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Reconstructive

Lymphatic Mapping and Preservation: Strategies to Reduce Lymphatic Damage and Its Consequences in Lower Limb Surgery

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Background: In the modern resurgence of reconstructive lymphatic surgery, the prevention of lymphatic damage often receives insufficient attention. Various scenarios in oncological, traumatic, reconstructive, and aesthetic plastic surgery offer opportunities to prevent lymphatic injury and its potential clinical consequences. This article presented the cumulative case series we have gathered to date, in which lymphatic vessels were mapped with a preventive intent—an approach we referred to as lymphatic mapping and preservation.

Methods: Lymphatic mapping with preventive intent was performed either indirectly using ultrasound (mapping the great saphenous vein and its branches) and/or directly using indocyanine green lymphography. Postoperatively, the presence, absence, and severity of lymphedema were assessed clinically, whereas the integrity and patency of the great saphenous vein were evaluated via ultrasound.

Results: Twelve cases of soft-tissue tumors of the medial thigh, 3 cases of traumatic wounds, and 6 cases involving flap planning were included. In all patients—except 4—it was possible to preserve the great saphenous vein and, presumably, a significant portion of the surrounding perisaphenous lymphatic tissue. Stage I or II lymphedema was observed in 6 patients (5 following soft-tissue tumor resection and 1 due to trauma).

Conclusions: Preservation of the great saphenous vein and the adjacent perisaphenous lymphatic-adipose tissue may help reduce iatrogenic damage to lymphatic collectors and the associated clinical manifestations. Lymphatic mapping and preservation is a straightforward approach that can be applied across multiple surgical scenarios and specialties. *(Plast Reconstr Surg Glob Open 2025;13:e7139; doi: 10.1097/GOX.0000000000007139; Published online 9 October 2025.)*

INTRODUCTION

Lymphedema affects millions globally, although its true prevalence and incidence are often underestimated due to differences in healthcare systems, population demographics, and the occurrence of risk factors such as cancer and infections. The 2022 World Health Organization data indicate more than 2.3 million new breast cancer cases and 660,000 new cervical cancer cases annually. Of these, 20%–40% of women are likely to develop lymphedema, highlighting the severity of the issue.[1–4] Among patients with soft-tissue sarcoma, despite the significant advantage of limb-sparing procedures over amputation, the incidence of secondary lymphedema following oncological treatments remains high, with reported rates reaching up to 42%.[5,6]

With the growing focus on lymphatic disorders, numerous specialized centers have emerged to explore novel treatment strategies. However, based on our experience, a significant proportion of lymphatic injuries is iatrogenic and unnecessary, frequently stemming from insufficient anatomical awareness of the lymphatic system and suboptimal surgical planning.

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To address this critical issue, we introduced the concept of lymphatic mapping and preservation (LMP),[7] a proactive strategy designed to assist surgeons across various specialties in avoiding unnecessary lymphatic injury to the major lymphatic pathways of the extremities. The LMP approach uses direct visualization techniques, such as indocyanine green (ICG) lymphography and indirect mapping via ultrasound. The preventive aspect of LMP is particularly important, given that current reconstructive interventions for lymphatic damage—such as lymphaticovenous anastomosis, vascularized lymph node transfer, and lymphatic flap transfers—require highly specialized training and extensive resources, and typically provide symptom relief rather than complete resolution.

Previous efforts aimed at reducing lymphatic injury have resulted in widely adopted surgical methods, such as sentinel lymph node biopsy,[8] reverse lymphatic mapping,[9,10] and modified lymphadenectomy protocols.[11] However, these methods have primarily focused on preserving lymph nodes rather than the principal lymphatic collectors responsible for lymph drainage from peripheral tissues to nodal basins.

Given that injury to these lymphatic collectors can lead to significant complications comparable to those observed following nodal damage—including lymphorrhea, lymphocele, and lymphedema[5,6,12,13]—we strongly believe that a more comprehensive approach to lymphatic preservation is needed. This expanded approach should encompass both lymph nodes and primary lymphatic collectors, ensuring their protection whenever feasible during surgical procedures.

The aim of this study is to present our experience with the application of the LMP strategy in lower limb surgery.

Takeaways

Question: Can lymphatic conditions, such as lymphedema, lymphocele, and fistula be avoided or minimized by preventing unnecessary iatrogenic damage to the lymphatic collectors of the lower limb?

Findings: Yes, in many surgical procedures on the lower limb, damage to the major lymphatic collectors may be avoided by mapping their course and preventing injury to them. This can prevent the onset or reduce the incidence of chronic lymphatic conditions.

Meaning: The prevention of iatrogenic lymphatic damage in lower limb surgery may lead to a reduction in chronic lymphatic conditions.

MATERIALS AND METHODS

We conducted a retrospective, single-center, nonrandomized study in accordance with the Declaration of Helsinki (1964, revised 2008) and with approval from the Cantonal Ethics Committee of Zurich (BASEC-Nr. 2024-02074).

All consecutive patients who underwent LMP between August 2022 and September 2024 were included in the study. The cohort consisted of patients with deep soft-tissue tumors of the medial thigh (deep to the fascia lata), traumatic wounds extending into the medial thigh, or patients undergoing reconstruction with flaps harvested from the medial thigh or medial lower leg. All patients were mapped and treated by the first author (A.F.). Data collected included age, sex, etiology, medical history, and relevant preoperative, intraoperative, and postoperative information. The International Society of Lymphology (ISL) classification was used to grade lymphedema when present postoperatively.

Definition of LMP

The LMP approach involves the use of preoperative and/or intraoperative methods to map the lymphatic pathways of the limb—either directly or indirectly—to protect them during surgery. Direct mapping is achieved through ICG lymphography, whereas indirect mapping, which is specific to the lower limb, involves identifying the great saphenous vein (GSV) as an anatomical reference using ultrasound.

Direct Mapping

Direct mapping of lymphatic vessels is performed using ICG lymphography. ICG dye is injected intradermally at multiple locations on the foot to delineate lymphatic vessels. Specifically, 0.2 mL of ICG solution (2.5 mg/mL) is injected into the first and third interdigital spaces, as well as at the medial and lateral malleoli. A near-infrared camera immediately visualizes the resulting linear lymphatic patterns. Manual distal-to-proximal compression can facilitate dye progression toward proximal limb segments. Visualized lymphatic pathways are marked on the skin with an indelible surgical marker to guide dissection (Fig. 1). Direct mapping may be difficult in certain situations, for example, in patients with markedly thickened subcutaneous tissue. In cases where the linear pattern cannot be visualized, or where ICG equipment is unavailable, indirect mapping can be extremely helpful in identifying the main lymphatic bundles.

Indirect Mapping

Indirect lymphatic mapping leverages the anatomical proximity of the main ventromedial lymphatic bundle to the GSV, particularly in the thigh.[14] The lymphatic collectors are most densely clustered within 3 cm anterior and posterior to the GSV and are located both superficial and deep to the superficial fascia, through which the GSV runs.

Fig. 1. Direct mapping of the lower limb. Lymphatic collectors are visualized using ICG lymphography and marked on the skin to guide surgical preservation.

Therefore, by marking the GSV and its accessory branches on the skin using an ultrasound device—commonly available in most hospitals—surgeons can indirectly infer the location of the principal lymphatic collectors and thus avoid their iatrogenic damage. Ultrasound presets for GSV visualization generally require no special adjustments; at our center, we consistently use a linear 6–15 MHz transducer. The resulting area, termed the "perisaphenous danger zone," is defined as the region within 3 cm anteriorly and posteriorly to the GSV and clearly marked on the skin (Fig. 2).

Although the highest density of lymphatic vessels lies within 3 cm of the GSV, the course of the collectors is tortuous. Given the frequently tortuous trajectory of lymphatic vessels, a broader safety margin of 5 cm from the GSV further enhances protection. As mentioned, GSV mapping is most valuable from the medial knee upwards, where the scattered collectors converge around the GSV.

Patient Groups

In the first group, consisting of patients with soft-tissue tumors, priority was consistently given to oncological safety, balancing radical resection with lymphatic preservation. In the second group of patients, consisting only of trauma patients, exclusively indirect mapping was performed. The integrity of the GSV was first evaluated in the emergency department via ultrasound. In the operating room, careful attention was paid to revising and closing the wound without compromising perisaphenous tissue or strangulating lymphatic vessels with sutures. In the third group, consisting of patients undergoing reconstruction with flaps from the medial thigh or medial lower leg, only indirect mapping was performed, maintaining a safety margin of 5 cm from the GSV.

Postoperative assessments included clinical staging of lymphedema using the ISL staging system, alongside ultrasound evaluation of GSV patency and continuity. In this study, lymphedema was defined as limb swelling persisting beyond 6 months postoperatively, predominantly affecting the treated limb, and associated with documented lymphatic injury due to preoperative radiotherapy or intraoperative damage. Diagnosis was clinically based, supported by context-specific factors, as pre- and postoperative lymphoscintigraphy were not routinely performed.

RESULTS

A total of 21 patients were enrolled and categorized into 3 distinct groups based on clinical (Table 1) indications. Twelve patients presented with deep soft-tissue tumors located in the medial thigh, 3 patients had traumatic injuries extending into the medial thigh, and 6 patients underwent reconstructive procedures involving flap harvest from the medial thigh or medial lower leg regions. The mean follow-up duration for the study population was 14 months, with a range of 12–22 months.

In the tumor group (n = 12), direct lymphatic mapping was performed preoperatively immediately after the induction of general anesthesia and repeated intraoperatively during and after tumor resection. Indirect mapping was conducted preoperatively to assess the anatomical position of the GSV and again postoperatively to evaluate the presence, patency, and alignment of the GSV after surgery.

Fig. 2. Anatomical relationship between the lymphatic collectors (black lines) and the GSV (blue line). The "danger zone" is delineated by 2 green lines placed 3 cm anterior and posterior to the GSV. The lymphatic collectors are consistently located within this area, with the exception of a short segment where 1 collector deviates beyond this boundary.

No immediate reparative lymphaticovenous anastomoses were performed. However, in 3 cases involving substantial soft-tissue defects and extensive lymphatic damage, flaps containing vascularized lymphatic tissue from the abdominal region—based on superficial circumflex iliac artery-superficial branch or superficial inferior epigastric artery perforators[15]—were transferred to fill dead spaces, introduce viable nonirradiated tissue, and potentially support lymphatic regeneration.

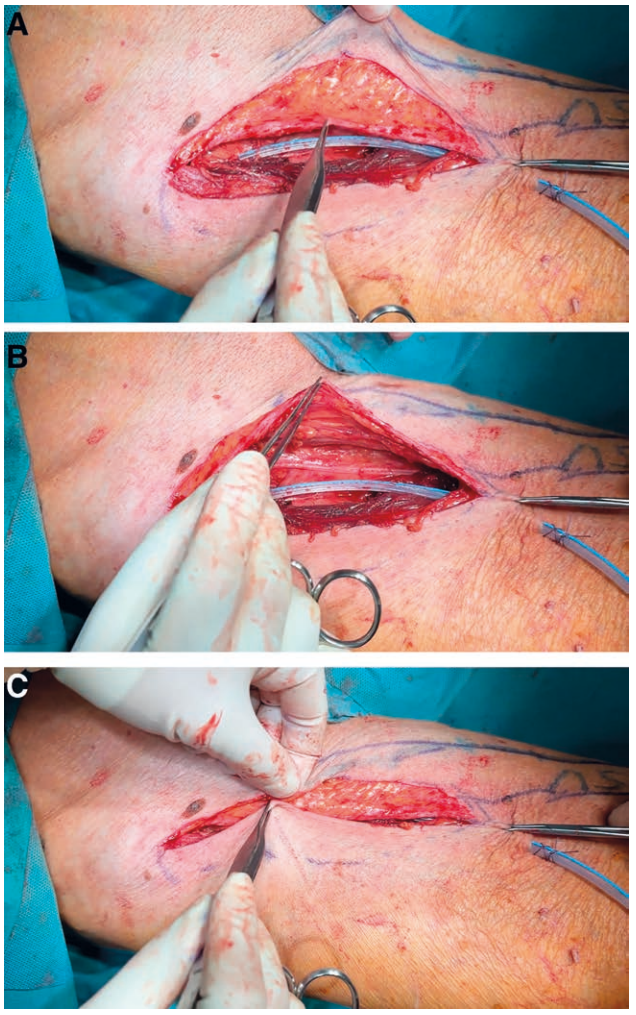

Fig. 3. Wound closure in a "high-risk" zone is performed using de-epithelialization (A) and inversion (C) of the wound margins. This technique allows for the preservation of the lymphatic pathways while simultaneously eliminating dead space (B).

This technique, commonly known as "lymphatic wicks" or lymphatic interpositional flap transfer, was applied selectively.[16,17]

In the trauma group (n = 3), no direct reconstruction of injured lymphatic vessels was attempted. Instead, meticulous wound debridement and anatomical tissue approximation were performed, specifically avoiding maneuvers that could further disrupt lymphatic structures, such as extensive mobilization of large skin and subcutaneous flaps. In cases where redundant skin or dog ears were observed in high-risk zones, these were not excised. Rather, they were de-epithelialized and buried to preserve the underlying lymphatic structures (Fig. 3).

In the reconstruction group (n = 6), surgical planning involved 4 profunda artery perforator flaps and 2 medial sural artery perforator flaps. In each case, mapping of the GSV proved essential for flap design, helping to define margins and maintain a safety distance of at least 5 cm from the vein, thereby minimizing the risk of injury to adjacent lymphatics.

Successful preservation of the GSV and adjacent perisaphenous lymphatics was achieved in all patients, except 4—3 from the tumor group and 1 from the trauma group. Clinical lymphedema, classified as stage I or II according to the ISL staging system, was observed in 6 patients overall: 5 patients following sarcoma resections and 1 patient from the trauma group. In all cases where the GSV was damaged, lymphedema developed. The interposition of lymphatic flaps (lymphatic wicks) did not prevent the development of clinical lymphedema.

DISCUSSION

This study demonstrates the practical implementation of the LMP strategy across various surgical contexts, aiming to enhance anatomical awareness and provide surgeons from various specialties with effective methods to minimize unnecessary lymphatic injury. Although our study's relatively small sample size and the absence of a control group limit the ability to draw definitive conclusions regarding clinical efficacy, the preservation of major lymphatic collectors—whenever technically achievable and oncologically safe—is both reasonable and justified.

Although lymphatic excision remains essential for malignancies with lymphatic dissemination such as melanoma or squamous cell carcinoma, this practice is neither necessary nor beneficial in other scenarios. Moreover, although the deep and superficial lymphatic systems are believed to partially compensate for each other in case of injury, this potential for compensation does not justify

Table 1. Patient Characteristics

Specific Cases	No. Patients	Mapping Method (Ultrasound)	Mapping Method (ICG)	Intraoperative Mapping	Clinical Lymphedema (Stage I or II)
Soft-tissue tumors	12	Yes	Yes	Yes	5
Traumatic wound	3	Yes	No	No	1
Flap planning	6	Yes	Yes	No	0
Total	21	21	21	12	6

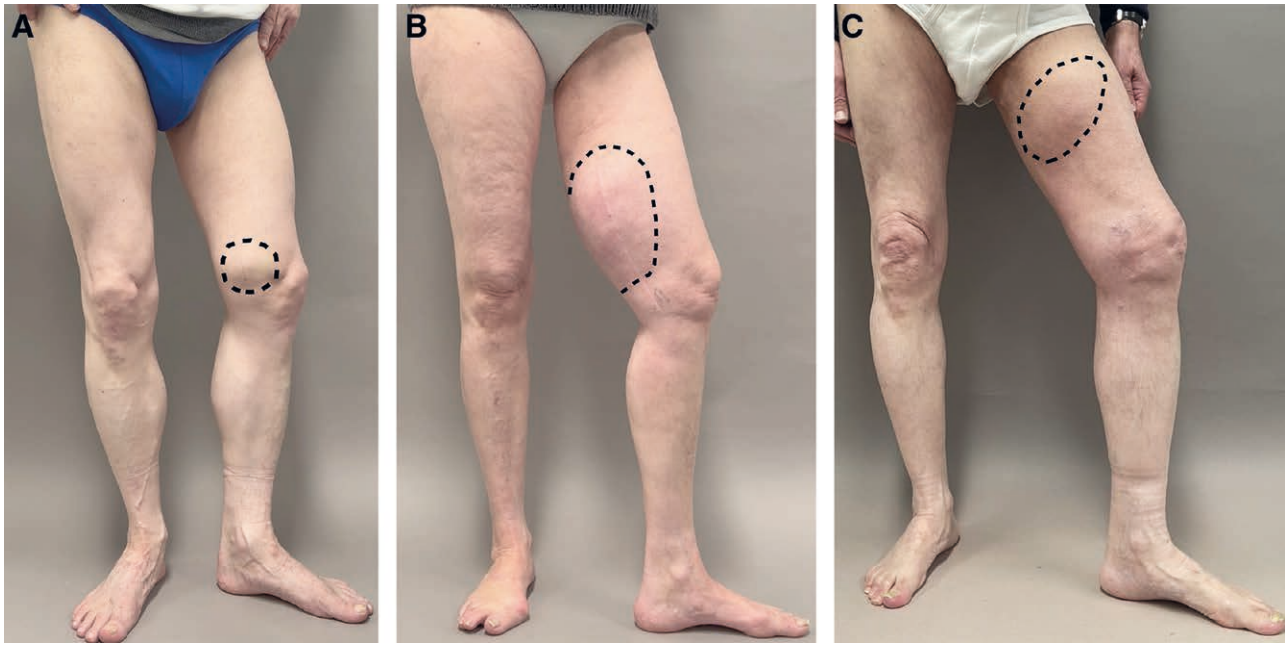

Fig. 4. Soft-tissue tumors of the medial thigh: differentiated liposarcoma (A), atypical lipomatous tumor (B), and myxoid liposarcoma (C) of the lower limb. In these cases, LMP can be applied to prevent unnecessary injury to lymphatic collectors.

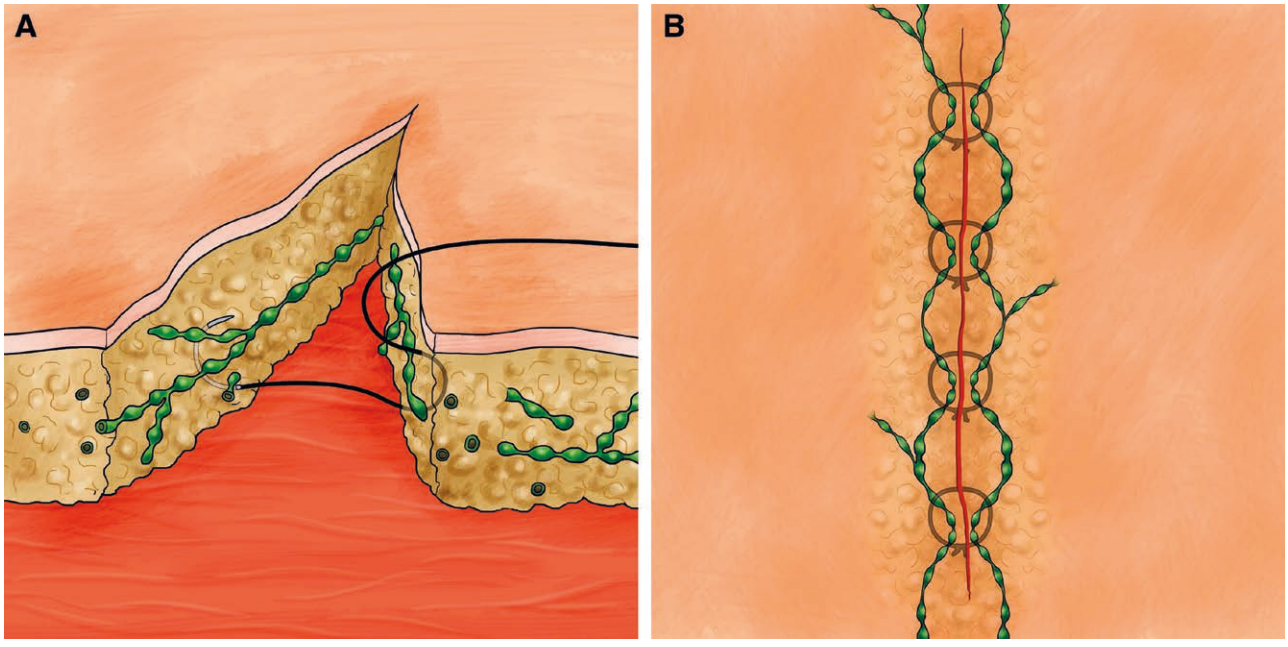

Fig. 5. Wound closure should avoid "big bites" involving perisaphenous tissue (A), as these can potentially strangulate the lymphatic collectors at various levels (B).

unintentional, nononcological, iatrogenic damage to lymphatic structures.

The ventromedial lymphatic bundle, the primary drainage pathway for the lower limb, can be reliably identified through direct methods (ICG lymphography) or indirect ultrasound mapping of the GSV. The GSV provides a practical and readily accessible anatomical landmark, easily visualized with standard ultrasound equipment available in most surgical settings. Unlike deeper structures, such as bones and muscles, the GSV lies within the same anatomical plane as the lymphatics and typically follows the natural laxity of skin and subcutaneous tissue.

To date, surgical efforts in lymphatic preservation have predominantly focused on lymph nodes.[8–11] We argue that attention should also be directed toward the collectors transporting lymph from the periphery to those same

Fig. 6. Example of suboptimal flap design. In this case, the flap was elevated and transposed without consideration of the lymphatic anatomy, resulting in disruption of both the GSV and the ventromedial lymphatic bundle.

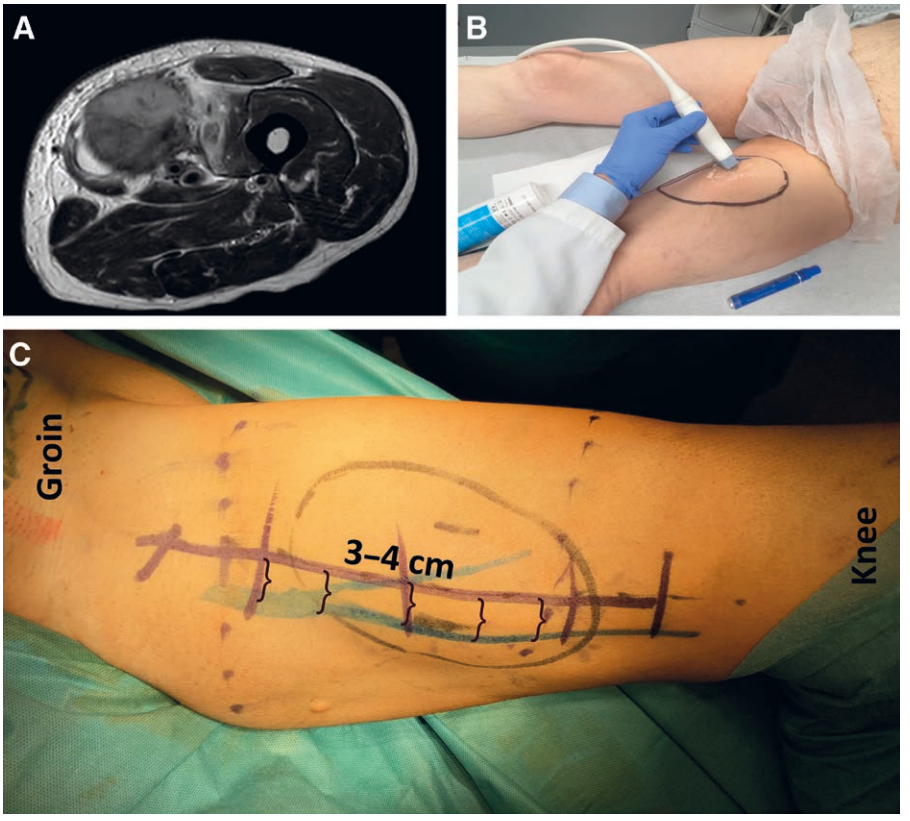

Fig. 7. Same patient as Figure 4C. A, A mixoid liposarcoma of the thigh was diagnosed and planned for excision. Preoperative indirect mapping of lymphatics was performed (B), marking a 3–4 cm "danger zone" (C).

nodes, as injury to these pathways can result in similar adverse outcomes, such as lymphoceles, lymphatic fistulas, and lymphedema. Enhancing subcutaneous tissue preservation, particularly around the GSV, substantially increases the likelihood of preserving essential lymphatic collectors.[14,18] The importance of preserving these collectors increases proximally in the lower limb, with maximal importance in the medial thigh—where collectors

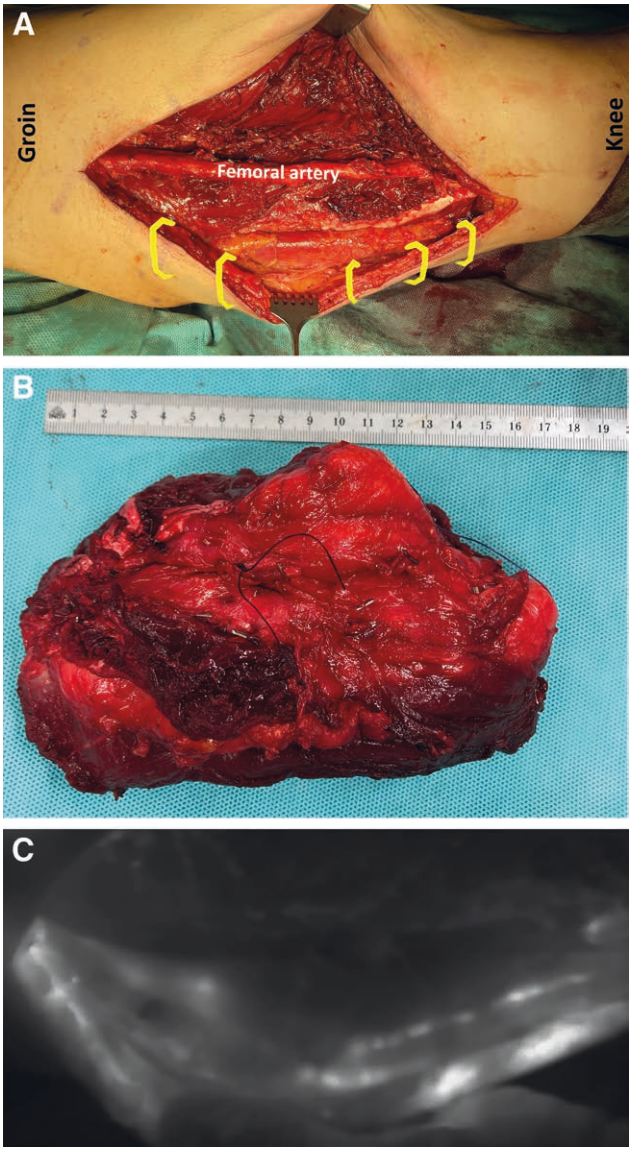

Fig. 8. Same patient as Figures 4C and 7. A and B, Postresection view of the medial thigh showing exposed femoral artery and preserved skin and perisaphenous subcutaneous tissue (highlighted with yellow circles). C, ICG lymphography reveals both preserved linear lymphatic pathways and leakage sites from injured collectors.

Fig. 9. Same patient as in Figures 4C, 7, and 8. A lymphatic wick flap based on the superficial circumflex iliac artery-superficial branch was interposed to fill the dead space and bridge the lymphatic defect using healthy abdominal lymphatics (A–C).

converge—and less critical distally, where lymphatics are less dense and responsible for smaller drainage territories. The same rationale could be applied to the upper limb; however, the anatomical relationship between the venous and lymphatic systems is less intimate than in the lower extremity. In the upper limb, lymphatic collectors tend to converge medially toward the axilla without notable clustering around the cephalic or basilic veins.

An additional point concerns the management of soft-tissue tumors, especially in the medial thigh area. In sarcoma cases (Fig. 4), preoperative neoadjuvant radiotherapy is often indicated, which unavoidably affects peritumoral tissues, including lymphatic collectors. Edema of the irradiated region is almost universally observed, and in some cases, swelling extends distally into the limb. We consider this to be, at least in part, radiation-induced lymphedema. Despite the presence of preexisting lymphatic damage at the time of surgical resection, we do not believe that additional excision or surgical injury to previously irradiated collectors is justifiable. Although their function may already be compromised, surgical removal likely results in complete and irreversible loss of function.

Within our series, patients whose ventromedial lymphatic collectors were excised due to tumor proximity consistently developed lymphedema, despite the interposition of lymphatic wick flaps.[16,17] Due to the limited sample size, we were unable to conclusively determine whether lymphatic flaps provided any protective or regenerative benefits.

Fig. 10. Long-term follow-up demonstrated wound healing, preserved GSV, and mild lymphedema of the affected limb.

In traumatic injuries involving the GSV or adjacent lymphatics, careful anatomical realignment and wound closure techniques may help reestablish lymphatic continuity and encourage lymphangiogenesis.[16] Careful superficial suturing rather than deep subcutaneous sutures ("big bites") is recommended to avoid inadvertent constriction of lymphatics (Fig. 5). Extensive tissue rearrangements should also be avoided (Fig. 6);[19–21] redundant skin or soft tissue in high-risk areas should preferably be de-epithelialized and inverted rather than excised (Fig. 3).

Awareness of lymphatic anatomy is also highly beneficial when designing reconstructive flaps, enabling surgeons to minimize lymphatic disruption and subsequently reduce postoperative complications (Figs. 7–10).

Beyond tumor resection, trauma management, and flap planning contexts addressed in this study, there are other surgical settings in which awareness of lymphatic anatomy is critical. One example is the medial thigh lift in aesthetic surgery. In this procedure, the excision of excess tissue is typically performed in the medial thigh—precisely where lymphatic collectors are most concentrated.

In our practice, careful technique adjustments—such as performing liposuction followed by skin-only excision—help preserve deeper lymphatic structures, making mapping unnecessary in such cases. Consequently, these aesthetic cases were excluded from the current analysis.

Despite our confidence in this approach, the study's short follow-up period represents a significant limitation due to the long time required for the complicating clinical conditions to manifest in their stable form. Further research with larger case series and longer follow-up is necessary to validate these findings and expand upon them. Although reconstructive lymphatic surgery holds promise for improving quality of life in patients with lymphatic damage, the challenges and limitations highlighted earlier must be acknowledged. Prevention should remain the absolute priority, with greater awareness and commitment to reducing the risk of lymphatic damage in all areas of surgical practice. The concept of LMP is designed to be simple, cost-effective, and accessible even in resource-limited settings.

CONCLUSIONS

The LMP approach is a simple and accessible technique to reduce unnecessary damage to major lymphatic collectors. Although sparing the GSV and the surrounding perisaphenous lymphatic tissue may not completely eliminate the risk of lymphatic complications, it establishes a valuable foundation for reducing their incidence. Active collaboration with other surgical specialists is essential for the broader implementation of this strategy.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

PATIENT CONSENT

Written informed consent was obtained from legally authorized representative(s) for the publication of anonymized patient information in this article.

ETHICAL APPROVAL

Approval for this study was obtained from the institutional review board. All procedures were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki (1975), as revised in 2008.

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