Review Article

Lymphedema surgery in breast cancer patients: a systematic review of preoperative evaluation and surgical planning

Pooja S. Yesantharao^, Dung H. Nguyen^

Division of Plastic & Reconstructive Surgery, Stanford University School of Medicine, Stanford, CA, USA

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Correspondence to: Dr. Dung H. Nguyen, MD PharmD. Professor, Division of Plastic & Reconstructive Surgery, Stanford University School of Medicine, 900 Blake Wilbur, MC 5348, Stanford, CA 94304, USA. Email: nguyendh@stanford.edu.

Background: As surgery becomes an established component of lymphedema care, it is important to define standardized criteria for patient selection and preoperative evaluation. This is a systematic review of the current literature and the senior author's experience, aimed at providing a comprehensive framework for the preoperative evaluation of and surgical planning for lymphedema surgery in breast cancer patients.

Methods: A structured literature search was performed using PubMed, MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials, and Web of Science databases. Inclusion criteria were: (I) English language; (II) original research article (i.e., not a review article or meta-analysis) published between January 1990 and August 2023; and (III) with a primary focus on preoperative evaluation and surgical planning for the treatment of secondary lymphedema in breast cancer patients. Covidence software (Melbourne, Australia) was used to synthesize and analyze included literature. The study workflow adhered to PRISMA guidelines. Risk of bias for each article was assessed using the validated Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool.

Results: In total, 11 studies were included. All were either clinical investigations comparing multiple techniques/protocols for preoperative evaluation/surgical planning for lymphedema surgery, or clinical perspective pieces by experts in the field. Overall risk of bias was moderate for eight studies and low for three studies. Synthesis of the literature demonstrated that in patients who have failed maximal medical therapy and have recalcitrant lymphedema symptoms, a combination of physical exam and diagnostic technologies are critical to (I) stage disease and to determine which surgical procedure is most appropriate, and (II) for surgical planning (e.g., determining the site of adequate lymphatic channels for lymphovenous anastomosis (LVA), determining where targeted liposuction can be undertaken safely). These data were combined with the senior author's experience to create an algorithm for lymphedema surgery planning.

Conclusions: This paper presents an evidence-based algorithm for lymphedema surgical planning designed to optimize volume reduction and symptomatic improvement in affected patients. As new technologies and developments in lymphedema surgery come to light, such algorithms for surgical planning should continue to evolve to help further improve outcomes in patients with this chronic and debilitating disease.

Keywords: Breast cancer; lymphedema surgery; lymphedema staging; preoperative evaluation; surgical planning

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^ ORCID: Pooja S. Yesantharao, 0000-0001-6643-0909; Dung H. Nguyen, 0000-0002-9494-7523.

Introduction

Background

Lymphedema after operative management of breast cancer remains an important survivorship issue in this patient population, with reported rates of up to 83% (1). As lymphedema surgery becomes an established component of lymphedema care, it is important to define standardized criteria for patient selection and preoperative evaluation (2). As with all operative interventions, lymphedema surgery is not without risk (3). Thus, understanding when lymphedema surgery provides the greatest value is of utmost importance to ensuring optimal patient care.

Rationale and knowledge gap

Currently, the relative novelty of lymphedema surgery has resulted in dynamic, constantly changing practices, as new information and techniques come to light. In fact, the current literature includes several differing preoperative protocols for lymphedema surgery (2,4,5). However, this can result in ambiguity regarding which patients would truly benefit from surgery. This ambiguity is compounded by the fact that there are currently many procedures available for patients, and determining which procedure is appropriate may not always be clear (6). Ideally, preoperative evaluation should allow surgeons to efficiently determine whether a lymphedema patient would benefit from surgery in a minimally invasive and cost-effective manner. Among those who are determined to be appropriate operative candidates, surgical planning should involve assessment measures that can be used to appropriately delineate which lymphedema surgery procedure would provide most clinical benefit, without duplication of effort or high resource costs (7).

Objective

Ultimately, a methodical approach to selecting and assessing appropriate candidates for lymphedema surgery can help to optimize patient outcomes. While prior literature reviews have investigated surgical planning for lymphedema surgery, the current study builds on the most recent literature to propose an algorithm for the preoperative evaluation of and operative planning for breast cancer-related lymphedema patients (8-10). As such, the current paper is a systematic review of the literature combined with the senior author's experience and serves to provide a comprehensive framework for the preoperative evaluation of and surgical planning for breast cancer patients undergoing lymphedema surgery. We present this article in accordance with the PRISMA reporting checklist (available at https://dx.doi.org/10.21037/abs-22-50).

Highlight box

Key findings

- This paper presents an evidence-based algorithm for lymphedema surgical planning to optimize volume reduction and symptomatic improvement in affected patients.

What is known and what is new?

- While surgery has become an established component of lymphedema care, there are no standardized criteria for patient selection and preoperative evaluation.
- This study compiles data from the literature and the senior author's experience to create an algorithm that can optimize lymphedema patient outcomes.

What is the implication, and what should change now?

- Lymphedema surgery is continually evolving, with no established guidelines or algorithms for surgical planning. This paper can help to guide providers with a surgical framework for lymphedema patients.

Methods

This is a systematic review of the senior author's experience combined with a scoping review the English-language literature investigating preoperative evaluation and surgical planning for lymphedema surgery in breast cancer patients. A structured literature search was performed (Appendix 1), using PubMed, MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials, and Web of Science databases. Covidence study software (Melbourne, Australia) was used to synthesize and analyze included literature. This review was not registered, the study protocol is as below.

Studies were selected using predefined inclusion criteria created using a Population, Intervention, Comparison, Outcome, Timing, and Setting (PICOTS) framework. Study inclusion criteria consisted of the following: (I) English language; (II) original research article (i.e., not a review article or meta-analysis) published between January 1990 and August 2023; and (III) with a primary focus on preoperative evaluation and appropriate surgical selection for the treatment of secondary lymphedema in breast cancer patients. Reference sections of included articles were reviewed to identify any further articles of interest.

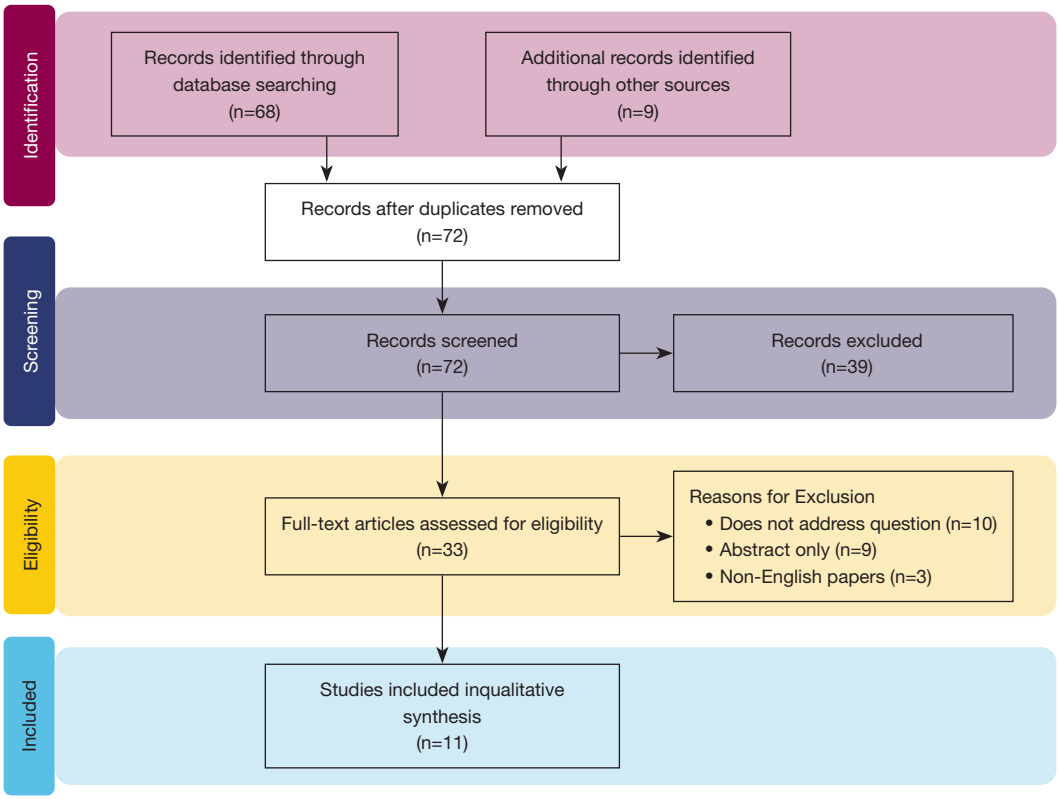

Figure 1 PRISMA study selection diagram.

The study workflow adhered to PRISMA guidelines (11). Two independent study team members screened articles identified through the literature search protocols described above. Study objectives, data, results, and conclusions were extracted for each study included in the final study cohort. Two independent study team members also assessed risk of bias for each article included in the final study cohort, using the validated Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool (12,13). Any discrepancies in screening outcomes were resolved through reviewer consensus.

Results

In total, 72 English language articles were identified from the initial query, of which 11 articles specifically investigating preoperative evaluation and surgical planning for lymphedema surgery in breast cancer patients were selected for inclusion in the study. *Figure 1* demonstrates the algorithm for selection of articles for study inclusion.

All included articles were either clinical investigations comparing multiple techniques/protocols for preoperative evaluation/surgical planning for lymphedema surgery, or clinical perspective pieces by experts in the field (*Table 1*) (5,14-26). Among the included clinical studies, overall risk of bias was moderate for 8 studies and low for three studies (Figure S1). All included articles provided information on preoperative patient assessment and/or surgical planning for operative management of lymphedema.

Discussion

This is a systematic review of the current literature and the senior author's practice regarding preoperative evaluation and operative planning for lymphedema surgery in breast cancer patients. We first discuss techniques for preoperative evaluation, and for determining when patients are surgical candidates. We then review protocols for surgical planning that have been demonstrated to optimize postoperative outcomes in this patient population.

Key findings and explanation—lymphedema staging and preoperative evaluation

Preoperative evaluation of breast cancer patients with

Table 1 Summary of selected articles

Study	Year published	Article type	Primary aims
Masia *et al.*	2016	Prospective cohort investigation	To investigate combined treatment for breast cancer related lymphedema (LVA + VLNT) and appropriate patient selection through preoperative assessment
Inbal *et al.*	2017	Retrospective cohort investigation	To investigate outcomes of LVA/VLNT for secondary lymphedema including breast cancer related lymphedema, and optimal patient selection
Masia *et al.*	2016	Retrospective cohort investigation	To present an evidence-based approach to surgical management of breast cancer related lymphedema and appropriate patient selection
Granzow *et al.*	2014	Retrospective cohort investigation	To investigate LVA, VLNT and liposuction in the treatment of patients with breast cancer related lymphedema and appropriate patient selection for each
Deptula *et al.*	2022	Retrospective cohort investigation	To investigate a novel treatment algorithm for surgical management of secondary lymphedema including breast cancer related lymphedema, based on patient preoperative characteristics
Park *et al.*	2023	Expert opinion	To investigate appropriate patient selection for a variety of surgical procedures for breast cancer related lymphedema
Ciudad *et al.*	2023	Retrospective cohort investigation	To determine an optimal surgical protocol for treatment of breast cancer related lymphedema through comprehensive preoperative evaluation of patients
McLaughlin *et al.*	2017	Expert opinion	Expert consensus statement detailing surgical treatment of breast cancer related lymphedema and appropriate patient selection
Park *et al.*	2023	Retrospective cohort investigation	To investigate how preoperative imaging can be used to optimize surgical treatment of breast cancer related lymphedema using LVA
Chang *et al.*	2016	Expert opinion	To present an expert consensus on surgical treatment of secondary lymphedema including breast cancer related lymphedema and appropriate patient selection
Kwon *et al.*	2021	Expert opinion	To present an approach for surgical management of lymphedema based on preoperative patient characteristics

LVA, lymphovenous anastomosis; VNLT, vascularized lymph node transfer.

secondary lymphedema should be used to confirm the lymphedema diagnosis and to stage the severity of disease, to determine whether the patient is a candidate for lymphedema surgery (7). The current literature presents several techniques for lymphedema staging and preoperative evaluation, with no clear agreement regarding the most optimal/cost effective strategy. Below we provide a strategy for preoperative evaluation based on consensus of the current literature and the senior author's practice.

First, there are multiple available clinical staging systems for lymphedema, including the Campisi, International Society of Lymphology (ISL), and the National Cancer Institute Common Technology Criteria for Adverse Events systems (27). The ISL system is one of the few staging systems that recognizes a "stage 0", which is a subclinical disease state where there is impaired lymphatic transport without clinically evident extremity swelling. As such, this is the system used in the senior author's practice to allow for early risk stratification of breast cancer patients at risk for lymphedema.

Among breast cancer patients with confirmed lymphedema, the literature reports several physical exam findings for evaluating the severity of disease. These include pitting edema, Stemmer sign, and skin changes (hyperkeratosis, skin ulceration, cellulitis) (28). Subjective exam findings may include feelings of heaviness, tightness, and discomfort in the affected extremity. Limb circumferential measurements are taken at predetermined anatomic landmarks of the affected extremity, and limb volume can be estimated using several techniques (e.g., water displacement, optoelectronic volumetry, three-dimensional imaging, calculated volume from circumferential measurements, etc.), with much debate regarding which technique is superior (29). Circumferential measurements are low cost and can have high reliability when performed by trained staff (30). More recently,

bioelectrical impedance has emerged as a useful addition to clinical exam in determining lymphedema staging. Bioimpedance involves the application of an alternating current through the affected extremity, and the measured resistance (impedance) to current flow can be measured to determine the fluid content of the tissue. Bioimpedance is a sensitive measurement tool for interstitial fluid changes, as it can account for changes in muscle mass unlike techniques such as volume displacement. In fact, studies have demonstrated that bioimpedance can reliably detect early-stage secondary lymphedema after breast cancer with nearly 100% sensitivity (31). Especially in subclinical disease or when physical exam findings are equivocal, bioimpedance can serve as a helpful adjunct to diagnosing and staging lymphedema. The senior author utilizes bioimpedance in addition to circumferential measurements completed by trained practitioners.

With regards to surgical planning, a number of imaging modalities have been reported to have utility in the literature, and the relative advantages versus disadvantages are described below (32,33). All breast cancer patients thought to have lymphedema should be evaluated with a duplex ultrasound of the affected extremity, to rule out deep venous thrombosis and venous insufficiency. Beyond ultrasound, however, there are multiple imaging modalities that have been described for the evaluation of lymphedema, including lymphoscintigraphy, computed tomography (CT), magnetic resonance (MR) imaging/lymphography, and indocyanine green (ICG) lymphangiography. A summary of these imaging techniques is presented in *Table 2*. Ultimately, these imaging techniques provide important information not only regarding the clinical characteristics of a patient's disease (e.g., fluid accumulation versus fibrofatty tissue buildup), but they also help with determining which operative procedure would be most appropriate if a patient were to undergo surgery.

Lymphoscintigraphy is often regarded the gold standard imaging technique for lymphedema (34,35). It measures the flow of interstitial fluid from the skin to the lymph nodes. Radioactive tracers that are specific to the lymphatic system are injected subcutaneously or intradermally in the webspace of the hand, and imaging is performed after a predetermined time interval. Patients are then asked to perform activity (walking, squeezing a ball in their hand) and repeat imaging is taken. Lymphoscintigraphy can qualitatively demonstrate impaired lymphatic function through delayed, asymmetric, or absent visualization of lymph nodes and through areas of dermal backflow. Lymph node tracer accumulation can also be used to quantitatively measure lymphatic function with lymphoscintigraphy, although quantitative lymphoscintigraphy analytic methods are not well established. While lymphoscintigraphy is a powerful tool to assess lymphatic flow and drainage, it has relatively poor spatial resolution. The surrounding anatomy is not clearly delineated in these images, which may be necessary to determine the extent of interstitial fluid versus fibrofatty tissue buildup and for surgical planning in complex cases. Furthermore, lymphoscintigraphy does not allow for dynamic image acquisition and involves exposure to a radioactive compound, although the tracers used have been demonstrated to be safe.

ICG lymphangiography is another technique that can be used to measure lymphatic flow and detect lymphatic malfunction (36). This technique is advantageous in that there is no radiation exposure, and it provides real-time high-resolution lymphatic mapping. Preoperatively, ICG lymphography can be used to identify suitable lymphatic channels for techniques such as lymphovenous anastomosis (LVA), to help guide placement of incisions. Intraoperatively and postoperatively, ICG lymphography can be used to confirm flow of lymphatic fluid into the newly created LVA. However, ICG is not excluded from blood vessels, and it is relatively unstable in solution. Thus, dye retention may be poor, and imaging may include blood vessels in addition to lymphatics. Furthermore, deeper lymphatic channels that are greater than two centimeters from the skin surface may not be captured by this technique.

CT and MR imaging are highly useful modalities, as they can evaluate for lymphedema and the severity of disease in the context of the surrounding tissues, by highlighting lymphatic channels and demonstrating accumulation of fluid within the soft tissues of the affected extremity. Anatomic findings include skin thickening, subcutaneous edema, and honeycombing of the soft tissues. As such, these imaging techniques help to determine whether excess volume in the affected limb is driven by fluid accumulation versus buildup of fibrofatty tissue, or a combination of the two. CT lymphangiography does expose the patient to radiation, which is a drawback of this technique, although it is faster than MR lymphangiography. MR imaging can demonstrate lymphatic channels, however the contrast is not specific to the lymphatic system unlike in lymphoscintigraphy, so nearby veins can also pick up contrast material (37). In such cases, evaluation of morphological features is necessary to determine which vessels are lymphatics (typically beaded in appearance with higher signal intensity). MR imaging

Table 2 Lymphedema imaging/evaluation modalities

Imaging technique	Description	Benefits	Limitations
Duplex ultrasound	Ultrasound imaging to evaluate the skin/subcutaneous tissue echogenicity	Noninvasive, no radiation exposure	Relatively low resolution, may be difficult to distinguish low-caliber lymphatic vessels from blood vessels
		Low cost, fast results	Only provides information about one focused area, difficult to get visualization of the entire extremity
		Can quickly evaluate for comorbid vascular conditions	Operator dependent
		Can detect lymphatic flow and surrounding anatomy including skin/subcutaneous tissue thickness, increased subcutaneous echogenicity	
Lymphoscintigraphy	Intradermal injection of Technetium-99m or another radionuclide that is picked up by lymphatic vessels and nodes, to image lymphatics	Good visualization of lymphatic vessels as well as dermal backflow in areas of disease	Radiation exposure
			Limited data regarding surrounding tissues/anatomy
			Cannot reliably detect early disease, relatively low resolution
CT lymphography	Intradermal injection of iodinated contrast to image lymphatics and surrounding tissue	Comprehensive morphologic/anatomic information of the affected extremity and lymphatics	Radiation exposure
			Time consuming and resource intensive
MR lymphography	Intradermal injection of gadolinium to evaluate lymphatics and surrounding tissues	Good spatial and temporal resolution, can evaluate lymphatic channels more than 2 cm deep unlike ICG lymphography and ultrasound	Time consuming and resource-intensive
		Can evaluate the entire extremity lymphatic system in the context of surrounding anatomy/tissue morphology	Can be difficult to distinguish lymphatic vessels from blood vessels
		No radiation exposure	
ICG lymphangiography	Intradermal injection of ICG to image lymphatics	Staging scale available for more objective determination of lymphatic function	Does not demonstrate surrounding anatomy/tissues
		Highly sensitive, can be used for preoperative planning	
		Can demonstrate dynamic lymphatic flow as well as static lymphatic anatomy in real-time	
Bioelectrical impedance	Impedance to electrical current is used to determine relative fluid composition of the affected extremity	Noninvasive, relatively low cost, no radiation exposure	Does not provide information regarding the actual lymphatics or images to guide surgical planning for physiologic procedures
		Reproducible results that can detect even early-stage lymphedema	

CT, computed tomography; MR, magnetic resonance; ICG, indocyanine green.

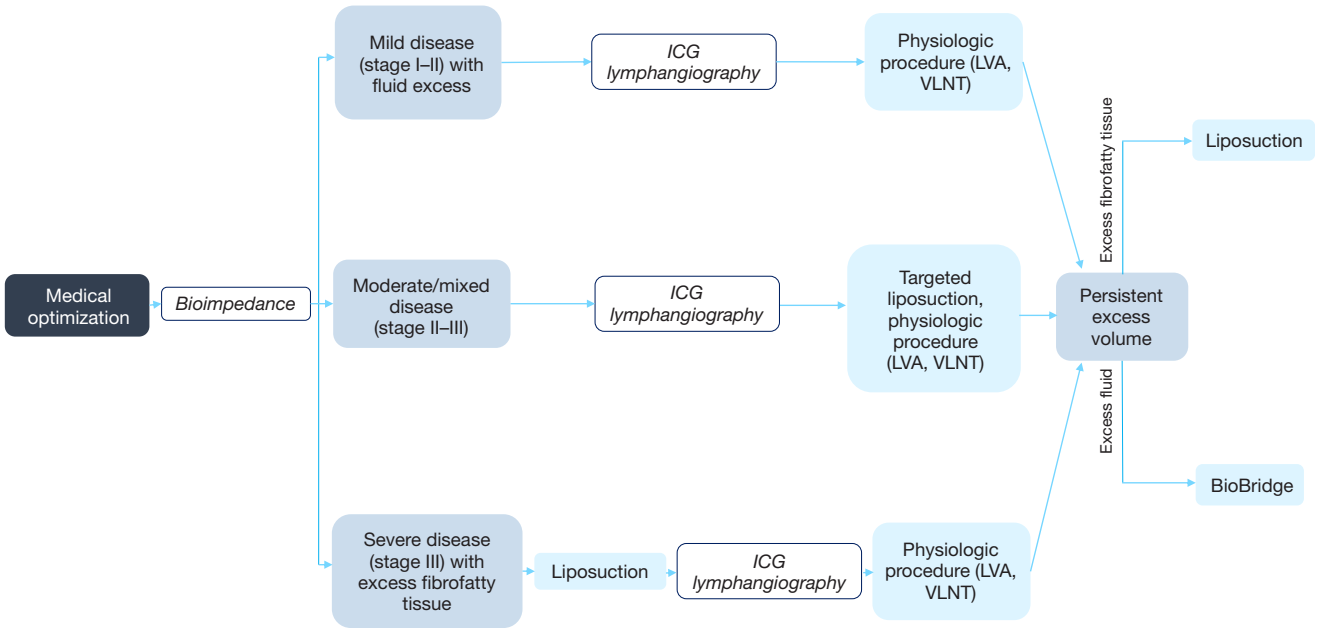

Figure 2 Surgical selection algorithm. ICG, indocyanine green; LVA, lymphovenous anastomosis; VNLT, vascularized lymph node transfer.

provides high contrast and good spatial resolution, which can be helpful to understand the extent of disease and for surgical planning. However, MR imaging is resource and time intensive, and may not be feasible for all patients and clinical contexts.

Key findings and explanations—surgical planning and procedure selection

Nonoperative, conservative measures (e.g., compressive garments, decongestive therapy) are widely regarded as the first-line treatment for secondary lymphedema. Expected volume reduction with conservative therapy is estimated to be up to 40% (38). Conservative therapy should be trialed for at least 6 months. Indications for operative management of secondary lymphedema include failed conservative management (i.e., clinical progression of disease despite maximal conservative therapy for at least 6 months) or intractable morbidity related to lymphedema despite conservative therapy (e.g., recurrent cellulitis, severe limitation of extremity function, substantial pain, diminished quality of life/substantial psychosocial distress). Among patients with cellulitis, surgery should only be undertaken after full resolution of the infection. The goals of lymphedema surgery are to halt disease progression and limit lymphedema-related morbidity including deformity, functional deficits, infection, and pain.

Lymphedema surgery can be categorized into two broad categories: physiologic and excisional/debulking procedures (2,39). Physiologic procedures include LVA and vascularized lymph node transfer (VLNT), as well as the implantation of novel biomaterials (nanofibrillar collagen scaffolds) designed to facilitate lymphatic drainage and encourage lymphangiogenesis in patients with secondary lymphedema (40). Excisional procedures are those that remove excess fibrofatty/lymphedematous tissue (e.g., liposuction, Charles procedure). Among patients determined to be appropriate candidates for surgery (i.e., failed maximal conservative therapy with refractory symptoms as described previously, appropriate candidates for surgery), our evidence-based algorithm for lymphedema surgery selection and sequencing is delineated in *Figure 2* (5,16,41). This algorithm is based on both clinical staging of disease as well as lymphatic imaging. Adherence to this algorithm has demonstrated sustained decrease in limb volume (median excess volume decreased from 29% preoperatively to –1% 2 years postoperatively) as well as reduced incidence of comorbid conditions such as cellulitis.

In our algorithm, all surgical candidates must be fully medically optimized and free of current infection prior to undergoing a procedure. Physical exam and the lymphatic mapping modalities mentioned previously are critical in

both determining which procedure is most appropriate, and for surgical planning for the chosen procedure. Preoperative MR imaging or bioimpedance measurements provide important information regarding the staging and relative fluid to fibrofatty tissue content contributing to volume excess in the affected extremity. This information is used to determine which operative approach is most appropriate. Bioimpedance is also a good and inexpensive tool to track outcomes after surgery. Additionally, for patients undergoing physiologic procedures, preoperative ICG lymphangiography is undertaken to determine whether there are adequate lymphatic targets for LVA (42).

In patients with relatively mild disease (stage I–II) with fluid excess (i.e., pitting edema with reversible swelling), physiologic procedures are recommended for initial treatment, as these procedures can help to restore lymphatic flow (4,43-48). On the other hand, in patients with moderate disease (stage II) with mixed fluid and fibrofatty tissue excess, combination therapy with targeted, lymph-sparing liposuction and a physiologic procedure is recommended (49). In these patients, lymphatic channels are demarcated using ICG lymphangiography and/or lymphazurin blue prior to liposuction to allow for selective wet liposuction that avoids the marked lymphatic channels. In fact, prior literature has also supported the use of a combined approach in such patients to improve volume reduction in the affected limbs (14).

In patients who have late-stage lymphedema (stage III) with predominantly fibrofatty tissue, initial recommended therapy is a debulking procedure (i.e., dry, circumferential liposuction), as a physiologic procedure would not address the extensive amount of fibroadipose tissue that has already accumulated in the affected extremity (50,51). This approach to chronic, fibrofatty tissue-dominated disease has been demonstrated to be effective in creating sustained reductions in limb volumes in prior literature as well (17,52). Furthermore, the extensive fibrofatty tissue buildup in these patients must first be addressed prior to considering a physiologic procedure in these patients, as the simple act of debulking itself may help to restore some degree of lymphatic flow. After a 1- to 1.5-year time interval, those with continued blocked distal lymphatics are then considered to be appropriate candidates for a physiologic procedure. Those with targetable lymphatics are recommended to undergo LVA, while those without targetable lymphatics are recommended to undergo VLNT. If the patient had a history of cellulitis, VLNT is preferentially used. This is because prior literature has demonstrated that VLNT offers improved therapeutic results over LVA in lymphedema patients with cellulitis (5,41). In these patients, LVA can also be undertaken in conjunction, if adequate targets for LVA were identified on preoperative ICG angiography.

Among patients with persistent excess volume after treatment as described above, additional procedures include liposuction if there is residual fibrofatty tissue, and nanofibrillar collagen scaffold placement in those with excess fluid volume. Nanofibrillar collagen scaffolds have been demonstrated to improve secondary lymphedema outcomes, especially in combination with physiologic procedures. These scaffolds not only provide a direct channel for lymphatic drainage via capillary effect, but they are also thought to encourage lymphangiogenesis. In this way, scaffold implantation can help to address any residual fluid excess even after physiologic surgery is undertaken (53).

Strengths and limitations

This study systematically reviews the existing literature and builds on this review using the senior author's experience to propose a succinct and evidence-based algorithm for surgical planning amongst lymphedema surgery candidates. However, this study is not without limitation. As a review paper, the strength of the reported information is dependent on the information available in the literature. However, this review utilized validated protocols for study design, data collection, and presents a comprehensive risk of bias assessment for all included articles to ensure transparency regarding the literature reviewed. In addition, as with all reviews, this study may have omitted relevant references. However, the study protocol for this review involved a rigorous search of six major scientific databases by two independent researchers, and thus the existing literature was comprehensively reviewed.

Comparison with similar research

Prior literature reviews on breast cancer-related lymphedema have summarized available clinical data on diagnostics and treatment of this disease (8-10). The current study provides an update on the most current published data on the topic, and it goes a step further to propose an algorithm for the preoperative evaluation of and operative planning for breast cancer-related lymphedema patients. This algorithm is based on both the literature and the senior author's experience, and it has been demonstrated

to improve patient outcomes after lymphedema surgery. As such, this study aims to provide readers with the information necessary to streamline preoperative evaluation and surgical planning in breast cancer patients undergoing lymphedema surgery.

Implications and actions needed

As imaging technology and software continue to advance, there are now virtual environments that allow for three-dimensional modeling of arm volume for patients with lymphedema currently under investigation (54). Such developments can help with surgical planning and track the efficacy of lymphedema treatment. Additionally, others are studying the application of augmented reality in superimposing preoperative lymphatic imaging onto the surgical field to allow for more accurate and efficacious identification of lymphatic channels for lymphaticovenous anastomosis (55). Such advances may help facilitate lymphaticovenous anastomosis even in challenging dissection fields, such as in patients who require a physiologic procedure after prior liposuction. LVA is less invasive than VLNT and does not require a donor site; such advances in imaging may facilitate LVA even in cases where adequate lymphatic channels are not easily discernible. Additionally, current research is investigating the use of ferumoxytol for MR lymphangiography (26). Ferumoxytol exhibits less diffusion into the venous system to allow for more robust and comprehensive assessment of the peripheral lymphatic system, thereby offering immediate translatable clinical application.

Conclusions

This article reviews strategies for preoperative evaluation and operative planning for lymphedema surgery in breast cancer patients, with the goal of maximizing postoperative outcomes in these patients. In patients who have failed maximal medical therapy and have recalcitrant symptoms, a combination of physical exam and diagnostic technologies are critical to (I) stage disease and to determine which surgical procedure is most appropriate, and (II) for surgical planning (e.g., determining the site of adequate lymphatic channels for LVA, determining where targeted liposuction can be undertaken safely). We present a review of the literature and an evidence-based algorithm for lymphedema surgery based on the senior author's practice. This algorithm incorporates both cutting-edge diagnostic technologies (e.g., bioimpedance) and novel therapeutic modalities (e.g., nanofibrillar collagen scaffolds), and is designed to optimize postoperative outcomes. As new technologies and developments in lymphedema surgery come to light, such algorithms for surgical planning should continue to evolve to help further improve outcomes in patients with this chronic and debilitating disease.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Supplementary

Appendix 1 Search strategy

Search strategy for PubMed/MEDLINE (August 2023)

[Mesh] = Medical subject headings
[tw] = textword: words in title, abstract, author keywords and MeSH

Search	Query	Items found
#1	(lymphedema surgery indications [tw] OR lymphedema surgery planning [tw] OR lymphedema preoperative planning [tw] OR lymphedema surgery patient selection [tw])	29

Search strategy for EMBASE (August 2023)

/exp = EMtree keyword with explosion
/de = EMtree keyword without explosion
:ab,ti = words in title OR abstract
NEXT/x = words next to each other in that order, x places apart

Search	Query	Items found
#1	'lymphedema NEXT/1 surgery'/exp OR 'lymphedema surgical planning'/exp OR 'lymphedema surgery patient selection'/exp:ab,ti	20

Search strategy for the Cochrane Central Register of Controlled Trials (August 2023)

ti,ab,kw = words in title, abstract or keyword

Search	Query	Items found
#1	Lymphedema surgery planning* or lymphedema surgery patient selection* or lymphedema surgery selection*:ti,ab,kw	10

Search strategy for Web of Science (August 2023)

TS = topic
NEAR/x = words near to each other in that order, x places apart

Search	Query	Items found
#1	TS = ("lymphedema surgery planning" OR "lymphedema surgery selection") OR TS = ("lymphedema patient selection" OR "lymphedema surgery patient selection") OR TS = ("lymphedema preoperative planning" OR "lymphedema surgical planning" OR "lymphedema surgery NEAR/1 selection*)	13

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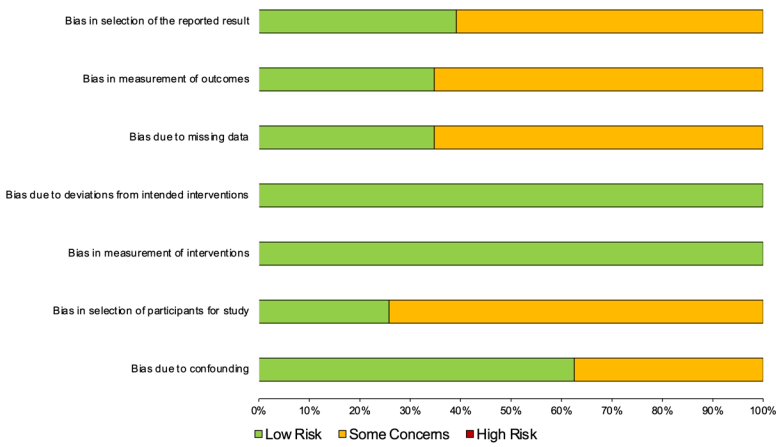

Figure S1 Results of risk of bias analyses.

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