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Novel Approach to Early Diagnosis and Management of Lymphedema Following Axillary Lymph Node Dissection in Breast Cancer Surgery

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Abstract

Lymphedema remains a significant complication following axillary lymph node dissection (ALND) in breast cancer surgery, contributing to impaired quality of life and increased healthcare costs. Early diagnosis and targeted intervention are critical to reducing lymphedema incidence and improving patient outcomes. This systematic review synthesizes current evidence on predictive tools for identifying high-risk individuals and evaluates the effectiveness of early multimodal interventions in mitigating lymphedema development. A comprehensive search of databases—including PubMed, Cochrane Library, and Embase—was conducted using keywords such as "lymphedema," "axillary lymph node dissection," "diagnosis," and "management." Selection criteria prioritized studies published between 2020 and 2025, with particular emphasis on observational and retrospective analyses. Key findings reveal that bioimpedance spectroscopy (BIS) and volumetric limb measurements provide sensitive early detection, while patient-reported outcomes enhance risk stratification. Notably, Valdez and Francis (2021) demonstrate the critical interplay of surgical techniques and lymphedema risk factors, reinforcing the need for refined operative strategies. Furthermore, interventions such as manual lymphatic drainage, compression therapy, and emerging biofeedback-guided rehabilitation have shown promise in reducing symptom severity. This review underscores the importance of personalized care pathways and highlights research gaps, including the need for standardized diagnostic protocols and expanded validation of predictive algorithms for optimal lymphedema management.

LITERATURE REVIEW

1. INTRODUCTION

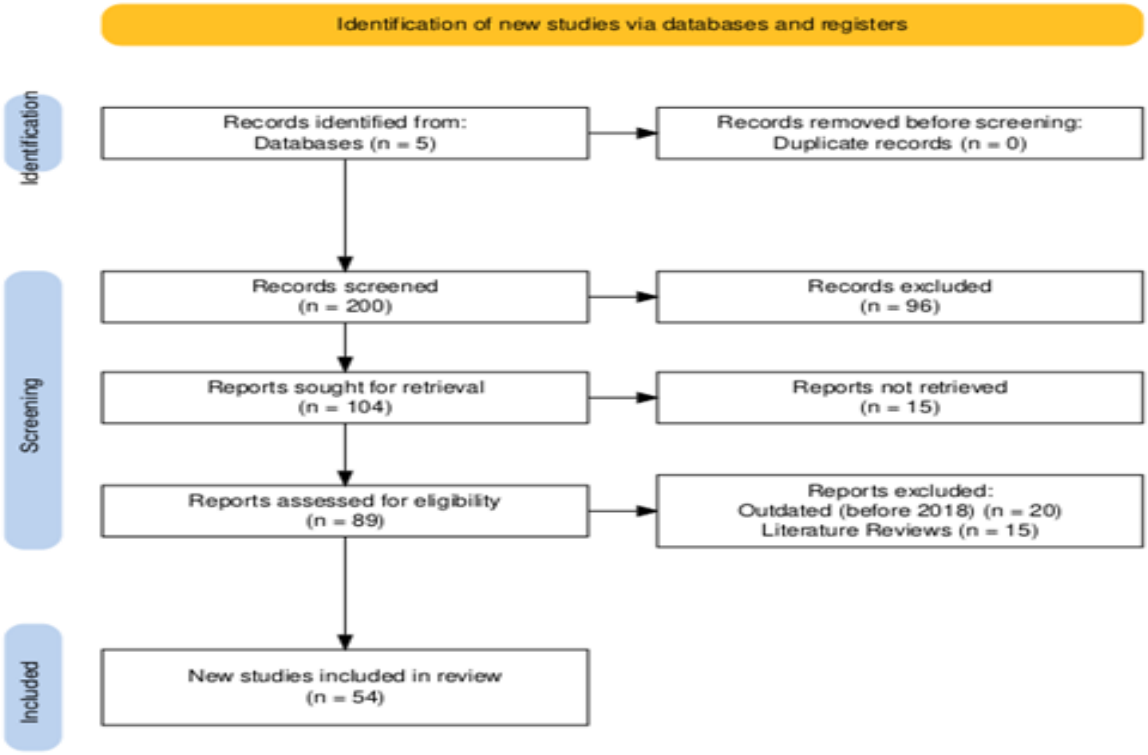
Lymphedema is a chronic, progressive condition that arises due to impaired lymphatic drainage following axillary lymph node dissection (ALND) in breast cancer patients. [1] This disruption of normal lymphatic flow leads to the accumulation of interstitial fluid, resulting in swelling, pain, functional impairment, and an overall decrease in quality of life. [2] The incidence of lymphedema following ALND varies widely, ranging from 6% to 56%, depending on factors such as the number of lymph nodes removed, radiation therapy, and patient-specific characteristics like BMI and genetic predisposition. [3] Despite advancements in surgical and therapeutic interventions, lymphedema remains a significant concern for breast cancer survivors, contributing to long-term morbidity and increased healthcare costs.

Early diagnosis and management of lymphedema are essential for improving patient outcomes, yet several challenges persist in clinical practice. One of the major obstacles is the delayed diagnosis of lymphedema, often occurring only after visible swelling or functional impairment has developed, reducing the effectiveness of early interventions. [4,5] Additionally, there is no universally accepted standard for screening and diagnostic criteria, leading to inconsistencies in identifying at-risk individuals and initiating preventive care. [6,7] Variability in treatment approaches further complicates management, as interventions such as manual lymphatic drainage (MLD), compression therapy, and exercise rehabilitation demonstrate varying degrees of

efficacy depending on patient adherence and clinical implementation. [8-10]

This literature review evaluates the effectiveness of predictive tools in identifying high-risk patients, examines emerging diagnostic technologies for early detection, and assess multimodal management strategies for lymphedema. By synthesizing current evidence, this review highlights gaps in the literature and proposes future directions for optimizing early detection and intervention strategies in lymphedema care.

2. METHODS



3. RISK FACTORS AND PREDICTIVE TOOLS FOR LYMPHEDEMA

Breast cancer-related lymphedema (BCRL) is a common and significant complication following axillary lymph node dissection (ALND). Understanding the risk factors is important in risk mitigation and early detection. Numerous studies have identified key contributors, such as age, body mass index (BMI), and surgical variables. However, variations in risk factors findings across studies highlights the complexity of BCRL and its diagnosis in breast cancer patients.

A study conducted at the Institute of Oncology Vojvodina in Sremska Kamenica, Serbia, analyzed 150 breast cancer patients over a five-year period and found that lymphedema severity was highest in patients aged 61 and older. [11] In contrast, researchers at the University of North Carolina Chapel Hill, identified 552 self-reported cases of BCRL and found the highest risk in younger Black women (under 50) and lowest risk in older non-Black women (over 50). [12] Similarly, a study done in 2022 found that Black patients have an odds ratio of 3.88 and Hispanic patients of 3.01 of developing BCRL compared to White patients. [13] These conflicting findings suggest that factors beyond age, such as tumor severity, aggressiveness of treatment, and access to care, may play a role in risk of lymphedema.

Research conducted at Seoul National University Hospital in Seoul, South Korea, analyzed 910 patient records and found an increase of lymphedema depending on the type of surgery. BCRL occurred in 6.1% of patients who underwent a sentinel lymph biopsy (SLNB), while 27% of patients developed BCRL that underwent axillary lymph nodes dissection (ALND). [14] This is supported by McLauglin et al. (2020) who reported patients quadruple the risk of BCRL when undergoing ALND as compared to SLNB. [1] Sentinel lymph biopsy is a less invasive surgery, which could contribute to these findings. Although fewer lymph nodes are typically removed during an axillary dissection, researchers did not find a significant association between the number of lymph nodes dissected and risk of BCRL. Patients that underwent a

mastectomy, rather than a breast conserving surgery, were significantly more likely to develop lymphedema. [14] These findings suggest that the extent and aggressiveness of surgical intervention plays an important role in the incidence of lymphedema. Numerous studies have identified chemotherapy and/or radiation as a risk factor. [12,14-16] A study published in 2022 displayed a correlation between BCRL, chemotherapy, and radiation, with 42.4% of patients receiving some type of chemotherapy and more than 80% receiving radiation. Specifically, 88.4% of the chemotherapy patients were receiving taxane-based chemotherapy. [16] Breast cancer patients are likely to receive other modalities of therapy, such as chemotherapy or radiation, in addition to surgical intervention. Therefore, identifying the risk between these therapies and BCRL is essential.

The same researchers also identified high body mass as a significant risk factor. [14] These findings are significant with a meta-analysis performed on twelve studies with a total of 2,102 BCRL patients. They found that the odds ratio for BCRL was 1.42 with a BMI between 25-30 kg/m^2 (overweight), when compared to patients with a BMI <25 kg/m². The odds ratio increased to 1.84 in patients with a BMI ≥30 kg/m² (obese). [17] The association between high BMI and increased risk of lymphedema highlights the necessity for personalized patient care in patients undergoing ALND. Pre-operative assessment of BMI could decrease the risk of developing BCRL.

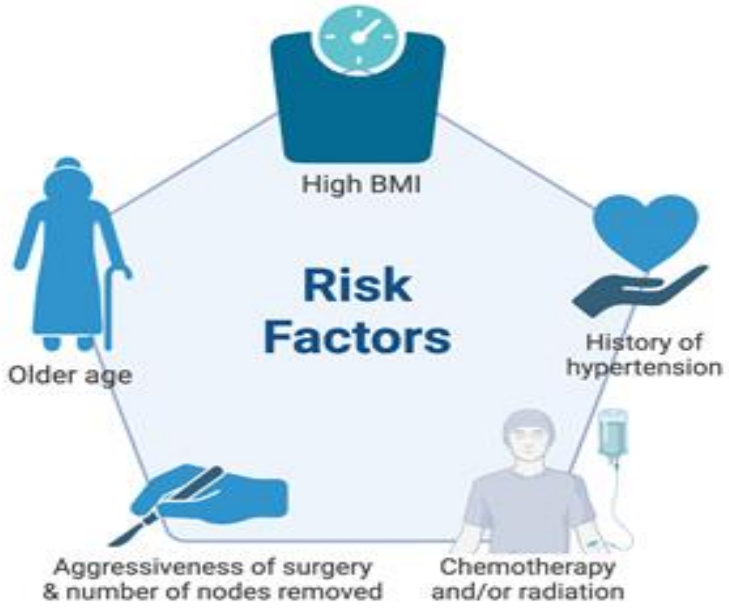


Figure 1. *This figure illustrates key risk factors for breast cancer-related lymphedema (BCRL). While older age has been associated with a higher risk, some studies suggest that younger Black women may be at higher risk. This highlights the complexity of BCRL and its risk factors. High BMI and history of hypertension are also significant risk factors. The aggressiveness of surgical treatment, specifically axillary lymph node dissection (ALND) compared to sentinel lymph node biopsy (SLNB), further increases risk of BCRL. Radiation and/or chemotherapy have been linked to BCRL, suggesting that the overall aggressiveness of cancer treatment may play a crucial role in the development of BCRL.*

The ability to identify risk factors of lymphedema is essential in developing predictive tools that allow for early detection and improved patient outcomes. A retrospective study in China analyzed 1,054 breast cancer patients and created a predictive tool, called a nomogram, to estimate clinical probability of BCRL. Four risk factors were included in the tool: age, number of positive lymph nodes, patient education level, and interpectoral (Rotter's) lymph node dissection. Although this study focused on interpectoral lymph node dissection, a similar predictive tool could be used for axillary lymph node dissection. The model displayed a moderate predictive performance with a C-index of 0.681 in a validation cohort, separate from the original patient database. [18] As additional risk factors could be added to this nomogram, this would allow for more accurate and precise early detection of BCRL.

Machine learning algorithms have shown to be a powerful and accurate predictive tool for BCRL. Patient data from Hainan Cancer Hospital in China was used to train (70%) and test (30%)

three different machine learning algorithms. Eighteen risk variables were used in this predictive tool. Some of the significant risk factors included the number of dissected lymph nodes, postoperative complications, use of chemotherapy and radiotherapy, aggressiveness of ALND, and history of hypertension. Of the three machine learning algorithms, the XGBoost demonstrated the best predictive performance with an area under the curve (AUC) of 0.99 in the training group and 0.89 in the validation group. [15] Accessible and accurate machine learning algorithms such as the XGBoost, serve as an incredible tool for clinicians to efficiently and accurately determine the risk of their patient developing BCRL.

4. Diagnostic Tools For Early Lymphedema Detection

Early detection of breast cancer-related lymphedema (BCRL) can mitigate the severity of the condition and therefore improve overall patient quality of life. A 2020 study with 1,100 patients found a significant decrease in quality of life associated with the presence of lymphedema. [19] This highlights the growing importance and relevance of diagnosing and treating the condition efficiently. However, the scientific consensus has been unclear on the gold-standard diagnostic tool for BCRL. Circumference tape measurements, perometry, bioimpedance spectroscopy, and imaging have all been diagnostic tools under investigation to determine the most effective tool for early detection.

Tape measurements have been widely used for assessing BCRL, however, studies have questioned their accuracy. Specifically, when compared with perometry, circumferential tape measurements were found to underestimate arm volume. [20] This finding suggests that the use of tape measurements alone could lead to underdiagnosis or late diagnosis of BCRL. Inter-rater reliability is an important factor to consider when using tape measurements. Tidhar et al. analyzed the reliability of circumferential tape measurements among 41 physiotherapists and found that when measurements were made when the same physiotherapists performed the measurements, 56% of arm and 80.5% of leg measurements were within 5% of the true mean volume. [21] These findings emphasize the importance of consistent provider care in patients post axillary lymph node removal, which may not be feasible in a clinical setting over multiple year surveillance.

Yang et al. found that perometry, an infrared optoelectronic scanning method, is more accurate than tape measurement. However, their study showed that subcutaneous echogenicity grade (SEG) proved to be the most accurate, specifically in the medial forearm. [22] This study highlights the concept of tissue composition analysis, as opposed to strictly using volume changes in diagnosis.

Another commonly used diagnostic tool for BCRL is water displacement. Researchers in the Netherlands tested the reliability and validity of water displacements using a Bravometer. Despite taking various precautions, such as placing the arm in the same spot every time, the standard deviation of water displacement was 0.7-0.8%. The researchers also analyzed the use of tape measurements and perometry, which had a standard deviation of 0.5% and 0.4 to 1.0%, respectively. [23] Although these standard deviation calculations are relatively low, they remain significant when detection of a small change in volume may indicate early onset of lymphedema.

Bioimpedance spectroscopy (BIS) has emerged as another diagnostic tool of BCRL. A study led by Dr. Chirag Shah at Tassig Cancer Institute detailed the high efficacy of BIS in reducing chronic lymphedema. Specifically, they highlight the importance of preoperative measurements as a baseline following surgical intervention. Over a three-year period, they found a relative reduction of 59% in chronic BCRL cases when BIS was used compared to tape measurements. Their recommendations include quarterly measurements in the first three years, biannually during years four and five, and annually every year after. They also recommend that the L-Dex (derived from BIS) score be lowered from 10 to 6.5 to determine when intervention or treatment is recommended to a patient. [24] Clinical guidelines provide a standardized and reliable approach for clinicians as they treat a higher variable condition, such as BCRL.

Barrio et al. conducted a study that compared the use of bioimpedance to that of volume displacement and found conflicting results. Their team found poor correlation between changes in water volume displacement and L-Dex measurements derived from bioimpedance. Of the 25 patients, 9 patients developed BCRL without any previous abnormal L-Dex measurements. [25] This study raises concern about the use of bioimpedance on its own and

suggests that it should be used in conjunction with other diagnostic tools. A study done in 2020 explored the potential of infrared 3D scanning device technology. The use of this device provided reliable measurements of limb volume in healthy subjects. [26] This technology shows promise as a preoperative and surveillance tool in breast cancer patients, offering a non-invasive and reliable method for early lymphedema detection. A multi-faceted approach that combines volumetric measurements, bioimpedance spectroscopy, and imaging, may offer the most comprehensive tool for early BCRL diagnosis, treatment, and improved patient quality of life.

Table 1. *This figure displays various diagnostic tools for BCRL, each with distinct advantages and limitations. Due to the complexity of breast cancer and its associated symptomatology, selecting an appropriate diagnostic tool requires accessibility and accuracy. While ultrasound and bioimpedance spectroscopy are non-invasive and effective, they may be limited due to cost and additional technician requirements. Tape measurement and water displacement are common and affordable tools, however, may be less precise and limited due to patient mobility restrictions. Understanding the advantages and limitations of diagnostic tools is crucial in early detection, personalized care, and effective BCRL screening in high-risk patients.*

Diagnostic Tool	Advantages	Limitations
Tape Measurement	Cost-effective, highly accessible	Operator variability
Perometry	Automated, less rater variability	Expensive machinery required
Water Displacement	Cost-effective	Increased patient involvement
Bioimpedance Spectroscopy (BIS)	Non-invasive	Subject to fluid changes in the body
Ultrasound	Non-invasive, portable	Ultrasound technician required
Infrared 3D Scanning	Non-invasive	Further validation and testing needed

5. Management Strategies for Lymphedema

5.1. Manual Lymphatic Drainage (Mld) and Lymphatic Stimulation Therapies

Manual lymphatic drainage (MLD) is a specialized massage technique designed to stimulate the lymphatic system, promoting fluid movement and reducing swelling in lymphedema patients. The physiological basis of MLD lies in its ability to enhance lymphatic contractility, increase lymphangiomotor activity [27-29], and facilitate the drainage of interstitial fluid into the venous circulation. By applying gentle, rhythmic pressure in a specific sequence, MLD helps redirect lymphatic flow away from congested areas, thereby alleviating swelling and improving tissue oxygenation. [30].

The effectiveness of MLD in early intervention has been well documented. A randomized controlled trial by Oliveira et al. (2018) evaluated the long-term effects of manual lymphatic drainage (MLD) and active exercises on physical morbidities, lymphoscintigraphy parameters, and lymphedema formation in patients who underwent breast cancer surgery. The study found that both MLD and active exercises were associated with improvements in shoulder range of motion and lymphatic parameters, although the cumulative incidence of lymphedema did not differ significantly between the groups over a 30-month follow-up period. [31].

5.2. Compression Therapy and Its Effectiveness

Treatment for lymphedema centers around controlling swelling through the use of gradient compression garments that apply a pressure of 20-60 mm Hg. [31] Compression garments can be prescribed as either prefabricated or custom made and should properly fit the patient. They can be produced in different forms such as gloves, arm sleeves, and stockings, all of which may exert different levels of pressure depending upon fabrication. [32] It is advised that they be worn during the waking hours and be replaced with short-compression banding at night. They must be washed daily and ideally replaced every 6 months. Compression therapy works to reduce the interstitial pressure of the extremity, reduce capillary filtration, and lymph production. [32] These garments also support the flow of lymphatic fluid, increase lymph resorption with lymphatic contraction, and increase fluid drainage from the affected tissues which in turn increases venous return. Overall, these garments are highly useful in helping to reduce limb volume, maintain skin integrity, and protect the limb from trauma and infection. [32]

Despite the effectiveness of compression garments and therapy, there remains the challenge of patient adherence. Lymphedema patients may need to wear these garments for the rest of their lives, which can be a challenging

daily task. [32] This treatment requires time, careful attention, lifestyle disruption, and significant costs, ultimately leading to low patient adherence. [33] In a discussion by Rockson et al. (2022), it was reported that the primary barriers to patient adherence include decreased self-efficacy as well as the burden of multiple treatment modalities. Another significant barrier is that these treatment supplies are not often covered by insurance in the United States and many other countries. As a result, many patients cannot receive the necessary compression supplies leading to the progression of their condition. [32,33] According to the Lymphedema Advocacy Group, there is a need for critical legislation that implements new coverage policies so that patients may receive the care they need. [31,33].

While the use of traditional compression garments is the standard of care, they are burdensome to use and require frequent wear as well as maintenance. [34] Recent studies have shown promise in the use of novel compression devices such as pneumatic compression devices (PCDs) and the Dayspring wearable sequential compression device. PCDs are a convenient option for patients with lymphedema because they improve lymphatic function, improve limb volume, and improve quality of life. They also reduce the risks associated with MLD related skin damage. However, PCDs have significant disadvantages because they need to be plugged in while in use and can be loud, bulky, and difficult to use. [33] Rockson et al. (2022) conducted a study comparing PCDs to the Dayspring and found that the Dayspring had all the advantages that PCDs included as well as being easier to use, less bulky, quiet, and allows for mobility during treatment. The Dayspring also exhibited increased adherence compared to PCDs. [33].

5.3. Exercise and Physical Therapy Approaches

Regular exercise has become increasingly important for alleviating the side effects of lymphedema. Exercise is beneficial in reducing breast cancer treatment related side effects, BCRL side effects, increasing cardiopulmonary capacity, muscle strength and mobility, and improved immune functioning. [35] Other benefits include increasing cancer survival and reducing metabolic growth factors, inflammation, and fatigue. [36] However, patients with BCRL have indicated barriers to participating in physical activity such as fatigue and the historically protective approach clinicians previously had with patients with BCRL. [35] In a cross-sectional study conducted by Kabak et al. (2020) it was determined that the majority of patients with BCRL preferred to do exercise of moderate intensity in the morning in a clinic/ sport center that is a combined-type, supervised, and structured exercise program with the most preferred type of exercise being walking or jogging.

The role of strength and resistance training should also be considered in patients with BCRL. In a controlled clinical trial conducted by Luz et al. (2018) compared two groups of participants who received differing treatments for BCRL. One group received the standard treatment modality that includes MLD, compression therapy, and exercises without resistance while the other received the standard treatment plus resistance exercises. The trial showed no appreciable difference between upper limb volume with edema, determining that strength training exercises are safe in patients with BCRL. It was also observed that exercise, with or without load, along with the standard treatment, reduced limb volume and increased shoulder strength. [37] These studies show promise in the incorporation of exercise into treatment modalities for BCRL. These and similar studies show the importance of physical activity and its overall benefit for patient quality of life and improved lymphatic function.

5.4. Biofeedback-Guided Rehabilitation and Emerging Therapies

Rehabilitation technology with sensor-enabled biofeedback technology is being increasingly used as a supplement to physical therapy. This technology can improve engagement with therapy and facilitate data-driven models of care. [38] Biofeedback in rehabilitation provides patients with information regarding a specific body function and allows them to self-regulate said function. [38] A conference paper from the 32nd International Symposium on Computer-Based Medical Systems (CBMS) posits that biofeedback systems can enhance adherence to exercise programs for BCRL patients by monitoring activity levels, providing positive feedback, and promoting goal attainment. Brennan et al. (2019) recommend that biofeedback systems should be discreet, lightweight, and easy to manipulate in order to be user friendly. It was also recommended that some users may benefit from biofeedback technology that can sync to mobile devices so that BCRL

patients may receive scheduled reminders to perform their exercise regimen as well as keep track of their progress. [38]

The requirements of rehabilitation technology that breast cancer patients desired were assessed in a qualitative study conducted by Brennan et al. (2020), where 10 patients were interviewed and provided input. The participants noted that they were motivated to exercise but felt that there was a lack of support and a lack of emphasis on the rehabilitation they were prescribed. [39] As a result, feelings of uncertainty and loneliness developed. Participants stated that they would have welcomed a rehabilitation technology support tool that was reliable, provided by their healthcare team, and focused on providing them with rehabilitation support after discharge. [39] While these studies provide insight into how biofeedback should be developed with a patient-centered approach, this technology has not been widely applied as of yet. [38] There is a need for the development of rehabilitation technology with biofeedback that includes these findings as well as large scale studies to be conducted on their efficacy.

6. Challenges in Standardizing Diagnosis And Treatment

The variability in lymphedema diagnostic criteria and measurement methodologies presents a significant challenge in standardizing care. The American Physical Therapy Association (APTA) suggests early detection of subclinical lymphedema by prospective surveillance using bioimpedance spectroscopy (BIS) or volume measurements, starting before surgery and continuing postoperatively. Standardized diagnostic techniques are essential for improving early identification and intervention. [40,41]

Also, the long-term financial impact of lymphedema treatment puts significant demand on healthcare systems, necessitating cost-effective alternatives. The Oncology Nursing Society (ONS) emphasizes the value of early detection and risk-reduction methods in lowering long-term expenditures. [42] Furthermore, ensuring the cost and accessibility of diagnostic technology is critical in low- and middle-income nations, where resources are few. [43] A cross-sectional analysis of insurance coverage in the United States found that, while most insurance companies cover non-programmable and programmable pneumatic compression, surgical debulking and physiologic procedures are underserved, particularly in the West, Southwest, and Southeast. [44,45]

Psychological and logistical constraints have a substantial influence on therapy adherence in lymphedema patients. A qualitative study of head and neck cancer patients found that hurdles such as insurance coverage, getting back to work, and accessibility of therapy impede continuous adherence. [46] The Oncology Nursing Society (ONS) guidelines stress patient education, self-massage, and compression garment usage for early lymphedema care. [42] Personalized instruction and longer treatment periods were proposed to improve adherence. Also, a study of breast cancer-related lymphedema (BCRL) at a safety-net hospital discovered that 58% of patients with BCRL obtained a physical or occupational therapy (PT/OT) referral, but only 56% completed it. [47] This demonstrates a considerable gap in treatment adherence, emphasizing the need for better patient education and support systems.

Clinical studies significantly underrepresented different patient groups. Historically, racial and ethnic minority groups have been disproportionately excluded from clinical trials, reducing the generalizability of research findings and contributing to inequities in early diagnosis and treatment. The American Society of Clinical Oncology (ASCO) and the Association of Community Cancer Centers (ACCC) have identified key strategies to address these disparities, including designing trials to minimize participation barriers, fostering partnerships with community leaders, and ensuring equitable access to high-quality care. [48] These efforts aim to increase the involvement of marginalized communities, ensuring that advances in lymphedema diagnosis and treatment are available to everyone, regardless of race or socioeconomic status. Healthcare providers may reduce inequities and promote more inclusive lymphedema care by employing focused outreach, culturally competent patient involvement, and financial support initiatives.

7. Future Directions in Lymphedema Research and Care

Lymphedema is one of the most debilitating complications of breast cancer treatment and contributes to a wide range of impairments to the affected extremity as well as psychosocial problems such as anxiety and depression. [49] While screening for BCRL is recommended, it is not the standard of care currently. There are also

no universal diagnostic criteria for BCRL, especially for subclinical lymphedema according to the British Journal of Cancer. [50] The lack of standardized diagnostic criteria makes the true incidence of lymphedema difficult to estimate. A standardization of lymphedema diagnosis and risk assessment is necessary in order to provide timely treatment for breast cancer patients that are high-risk for BCRL.

A study conducted by Bundred et al. (2020), has provided needed novel screening recommendations that may assist in creating a standardized approach to the diagnosis and risk assessment associated with BCRL. [50] The first recommendation that was proposed is that baseline measurements comparing both arms should be used as a baseline for the assessment of risk of developing BCRL prior to surgery. Another recommendation that was cited in this study includes that relying on self-reported symptoms alone can lead to misdiagnosis, overtreatment, and increased healthcare costs for both the patient and institution. Self-reported symptoms should be corroborated with arm volume measurements to avoid this issue. [19] Bundred et al. (2020) observed that the risk of progression in a low-risk group cannot be ignored and recommended that resources should be geared towards high-risk populations whilst the low-risk population be provided education to ensure self-referral if any new symptoms occur. It was also noted that, if resources allow, all patients should be screened. [19] While these recommendations provide useful insight into creating a standardization of care, there is still more work to be done. Future directions include controlled, long-term studies that delineate the accuracy of screening tools such as BIS as well as identify the true threshold for early treatment.

Other future directions that lymphedema research and care can take are in the form of artificial intelligence (AI) and machine learning. A web-based study conducted by Fu et al. (2018) utilized mobile health (mHealth) to develop real-time patient-centered symptom reporting and clinical analytics. These data were collected in order to increase the precision of early detection of lymphedema as well as improve long term clinical decision support for breast cancer patients. They collected patients' real-time symptoms using a mHealth system, and this data was analyzed using 5 different machine learning algorithms. The best performing algorithm was artificial neural network (ANN), which had an accuracy of 93.75%, sensitivity of 95.65%, and specificity of 91.03% in detecting lymphedema. [51] Conducting real-time lymphedema assessment has the potential to enable patients and healthcare providers to accurately monitor their lymphedema risk, seek timely intervention, reduce healthcare costs, and may even reduce anxiety in breast cancer survivors who are at risk of lymphedema. [51] Future endeavors within this area include increased data collection and future biomarker data to improve machine learning algorithms used and improve early detection of lymphedema.

Emerging interventions and the need for increased clinical trials is another area of study that is important in the advancement of lymphedema care. One such intervention is the development of predictive models using blood tests and therapy data. Trinh et al. (2023), conducted a study that collected data from 2,137 patients to develop a rapid screening tool for patients at risk for lymphedema. The use of blood tests and chemotherapy data help to minimize human error and possible under- or over-reporting of symptoms associated with patient self-reports. Their data exhibited satisfactory performance in predicting lymphedema and was more reliable in terms of diagnosis than self-reporting. [52] This lays a foundation for future studies using this predictive model to more rapidly and accurately screen patients for lymphedema and may predict the stages of lymphedema. The proposed models of Fu et al. (2018) and Trinh et al. (2023) may even have the possibility to create more personalized care for patients with lymphedema by taking into account real-time self-reporting, the use of blood tests, and chemotherapy data.

Another area of interest includes the need for future studies that examine the long-term effects of treatments such as MLD and compression therapy. In terms of MLD, there is a lack of standardization in treatment protocols and limited accessibility to certified lymphedema therapists, as noted above. This in turn has caused MLD to remain underutilized despite its benefits in the treatment of BCRL. A randomized, single-blinded, controlled crossover trial conducted by Da Cuña-Carrera et al. (2024) determined that the absence of MLD in BCRL worsened volume measurements and symptoms such as arm heaviness. However, it was noted that future studies need to be conducted in order to compare the associated benefits with other techniques, including therapeutic exercise, to see whether

MLD could be as valid an option as therapeutic exercise. [53] In terms of compression therapy, there is a call for studies that evaluate the long-term effects of this therapy using large sample sizes. There is also a need for improvement of adherence to this treatment method by the creation of training programs to reduce patient anxiety about garment use as well as considerations for designs that are aesthetic, functional, and more tailored to the patient's needs. [32]

Lastly, there must be strategic recruitment of an ethnically diverse cohort for future studies regarding BCRL. Sturgeon et al. (2018) discuss that Black women are more likely to experience adverse effects of cancer treatment, such as BCRL, and are found to have lower awareness of this chronic condition. In order to meet the unique needs of ethnically diverse populations, research must include a sufficient number of ethnic minority cancer survivor populations within intervention studies, especially since treatment modalities may need to be adjusted to meet their unique needs. [54] Sturgeon et al. (2018) had a specific goal of recruiting at least 35% Black women into their study and successfully demonstrated its feasibility, but there remains a research gap in the representation of multiethnic groups within cancer research. Better representation within cancer research, especially that pertaining to BCRL, will lead to more convincing study results and enable healthcare providers to shape BCRL care in a manner that is relevant to all ethnicities and backgrounds. [54]

8. CONCLUSION

This methodical review underscores the continuous challenges and evolving treatment strategies in the management of lymphedema following axillary lymph node dissection (ALND) in breast cancer patients. Despite rapid advancements in surgical techniques and post-operative interventions, lymphedema remains a notable contributor to morbidity, further influencing patients' quality of life and inflating healthcare costs. When consolidating current literature, early detection and targeted intervention such as bioimpedance spectroscopy and volumetric limb measurements are compelling and reliable methods to indicate high-risk patients, directly resulting in a high percentage decrease in postoperative complications. Beyond operational management, compression therapy and biofeedback-guided rehabilitation also contributes to the current multimodal intervention design. While there are various effective ways in which lymphedema following ALND can be treated, this review highlighted limitations such as a need for standardized patient guidelines and uncertainty surrounding patient adherence. Future research should focus on addressing these limitations through patient-controlled, long-term studies in order to gain an objective evaluation of the therapy and diagnostic efficacy. Furthermore, ensuring access to care in underserved communities and justice in healthcare are crucial for ensuring equitable outcomes. Using current limitations to inform future research, we aim to advance the current state of lymphedema care and enhance quality of life for breast cancer survivors.

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