ORIGINAL RESEARCH

The Impact of Flap Vascular Pressurization Technique on the Repair of Large-Area Soft Tissue Defects in Limbs

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ABSTRACT

Objective • This study investigated the impact of the flap vascular pressurization technique on repairing large-area soft tissue defects in the limbs.

Methods • This study employed a randomized controlled trial design to enroll patients with large-area skin defects in the limbs, accompanied by exposed deep tissues such as nerves, blood vessels, bones, and tendons, for various reasons between July 2020 to July 2022. The patients were randomly assigned into two groups using a random number table method. The control group (n = 30) underwent traditional anterior lateral thigh flap repair, while the experimental group (n = 30) underwent flap repair using the vascular pressurization technique. Clinical indicators, flap survival, scar formation, and satisfaction were compared between the two groups.

Results • There were no significant differences in operation time, intraoperative blood loss, and length of hospital stay between the two groups ($P > .05$). The flap survival rate in the experimental group (90.00%, 27/30) was significantly higher than that in the control group (66.67%, 20/30) ($P < .05$). The Manchester Scar Scale (MSS) scores in the experimental group were significantly higher than those in the control group ($P < .05$). The satisfaction rate in the experimental group (93.33%, 28/30) was significantly higher than that in the control group (73.33%, 22/30) ($P < .05$).

Conclusion • The use of the flap vascular pressurization technique for the repair of soft tissue defects in the limbs can significantly increase flap survival rate, improve scar formation, and enhance patient satisfaction, thereby demonstrating good clinical value. The flap vascular pressurization technique can be promoted as a reliable method for repairing large-area skin defects in the limbs, thereby contributing to the advancement of specialized fields. (*Altern Ther Health Med.* 2023;29(6):328-332).

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INTRODUCTION

Extensive soft tissue defects in the limbs often involve exposed deep tissues, including nerves, blood vessels, bones, and tendons, resulting from infection, trauma, and other causes.[1] Current methods for repairing such defects include free flaps[2] and pedicle flaps.[3] While free flap repair is the primary approach for extensive soft tissue defects in the limbs, large flap sizes can lead to venous reflux obstruction or inadequate blood supply, resulting in flap necrosis or poor survival outcomes. On the other hand, pedicle flaps have certain limitations in addressing large soft tissue wounds. The concept of "vascular pressurization" was introduced in 2016, emphasizing the crucial role of blood supply in the survival of large skin flaps. However, its application has been limited due to technological immaturity, challenging anatomical procedures, and vascular variations.[4] With advancements in imaging and medical technology, color Doppler ultrasound and CT angiography (CTA) have become widely used in diagnosing vascular diseases of the limbs. Although traditional skin grafting can restore damaged skin, its applicability is limited, and inadequate repair may necessitate multiple surgeries, adversely impacting the patient's physical and mental well-being. Clinical vascular assessment, including anatomical examination and Doppler ultrasound blood flow detection, can be combined with "vascular pressurization" principles to develop tailored treatment plans to improve the survival rate of large anterolateral thigh flaps.[5] Therefore, this study investigated the use of the flap vascular pressurization technique in repairing extensive soft tissue defects in the limbs and explored its efficacy.

PATIENTS AND METHODS

Study Design and Patients

The study employed a randomized controlled trial design, and patients with large skin defects in all four limbs, accompanied by exposed deep tissues such as nerves, blood vessels, bones, and tendons, were enrolled as research subjects from July 2020 to July 2022. Patients were divided into two groups by random number grouping method.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) injury to surgery time ≤ 6 h; (2) patients able to tolerate surgery without contraindications; (3) absence of severe wound contamination or destructive tissue defects; (4) patients or their family members who were informed about their condition and the surgical procedure and treatment plan. Exclusion criteria were: (1) patients with severe lower limb vascular thrombosis and disease; (2) patients with small limb skin defects not requiring skin flap transplantation repair; (3) patients with less than 3 months of follow-up.

The patients were randomly divided into two groups: a control group and an experimental group, with 30 cases in each group. The two groups had no significant differences in general information ($P > .05$). The ethics committee of our hospital approved the study.

Control Group

The control group consisted of 18 males and 12 females. The age range was 27 to 63 years, with an average age of (45.17 ± 5.62) years. The causes of injury included 16 cases of traffic accidents, 5 cases of electric shock, and 9 cases of burns. The injured sites comprised 9 cases of the left lower leg and left foot, 3 cases of the right knee joint, and 11 cases of the right elbow joint and right arm. Additionally, there were 7 cases of the left arm and left hand.

Experimental Group

The experimental group consisted of 15 males and 15 females. The age range was 25 to 65 years, with an average age of (44.83 ± 5.49) years. The causes of injury included 13 cases of traffic accidents, 7 cases of electric shock, and 10 cases of burns. The injured sites comprised 11 cases of the left lower leg and left foot, 3 cases of the right knee joint, 9 cases of the right elbow joint and right arm, and 5 cases of the left arm and left hand. Additionally, there were 2 cases of the left knee joint.

Surgical Procedure and Flap Repair Technique

The control group underwent traditional prepatellar lateral skin flap repair. The procedure involved preoperative Doppler ultrasound blood flow detection in identifying the first musculocutaneous perforating artery of the descending branch of the lateral femoral circumflex artery near the midpoint between the outer upper edge of the patella and the anterior superior iliac spine. The skin flap was designed based on the identified location, with a size 10% to 20% larger than the wound, incorporating two perforating points at the distal end and upper third of the skin flap, respectively.

The dissection of the descending branch of the lateral femoral circumflex artery, along with the outer edge of the skin flap and fascia incisions, was performed under a headlight. After identifying and isolating the perforating vessels, the wide fascia was incised, and the perforating vessels were released using a retrograde technique. The proximal perforating vessel was freed up to the origin of the descending branch of the lateral femoral circumflex artery, with preservation of its major branches.

On the opposite side of the incised skin flap, the distal perforating vessel was clamped using vascular clamps and released approximately 5-6 cm towards the proximal end before being ligated and cut, thereby releasing the skin flap. Using a microscope, the proximal perforating vessel was anastomosed with the descending branch of the lateral femoral circumflex artery, while the distal perforating artery and its accompanying vein were anastomosed with the accompanying vein branch of the femoral artery. Heparin was administered to flush the proximal conduit, ensuring unobstructed anastomotic vessels and confirming the absence of leaks at the anastomotic site.

The experimental group underwent skin flap repair using the vascular augmentation technique. The procedure included a preoperative blood vessel distribution and development evaluation based on the patient's lower limb CTA and Doppler ultrasound blood flow assessment. The design of the skin flap was meticulously customized to match the shape of the wound, ensuring that the flap incorporated at least two sets of perforating blood vessels. Following anesthesia, the extensive skin and muscle defect on the limbs was debrided, and the recipient site was exposed for the anastomosis of arteries and veins. Based on the preoperative skin flap design, one side of the skin was incised, and the entry points of the perforating blood vessels at the surgical site were confirmed and identified.

The entry points were adjusted accordingly, considering the location, size of the wound, and reference points of the perforating blood vessels within the skin flap. This adjustment ensured that the skin flap contained a minimum of two perforating blood vessels. Subsequently, the skin flap was harvested, and the perforating blood vessels and pedicle were exposed. Successive occlusion of different single perforating blood vessels from various directions or sources was performed to assess their impact on the blood flow of the skin flap.

Based on these observations, the major anastomotic blood vessels and the augmentation of anastomotic blood vessels were identified. Subsequently, the skin flap harvested from the anterior lateral thigh was mobilized and transplanted to the recipient site. The primary perforating artery and vein within the skin flap were anastomosed to the recipient's corresponding major artery and vein, respectively. Another set of perforating arteries and veins at the distal end of the skin flap was anastomosed to other arteries and veins at the recipient site to enhance blood pressure. The anastomosed blood vessels were observed to be patent, ensuring a good

blood supply to the skin flap. Finally, the wound and donor site were closed and repaired.

Observation Indicators

Clinical Indicators. A comparison was made between the two groups regarding the duration of surgery, intraoperative blood loss, and length of hospital stay.

Flap Survival. Flap survival in both groups was assessed through various measures. Following flap surgery, "three-anti" treatment (anti-infection, anti-spasm, and anti-coagulation) was administered. Sutures were removed approximately 12 days after flap survival, and the pressure dressing was removed 1 week after skin graft surgery to evaluate flap survival. Flap function was evaluated based on 10 indicators, such as sweating and skin color. Each indicator was scored on a scale of 1-10, resulting in a total score of 100. Flap necrosis was indicated by a score below 40, with higher scores indicating a higher flap survival rate.

Scar Condition. The scar condition was assessed during suture removal in the two groups. The Manchester Scar Scale (MSS)[6] was utilized to evaluate the scar condition, considering five indicators: original wound, the texture of the graft or flap, donor site scars, sensation, and function. Each indicator was scored on a scale of 1-4 points, with 1 representing the best condition and 4 indicating the worst. A higher score corresponds to a worse scar condition. The evaluation team, comprising two physicians and two nurses, followed unified standards and norms. They were proficient in utilizing the evaluation form and independently scored each patient. The final score for each parameter was determined by calculating the average score from the four raters.

Satisfaction. Patient satisfaction was assessed using the evaluation criteria of the British Medical Research Association.[7] The evaluation involved scoring on a scale of 0 to 5, with 0 representing "very dissatisfied" and 5 indicating "very satisfied." The scores were categorized as follows: very dissatisfied, dissatisfied, basically satisfied, satisfied, and very satisfied. The satisfaction rate was calculated using the formula:

$$\text{Satisfaction Rate} = 1 - ((\text{number of very dissatisfied} + \text{number of dissatisfied}) / \text{total number of patients}) \times 100\%$$

Statistical Analysis

Data statistics and analysis were performed using IBM SPSS Statistics version 24.0 (IBM, Armonk, NY, USA). Descriptive statistics were presented as mean ± standard deviation (SD) for quantitative data. Within-group and between-group comparisons were conducted using *t* tests. Count data were presented as frequency (percentage), and χ^2 tests were used for analysis. The significance level was set at $\alpha = 0.05$.

RESULTS

Comparison of Surgical Conditions between the Two Groups

There were no significant differences in operation time, intraoperative blood loss, and hospital stay between the two groups ($P > .05$), as presented in Table 1.

Table 1. Comparison of Surgical Conditions Between the Two Groups ($\bar{x} \pm s$)

Group	Number of Cases	Procedure Time (min)	Intraoperative Blood Loss (ml)	Length of Stay (days)
Control Group	30	7.67 ± 1.55	169.37 ± 24.17	29.14 ± 3.52
Exp Group	30	7.49 ± 1.43	166.62 ± 22.86	27.81 ± 3.40
t		0.467	0.453	1.489
P value		.642	.652	.142

Note: The values in the table represent mean ± standard deviation.

Table 2. Comparison of Flap Survival Between the Two Groups [case (%)]

Group	Number of Cases	Survival	Partial Necrosis	Total Necrosis	Survival Rate
Control Group	30	20 (66.67)	7 (23.33)	3 (10.00)	20 (66.67)
Exp Group	30	27 (90.00)	2, 6.67	1 (3.33)	27 (90.00)
χ^2					4.812
P value					.028

Note: The values in the table represent the number of cases and percentages.

Comparison of Flap Survival between the Two Groups

The skin flap survival rate in the experimental group was 90.00% (27/30), which was significantly higher than the 66.67% (20/30) observed in the control group ($P < .05$), as indicated in Table 2.

Comparison of Scars between the Two Groups

The MSS scores in the experimental group were significantly higher than those in the control group ($P < .05$), as presented in Table 3.

Comparison of Satisfaction between the Two Groups

The satisfaction rate in the experimental group was significantly higher at 93.33% (28/30) compared to 73.33% (22/30) in the control group ($P < .05$), indicating a higher level of satisfaction in the experimental group. Refer to Table 4 for details.

DISCUSSION

Various types of accidents, including traffic accidents and falls, can result in varying degrees of trauma, often leading to extensive soft tissue injuries in the limbs, which are commonly observed in clinical practice. Limbs play a crucial role in daily movement, work, and overall quality of life, as they contain a dense network of blood vessels and nerves. Injuries to the limbs not only cause physical pain to the patients but also directly impact their overall health and well-being.[9]

Currently, surgical methods are commonly employed for the clinical repair of limb injuries. While traditional skin grafting can address damaged skin, its applicability is limited. In cases where the repair is insufficient, multiple surgeries

Table 3. Comparison of Scar Between The Two Groups ($\bar{x} \pm s$, points)

Group	Number of Cases	Primitive Wound	Texture	Donor Site Scar	Feeling	Function	Total Score
Control Group	30	2.15 ± 0.61	2.27 ± 0.63	2.36 ± 0.58	2.37 ± 0.69	1.93 ± 0.55	11.08 ± 3.06
Exp Group	30	1.13 ± 0.32	1.04 ± 0.28	1.21 ± 0.33	1.25 ± 0.36	1.01 ± 0.22	5.64 ± 1.51
t		8.110	9.772	9.439	7.882	8.414	8.732
P value		<.001	<.001	<.001	<.001	<.001	<.001

Note: The values in the table represent the mean ± standard deviation ($\bar{x} \pm s$) scores.

Table 4. Comparison of Satisfaction Between the Two Groups [Case (%)]

Group	Number of Cases	Very Satisfied	Satisfied	Basically Satisfied	Not Satisfied	Very Dissatisfied	Satisfaction
Control Group	30	5 (16.67)	9 (30.00)	8 (26.67)	7(23.33)	1 (3.33)	22 (73.33)
Exp Group	30	7 (23.33)	10 (33.33)	11(36.67)	2, 6.67	0 (0.00)	28 (93.33)
t							4.320
P value							.038

Note: The values in the table represent the number of cases and percentages.

may be required, significantly impacting the patient's physical and mental well-being. Therefore, there is a need for alternative approaches that offer more comprehensive and effective solutions.[4,10]

The concept of "vascular augmentation" involves enhancing the blood supply to the distal end of a flap through vascular anastomosis.[11] In recent years, this concept has introduced innovative approaches for addressing extensive soft tissue defects in limbs. Studies focusing on the origin of blood vessels[12] have revealed the diverse blood supply to the anterior lateral skin of the thigh. The presence of oblique branches offers new possibilities for selecting vascular pedicles, thereby increasing the success rate and flexibility of flap harvesting. Based on this premise, the present study employed the technique of vascular augmentation of flaps for repairing extensive soft tissue defects in limbs, yielding the following outcomes. The comparison of clinical indicators between the two groups revealed no statistically significant differences in operation time, intraoperative blood loss, and length of hospital stay. These findings suggest that utilizing vascular augmentation techniques for skin flap repair did not significantly impact these factors.

The comparison of skin flap survival rates between the two groups demonstrated that the experimental group exhibited a higher rate of 90.00% (27/30) compared to the control group's rate of 66.67%. These findings indicate that using vascular augmentation techniques for repairing extensive skin and soft tissue defects in limbs can significantly enhance the survival rate of skin flaps. This improvement in survival rate can be attributed to the large area skin flap, which is meticulously designed with multiple modes and carries two or more perforating blood vessels from different sources. The utilization of vascular augmentation techniques ensures enhanced harvestable area and maintains blood vessel patency after skin flap transplantation. Moreover, it serves as a compensatory mechanism for flap survival by establishing an additional anastomotic site in case of a vascular crisis at one site.[13] As a result, the survival rate of the anterior lateral thigh free skin flap is significantly increased.

Vascular augmentation, by connecting the distal blood vessels of the skin flap, enhances blood circulation in the distal portion, effectively preventing venous congestion and improving blood supply to the skin flap. This technique demonstrates significant clinical utility and application value. Liu Daiming[14] conducted research on the augmentation of blood supply in perforator skin flaps, demonstrating a significant improvement in the blood supply of the flaps following vascular augmentation. The perfusion of the augmented blood vessels was enhanced, resulting in increased blood supply to the distal portion of the skin flap. These findings align with the results of the current study.

The comparison of scar conditions and satisfaction between the two groups revealed that the experimental group exhibited higher MSS scores and a satisfaction rate of 93.33% (28/30) compared to the control group's rate of 73.33% (22/30). These findings suggest that using vascular augmentation techniques in skin flap repair can contribute to improved scar conditions and increased patient satisfaction. The enhanced survival rate of the skin flap reduces the financial burden associated with reoperations, while the improvement in scar conditions alleviates the psychological distress caused by prominent postoperative scars. These outcomes yield considerable social and personal benefits, resulting in significantly heightened patient satisfaction.

Study Limitations

However, one of the limitations of this study is the small sample size, which may have impacted the reliability and generalizability of the findings. The limited number of participants might have introduced potential biases and limited the statistical power of the analysis. Therefore, caution should be exercised when interpreting the results,

and future studies with a larger sample size are needed to validate and provide more comprehensive insights into the examined clinical indicators.

CONCLUSION

In conclusion, using the flap vascular pressurization technique to repair extensive soft tissue defects in the limbs has demonstrated significant benefits. This technique effectively enhances the survival rate of flaps, improves scar conditions, and enhances patient satisfaction. The findings of this study support the clinical application and promotion of the flap vascular pressurization technique as a reliable and effective method for repairing large-area skin defects in the limbs. Implementing this technique can contribute to advancements in specialized fields related to limb reconstruction and promote overall medical progress. Further research and clinical studies are warranted to validate and expand upon these findings.

CONFLICT OF INTEREST

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

AUTHORS' CONTRIBUTIONS

CH and YW designed the study and performed the experiments, HC and ZH collected the data, MC and WW analyzed the data, and CH and YW prepared the manuscript. All authors read and approved the final manuscript.

FUNDING

This study was supported by the Key Research and Development Program of Hainan Province (Grant No. ZDYF2020128).

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