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Evolving Strategies in Lymphedema Surgery

Hyung Hwa Jeong MD

Department of Plastic and Reconstructive Surgery, Soonchunhyang University Bucheon Hospital, Soonchunhyang University College of Medicine, Bucheon, Republic of Korea

The surgical management of lymphedema has evolved substantially, shifting from ablative approaches toward physiologic reconstruction aimed at restoring lymphatic drainage. Ablative procedures, including suction-assisted liposuction and excisional techniques, continue to play a meaningful role in symptom control and may be combined synergistically with physiologic surgery. Physiologic procedures — principally lymphaticovenular anastomosis (LVA) — are most effective in early-stage disease, where residual lymphatic function remains intact. Emerging adjunctive therapies, including nanofibrillar collagen scaffolds aim to promote lymphangiogenesis and extend the reach of physiologic reconstruction. A comprehensive, stage-specific treatment algorithm integrating these modalities represents the foremost goal in advancing lymphatic surgery.

Key Words: Lymphedema · Surgical Management · Physiologic Reconstruction

INTRODUCTION

Lymphedema remains a chronic and often progressive condition characterized by lymphatic dysfunction, resulting in interstitial fluid accumulation, inflammation, and fibrosis[1]. Lymphedema was traditionally regarded as irreversible in its advanced stages; however, as understanding of its pathophysiology has deepened, the management of lymphedema has evolved substantially over the past decades[2]. Early surgical strategies relied largely on ablative approaches, but the paradigm has since shifted toward physiologic reconstruction, with the goal of restoring lymphatic drainage and improving long-term functional outcomes.

This transition reflects a broader conceptual evolution — from treating the consequences of lymphatic failure to addressing its underlying pathophysiology. Among the innovations enabling this shift, advances in imaging have played a central role. In particular, ultrasonography has emerged as a practical and increasingly indispensable tool in lymphatic microsurgery, enabling real-time visualization of lymphatic structures and adjacent venous anatomy, and thereby facilitating a more precise and individualized surgical approach[3].

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Address for correspondence: **Hyung Hwa Jeong,** MD
Department of Plastic and Reconstructive Surgery, Soonchunhyang University Bucheon Hospital, Soonchunhyang University College of Medicine, 170, Jomaru-ro, Bucheon-si, Gyeonggi-do, 14584, Republic of Korea
Tel: +82-32-621-5316, Fax: +82-32-621-6562
E-mail: jhh7989@gmail.com

Evolution of Surgical Strategies: From Ablative to Physiologic

Surgical management of lymphedema can be broadly categorized into two approaches:

- Ablative procedures, including liposuction and excisional techniques, focus on removing fibroadipose tissue to reduce limb volume. Ultrasound assisted liposuction (UAL), Power assisted liposuction (PAL), Suction assisted liposuction (SAL) are used for suction-assisted ablative surgery[4]. A representative traditional ablative surgery is Charles' procedure, in which edematous tissues are excised and the resulting raw surfaces are covered with skin grafts harvested from the removed tissue.

- Physiologic procedures aim to re-establish lymphatic drainage pathways. Lymphaticovenular anastomosis (LVA) and vascularized lymph node transfer (VLNT) represent the cornerstone techniques in this category. LVA is particularly effective in early-stage disease, where residual lymphatic function can be harnessed. VLNT tends to be favored in advanced disease, where the main goal is reconstruction of compromised lymphatic system.

Ablative surgery can be regarded as a conventional, non-cutting-edge modality, however, it still plays a significant role in controlling symptoms. Recently, the paradigm has evolved to include suction-assisted ablative surgeries as an adjunctive treatment to physiologic surgery[5]. This combination aims for synergistic effects: while physiologic procedures (like LVA or VLNT) address the underlying drainage failure, ablative treatment provides immediate symptom improvement, leading to higher patient satisfaction and quality of life[6]. Furthermore, because the outcomes of physiologic surgery can vary and take time to manifest, ablative treatment serves as a critical bridge during the window period, helping to maintain patient compliance throughout the long-term recovery process.

Beyond suction-assisted surgery, excisional approaches remain a viable and effective surgical option. The earliest and most radical of these is Charles' procedure, first described in 1912[7]. Although it carries significant morbidity and cosmetic consequences, excisional surgery can be particularly effective in cases of localized lymphedema, especially when complicated by morbid obesity. Furthermore, it may be combined with physiologic surgery in the management of localized lymphedema or lymphangioma[8,9].

Since its introduction by Jacobson et al. in 1963, physiologic surgery for the treatment of lymphedema has continued to evolve[10]. Obstructive lymphedema, particularly secondary lymphedema following oncologic treatment, is initiated by lymphatic obstruction. In its early stages, this leads to lymphatic hypertension and vessel dilation. Over time, persistent stasis induces structural changes including lymphosclerosis, extravasation of protein-rich fluid, and progressive fibrosis of the surrounding tissues[11].

These pathologic changes are not merely descriptive — they define the therapeutic window for intervention. In early-stage disease, lymphatic channels may still remain patent and functional despite elevated pressure. In advanced stages, however, irreversible destruction of the lymphatic architecture renders both conservative management and physiologic reconstruction far less effective.

Therefore, timely assessment of disease severity and prompt initiation of appropriate treatment are critical. Complete decongestive therapy (CDT) should be started without hesitation in the early stages. Furthermore, careful evaluation of the severity and functional status of the lymphatic system prior to performing physiologic surgery is essential for achieving favorable outcomes.

The success of physiologic surgery depends not only on technical execution but also on appropriate patient selection and accurate identification of functional lymphatics. This underscores the need for reliable preoperative and intraoperative imaging.

Extending the Paradigm: Adjunctive Therapies Using Nanofibrillar Collagen Scaffolds

Nanofibrillar collagen scaffolds (Biobridge®) are designed to promote lymphangiogenesis by providing a structural framework that guides endothelial cell migration and new vessel formation. Preclinical studies have demonstrated enhanced vascular growth and modulation of inflammatory responses within these matrices[12,13]. This concept was primitively explored through the threading of a silk suture along the subcutaneous plane of the affected extremity, with the intention of bridging the area of obstruction and establishing a conduit through which lymphatic fluid could drain[14].

Clinically, those nanofibrillar scaffold has been applied in conjunction with procedures such as scar release and physiologic surgeries like LVA or lymph node to vein anastomosis (LNVA), with the aim of promoting new lymphatic channel formation. The implantation

of multiple scaffold tracts along the affected limb may facilitate longitudinal lymphatic regeneration[13].

While early results are promising, further studies are needed to define optimal indications and long-term outcomes. The integration of imaging modalities such as ultrasonography may enhance the precision of scaffold placement and improve therapeutic efficacy.

Future Directions

The future of lymphatic surgery lies in the convergence of advanced imaging, microsurgical technique, and regenerative medicine. Development of objective metrics for lymphatic function would refine both patient selection and outcome evaluation. Continued innovation in scaffold design and cellular therapies may broaden the applicability of physiologic reconstruction. Ultimately, the goal is a comprehensive, stage-specific treatment algorithm that harnesses these technologies to maximize patient outcomes.

CONCLUSION

The management of lymphedema has undergone a fundamental paradigm shift — from ablative symptom control toward physiologic restoration of lymphatic function. However, ablative and physiologic approaches are no longer mutually exclusive; rather, their strategic combination offers synergistic benefits. Emerging therapies such as nanofibrillar collagen scaffolds further expand the therapeutic armamentarium by promoting lymphangiogenesis. Continued innovation and prospective investigation will be essential in establishing evidence-based, stage-specific algorithms that maximize patient outcomes and quality of life.

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