

Cross-Leg Flap: An Effective Alternative for Limb Salvage in Complex Trauma

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ABSTRACT

Although microsurgery is the current gold standard for the reconstruction of lower extremity defects, the cross-leg flap remains vital when free tissue transfers are not feasible (due to vascular compromise, lack of recipient vessels, or limited resources). The technique has evolved since its description in 1854, with notable advancements including the introduction of the fasciocutaneous flap (Ponten, 1983) and the development of microsurgical variants. Its key indications include severe trauma, absence of local vessels supply, previous flap failures, and resource-limited settings. However, there are relative contraindications such as bilateral trauma or lack of patient cooperation.

Among its advantages are its reliability, robustness, independence from local vessels, and technical simplicity. Disadvantages include prolonged immobilization (3-4 weeks), the need for two surgical stages, and potential aesthetic outcomes that may require revisions. Complications vary (necrosis, infection, etc.) but are accompanied by a generally high success rate.

Postoperative management is crucial, focusing on immobilization with external fixators, flap monitoring, pain control, and early physiotherapy. The pedicle is divided once the flap has developed sufficient vascularization (approximately 3-4 weeks).

KEYWORD: Lower extremity, cross leg flap, trauma, microsurgery, vascular injury.

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INTRODUCTION

The reconstruction of complex defects in the lower extremity, particularly those involving soft tissue loss and vascular compromise, represents a significant challenge for the reconstructive surgeon [1, 2]. Historically, the choice of reconstructive technique has evolved, from local and regional flaps to the advent of microsurgery and free flaps. However, in situations where the vascular integrity of the injured limb is compromised or suitable recipient vessels are unavailable, cross-leg flaps emerge as a viable and reliable alternative for limb salvage [3, 4].

The complexity of lower extremity injuries, often resulting from high-energy trauma, burns, infections, or oncologic resections, demands a deep understanding of local anatomy and the various reconstructive options available [5]. Although microvascular free flaps are considered the gold standard for covering large defects and reconstructing exposed vital structures, their success depends on the availability of healthy recipient vessels and the surgical team's expertise in microsurgery [6, 7].

In this context, cross-leg flaps offer a robust solution, particularly in resource-limited settings or for patients who

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are not candidates for free tissue transfer due to comorbidities or the extent of vascular injury [8].

The cross-leg flap technique has a rich history in reconstructive surgery, dating back to the mid-19th century. It was first described by Frank H. Hamilton in 1854, who named it "helcoplasty," referring to the treatment of ulcerative lesions [1]. Initially, these flaps were performed as random cutaneous flaps, limiting their length-to-width ratio to 1:1 and requiring a "flap delay" to ensure viability, thus prolonging hospital stays and the number of surgical procedures [1].

A significant milestone in the evolution of this technique was the introduction of the fasciocutaneous flap concept by Ponten in 1983. This advancement allowed the inclusion of deep fascia in the flap, significantly improving its vascularization and enabling length-to-width ratios of up to 1:3 or 1:3.5, making the procedure safer and more predictable [1, 5].

With the advent of microsurgery in the 1970s and 1980s, free flaps became the "gold standard" for lower extremity reconstruction, relegating the cross-leg flap to a secondary role [2, 4]. However, despite the popularity of free flaps, the cross-leg flap has retained its relevance in specific situations where free tissue transfer is not feasible, such as in cases of severe vascular compromise, absence of suitable recipient vessels, or in resource-limited settings [2, 3, 4].

Classification and Types of Cross-Leg Flaps

Throughout its history, the cross-leg flap has evolved, giving rise to a variety of techniques and classifications. A comprehensive classification, proposed by Sabry et al. [1], is based on the type of tissue transferred and the flap's vascularization pattern. This classification, enriched with contributions from other authors, allows for a better understanding of the options available for lower extremity reconstruction.

Cutaneous Flaps

Cutaneous flaps were the first to be described. Initially, they were designed as random pattern flaps, with a length-to-width ratio of 1:1, often requiring a flap delay to ensure survival. Subsequently, with a better understanding of cutaneous vascularization, axial pattern flaps were developed, allowing ratios of up to 1:3 [1].

Fasciocutaneous Flaps

The introduction of the fasciocutaneous flap concept by Ponten revolutionized the technique by including deep fascia, significantly improving the flap's vascularization. These flaps are based on perforating arteries and can be of different types, depending on the dominant artery:

- **Posterior Tibial Artery Flap:** One of the most commonly used, it can be designed with a distal or proximal base [1, 2].
- **Peroneal Artery Flap:** Based on the septocutaneous perforators of the peroneal artery [1, 2].
- **Sural Artery Flap:** Can be distally or proximally based, offering a versatile option for defects in the distal third of the leg and foot [1, 2].

- **Saphenous Artery Flap:** Based on the saphenous artery, nerve, and vein [1].

Muscle and Musculocutaneous Flaps

In cases requiring greater tissue volume or better coverage of exposed bone, muscle or musculocutaneous flaps can be used. The most commonly utilized muscles are the gastrocnemius, soleus, and gracilis [1]. These muscle flaps can be covered with a partial-thickness skin graft.

Cross-Leg Free Flaps

In the era of microsurgery, the concept of the cross-leg free flap has emerged. This technique involves transferring a free flap (such as the latissimus dorsi or anterolateral thigh flap) that is anastomosed to the vessels of the healthy contralateral leg. The vascular pedicle is divided in a second surgical stage once the flap has developed neovascularization from the recipient bed [6, 7, 8]. This technique is particularly useful for extensive defects or when no suitable recipient vessels are available in the injured limb.

Modified Flaps

Various modifications of the technique exist, such as pre-laminated flaps, fillet flaps (using tissue from an amputated limb), and the Crane principle, which involves transferring subcutaneous tissue and fascia to cover the defect [1].

Indications and Contraindications

The selection of a cross-leg flap for reconstructing lower extremity defects is based on a careful evaluation of the patient's characteristics, the nature of the injury, and the availability of other reconstructive options. While free flaps are the gold standard, there are specific situations where the cross-leg flap becomes the preferred or even the only viable option [2, 4].

Indications

The main indications for the use of cross-leg flaps include [1, 2, 3, 4, 5]:

- **Severe Trauma:** Particularly those resulting in large soft tissue losses, bone, tendon, or neurovascular exposure, and where ipsilateral recipient vessels are damaged or absent. This includes traffic accidents, crush injuries, gunshot wounds, electrical burns, and explosive injuries [1, 2, 4].
- **Absence of Suitable Recipient Vessels:** When no healthy recipient vessels are found in the injured limb for microvascular anastomosis, due to the initial trauma, previous surgeries, or conditions like peripheral arterial disease [2, 3, 4].
- **Failure of Previous Free Flaps:** In cases where a microvascular free flap has failed, the cross-leg flap can serve as a salvage option for limb preservation [4, 7].
- **Limited Resources:** In centers where microsurgical expertise or the necessary equipment for free tissue transfer is unavailable [2, 4, 5].
- **Patient Conditions:** Patients with comorbidities contraindicating prolonged surgeries under general

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anesthesia or those at high risk of microvascular thrombosis [2, 4].

- **Defects in the Distal Third of the Leg and Foot:** These areas have poor vascularization and often require complex reconstructive techniques [2, 5].
- **Chronic Infections or Ulcers:** In cases of osteomyelitis or diabetic ulcers requiring soft tissue coverage [7].

Relative Contraindications

Although there are no strict absolute contraindications, certain conditions may make the cross-leg flap less favorable or require a more thorough evaluation [2, 4, 5]:

- **Severe Bilateral Trauma:** If both lower extremities are severely compromised, the availability of a healthy donor site for the cross-leg flap is limited [1].
- **Severe Peripheral Vascular Disease in the Donor Limb:** Although the flap is taken from the contralateral leg, significant vascular disease in the donor limb could compromise flap viability [2].
- **Lack of Patient Cooperation:** Prolonged immobilization of both limbs can be challenging for some patients, especially children or those with cognitive issues [5].
- **Aesthetic Expectations:** While functionally effective, cross-leg flaps may result in considerable tissue volume or require secondary revisions to improve contour, especially around the heel and ankle [4, 5].
- **Need for Large Bony Components:** In extensive bony defects requiring vascularized bone, free flaps with bone (such as the free fibula) may be more suitable [1].

The decision to use a cross-leg flap must be individualized, weighing the potential benefits against the risks and limitations, always seeking the best functional and aesthetic outcome for the patient.

Advantages and Disadvantages Compared to Other Reconstructive Techniques

The choice of reconstructive technique for complex lower extremity defects is critical and depends on multiple factors. Cross-leg flaps, despite the evolution of microsurgery, maintain a relevant role due to their distinctive characteristics compared to other options [2, 4].

Advantages

The advantages of cross-leg flaps include [1, 2, 3, 4, 5]:

- **Reliability and Robustness:** They have demonstrated high flap survival rates, approaching 100% in some studies, making them a highly reliable reconstructive option [2, 4, 5].
- **Independence from Local Recipient Vessels:** They are particularly useful when local vessels in the injured limb are damaged, sclerosed, or absent, preventing the use of a free flap [2, 3, 4].

- **Technical Simplicity (Compared to Microsurgery):** Pedicled cross-leg flaps do not require advanced microsurgical expertise or specialized equipment, making them accessible in a wider range of clinical settings [1, 2, 5].
- **Shorter Surgical Time:** Generally, the operating time for raising and inserting a pedicled cross-leg flap is less than that of a free flap, benefiting patients with comorbidities or in acute trauma situations [4, 5].
- **Coverage of Large Defects:** They allow the transfer of a significant amount of soft tissue, essential for covering extensive defects with exposure of vital structures like bone, tendons, and vessels [1, 2].
- **Similar Tissue Quality:** They provide tissue from the same extremity, potentially leading to better integration and a more natural appearance compared to flaps from other body regions [5].
- **Salvage Option:** They are an excellent alternative when attempts at reconstruction with free flaps have failed [4, 7].

Disadvantages

Despite their advantages, cross-leg flaps also present significant limitations [1, 2, 4, 5]:

- **Prolonged Immobilization:** The need to keep both limbs immobilized in a fixed position for several weeks (typically 3-4 weeks) is a major drawback. This can cause discomfort, joint stiffness, and require external fixation (cast or orthopedic fixator) [1, 2, 3].
- **Two Surgical Stages:** Most cross-leg flaps require a second surgical stage to divide the pedicle, involving an additional procedure and extending hospital stay [1, 2].
- **Donor Site Morbidity:** Although generally low, there may be complications at the donor site, such as partial skin graft loss or aesthetic issues [4, 5].
- **Mobility Restrictions:** During the immobilization period, the patient's mobility is severely restricted, affecting their quality of life and requiring postoperative physiotherapy [1, 3].
- **Limitations in Bone Reconstruction:** While they can cover bony defects, they do not transfer vascularized bone, which can be a limitation in large or complex bony defects requiring union [1].
- **Aesthetic Outcome:** Although they provide functional coverage, the flap volume can be considerable, sometimes requiring debulking procedures to improve contour, especially in the ankle and foot [4, 5].

In summary, while free flaps offer a single-stage solution with greater versatility in composite tissue transfer, cross-leg flaps are an invaluable option in scenarios where microsurgery is not feasible or has failed, providing reliable and robust coverage for limb salvage.

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Associated Complications

Although cross-leg flaps are considered a reliable and robust reconstructive option, they are not without complications. Understanding these potential issues is crucial for preoperative and postoperative management, as well as for adequately informing the patient about the risks associated with the procedure [1, 2].

Complications can be classified into those directly related to the flap, the donor site, immobilization, and systemic complications:

Flap-Related Complications

- **Flap Necrosis:** Although the survival rate is high, partial or total flap necrosis can occur. Marginal necrosis is the most common and typically resolves with conservative management. Total necrosis is rare but devastating [1, 4, 5]. Factors such as excessive flap extension, inadequate tension, underlying hematoma, or infection can contribute to necrosis [1].
- **Hematoma:** Blood accumulation beneath the flap can compromise its vascularization and increase the risk of infection. Meticulous hemostasis during surgery is essential to prevent this complication [1].
- **Infection:** Surgical site or flap infection can occur, especially in contaminated traumatic wounds. Adequate debridement of the recipient bed before flap application is essential to minimize this risk [1].
- **Wound Dehiscence:** Separation of wound edges may require additional sutures or wound care [5].
- **Contour and Volume Issues:** Flaps can be bulky, especially around the ankle and heel, potentially requiring debulking procedures in a later stage to improve aesthetic and functional outcomes [4, 5].
- **Prolonged Pain:** Some patients may experience persistent pain at the flap or donor site [7].

Donor Site-Related Complications

- **Partial Skin Graft Loss:** The donor site of the flap is often covered with a partial-thickness skin graft (STSG). Partial loss of this graft may require regrafting [1, 5].
- **Donor Site Morbidity:** Although generally minimal, there may be unsightly scars or discomfort at the site where the flap was harvested [4].

Immobilization-Related Complications

Prolonged immobilization of both limbs is an inherent feature of the technique and can lead to several complications [1, 3, 5]:

- **Joint Stiffness:** Immobilization of joints (knee, ankle) can result in stiffness. Early physiotherapy and passive movement can help mitigate this risk [1, 5].
- **Pressure Ulcers:** Pressure areas, such as the heels, Achilles tendon, and malleoli, must be adequately padded to prevent pressure ulcer formation [1].

- **Nerve Damage:** Prolonged pressure on nerves, such as the common peroneal or posterior tibial nerve, can cause neuropathies [1].
- **Deep Vein Thrombosis (DVT):** The risk of DVT increases with prolonged immobilization. Appropriate prophylaxis and ankle pump exercises can reduce this risk [1].

Systemic Complications

- **Genitourinary Infections:** These can occur due to difficulties in maintaining hygiene during the immobilization period [1].

It is important to note that, despite these potential complications, studies demonstrate that cross-leg flaps, especially fasciocutaneous ones, have a high success rate and an acceptable complication profile, making them a valuable tool in the reconstructive surgeon's arsenal [2, 7].

Fixation and Postoperative Management

The viability of a cross-leg flap largely depends on adequate immobilization and meticulous postoperative management. The primary goal is to ensure stability of both limbs to allow neovascularization of the flap from the recipient bed while minimizing complications associated with prolonged immobilization [1, 3].

Fixation Methods

Immobilization of the limbs is a critical aspect and has evolved over time. The most common methods include:

- **Plaster of Paris Casts:** Traditionally, casts have been used to immobilize both legs in a position that maintains the flap without tension. However, casts can be bulky, hinder hygiene and flap monitoring, and do not allow fine adjustments [1, 5].
- **External Fixators:** The use of external fixators has represented a significant advancement in immobilization. They offer several advantages over casts, including [1, 3, 5]:
 - **Optimal Stability:** They provide rigid fixation that ensures the flap's position and prevents unwanted movement.
 - **Ease of Monitoring:** They allow easy access to the flap for inspection and wound care.
 - **Fine Adjustments:** They enable small adjustments in limb position to optimize flap tension.
 - **Hygiene:** They facilitate patient hygiene and skin care.
 - **Patient Comfort:** Although immobilization remains challenging, external fixators can be more comfortable than casts over the long term.
 - **Examples:** Various external fixator configurations have been used, including two crossed Kirschner wires through both tibias, Steinmann pins connected with steel bars, and the Ilizarov external fixator [1].

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Postoperative Management

Postoperative management of a cross-leg flap is essential to ensure its success and prevent complications. It includes:

- **Flap Monitoring:** Constant observation of the flap's color, temperature, capillary refill, and turgor to detect early signs of vascular compromise [5].
- **Pain Control:** Appropriate administration of analgesics to manage discomfort associated with surgery and immobilization [5].
- **DVT Prophylaxis:** Measures to prevent deep vein thrombosis, such as the use of low-molecular-weight heparin and ankle pump exercises (if possible) [1].
- **Wound Care:** Regular dressings of the flap and donor sites, ensuring a clean, infection-free environment [1].
- **Nutrition:** Ensuring adequate nutrition to promote wound healing [5].
- **Physiotherapy:** Early rehabilitation is crucial to prevent joint stiffness and restore function. This can begin even before pedicle division with isometric exercises and, once the flap is divided, with active and passive mobilization [1, 5].

Section	Content Summary
Introduction	- Reconstruction of complex lower limb defects is challenging.\n- Evolution from local/regional flaps to microsurgery/free flaps.\n- Cross-leg flaps as a reliable alternative when vascular integrity or recipient vessels are compromised.\n- History dating back to 1854; significant developments include Ponten's fasciocutaneous flap (1983).
Classification and Types of Cross-Leg Flaps	- Cutaneous Flaps: Random pattern (ratio 1:1), axial pattern (up to 1:3.5).\n- Fasciocutaneous Flaps: Based on perforating arteries; types include posterior tibial, peroneal, sural, saphenous.\n- Muscle/Musculocutaneous Flaps: For greater tissue volume (gastrocnemius, soleus, gracilis).\n- Cross-Leg Free Flaps: Microsurgical transfer from contralateral limb.\n- Modified Flaps: Pre-laminated, fillet, Crane principle.
Indications	- Severe trauma with soft tissue/bony exposure.\n- No suitable recipient vessels.\n- Free flap failure.\n- Resource-limited settings.\n- Patient contraindications for lengthy surgeries.\n- Defects in distal leg/foot.\n- Chronic infections/ulcers.
Contraindications	- Severe bilateral trauma.\n- Significant vascular disease in donor limb.\n- Poor patient cooperation.\n- Aesthetic concerns.\n- Need for vascularized bone transfer for large bony defects.
Advantages	- Highly reliable (close to 100% survival).\n- Does not rely on local vessels.\n- Simpler surgical technique.\n- Shorter operative time.\n- Covers large defects.\n- Better tissue integration.\n- Salvage option after free flap failure.
Disadvantages	- Prolonged immobilization (3-4 weeks).\n- Need for two-stage surgery.\n- Donor site morbidity.\n- Severe mobility restrictions during immobilization.\n- Limited in large bony defect reconstruction.\n- Possible aesthetic issues requiring secondary procedures.
Complications	- Flap: Necrosis, hematoma, infection, wound dehiscence, bulky tissue, pain.\n- Donor site: Skin graft loss, scarring.\n- Immobilization: Joint stiffness, pressure ulcers, nerve damage, DVT.\n- Systemic: Infections.\n- High success rate despite these risks.
Fixation and Postoperative Management	- Fixation: Casts, external fixators (more stability, ease monitoring).\n- Monitoring: Flap color, temperature, capillary refill.\n- Care: Pain control, DVT prophylaxis, wound care, nutrition, physiotherapy.\n- Pedicle Division: At 3-4 weeks after ensuring neovascularization, with clamping test.
Case Report Summary	- 30-year-old male with left ankle open fracture (AO 43A1.2).\n- Treatment: External fixation, then internal fixation.\n- Large distal leg defect with bone exposure.\n- Decision: Cross-leg flap due to resource limitations.\n- Technique: Random full-thickness flap from right gastrocnemius region.\n- Outcome: Flap divided at 3 weeks, 100% graft integration, no complications.
Conclusion	- Cross-leg flaps remain valuable, especially when free flaps aren't feasible.\n- Evolution from simple to perforator and free flaps improved outcomes.\n- External fixators enhanced postoperative management.\n- Reliability and simplicity make it indispensable in complex cases.\n- Proper planning and management are key to success.

Pedicle Division

Pedicle division of the flap is the second surgical stage and is performed once the flap has developed sufficient vascularization from the recipient bed. The average time for pedicle division varies but generally ranges between 3 and 4

weeks (21 days is a common average) [1, 2, 4]. Before division, a pedicle clamping test can be performed to confirm flap viability. If no signs of ischemia are present, the pedicle is divided, and the flap is fully adapted to the defect. The donor site is covered with a partial-thickness skin graft [1, 5].

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Adequate postoperative management and fixation are fundamental pillars for the success of cross-leg flaps,

enabling limb salvage in complex situations where other reconstructive options are not viable.

Case report: Male, 30 years old, single, with no relevant hereditary family history. Personal medical-surgical history, chronic degenerative conditions, transfusions, and allergies were inquired about and denied. Positive smoking history for 8 years, 2 cigarettes per day. Current condition began on January 16, 2021, following a fall from 2 meters onto the left foot, resulting in an open fracture with bone exposure at the left ankle. Diagnosis of an open left tibia and fibula fracture, classified as 43A1.2 by the AO system, was established. Open reduction and external fixation were



Fig.1 Lower third extremity diffect and bone exposure of the left leg.

performed by the trauma service. Subsequently, open reduction and internal fixation with osteosynthesis material were carried out. The patient presented lower third diffect of the left leg with bone exposure (fig1). Evaluation by the plastic and reconstructive surgery service was conducted for skin coverage of the distal third of the left leg. Due to the wound's extent and the lack of microsurgery services, a cross-leg flap was decided upon.

Surgical technique: The donor area for a skin graft was approached, harvesting from the right inguinal-abdominal region to obtain a full-thickness graft. Subsequently, a random cross-leg flap was raised (fig.3) from the right leg at the gastrocnemius level, dissecting down to the subcutaneous tissue until fascia was observed. An area from the donor



Fig.2 Skin graft in the donnor site.

site equivalent to the total contralateral defect was taken for skin coverage of the exposed area. The cross-leg flap was fashioned and placed over the receptor site of the left leg, secured with simple 3-0 nylon sutures. A full-thickness graft was then applied to the donor area and fixed with simple sutures(fig.2)

The cross-leg flap was released 3 weeks after the initial surgical stage, achieving 100% integration of the graft in the donor area. No complications were documented.



Fig. 3 Rise of the cross leg flap right leg.



Fig.4 Post surgery photo of cross leg flap.



Fig.5 Post surgery photo of donor site

Conclusion

Cross-leg flaps, with their rich history and evolution, continue to be an invaluable tool in the arsenal of plastic and reconstructive surgeons, particularly for salvaging lower extremities with complex defects. Despite the rise of microsurgery and free flaps, the latter are not always feasible due to the absence of suitable recipient vessels, patient comorbidities, or resource limitations [2, 4]. In such scenarios, the cross-leg flap offers a reliable and robust alternative, with high success rates in covering extensive defects and preserving the limb [2, 5].

The technique's evolution, from random cutaneous flaps to perforator-based fasciocutaneous flaps and, more



Fig.6 Cross leg flap after flap release.



Fig.7 Post surgery photo front view of the receptor site.

recently, cross-leg free flaps, has expanded its indications and improved outcomes [1, 6]. The implementation of external fixators for immobilization has significantly mitigated one of the technique's primary drawbacks, enhancing patient comfort and facilitating postoperative management [1, 3].

While prolonged immobilization and the need for a second surgical stage are important considerations, the advantages in terms of reliability, technical simplicity (for pedicled flaps), and the ability to salvage otherwise irreparable limbs outweigh these limitations in selected cases [4, 5]. A thorough understanding of indications, meticulous surgical planning, and careful postoperative management are essential to optimize outcomes and minimize complications [1, 2].

Ultimately, the cross-leg flap stands as a testament to adaptability and innovation in reconstructive surgery, demonstrating that classical techniques, when applied with discernment and adapted to modern needs, remain fundamental to patient well-being.

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