects' informed consent is not required for this study.

Patients

This study enrolled patients who underwent bilateral ALT flap somatic penetrating ultrasonography for various reasons at our hospital between January 2018 and December 2022. Patients were aged between 18 and 80 years, with an American Society of Anesthesiologist classification not higher than grade 2, without systemic diseases affecting surgery or anesthesia, and without hormone-related systemic diseases affecting systemic lipid metabolism. Patients with lower limb deformities or functional abnormalities due to surgical or other treatment factors and those with lower limb muscle atrophy caused by congenital or developmental factors were excluded from the study.

Grouping

In this study, "gender" is the primary grouping variable for the final analysis. Considering the significant impact of BMI on flap thickness, this study included BMI as a secondary indicator to accurately analyze the effects of gender. BMI was categorized into four different intervals based on the BMI classification criteria: BMI < 18.5 (lean), $18.5 \leq \text{BMI} < 24.0$ (normal), $24.0 \leq \text{BMI} < 28.0$ (overweight), and BMI ≥ 28.0 (obese). However, due to the limited proportion of individuals with BMI < 18.5 or BMI ≥ 28.0 , the population was grouped into two categories: BMI < 24.0 and BMI ≥ 24.0 .

Ultrasonic measurement of ALT flap thickness

In this study, ALT flap thickness was defined as the distance between the fascia at the junction of the rectus femoris and the superficial surface of the lateral femoral muscle to the skin surface. To determine the measurement locations, the anterior superior iliac spine and the lateral border of the patella were connected, creating a line that overlapped the muscle gap between the rectus femoris and lateral femoris muscles. The midpoint of this line was identified as point B, with point A designated as the midpoint between the anterior superior iliac spine and point B, and point C as the midpoint between point B and the lateral border of patella.¹¹ The thickness of the ALT flap was measured at the cross-sectional locations of points A, B, and C using color Doppler ultrasound (Arietta 70, Hitachi Aloka, ultrasound probe L64, frequency 7–10 MHz) to detect the vertical distance between the broad fascia and the skin surface at the junction of the rectus femoris and superficial lateral femoral muscles at each point.

Ultrasonic measurement of the ALT flap vascular diameter of the perforators

During the process of measuring the vascular diameter of the perforators of the ALT flap, the sonographer identified the main stem of the vessel based on the approximate surface position of the descending and oblique branches of the lateral rotator femoral artery and located the subcutaneous distribution of the perforators of the ALT flap. In this study, multiple perforators were found in most subjects' ALT flaps, distributed both above and below point B. If more than one perforator was found, the average of multiple perforators was calculated.

Ultrasonic measurement of the ALT flap vascular pedicle length

In clinical practice, the measurement of the ALT flap vascular pedicle length is demarcated from the branching point of the superficial femoral artery or the lateral circumflex femoral artery to the point where it transverses the fascia lata of the thigh. Physicians measured the vascular pedicle length of the ALT flap by tracing the superficial femoral artery or lateral circumflex femoral artery from its origin to its crossing of the fascia lata, marking this route on the skin.

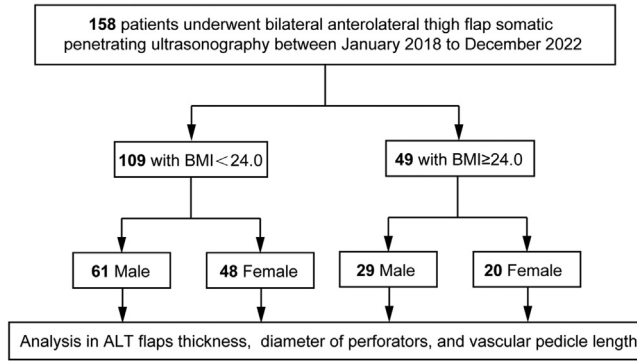


Figure 1. Study population.

Table 1

Characteristics of patients who underwent bilateral ALT flap somatic penetrating ultrasonography with BMI < 24.0 and BMI ≥ 24.0.

	BMI <24.0 (n = 109)	BMI ≥24.0 (n = 49)	
Characteristics	n (%)		p value [#]
Age, (y)			0.4316
≤30	6 (5.50)	1 (2.04)	
31–50	30(y (27.52)	10 (20.41)	
51–70	57 (52.29)	32 (65.31)	
>70	16 (14.68)	6 (12.24)	
Gender			0.7053
Male	61 (55.96)	29 (59.18)	
Female	48 (44.04)	20 (40.82)	

[#] p value was calculated using the χ^2 test.

Statistical analysis

This study used GraphPad Prism 7.0 for statistical analysis, with BMI as a key variable to explore gender differences in ALT flap characteristics. The chi-square test evaluated the impact of age and gender on these characteristics, with $p > 0.05$ indicating no significant difference. Multiple t-tests analyzed variations in flap thickness across genders and BMI categories and the diameter of the perforators and pedicle lengths between genders within BMI groups. An unpaired t-test compared flap thickness between men and women across BMI strata, considering $p < 0.05$ as significant.

Results

Patients

From January 2018 to December 2022, a total of 158 patients who underwent bilateral ALT flap ultrasonography at the Ninth People’s Hospital of Shanghai Jiaotong University School of Medicine were enrolled in this study. Of the total patients, 109 (68.99%) had BMI < 24.0, whereas 49 (31.01%) had BMI ≥ 24.0 (Figure 1). There was no statistical difference in the distribution of gender and age between the groups. Table 1 summarizes the characteristics of patients between two groups.

Effect of gender on ALT flap thickness

In patients with BMI < 24, the thickness of the ALT flap was found to be lower in men than in women at points A, B, and C. At point A, ALT flap thickness was 14.86 mm for females and 10.64 mm for males ($p < 0.0001$). Similarly, at point B, ALT flap thickness was 11.08 mm for females and 7.12

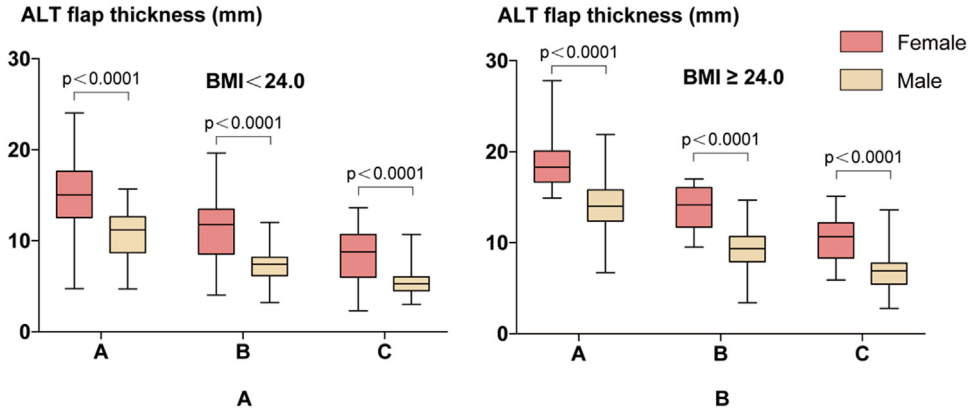


Figure 2. Impact of gender on ALT flap thickness. A. Gender comparison of ALT flap thickness in the BMI < 24.0 group. Points A, B, and C in the BMI < 24.0 group showed a significantly greater thickness in females compared to males (all p-values < 0.0001, multiple t-test). B. Gender comparison of ALT flap thickness in the BMI ≥ 24.0 group. Points A, B, and C in the BMI ≥ 24.0 group exhibited a significantly greater thickness in females compared to males (all p-values < 0.0001, multiple t-test).

mm for males ($p < 0.0001$); at point C, it was 8.36 mm for females and 5.34 mm for males ($p < 0.0001$). Likewise, in the BMI ≥ 24.0 group, ALT flap thickness was smaller in males than in females at points A, B, and C. At point A, ALT flap thickness was 18.59 mm for females and 13.83 mm for males ($p < 0.0001$); at point B, it was 13.77 mm for females and 9.29 mm for males ($p < 0.0001$); at point C, it was 10.47 mm for females and 6.78 mm for males ($p < 0.0001$; Figure 2). There was no difference in ALT flap thickness between the left and right sides of individuals (Supplementary Contents Part 1).

Effect of gender on vascular diameter of ALT flaps

In patients with BMI < 24.0, the ALT flap vascular diameter of the perforators was smaller in men than in women, both above and below point B. Above point B, the vascular diameter was 0.67 mm in females and 0.62 mm in males ($p = 0.0260$), whereas below point B, it was 0.59 mm in females and 0.53 mm in males ($p = 0.0106$). In patients with BMI ≥ 24.0, the ALT flap vascular diameter of the perforators was also lower in men than in women, both above and below point B. Above point B, the vascular diameter was 0.78 mm in females and 0.68 mm in males ($p = 0.0053$), whereas below point B, it was 0.74 mm in females and 0.58 mm in males ($p < 0.0001$; Figure 3). There was no difference in the ALT flap vascular diameter of the perforators between the left and right sides of individuals (Supplementary Contents Part 2).

Effect of gender on the ALT flap vascular pedicle length

In patients with BMI < 24.0, the ALT flap vascular pedicle length was 40.68 cm in females and 42.48 cm in males ($p < 0.0001$). For patients with BMI ≥ 24.0, the vascular pedicle length of the perforators in the ALT flap was 40.32 cm in females and 42.05 cm in males ($p = 0.0010$; Figure 4). There was no difference in vascular pedicle length of ALT flaps between the left and right sides of individuals (Supplementary Contents Part 3).

Discussion

This retrospective clinical study indicated that women generally have greater ALT flap thickness and vascular diameter of the perforators than men at the same BMI, whereas the vascular pedicle length shows the opposite trend.

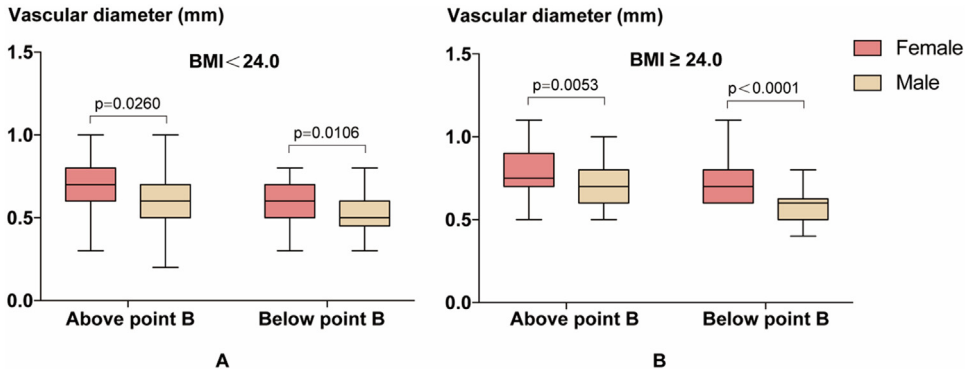


Figure 3. Effect of gender on vascular diameter of ALT flaps. A. Gender comparison of vascular diameter of ALT flaps in the BMI < 24.0 group. The vascular diameter in the BMI < 24.0 group was significantly larger in females compared to males, both above point B ($p = 0.0260$, t-test) and below point B ($p = 0.0106$, t-test). B. Gender comparison of vascular diameter of ALT flaps in the BMI ≥ 24.0 group. The vascular diameter in the BMI ≥ 24.0 group was significantly larger in females compared to males, both above point B ($p = 0.0053$, t-test) and below point B ($p < 0.0001$, t-test).

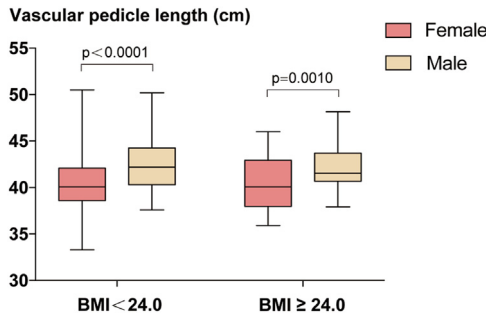


Figure 4. Impact of gender on vascular pedicle length of ALT flaps. The vascular pedicle length was significantly longer in females compared to males in both the BMI < 24.0 group ($p < 0.0001$, t-test) and the BMI ≥ 24.0 group ($p = 0.0100$, t-test).

Many factors can affect the success of ALT flap preparation and postoperative management. On one hand, the thickness of the flap is a critical factor influencing the quality of life for patients after surgery. For instance, in cases of tissue defects near the corners of the mouth, an excessively thick flap can impede mouth closure or restrict mouth opening postsurgery, whereas a thin flap can lead to issues such as corner absence, poor closure, and excessive salivation. Moreover, a thick flap in soft-tissue defects of the floor of the mouth can limit tongue extension movements.¹² On the other hand, vascular factors also have a significant impact on the survival of the flap.^{13–15} The blood supply to the ALT flap is derived from the lateral circumflex femoral artery, with perforating vessels branching off from the descending branch of the lateral circumflex femoral artery.¹⁵ These perforating vessels traverse the lateral femoral muscle and reach the subcutaneous tissue, providing the necessary blood circulation for the entire ALT flap. Consequently, any vascular injury during the intraoperative phase or postoperative distortion or compression can result in vascular crisis or, in severe cases, necrosis of the ALT flap. Previous literature extensively discussed the causes, management options, and effects of vascular crises on the ALT flap.¹⁰ Currently, although the clinical success rates for ALT flap preparation are satisfying, a few literature reported the customized flap design tailored to the unique anatomical features of individual patients' ALT flaps.

Our study revealed that ALT flap thickness in females is greater than in males. To minimize bias potentially caused by the patient's anatomical factors, ALT flap thickness variations between the left and right sides at specific points were also examined (points A–C), with no significant differences in

laterality. In terms of vascular-related properties, female patients exhibited higher vascular diameter of the perforators than males at points A, B, and C. The underlying reason for this disparity remains unclear, and a correlation may exist between the vascular diameter of the perforators and the flap thickness. Patients with BMI ≥ 24.0 had greater vascular diameter than those with BMI < 24.0 , although further validation is required to confirm this correlation. Results regarding the effect of gender on the length of the vascular pedicle revealed that the length of the vascular pedicle was consistently shorter in female subjects than in males. This observation could be attributed to the height difference between females and males, resulting in distinct variations in the length of the lower limbs.

Study Limitations

This study has several limitations to consider. First, the ultrasound measurement process involves applying pressure to the soft tissue, leading to underestimating the true value of flap thickness. Second, during the measurement of the vascular pedicle's length, ultrasound imaging may not precisely represent the vessel's curvature, potentially leading to an underestimation of the actual length. Lastly, ultrasound is a subjective investigation and can be influenced by the skill and expertise of the examining physician. Despite its limitations, ultrasound continues to be a valuable tool for assessing the vascular status of the lower extremities, especially useful in the preoperative assessment of ALT flaps due to its convenience and noninvasive nature. This study enhanced the preoperative planning paradigm for ALT flap procedures by integrating gender and BMI as critical factors in the assessment criteria. Incorporating gender, BMI, and ALT flap anatomical properties as assessment criteria can refine preoperative planning for ALT flaps, improving surgical success, reducing complications, and offering a strategic framework for enhanced clinical outcomes.

Conclusions

Gender is a significant factor influencing ALT flap characteristics, including flap thickness, vascular diameter of the perforators, and length of the vascular pedicle. Specifically, women exhibit greater ALT flap thickness and larger vascular diameter of the perforators than men, whereas men have a longer length of the vascular pedicle. These findings highlighted the importance of considering gender-related differences in the preoperative planning and surgical management of ALT flaps.

Statement of Financial Disclosures, Conflicts of Interest, and Products

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Conflicts of interest: No conflicts of interest in this article.

Ethical Approval: The Medical Ethics Committee of the Ninth People's Hospital of Shanghai Jiaotong University School of Medicine approved this clinical study (SH9H-2021-T19-2). Because this study involved the retrospective collection of patients' medical history data, it will be conducted only after obtaining approval from the Medical Ethics Committee through an Application for Informed Consent Waiver. The subjects' informed consent is not required for this study.

Author contribution: All authors made significant contributions to the completion of this study. Profs. Xingjun Qin, Yue He, and Ping Xiong were responsible for the study design and conception. The initial draft of the manuscript was prepared by Mrs. Jianxin Yin and Dr. Lei Wang. Mr. Zhouyang Wang and Yanni Shi conducted the data collection and analysis. All authors provided valuable feedback on earlier versions of the manuscript. Finally, all authors have read and approved the final version of the manuscript.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi: 10.1016/j.jpra.2024.06.006](https://doi.org/10.1016/j.jpra.2024.06.006).

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