ORIGINAL RESEARCH

The Application of Preoperative Computed Tomography Angiography and Color Ultrasound Assisted Lower Limb Perforator Flap Design in the Repair of Lower Limb Soft Tissue Defects

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ABSTRACT

Objective • The goal of this study was to explore the application effect of preoperative computed tomography (CT) angiography and color ultrasound-assisted design of lower limb perforator flaps in the repair of lower limb soft tissue defects. Repair of soft tissue defects in the lower limbs is a challenging surgical task, and accurate preoperative location of vascular structures and detailed design of the surgical plan are crucial to the success of the surgery. This study aims to improve the accuracy and effectiveness of lower limb perforator flap repair surgery by introducing CT angiography and color ultrasound technology.

Methods • Sixty-four patients who underwent lower limb soft tissue defect repair with perforator flaps were enrolled at our hospital from February 2020 to February 2023. According to their admission time, they were divided into two groups: 32 patients admitted before June 31, 2022, were included in the control group, and preoperative color Doppler ultrasound was used to assist in designing the lower limb perforator flap; 32 patients admitted after June 31, 2022, were included in the study group, and preoperative CT angiography and color Doppler ultrasound were used to assist in designing the lower limb perforator flap. Specifically, we conducted detailed records and analyzes of patients' age distribution, gender ratio, and relevant medical history. This demographic information will help reveal whether there are differences in the effectiveness of preoperative CT angiography and color ultrasound-assisted lower extremity perforator flap design among different patient groups. By considering these key factors, we can more accurately assess the actual utility of new technologies in different patient groups and provide more specific guidance for clinical practice.The therapeutic effects of the two groups of patients were recorded. The differences between the preoperative CT angiography measurements and intraoperative actual measurements of the study group were compared. Clinical indicators, sensory function in the graft area, flap survival rate, flap complication rate, and donor area complication rate were compared between the two groups. The satisfaction of patients in the two groups with the recovery of the surgical area was also compared.

Results • The treatment success rate of the study group was higher than that of the control group ($P < .05$). There was no significant difference in the preoperative CT angiography measurements (shallow branch localization, shallow branch starting diameter, shallow branch length, deep branch starting diameter) and intraoperative actual measurements of the study group ($P > .05$). The operation time and intraoperative blood loss of the study group were shorter than those of the control group ($P < .05$), and there was no significant difference in flap harvesting area and length of hospital stay between the two groups ($P > .05$). There was a difference in sensory function in the graft area between the two groups, with a higher proportion of S4 grade in the study group and better recovery compared to the control group ($P < .05$). There was no significant difference in satisfaction evaluation between the two groups ($P > .05$).

Conclusion • Preoperative CT angiography and color ultrasound-assisted design of lower limb perforator flaps have shown significant clinical advantages in repairing lower limb soft tissue defects, improving treatment effects and surgical efficiency. In clinical practice, this technology is expected to reduce surgical complexity, shorten surgical time, reduce the risk of intraoperative bleeding, and achieve effective defect repair while maintaining or improving the patient's sensory function.

However, there are some limitations to the study, such as the relatively small sample size and single-center nature. Future research can optimize the operation process of this technology, expand the scope of research, and explore its application in the repair of soft tissue defects caused by specific causes. This technology may provide more precise and effective options for personalized treatment, especially for patients who need to preserve more sensory function. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

Recently, high-energy injuries have increasingly become a cause of soft tissue defects in the lower extremities.[1] The occurrence of soft tissue defects in the lower limbs may lead to the exposure of muscles, tendons and bones. If not treated in time, it may lead to infection and pose a threat to the patient's life.[2] Flap treatment is an important method for repairing soft tissue injuries, and the anteroventral lateral thigh flap is known as a universal flap due to its stable blood supply, relatively thick vascular pedicle, and stable donor area.[3,4] Flap therapy involves transplanting healthy skin and tissue from one site to the affected area to cover or repair a soft tissue defect. This is a key method of treating these

Table 1. Comparison of basic information between two groups [means±SDs, n (%)].

Group	Age	Sex		BMI	Injury location		Time from injury to treatment	Injury cause		
		Male	Female		Left	Right		Burn	Traffic accident	Crush injury
Control group (n = 32)	43.59±8.98	23(71.88)	9 (28.13)	22.12±2.41	17(53.13)	15(46.88)	6.64±2.15	12 (37.50)	8 (25.00)	12 (37.50)
Study group (n = 32)	44.45±9.97	21(65.63)	11(34.38)	22.34±2.34	15(46.88)	17(53.13)	6.71±1.98	11 (34.38)	6 (18.75)	15 (46.88)
χ^2/t	-0.363	0.2091		-0.370	0.250		-0.135	0.663		
P value	.718	.590		.712	.617		0.893	.718		

defects because it allows doctors to use the patient's tissue to reduce the risk of rejection, provide better cosmetic and functional recovery, and reduce the potential risk of complications. Flap treatment is essential to repair soft tissue defects, improve wound healing, and reconstruct damaged areas. However, most parts of this area require grafting, which carries significant risks of postoperative necrosis and severe pain. Subsequently, the anteroventrolateral thigh flap was optimized in clinical practice, and the concept of perforator flap was introduced, which was gradually applied in clinical soft tissue injury repair and was of great significance in improving flap survival rate and patient prognosis.[5] Accurate prior assessment of the vascular anatomy of the perforator flap is required.[6,7] Color ultrasound is commonly used to locate perforator vessels, but subcutaneous fat thickness affects this approach and requires a high level of skill on the part of the physician.[8] It may be mentioned that these defects may arise from various causes, including trauma, disease, or surgical resection, and may have an important impact on the patient's function and quality of life. As the population ages and chronic diseases increase, managing soft tissue defects becomes even more important. Additionally, challenges with current treatments, such as scarring, loss of sensation, and impaired function, can serve as issues that need to be addressed. Computed tomography (CT) angiography has high resolution for visualizing perforator vessels and can provide clear images of muscles and surrounding vascular structures. [9] According to a study 10 , the combined application of CT angiography and color ultrasound can comprehensively and objectively reflect the status of the perforator vessels in the anteroventrolateral thigh region. However, current research on the combined use of preoperative CT angiography and color ultrasound to repair lower extremity soft tissue defects is still limited. This study aims to use these two technologies for preoperative design of lower limb perforator flaps, hoping to provide ideal imaging guidance for clinical operations. Next, let's explore our research methods further to gain insights into this area.

MATERIALS AND METHODS

Basic information

A total of 64 patients who underwent lower limb soft tissue defect repair with perforator flaps were enrolled at our hospital from February 2020 to February 2023. The sample size was chosen due to resource constraints, feasibility considerations, and based on previous similar studies. Patients were grouped based on their admission dates: 32 patients admitted before June 30, 2022, were included in the control group, and preoperative color ultrasound was used to assist in designing the lower limb perforator flap. The remaining 32 patients admitted after June 31, 2022, were included in the study group, and preoperative CT angiography and color ultrasound were used to assist in designing the lower limb perforator flap. (*P* > .05). See Table 1 for details. This study has been approved by the Ethics Committee of No. 971 Hospital of the People's Liberation Army Navy.

Inclusion criteria:

(1) Patients aged between 18 and 65 years. (2) Patients with visible large-scale soft tissue defects, with a maximum defect diameter of 6 cm or more. (3) Based on clinical assessment, patients have surgical indications for lower limb soft tissue defect repair. (4) No acute or chronic inflammatory diseases occurred in the three months prior to enrollment. Patients aged 18-65 years were selected because patients in this age group are generally better able to tolerate surgery and postoperative recovery and have a better ability to heal themselves. In addition, large visible soft tissue defects mean that the defect area is larger and requires more complex repair and coverage. These larger defects often require flap treatment to ensure good healing and functional recovery. Therefore, research mainly focuses on such cases to explore effective treatments.

Exclusion criteria:

(1) Patients with conditions such as anemia, hypoalbuminemia, diabetes, or other conditions that may affect the postoperative recovery of patients. (2) Female patients who are pregnant or breastfeeding. (3) Patients with severe underlying medical conditions and poor overall health. (4) Patients who did not complete the entire treatment course at our hospital and withdrew from the study prematurely.

Methods

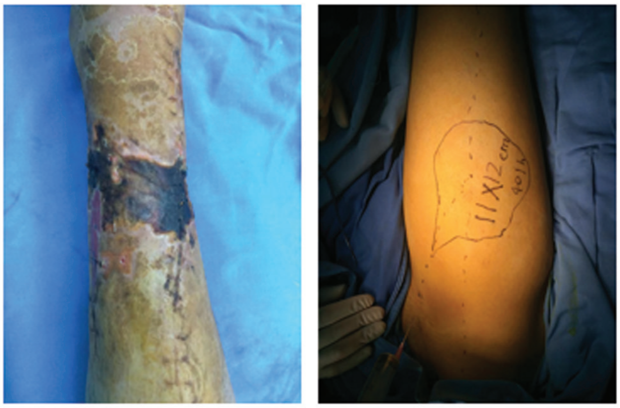
In the control group, color ultrasound was used to assist in the preoperative design of lower limb perforator flaps. The instrument used was a Philips IU22 color ultrasound machine with a frequency range of 10 to 18 MHz. The ultrasound transducer operates in multiple directions along the axis of the descending branch of the lateral femoral artery. Combined with pulse Doppler examination, the number, origin, inner diameter, flow rate and course of the perforator vessels were determined and recorded. According to the shape, size and depth of the wound, confirm the location of the perforator vessels on the skin surface and mark the perforator points. The flap was designed with the line connecting the two perforators as the flap axis.

For the observation group, preoperative design of lower limb perforator flaps was performed with the assistance of CT angiography, combined with color ultrasound. After color ultrasound localization, CT angiography was used to verify the accuracy of ultrasound localization, following the same ultrasound procedure as the control group. The instrument used is a German Siemens 320-slice dual-source spiral CT. The scan range extends from the pelvic area to the level of the healthy knee. Parameters were set to 120 kV, 200 mA, and slice thickness 0.5 mm. Iodophenol was used as contrast agent. Observe anatomical parameters such as the location of the superficial branch, the starting diameter of the superficial branch, the length of the superficial branch, and the starting diameter of the deep branch. The course of the distal perforator vessels and their relationship with adjacent tissues were also observed.

The evaluation methods of the two groups of clinical indicators are clearly defined as follows: First, in terms of "efficacy" evaluation, we use postoperative recovery as the main criterion. This includes assessment of scar healing, hand function, flap survival, and sensory function. Specifically, flap survival was assessed by examining the appearance of the flap weeks and months after surgery to ensure there was no flap necrosis or ulceration. Assessment of sensory function includes testing whether the patient can feel stimuli such as touch or pain, and how quickly those sensations return. These parameters were evaluated through regular postoperative clinical examinations and observations to ensure consistency and objectivity of assessment in both groups.By clearly defining how these clinical measures are assessed, we can gain a clearer picture of the differences between the two groups, which can help us more fully understand differences in efficacy. At the same time, this also ensures the reproducibility of the study methods in other studies.

Flap design: Based on the three-dimensional model of the healthy side lower limb perforators and the shape, size, and depth of the wound on the affected side, appropriate perforator entry points were selected and connected. First, we selected a suitable perforation entry point. This choice is based on a comprehensive consideration of multiple factors. First, we make sure the entry point is away from major blood vessels and neural structures to reduce the risk of complications. Second, we considered the location of the lesion to ensure that the entry point provided optimal visualization and ease of surgical resection. Finally, we evaluate the patient's individual anatomy to ensure that the flap is designed to minimize damage to surrounding tissue. Selection of the appropriate perforation entry point is critical as it directly affects the effectiveness of the procedure and patient recovery. When designing the flap, we ensured the best entry point by incorporating the patient's anatomy and tumor location, as well as intraoperative real-time imaging data. This ensures that we are able to minimize the risk of intraoperative complications while achieving effective tumor resection. The width of the flap was determined based on the width determined during preoperative pinch tests (Figure 1).

Figure 1. Flap design of a representative patient with postoperative flap necrosis.



Observational parameters

The efficacy of both patient groups was meticulously recorded, and a comparative analysis was conducted on the disparities between preoperative CT angiography measurements and intraoperative actual measurements in the study group. Various clinical indicators, including sensory function in the graft area, flap survival rate, flap complication rate, donor area complication rate, and patient satisfaction with the surgical area, were meticulously compared between the two groups.

Efficacy Evaluation: The assessment of efficacy involved evaluating the flap survival, central area blood supply, texture, wound healing, and functional recovery of patients, with a maximum score of 100 points. Scores falling below 60 points were classified as relatively poor efficacy, while those in the range of 61-70 points were deemed acceptable, 71-90 points as good, and scores surpassing 90 points as excellent. The treatment success rate was computed as the ratio of excellent and good cases to the total number of cases, expressed as a percentage.[11]

Sensory Function Assessment: One month post-surgery, the sensory function of the graft area was assessed using a five-level scale:

S0: No sensory perception and no response to stimulation
S1: Reaction to deep pain sensation
S2: Superficial pain sensation and improved tactile sensation
S3: Superficial pain sensation, relatively good tactile sensation recovery, and recovery of two-point discrimination
S4: Complete sensory recovery[12]

Patient Satisfaction: Patient satisfaction was gauged using a department-designed questionnaire with a total score of 10 points. Scores of 9 points or higher were considered satisfied, scores lower than 9 points but higher than 6 points were categorized as moderately satisfied, and scores below 6 points were deemed dissatisfied. The satisfaction rate was calculated as the proportion of satisfied and moderately satisfied cases to the total number of cases.

Statistical analysis

Statistical analysis was performed using Statistic Package for Social Science (SPSS) 23.0 software (IBM, Armonk, NY,

Table 2. Comparison of efficacy between the two groups (n/%)

Group	Excellent	Good	Acceptable	Poor efficacy	Treatment success rate
Control group (n = 32)	14(43.75)	7(21.88)	6(18.75)	5(15.63_	21(65.63)
Study group (n = 32)	19(59.38)	9(21.88)	3(18.75)	1(3.13)	28(87.50)
χ^2					4.267
P value					.039

Table 3. Comparison of preoperative CT angiography measurements and intraoperative actual measurements in the study group (means±SDs).

Group	Superficial branch localization point (cm)	Starting diameter of the superficial branch (mm)	Length of the superficial branch (cm)	Starting diameter of the deep branch (mm)
Preoperative (n = 32)	11.23±0.64	0.71±0.12	3.22±0.65	0.98±0.21
Intraoperative (n = 32)	11.26±0.55	0.78±0.19	3.31±0.71	0.99±0.23
t	-0.201	-1.762	-0.529	-0.182
P value	0.841	0.083	0.599	0.856

Table 4. Comparison of clinical indicators between the two groups (means±SDs).

Group	Operation time (min)	Intraoperative blood loss (ml)	Hospital stays (d)	Flap harvesting area (cm²)
Control group (n = 32)	281.45±61.01	304.45±65.11	22.78±5.16	145.96±63.48
Study group (n = 32)	236.22±45.15	245.56±41.26	21.48±3.89	155.12±43.48
t	3.371	4.322	1.138	-0.673
P value	.001	.000	.259	.503

Figure 2. Surgical procedure of flap graft in a patient with postoperative flap necrosis.

USA). Categorical data such as patient injury location, gender, cause of injury, sensory function, efficacy, and satisfaction were presented as counts and percentages, and chi-square tests were used for comparison. Continuous variables such as age, BMI, time from injury to treatment, superficial branch localization point, starting diameter of the superficial branch, length of the superficial branch, starting diameter of the deep branch, etc., were presented as means ± SDs. Independent sample *t* tests were used for between-group comparisons, and paired *t* tests were used for within-group comparisons. The significance level was set at α=0.05. In our study, the t test was used to analyze whether there were significant differences in the average values of the two groups on some key clinical indicators, such as operation time, postoperative recovery scores, etc. Through the *t* test, we can determine whether the performance of these numerical variables under different operating methods is statistically significant. Paired *t* tests may be used to analyze whether specific indicators, such as sensory function scores, have changed significantly in the same group of patients before and after surgery.

RESULTS

Comparison of efficacy between the two groups

In Table 2, we compare the efficacy of the two groups of patients. In the control group, 14 patients (43.75%) achieved excellent results, 7 patients (21.88%) performed well, 6 patients (18.75%) had acceptable results, and 5 patients (15.63%) had poor results. The treatment success rate was 65.63%. In the study group, 19 patients (59.38%) showed excellent results, 9 patients (21.88%) showed good results, 3 patients (18.75%) had acceptable results, and 1 patient (3.13%) had relatively good results. Difference. The treatment success rate is 87.50%. The chi-square test result showed that χ^2=4.267 and the *P* value was .039, indicating that there was a significant difference between the two groups.

Comparison of preoperative CT angiography measurements and intraoperative actual measurements in the study group

In Table 3, we compare the preoperative CT angiographic measurements and the actual intraoperative measurements in the study group. The results showed that before surgery, the measured location point of the superficial branch was 11.23±0.64 cm, the starting diameter of the superficial branch was 0.71±0.12 mm, the length of the superficial branch was 3.22±0.65 cm, and the starting diameter of the deep branch was 0.98±0.21 mm. The intraoperative measurement results showed that the location point of the superficial branch was 11.26±0.55 cm, the starting diameter of the superficial branch was 0.78±0.19 mm, the length of the superficial branch was 3.31±0.71 cm, and the starting diameter of the deep branch was 0.99±0.23 mm. The *t* test results showed that in all measured parameters, the differences between preoperative and intraoperative were not significant ($P > .05$).

Comparison of clinical indicators between the two groups

The study group had shorter operation time and lower intraoperative blood loss compared to the control group ($P < .05$). There were no significant differences between the two groups in terms of flap harvesting area and length of hospital stay ($P > .05$). Detailed information is shown in Table 4 and Figure 2.

Comparison of sensory function in the graft area between the two groups

There was a difference in sensory function in the graft area between the two groups, with a higher proportion of S4 grade in the study group, indicating better recovery compared to the control group ($P < .05$). Detailed information is shown in Table 5.

Comparison of flap survival rate, flap complication rate, and donor area complications between the two groups

There were no significant differences between the two groups in terms of flap survival rate and donor area complication rate ($P > .05$). However, the study group had a lower flap complication rate compared to the control group ($P < .05$). Detailed information is shown in Table 6 and Figure 3.

Table 5. Comparison of sensory function in the graft area between the two groups (n/%).

Group	S_0	S_1	S_2	S_3	S_4
Control group (n = 32)	0(0.00)	2(6.25)	12(37.50)	15(46.88)	3(9.38)
Study group (n = 32)	0(0.00)	0(0.00)	9(28.13)	11(34.38)	12(37.50)
χ^2					8.444
P value					.038

Table 6. Comparison of flap survival rate, flap complication rate, and donor area complications between the two groups (n/%).

Group	Flap survival rate	Flap complication rate	Donor area complication
Control group (n = 32)	31(96.88)	10(31.25)	2(6.25)
Study group (n = 32)	30(93.75)	3(9.38)	0(0.00)
χ^2	0.350	4.730	2.065
P value	.554	.030	.151

Figure 3. A representative patient showed good flap healing at 2 weeks and 2 months postoperatively, and no complication was found.

Table 7. Comparison of satisfaction rate between the two groups (n/%).

Group	Satisfied	Moderately satisfied	Dissatisfied	Satisfied rate
Control group (n = 32)	12(37.50)	8(25.00)	12(37.50)	20(62.50)
Study group (n = 32)	16(50.00)	7(21.88)	9(28.13)	23(71.88)
χ^2				0.638
P value				.424

Comparison of satisfaction rate between the two groups

There were no significant differences in satisfaction evaluations between the two groups (*P* > .05). Detailed information is shown in Table 7.

The results of the study showed that the research group using preoperative CT angiography combined with color ultrasound performed significantly better in terms of treatment success rate (87.50%), compared with 65.63% in the control group. This advantage can be attributed to the provision of more comprehensive and objective perforator flap design information, thereby improving surgical accuracy and success. For patients, this means better clinical outcomes and surgical success rates, which are expected to accelerate recovery and improve quality of life.

However, the study has some limitations, including a relatively small sample size and patient selection bias that is difficult to completely avoid. Future multicenter studies will help validate the broad applicability and effectiveness of this approach. These limitations need to be addressed in future studies to further confirm the study conclusions.

DISCUSSION

Perforator flap transplantation is an essential method for treating soft tissue injuries. In the past, clinical practice often relied on the surgeon's experience for flap design. However, this approach may not effectively address complex vascular variations or provide personalized flap designs for individual patients. Color ultrasound has certain advantages in displaying the distribution and blood flow characteristics of the main trunk and branches of the anterior lateral femoral artery. Still, it demands a high level of technical proficiency, and it lacks a certain degree of specificity, which can result in false-positive results.[13] The aforementioned influencing factors in color ultrasound examinations may lead surgeons to modify the flap harvesting plan during surgery or even result in surgical failure.[14] This study aimed to investigate the application of preoperative CT angiography and color ultrasound assistance in the design of lower limb perforator flaps for soft tissue defect repair. During CT angiography and surgery, this study adopted state-of-the-art safety measures to ensure maximum patient safety. Ethical approval and informed consent procedures were followed, protecting patients' rights and privacy.

Our current study indicated that the treatment success rate of the study group was significantly higher than that of the control group. Moreover, the comparison between preoperative CT angiography measurements (superficial branch localization point, starting diameter of the superficial branch, length of the superficial branch, starting diameter of the deep branch) and intraoperative actual measurements in the study group showed no significant differences (*P* > .05). This suggests that utilizing preoperative CT angiography and color ultrasound assistance for lower limb perforator flap design allows for precise measurement of perforator vessels and identification of their anatomical characteristics and provides a reliable basis for flap design. Previous study has shown that CT angiography combined with intraoperative ultrasound for diagnosing perforator arteries can achieve a compliance rate of up to 100%, offering optimal reference information for surgeons.[15,16] In this study, the observation group used both imaging techniques for guidance, allowing the surgeons to accurately determine the course and location of lower limb perforator vessels. Consequently, they were able to select suitable perforators and construct the anatomical structure of the lower limb perforator flap, reducing the complexity of flap design and improving precision in both flap design and intraoperative harvesting.

Our study demonstrated differences in sensory function recovery in the graft area between the two groups, with the study group showing a higher proportion of S4-level outcomes and better overall recovery compared to the control group. By combining color ultrasound with vascular angiography, the study group gained a more comprehensive understanding of the vascular anatomy of the anterior lateral femoral flap, leading to more accurate perforator localization, precise preoperative planning, and intraoperative navigation.

CT angiography, in particular, assists surgeons in selecting a more suitable lower limb region as the flap donor site. It enables precise measurements of vascular pedicle length, course, distances between perforators, and assessment of flap blood flow perfusion.[17,18] Accurately obtaining this information preoperatively reduces flap harvesting time, ensures that the surgery proceeds as planned maintains good flap blood supply, and enhances flap graft survival rates. Additionally, it contributes to the recovery of sensory function in the graft area. It is worth noting that perforator vessels in the anterior lateral thigh region have traditionally received less clinical attention. However, the introduction of oblique branches, as seen in this study, can complement anatomical knowledge. Furthermore, this study highlighted the significance of CT angiography in identifying these special perforator vessel types, which can aid in optimizing flap design and surgical outcomes.

The importance of identifying oblique branches in surgery cannot be ignored as it is related to the success of the surgery and the safety of the patient. Oblique branches are important structures in the vascular system and play a critical blood supply role, especially in teeth and oral tissues. Their importance and potential risks are detailed below: Blood supply function: The oblique branches provide the blood supply to the mandible. This key bony structure supports teeth and oral tissues. Inadvertent damage to the oblique branches during surgery may result in insufficient blood supply, which may have serious consequences for the mandible and the teeth it supports. If the blood supply is insufficient, problems such as tissue necrosis, loose teeth, and fractures may occur. Surgery Success: During dental surgery, the dentist or oral surgeon may need to perform tooth extractions, dental implants, or other dental procedures. Good blood supply to the oblique branches is a key factor in surgical success as it aids in post-traumatic healing and reduces the risk of complications. Potential Complications: If the oblique branches are not identified during surgery and are accidentally injured, a number of problems can result. This includes bleeding, which may be severe and require additional management and hemostatic measures. Additionally, there is an increased risk of complications such as fractures, tissue death, infection, and tooth loss.

Therefore, it is crucial to identify and carefully handle oblique branches to ensure surgical success and patient safety. This can be achieved through detailed pre-imaging evaluation, clear surgical planning, and an adequately trained medical team. If the location of an oblique branch is suspected during surgery, medical professionals will often take additional steps to protect it to avoid potential damage. Not only does this help avoid complications, it also contributes to the success of the surgery and the patient's recovery.

Our current study also indicated that the surgical time and intraoperative blood loss were both significantly reduced in the research group compared to the control group. In the control group, which relied solely on color ultrasound for perforator localization, accuracy was compromised. During the surgical dissection of blood vessels, it was often challenging to effectively identify and connect the descending branches of the lower limb perforator to the distal vessels. This necessitated the use of a retrograde technique to free the perforator vessels, resulting in time consumption and increased donor site damage.[19] The combination of CT angiography with color ultrasound effectively mitigates ineffective dissections during surgery, reduces intraoperative bleeding, and saves valuable surgical time.

The results of this study revealed that there was no significant difference in satisfaction ratings between the two groups. Preoperative color ultrasound combined with CT angiography examination can predict the presence of oblique branches, thereby preventing the occurrence of the "oblique branch trap" and making surgery safer.[20] The observation group had shorter surgical times, reduced intraoperative bleeding, and achieved superior clinical outcomes, which did not negatively impact patient satisfaction. It is important to note that this study had a relatively small sample size, which could introduce some bias in the experimental results. Further research with a larger sample size is needed to confirm the advantages of preoperative CT angiography and color ultrasound-assisted lower limb flap design for soft tissue repair in the lower limb.

Compared with previous studies, this study highlights the excellent performance of the combined application of preoperative CT angiography and color ultrasound in perforator flap surgery. This integrated approach has unique advantages in providing more detailed perforator information compared to similar techniques or interventions, bringing new possibilities to clinical practice.

Areas for future research could have multiple directions based on this study. First, optimization of surgical techniques, including improved flap design and application, can continue to be explored to improve flap survival and sensory recovery. In addition, research on postoperative rehabilitation methods and interventions can accelerate patients' functional recovery, including best practices for rehabilitation exercises, lifestyle changes, and rehabilitation care. The application of tissue engineering and regenerative medicine is also a promising area to improve the repair of soft tissue defects through biomaterials or cell therapies. In addition, studying scar management methods to reduce scar formation and improve scar aesthetics is also a direction worthy of further research.

Further research into postoperative sensory recovery, including neurodegenerative therapies or other approaches, will help improve postoperative sensory function. Surveys of long-term outcomes can assess patients' quality of life, functioning, and life satisfaction many years later. Finally, a multicenter study would help validate the findings of this study and ensure their generalizability across different patient populations and clinical settings. These areas of research will provide more options and opportunities to improve soft tissue defect repair.

The clinical significance of this study is significant, highlighting the practical advantages of the combined application of preoperative CT angiography and color ultrasound in lower limb perforator flap surgery. Improving surgical success rates, shortening surgical time, and improving sensory recovery will directly impact patients' recovery and quality of life. Improved surgical success rates mean fewer complications and better surgical outcomes, while reduced surgical time reduces surgical burden on patients. The improvement of sensory recovery is directly related to the patient's daily function and life experience, providing the patient with a more comprehensive treatment.

Although the study has some limitations, such as a relatively small sample size and a single-center design, the results are generally generalizable. In future multicenter studies, the applicability of this approach in different patient populations and clinical settings can be more comprehensively evaluated to better understand its broad applicability.

These findings have practical implications for healthcare practitioners and surgeons, providing them with an effective method to improve the design of lower extremity perforator flap surgeries. This will directly impact clinical practice, improve surgical efficiency, reduce the workload of medical staff, and at the same time improve patients' surgical experience and recovery effects.

By improving sensory recovery and reducing surgical time, this approach is patient-centered and focuses on the patient's actual experience and quality of life. Positive feedback from patients will further reinforce the practical relevance of this approach.This study provides a new perspective and method for the design of lower limb perforator flap surgery, and provides important inspiration for future clinical practice and research. By combining advanced imaging technologies, we can plan surgeries more precisely, improve patient outcomes, and bring substantial progress to the entire field of medicine. Future research could further validate the results of this study in a larger sample population and explore other potential influencing factors in depth. In addition, the research field can be expanded to explore the application of new preoperative imaging techniques in other types of surgeries.

In conclusion, preoperative CT angiography and color ultrasound-assisted lower limb perforator flap design exhibit significant clinical advantages in the repair of soft tissue defects in the lower limb. This approach can enhance treatment outcomes and surgical efficiency while preserving or improving patients' sensory function. It holds promising prospects for the repair of lower limb soft tissue defects.

ETHICAL COMPLIANCE

This study was approved by the ethics committee of No.971 Hospital of the People's Liberation Army Navy. Signed written informed consent were obtained from the patients and/or guardians.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest to report relevant to this article.

AUTHOR CONTRIBUTIONS

LY, YC and XL designed the study and performed the experiments, DY and JZ collected the data, HZ, HF and YJ analyzed the data, LY, YC and XL prepared the manuscript. All authors read and approved the final manuscript. LY and YC contributed equally to this work

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