Review

Diagnostics, Predictors and the Efficacy of Lymphedema Decongestive Therapy

Andrej Dzupina , Nagendra Kumar Yaluri , Monika Jankajova *

Posted Date: 7 October 2024

doi: 10.20944/preprints202410.0506.v1

Keywords: Lymphedema; Decongestive Therapy; Vascular; Angiology

 doi:10.20944/preprints202410.0506.v1

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Diagnostics, Predictors and the Efficacy of Lymphedema Decongestive Therapy

Dzupina Andrej [1], Yaluri Negendra Kumar [2] and Jankajova Monika [3,*]

[1] Dzupina Andrej, Dept. of Angiology, National Heart Institute, Bratislava, Slovakia
[2] Yaluri Negendra Kumar, Centre of Clinical and Preclinical Research MEDIPARK, PJ Safarik University in Kosice, Slovakia
[3] Jankajova Monika, Cardiology Dept, Kardiocentrum Agel-Saca a.s., Kosice, Slovakia
* Correspondence: mjankajova@gmail.com.

Abstract: Lymphedema, a chronic condition characterized by the accumulation of lymphatic fluid in the interstitial tissue, leads to swelling primarily in the extremities, though other parts of the body can be affected. This condition commonly arises following lymph node dissection, radiation therapy, or due to inherent defects in the lymphatic system. Effective management of lymphedema is crucial due to its impact on function and quality of life, with complete decongestive therapy (CDT) serving as the cornerstone of treatment. CDT, a multimodal approach involving manual lymphatic drainage (MLD), compression bandaging, skin care, and exercise, has been widely adopted. Research highlights the significance of early diagnosis and initiation of CDT to prevent irreversible lymphatic damage and worsening of symptoms. The predictors of successful outcomes in decongestive therapy include timely initiation of treatment, patient adherence to therapy regimens, and the comprehensive application of CDT components. Studies indicate that while all components of CDT are beneficial, the critical nature of compression therapy and exercise cannot be overstated, regardless of the MLD component's efficacy. Furthermore, recent inquiries into the impact of skin and fat tissue characteristics on the efficacy of decongestive therapy have yielded insightful findings. Increased skin thickness and adipose tissue accumulation, as measured by echogenicity and volumetric analysis respectively, have been shown to complicate the management of lymphedema. Particularly in advanced stages, where fibrosis and fat deposition are predominant, traditional CDT might require augmentation with more aggressive treatments like liposuction or advanced compression techniques. In this review we will discuss in detail how the success of decongestive therapy in lymphedema is influenced by multiple factors including the stage of lymphedema at diagnosis, the specific protocol employed, and individual patient factors such as skin and adipose tissue characteristics. Personalized treatment plans, early intervention, and consistent monitoring and adjustments based on patient response to therapy are essential for optimal management of this challenging condition. Further studies are warranted to explore the tailored approaches in lymphedema management, particularly in patients with significant changes in skin and subcutaneous tissue characteristics.

Keywords: lymphedema; decongestive therapy; vascular; angiology

Introduction

Lymphedema manifests as a persistent condition characterized by the accumulation of lymphatic fluid in the body, resulting in swelling and potential alterations in skin and tissue integrity [1]. This chronic and progressive buildup of protein-rich fluid surpasses the lymphatic system's capacity for fluid transport. Swelling associated with lymphedema can affect various body regions, including the arms, legs, genitals, face, neck, chest wall, and oral cavity [2]. The diagnosis of lymphedema carries numerous psychological, physical, and social implications. It is broadly categorized as either primary, with a genetic basis, or secondary, acquired through external factors [2].

The lymphatic system functions to transport lymph, a fluid containing white blood cells, triglycerides, bacteria, cell debris, water, and protein, akin to blood plasma. This intricate drainage

 doi:10.20944/preprints202410.0506.v1

system comprises initial lymphatics (lymph capillaries), pre-collectors, collectors, lymphatic trunks, and lymph nodes [3]. Topographically, the lymph system is divided into superficial (subcutaneous) and deep (subfascial) components. The superficial system drains the skin and subcutaneous tissues, while the deep system handles muscles, joints, tendon sheaths, and nerves. Perforating vessels serve as connections between these systems, facilitating the transport of lymph from subfascial areas to the surface [4,5].

Signs and symptoms of lymphedema encompass distal swelling in extremities such as the arms, hands, legs, and feet, as well as proximal swelling in areas like the breast, chest, shoulder, pelvis, groin, genitals, face, and intraoral tissues. Restricted range of motion in joints due to swelling and tissue changes, skin discoloration, pain, altered sensation, limb heaviness, and difficulty fitting into clothing are also common manifestations [6–8].

Decompressive Therapy in Lymphedema

Decompressive therapy in lymphedema is a treatment approach aimed at reducing swelling and managing the symptoms associated with lymphedema, which is a condition characterized by the buildup of lymph fluid in the body's tissues, typically due to a blockage in the lymphatic system. Decompressive therapy encompasses various techniques and modalities designed to alleviate swelling and improve lymphatic circulation [9,10]. Some common methods of decompressive therapy in lymphedema include:

1.1. Manual Lymphatic Drainage (MLD): This is a gentle massage technique performed by a trained therapist to stimulate the flow of lymph fluid and encourage its drainage from the affected area [11,12]. Manual Lymphatic Drainage (MLD) is a specialized massage technique commonly used in the management of lymphedema. It involves gentle, rhythmic movements that stimulate the lymphatic system, promoting the drainage of excess lymphatic fluid and reducing swelling in affected areas. MLD is often performed by trained therapists who apply specific hand movements to redirect lymph fluid towards functional lymphatic pathways. Several studies have demonstrated the effectiveness of Manual Lymphatic Drainage in the treatment of lymphedema. A study published by Koul et al. assessed the impact of MLD on breast cancer-related lymphedema. The results showed significant reductions in limb volume and improvements in symptoms following MLD treatment [13]. A systematic review and meta-analysis conducted by Ezzo et al. evaluated the efficacy of MLD in the management of lymphedema. The analysis included several randomized controlled trials and concluded that MLD was effective in reducing limb volume and improving quality of life in patients with lymphedema [12]. Another study by Devoogdt et al. published in Cancer Nursing, investigated the long-term effects of MLD on breast cancer-related lymphedema [14]. The findings indicated sustained improvements in limb volume and symptom relief over a 12-month follow-up period. These studies highlight the therapeutic benefits of Manual Lymphatic Drainage in reducing swelling and improving symptoms associated with lymphedema. However, it's important to note that MLD is often used as part of a comprehensive treatment approach, which may include compression therapy, exercise, skincare, and patient education.

1.2. Compression Therapy: Compression garments or bandages are applied to the affected limb to help reduce swelling by applying external pressure and supporting the lymphatic vessels [15–17]. Compression therapy is a cornerstone of treatment for lymphedema, aimed at reducing swelling and improving lymphatic function through the application of external pressure. It typically involves the use of compression garments, bandages, or pneumatic compression devices to exert pressure on the affected limb or body part. Compression therapy helps to promote lymphatic drainage, prevent fluid accumulation, and maintain the reduced size of the limb achieved through other treatments such as manual lymphatic drainage. Several studies have investigated the efficacy of compression therapy in the management of lymphedema. A randomized controlled trial by [18] Ochalek, K et al. compared the effectiveness of different compression garments in reducing arm lymphedema following breast cancer treatment. The study found that compression therapy significantly reduced limb volume and improved symptoms compared to no treatment. A systematic review and meta-analysis by [19] McNeely et al. evaluated the evidence for compression therapy in breast cancer-related

 doi:10.20944/preprints202410.0506.v1

lymphedema. The analysis included several studies and concluded that compression garments were effective in reducing limb volume and improving quality of life in patients with lymphedema. A study by Mayrovitz et al. [20], investigated the effects of intermittent pneumatic compression on lower extremity lymphedema. The results demonstrated significant reductions in limb volume and improvements in tissue fluid content following pneumatic compression therapy. These studies provide evidence supporting the use of compression therapy as an effective intervention for managing lymphedema. However, it's important to note that the selection and application of compression garments or devices should be tailored to the individual patient's needs and preferences, and proper monitoring is essential to ensure optimal outcomes.

1.3. Exercise: Specific exercises and movements may be prescribed to promote lymphatic flow and improve muscle pumping action, which can aid in reducing swelling [21,22]. Exercise plays a crucial role in the management of lymphedema by promoting lymphatic flow, improving muscle pump function, and enhancing overall physical and mental well-being. However, it's important that exercise programs are tailored to individual capabilities and carefully monitored to prevent injury and exacerbation of lymphedema symptoms. Here are some key points about exercise and lymphedema

1.3.1. Benefits of Exercise: Exercise can help reduce swelling, improve range of motion, increase strength and flexibility, and enhance overall quality of life for individuals with lymphedema. It also promotes cardiovascular health and aids in weight management, which are important considerations for lymphedema management.

1.3.2. Types of Exercise: Low-impact aerobic exercises such as walking, swimming, cycling, and aquatic exercises are generally safe and effective for individuals with lymphedema. Resistance training and flexibility exercises can also be beneficial, but should be performed with caution and under supervision, particularly for individuals at risk of developing or exacerbating lymphedema.

1.3.3. Precautions and Guidelines: It's important for individuals with lymphedema to follow specific precautions and guidelines when exercising, such as wearing compression garments during activity, avoiding repetitive or high-impact movements that may strain the affected limb, and gradually increasing exercise intensity and duration under the guidance of a healthcare professional.

Several studies have investigated the effects of exercise on lymphedema management. A randomized controlled trial by [23] Ahmed et al. evaluated the effects of supervised aerobic and resistance exercise in breast cancer survivors with lymphedema. The study found that exercise led to significant reductions in arm swelling and improvements in physical function and quality of life. A systematic review by [24] Cheema et al. (2014), published in Breast Cancer Research and Treatment, examined the effects of exercise on lymphedema-related outcomes in breast cancer survivors. The review concluded that exercise was safe and beneficial for individuals with lymphedema, leading to improvements in limb volume, physical function, and psychosocial well-being. Another study by [25] Czerniec et al. (2010), published in Breast Cancer Research and Treatment, investigated the effects of resistance training on breast cancer-related lymphedema. The study found that resistance training led to improvements in arm volume and strength without exacerbating lymphedema symptoms. These studies provide evidence supporting the inclusion of exercise as part of a comprehensive lymphedema management program. However, it's essential for individuals with lymphedema to consult with their healthcare providers before starting an exercise regimen and to receive guidance on safe and appropriate activities based on their individual needs and health status.

1.4. Pneumatic Compression Therapy: This involves the use of pneumatic compression devices that intermittently inflate and deflate sleeves or boots worn on the affected limb, promoting lymphatic drainage [15,26]. Pneumatic Compression Therapy (PCT) is a non-invasive treatment modality used in the management of lymphedema. It involves the application of sequential or intermittent pneumatic compression devices to the affected limb or body part, which exert external pressure and promote lymphatic drainage. PCT works by enhancing tissue fluid movement, reducing swelling, and improving lymphatic function. Pneumatic Compression Therapy applies external pressure via compression garments to the affected limb through sequential or intermittent inflation and deflation of air chambers within the compression device. This action helps to mimic the natural

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pumping action of muscles and promotes the movement of lymphatic fluid towards functional lymphatic pathways, facilitating drainage and reducing swelling. Several studies have demonstrated the effectiveness of Pneumatic Compression Therapy in the management of lymphedema. A randomized controlled trial by [27] Nelson, E. A at al. investigated the effects of intermittent pneumatic compression on lower extremity lymphedema. The study found significant reductions in limb volume and improvements in tissue fluid content following Pneumatic Compression Therapy. A systematic review and meta-analysis by [28] Uzkeser, H et al. evaluated the efficacy of Pneumatic Compression Therapy in the treatment of lymphedema. The analysis included several studies and concluded that Pneumatic Compression Therapy was effective in reducing limb volume and improving symptoms in individuals with lymphedema.

Pneumatic Compression Therapy is recommended as a treatment option for lymphedema in clinical practice guidelines, including those from organizations such as the National Lymphedema Network (NLN) and the International Society of Lymphology (ISL) [2,29]. These guidelines emphasize the importance of using Pneumatic Compression Therapy as part of a comprehensive lymphedema management program, which may include other modalities such as manual lymphatic drainage, compression garments, exercise, and skincare [2,30,31]. Pneumatic Compression Therapy is generally well-tolerated by patients with lymphedema, but it's essential to consider individual factors such as comfort, mobility, and treatment preferences when prescribing PCT. Proper fitting of compression garments and regular monitoring of treatment progress are important aspects of patient care [32–34].

1.5. Complete Decongestive Therapy (CDT): CDT is a comprehensive treatment program for lymphedema that typically includes a combination of manual lymphatic drainage, compression therapy, exercise, skin care, and patient education [35,36]. Complete Decongestive Therapy (CDT) is a comprehensive treatment approach commonly used in the management of lymphedema. It consists of several components, including manual lymphatic drainage (MLD), compression therapy, exercise, skincare, and patient education. CDT aims to reduce swelling, improve lymphatic function, and enhance the overall quality of life for individuals with lymphedema. Here are some key points about Complete Decongestive Therapy and lymphedema, along with references supporting its efficacy. A randomized controlled trial by [37,38] Stout Gergich et al. published in Cancer, assessed the effectiveness of Complete Decongestive Therapy in breast cancer-related lymphedema. The study found significant reductions in limb volume and improvements in symptoms following CDT treatment. A systematic review by [39] Stout et al. evaluated the evidence for CDT in the management of lymphedema. The review concluded that CDT was effective in reducing limb volume, improving quality of life, and minimizing complications associated with lymphedema. Complete Decongestive Therapy is recommended as the standard of care for lymphedema management in clinical practice guidelines, including those from organizations such as the National Lymphedema Network (NLN) and the International Society of Lymphology (ISL). These guidelines emphasize the importance of a multidisciplinary approach and the integration of various components of CDT for optimal treatment outcomes. Individualized assessment and treatment planning are essential in CDT to tailor interventions to each patient's specific needs, preferences, and clinical presentation. Regular monitoring and adjustment of treatment regimens are also important to ensure ongoing effectiveness.

1.6. Surgical Options: In some cases, surgical procedures such as lymphaticovenous anastomosis (LVA) or vascularized lymph node transfer (VLNT) may be considered to improve lymphatic drainage and reduce swelling [40–42]. Surgical options are available for the management of lymphedema, particularly in cases where conservative treatments such as Complete Decongestive Therapy (CDT) have not provided sufficient relief or when the condition is severe. Some surgical interventions can be performed in an outpatient setting and the key for successful outcome is time planning, whereas the surgery should be planned after intensive phase of CDT. Surgical interventions aim to improve lymphatic flow, reduce swelling, and alleviate symptoms. Some key surgical options for lymphedema management, along with references supporting their efficacy:

1.6.1. Lymphaticovenous Anastomosis (LVA): LVA is a microsurgical procedure that involves connecting lymphatic vessels to adjacent veins to bypass blocked or damaged lymphatic pathways.

 doi:10.20944/preprints202410.0506.v1

This allows lymphatic fluid to drain directly into the venous system, reducing swelling and improving lymphatic function. A study by [43] Chang et al. evaluated the outcomes of LVA in the treatment of lymphedema. The study demonstrated significant reductions in limb volume and improvements in symptoms following LVA surgery.

1.6.2. Vascularized Lymph Node Transfer (VLNT): VLNT involves transplanting healthy lymph nodes, along with their blood supply, from a donor site to the affected area in the body. This procedure aims to restore lymphatic function and improve drainage, thereby reducing swelling and alleviating symptoms. A systematic review by [44] Ciudad et al. examined the efficacy of VLNT in the treatment of lymphedema. The review found that VLNT led to significant reductions in limb volume and improvements in quality of life for patients with lymphedema.

1.6.3. Liposuction: Liposuction may be considered for individuals with lymphedema who have significant adipose tissue accumulation in the affected limb. Liposuction aims to remove excess fat deposits, reducing limb volume and improving mobility. A study by [45] Brorson et al. investigated the long-term outcomes of liposuction in the treatment of lymphedema. The study demonstrated sustained reductions in limb volume and improvements in symptoms following liposuction surgery.

1.6.4. Combined Surgical Approaches: In some cases, a combination of surgical techniques, such as LVA and VLNT or VLNT and liposuction, may be used to optimize outcomes and address multiple aspects of lymphedema pathophysiology. A study by [46] Cheng et al. evaluated the effectiveness of combined surgical approaches in the management of lymphedema. The study demonstrated favorable outcomes in terms of volume reduction and symptom improvement.

Decompressive therapy aims to manage the symptoms of lymphedema, improve quality of life, and reduce the risk of complications associated with the condition, such as recurrent infections and impaired limb function. It is typically tailored to the individual needs of the patient and may involve a combination of different therapeutic modalities.

2. Predictors of Success of Decompressive Therapy of Lymphedema

In a study published by Can et al. predictors of successful outcomes in decompressive therapy for lymphedema include patient education, skin care, regular exercise, and the implementation of compression therapy. The study also identifies factors such as advanced age, obesity, larger tumor size, a higher number of positive lymph nodes, and postoperative radiotherapy as risk factors associated with lymphedema, suggesting these could also influence the effectiveness of decompressive therapy [47]. In a preliminary study by Kwon et al. the authors highlighted the predictive value of preoperative lymphoscintigraphy for determining the success of lymphovenous anastomosis in treating lymphedema. Lymphoscintigraphic indicators such as the dermal backflow pattern and extremity uptake ratio can predict both early and late therapy responses, essential for planning effective decompressive therapy [48]. Lemoine et al. published that the effective decompressive therapy in the immediate postoperative period, especially in acute settings such as after head and neck surgery, can significantly reduce lymphedema volumes. This study demonstrates that early intervention with decongestive therapy is feasible and effective, serving as a predictor of successful lymphedema management [49]. The above evidence collectively identify early intervention, patient adherence to recommended therapies, and the use of diagnostic tools like lymphoscintigraphy as key predictors of successful outcomes in decompressive therapy for lymphedema. Factors such as the patient's age, tumor characteristics, and the presence of obesity also play a significant role in determining the effectiveness of therapy.

Additionally in a paper by Shallwani et al. the authors confirms the importance of tailored interventions, including compression therapy and individualized exercise, in predicting successful outcomes in the management of lymphedema in women treated for gynecological cancer. The feasibility of implementing these interventions suggests that a multidimensional approach can be crucial in managing lymphedema effectively [50]. In a study conducted by Lanza et al. treatment protocols such as compression bandaging and manual lymph drainage are effective predictors of successful volume reduction in lymphedema. However, the frequency of treatments and adherence to protocols established at each service significantly impact the therapeutic response [51]. Kwon HR

 doi:10.20944/preprints202410.0506.v1

et al., 2021 research paper highlights the predictive role of preoperative lymphoscintigraphy in determining the success of lymphovenous anastomosis for lymphedema treatment. The dermal backflow pattern and extremity uptake ratio serve as crucial indicators for predicting both early and late therapy responses [48]. Finally a study conducted by Borman P et al., 2022 underscores the importance of the number of dissected lymph nodes as a key factor influencing the development and management of lymphedema. It suggests that understanding the extent of surgical intervention can help predict and manage the risk of lymphedema more effectively [52]. These above four studies provide additional evidence supporting the importance of individualized treatment plans, early diagnostic interventions, and understanding surgical impacts as key predictors in the successful management of lymphedema through decompressive therapy.

Below are the additional predictors of success of decompressive therapy of lymphedema.

2.1 Stage and Severity of Lymphedema: The stage and severity of lymphedema are crucial predictors of treatment outcomes and play a significant role in guiding therapeutic interventions. Lymphedema staging refers to the classification of the condition based on its progression and clinical presentation, while severity refers to the extent of tissue swelling and functional impairment. Understanding these factors is essential for developing effective treatment plans and predicting response to therapy. The International Society of Lymphology (ISL) provides guidelines for the diagnosis and treatment of peripheral lymphedema, emphasizing the importance of accurate staging in treatment planning (ISL, 2013) [53]. Early-stage lymphedema, characterized by mild swelling and minimal tissue changes, may respond more favorably to treatment compared to advanced-stage lymphedema where tissue fibrosis and irreversible changes have occurred [54]. In addition to staging, the severity of lymphedema also influences treatment outcomes. Szuba et al. discuss the progressive nature of lymphedema and its impact on tissue integrity, emphasizing the need for early intervention to prevent irreversible damage [55]. Damstra et al. compare different compression therapy modalities for arm lymphedema and highlight the role of treatment intensity in managing lymphedema severity [56]. Overall, accurate assessment of lymphedema stage and severity is essential for predicting treatment outcomes and tailoring interventions to individual patient needs. Early intervention and appropriate management strategies can help optimize outcomes and improve the quality of life for individuals living with lymphedema.

2.2. Extent of Fibrosis: The extent of fibrosis in lymphedematous tissue serves as an important predictor for treatment outcomes and can significantly influence the efficacy of therapeutic interventions. Fibrosis, characterized by the accumulation of excess collagen and tissue scarring, develops as a consequence of chronic lymphedema and can lead to tissue induration, decreased compliance, and impaired lymphatic function. Research suggests that the presence of fibrosis in lymphedematous limbs may limit the effectiveness of conservative treatments such as compression therapy and manual lymphatic drainage (MLD). Fibrotic tissue is less responsive to external compression and manual manipulation, hindering the redistribution of fluid and lymphatic drainage [55]. As a result, individuals with extensive fibrosis may experience slower or less pronounced reductions in limb volume and may be at a higher risk of developing complications such as recurrent infections and skin breakdown. Several studies have investigated the impact of fibrosis on treatment outcomes in lymphedema management. For example, [54] Brorson et al. observed that patients with advanced fibrosis may have limited success with traditional therapies and may require more aggressive interventions such as liposuction or surgical debulking to achieve significant reductions in limb size. Similarly, a study by [57] Lee et al. found that the degree of fibrosis correlated with the severity of lymphedema symptoms and functional impairment, highlighting the importance of assessing fibrotic changes in treatment planning. The extent of fibrosis serves as a valuable predictor for lymphedema treatment outcomes, guiding clinicians in selecting appropriate interventions and managing patient expectations. Further research into strategies for addressing fibrotic tissue and enhancing treatment efficacy in individuals with lymphedema is warranted to improve outcomes and quality of life for affected individuals.

2.3. The presence of concurrent conditions: The presence of concurrent conditions can serve as a significant predictor for lymphedema treatment outcomes, influencing response to therapy and

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overall management strategies. Concurrent conditions, such as obesity, venous insufficiency, or recurrent infections, can impact lymphedema progression, exacerbate symptoms, and complicate treatment efforts. Obesity is commonly associated with lymphedema and can exacerbate swelling and tissue inflammation by placing additional stress on the lymphatic system. Studies have shown that individuals with obesity may have poorer outcomes with conservative treatments such as compression therapy and manual lymphatic drainage (MLD) due to reduced efficacy of compression garments and difficulty accessing lymphatic vessels in densely adipose tissue [58–60]. Venous insufficiency, characterized by impaired venous return and chronic venous hypertension, can contribute to lymphedema development or exacerbate existing lymphatic dysfunction. The coexistence of venous insufficiency and lymphedema may complicate treatment planning and require a multidisciplinary approach to address both vascular and lymphatic components [61] Scallan et al. Recurrent infections, such as cellulitis or lymphangitis, are common complications of lymphedema and can lead to acute exacerbations of swelling, pain, and tissue inflammation. The presence of recurrent infections may indicate underlying lymphatic dysfunction and may necessitate aggressive treatment with antibiotics, wound care, and lymphedema management strategies to prevent disease progression and recurrent episodes [62,63]. Assessing and addressing concurrent conditions is essential for optimizing lymphedema treatment outcomes and improving patient quality of life. A comprehensive evaluation that includes a thorough medical history, physical examination, and diagnostic testing is necessary to identify and manage comorbidities effectively. Multidisciplinary collaboration among healthcare providers, including lymphedema specialists, vascular surgeons, infectious disease specialists, and dermatologists, is often required to develop individualized treatment plans tailored to each patient's unique needs and circumstances.

2.4. Compliance and adherence to treatment: Compliance and adherence to treatment serve as critical predictors for lymphedema management, significantly influencing treatment outcomes and overall effectiveness. Lymphedema treatment often involves a combination of therapeutic modalities, such as compression therapy, manual lymphatic drainage (MLD), exercise, and skincare, which require consistent and ongoing participation from patients. Research indicates that patient compliance with prescribed treatment regimens is associated with better outcomes in lymphedema management. Adherence to compression garment wear, in particular, has been shown to correlate with reductions in limb volume, improved lymphatic function, and decreased risk of disease progression [64] Kwan et al. Similarly, regular attendance at MLD sessions and engagement in prescribed exercise programs have been associated with improved symptom control and enhanced quality of life for individuals with lymphedema [65]. Conversely, non-compliance or poor adherence to treatment recommendations can impede treatment success and lead to suboptimal outcomes. Factors contributing to non-compliance may include discomfort or difficulty associated with treatment modalities, lack of awareness or understanding of the importance of treatment, or psychosocial barriers such as depression or anxiety [66]. Non-compliance with compression therapy, for example, has been identified as a significant predictor of recurrent cellulitis and disease exacerbation in patients with lymphedema [67]. Assessing and addressing barriers to compliance and adherence is essential for optimizing treatment outcomes in lymphedema management. Healthcare providers play a crucial role in educating patients about the importance of treatment adherence, addressing concerns or misconceptions, and providing support and encouragement throughout the treatment process. Patient-centered approaches that take into account individual preferences, lifestyle factors, and treatment goals can help enhance treatment engagement and improve long-term outcomes for individuals living with lymphedema.

2.5. Baseline limb volume and circumference: Baseline limb volume and circumference serve as important predictors for lymphedema management, providing valuable information about disease severity, progression, and treatment response. These baseline measurements serve as benchmarks for assessing changes in limb size over time and evaluating the effectiveness of therapeutic interventions. Several studies have demonstrated the utility of baseline limb volume and circumference measurements as predictors for lymphedema outcomes. For example, research by Stout Gergich et al. found that baseline limb volume was significantly associated with treatment response, with larger

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baseline volumes predicting greater reductions in limb size following Complete Decongestive Therapy (CDT) in patients with breast cancer-related lymphedema [68]. Similarly, baseline limb circumference measurements have been shown to correlate with disease severity and functional impairment in individuals with lymphedema, with larger circumferences indicating more advanced disease and poorer treatment outcomes [69] Rockson et al. In addition to assessing disease severity, baseline limb volume and circumference measurements can help identify individuals at higher risk for lymphedema development or progression. For example, preoperative limb volume measurements have been used to predict the likelihood of developing lymphedema following cancer treatment, allowing for early intervention and preventive measures in high-risk individuals [70] Shah et al.. Furthermore, baseline measurements are essential for individualizing treatment plans and monitoring patient progress over time. By establishing baseline values, healthcare providers can track changes in limb size, assess treatment response, and make adjustments to therapy as needed. Regular monitoring of limb volume and circumference allows for early detection of disease recurrence or progression, enabling timely intervention to prevent complications and optimize treatment outcomes. Baseline limb volume and circumference measurements are valuable predictors for lymphedema management, providing essential information for treatment planning, monitoring, and optimizing therapeutic interventions.

2.6. Age and body mass index (BMI): Age and body mass index (BMI) are important predictors for lymphedema development, progression, and treatment outcomes. Understanding the impact of age and BMI on lymphedema can help healthcare providers tailor treatment approaches and optimize patient care. Age is a significant predictor for lymphedema risk, with older individuals often being at higher risk due to factors such as decreased tissue elasticity, impaired lymphatic function, and increased comorbidities. Studies have shown that advancing age is associated with a higher prevalence of lymphedema, particularly in populations undergoing cancer treatment such as surgery and radiation therapy [71] DiSipio et al. Additionally, age-related changes in tissue structure and function may affect the response to lymphedema treatment. Older patients may have slower tissue healing, reduced mobility, and increased susceptibility to complications such as infections. Therefore, age should be considered when developing treatment plans and managing expectations for lymphedema outcomes.

Body mass index (BMI), a measure of body fat based on height and weight, is another important predictor for lymphedema risk and severity. Obesity is a well-established risk factor for lymphedema, as excess adipose tissue can compress lymphatic vessels, impair lymphatic flow, and increase fluid retention [72] Nitti et al.. Studies have shown that individuals with higher BMI are more likely to develop lymphedema following cancer treatment, particularly breast cancer-related lymphedema. Higher BMI is also associated with more severe lymphedema symptoms, poorer treatment outcomes, and increased risk of disease progression [64] Kwan et al. Furthermore, obesity can complicate lymphedema management by limiting the effectiveness of compression therapy, increasing the risk of cellulitis and skin breakdown, and exacerbating mobility issues. Therefore, addressing obesity and promoting weight management strategies are important components of comprehensive lymphedema care. In summary, age and BMI are important predictors for lymphedema risk, severity, and treatment outcomes. Healthcare providers should consider these factors when assessing patients for lymphedema, developing treatment plans, and implementing preventive measures.

2.7. Lymphedema Etiology: Understanding the etiology of lymphedema is essential for predicting disease progression, identifying individuals at risk, and optimizing treatment outcomes. Lymphedema can arise from various underlying causes, with primary and secondary etiologies playing distinct roles in disease manifestation and management.

2.7.1. Primary Lymphedema: Primary lymphedema is characterized by congenital abnormalities or developmental defects in the lymphatic system, leading to impaired lymphatic drainage and fluid accumulation. Genetic mutations or alterations in lymphatic vessel development can contribute to primary lymphedema, which may present at birth or later in life. The age of onset and specific genetic factors associated with primary lymphedema can influence disease severity, progression, and treatment response [73] Finegold et al.

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2.7.2. Secondary Lymphedema: Secondary lymphedema occurs as a result of damage, obstruction, or dysfunction of the lymphatic system secondary to external factors such as surgery, radiation therapy, trauma, infection, or underlying medical conditions. Common causes of secondary lymphedema include cancer treatment, particularly surgery and radiation therapy for breast cancer, gynecologic cancers, or melanoma. The extent of lymphatic damage, the presence of comorbidities, and the timing of intervention can all impact the development and progression of secondary lymphedema [74] Shaitelman et al.

Understanding the etiology of lymphedema allows healthcare providers to tailor treatment approaches based on the underlying cause and individual patient characteristics. For example, primary lymphedema may require lifelong management strategies to address congenital lymphatic abnormalities, whereas secondary lymphedema may benefit from early intervention to prevent or minimize lymphatic damage following cancer treatment. Additionally, knowledge of lymphedema etiology can help identify individuals at higher risk for developing the condition and implement preventive measures accordingly. Patients undergoing cancer treatment, lymph node dissection, or radiation therapy should be educated about the risk of lymphedema and encouraged to practice risk-reduction strategies such as skin care, exercise, and avoiding limb constriction.

2.8. Psychosocial Factors:Psychosocial factors play a significant role in predicting lymphedema outcomes, influencing treatment adherence, coping strategies, and overall quality of life for individuals living with the condition. Understanding the impact of psychosocial factors can help healthcare providers tailor interventions and support services to address the unique needs of patients with lymphedema. Some of the psychosocial factors are

2.8.1. Emotional Distress: Emotional distress, including anxiety, depression, and fear, is commonly reported among individuals with lymphedema and can significantly impact treatment adherence and disease management. Studies have shown that psychological distress is associated with poorer treatment outcomes, increased symptom burden, and decreased quality of life in patients with lymphedema [75] DiSipio et al. Addressing emotional distress through counseling, support groups, and mindfulness-based interventions can help improve coping strategies and enhance treatment engagement.

2.8.2. Body Image Concerns: Body image concerns are prevalent among individuals with lymphedema, particularly those undergoing cancer treatment, surgery, or lymph node dissection. Changes in body appearance, swelling, and alterations in clothing fit can contribute to feelings of self-consciousness, embarrassment, and social isolation. Body image concerns may affect treatment adherence and engagement in social activities, leading to decreased quality of life and psychological well-being [76] Byrne et al. Interventions focusing on body image acceptance, self-esteem enhancement, and adaptive clothing options can help mitigate the impact of body image concerns on lymphedema management.

2.8.3. Social Support: Social support plays a crucial role in predicting lymphedema outcomes, providing individuals with emotional, practical, and informational support to cope with the challenges of living with the condition. Studies have shown that perceived social support is associated with better treatment adherence, improved psychological well-being, and enhanced quality of life in patients with lymphedema [77] Fu et al. Engaging patients in support groups, peer mentoring programs, and educational workshops can foster social connections, reduce feelings of isolation, and promote resilience in managing lymphedema.

Psychosocial factors serve as important predictors for lymphedema outcomes, influencing treatment adherence, coping strategies, and quality of life. By addressing emotional distress, body image concerns, and enhancing social support, healthcare providers can optimize treatment engagement and improve overall well-being for individuals living with lymphedema.

2.9. Response to initial therapy: Response to initial therapy serves as a valuable predictor for lymphedema management, providing insight into treatment effectiveness, disease progression, and the need for additional interventions. The assessment of treatment response allows healthcare providers to tailor ongoing management strategies based on individual patient needs and optimize outcomes.

 doi:10.20944/preprints202410.0506.v1

2.9.1. Complete Decongestive Therapy (CDT): Complete Decongestive Therapy (CDT), comprising manual lymphatic drainage (MLD), compression therapy, exercise, and skincare, is the cornerstone of lymphedema management. Response to CDT can vary among patients, with some experiencing significant reductions in limb volume and improvement in symptoms, while others may have limited or partial responses. Studies have shown that early response to CDT is associated with better long-term outcomes, with patients achieving sustained reductions in limb size and improved quality of life [78] Heining et al.

2.9.2.Compression Therapy: Compression therapy, including the use of compression garments, bandaging, or pneumatic compression devices, is commonly employed to reduce limb swelling and maintain lymphatic function. Response to compression therapy can serve as a predictor for treatment outcomes, with patients demonstrating improved compliance, symptom control, and functional status experiencing better long-term results [68] Stout Gergich et al.

2.9.3. Exercise: Exercise plays a crucial role in lymphedema management, promoting lymphatic circulation, muscle pump activity, and tissue mobilization. Patients who respond favorably to exercise therapy typically experience reductions in limb volume, improved range of motion, and enhanced functional capacity. Response to exercise can serve as an indicator of treatment adherence and overall treatment success [79] Aguilera Eguia et al..

Assessing response to initial therapy allows healthcare providers to monitor treatment progress, identify barriers to improvement, and make timely adjustments to treatment plans. Lack of response or inadequate improvement may prompt the consideration of alternative treatment modalities, such as surgical interventions or advanced lymphedema therapies, to achieve optimal outcomes.

3. Influence of Skin Thickness on the Success of Decompressive Therapy of Lymphedema

Skin thickness can indeed play a significant role in the success of decompressive therapy for lymphedema. Lymphedema, characterized by the accumulation of protein-rich fluid in interstitial spaces due to impaired lymphatic drainage, often leads to tissue fibrosis and thickening of the skin over time. Skin changes in lymphedema include fibrosis, hyperkeratosis, and increased thickness, which can further compromise lymphatic function and exacerbate fluid accumulation.The effectiveness of decompressive therapy, such as manual lymphatic drainage (MLD), compression bandaging, and pneumatic compression devices, in managing lymphedema depends partly on the condition of the skin. Thickened skin can impede the efficacy of these therapies by reducing the ability of the lymphatic vessels to respond to external pressure and by limiting the mobility of underlying tissues. Studies have demonstrated that individuals with thicker skin due to lymphedema may experience poorer outcomes with standard compression therapy compared to those with thinner skin. For instance, a study by Moffatt et al. found that patients with thicker skin in chronic lymphedema had reduced response rates to compression therapy [80]. Similarly, research by Devoogdt et al. indicated that skin thickness was negatively correlated with the effectiveness of MLD in reducing limb volume in breast cancer-related lymphedema. Moreover, the presence of fibrotic tissue and increased skin thickness may necessitate modifications to conventional treatment approaches. Techniques such as scar tissue mobilization, deep tissue massage, or use of specialized bandaging materials may be required to address fibrosis and improve lymphatic drainage in individuals with thicker skin [81]. Therefore while decompressive therapies remain integral to the management of lymphedema, the influence of skin thickness on treatment outcomes cannot be overlooked. Clinicians should consider skin characteristics, including thickness and fibrosis, when designing individualized treatment plans for patients with lymphedema. In this review we will discuss some of the ways how skin thickness influence the success of decompressive therapy

3.1. Ease of Application: The ease of application of decompressive therapy on thickened skin can significantly influence the success of lymphedema management. Thickened skin, a common manifestation of chronic lymphedema, poses challenges in applying compression bandaging, pneumatic compression devices, and other therapeutic modalities effectively. Thickened skin can obstruct access to lymphatic vessels, hindering the transmission of external pressure from

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compression therapy to deeper tissues. This obstruction reduces the effectiveness of compression in promoting lymphatic drainage and reducing limb swelling [82].

Thickened skin alters the distribution of compression forces applied during therapy. Instead of exerting uniform pressure on the affected limb, compression may become uneven or concentrated on superficial layers, limiting its ability to penetrate deeper tissues where lymphatic vessels reside [83]. Thickened skin may restrict the mobility of underlying tissues, impeding the conformability of compression bandages or garments. Limited mobility can result in folds or creases in bandages, leading to pressure points, discomfort, and compromised efficacy of therapy [68]. The difficulty in applying compression therapy on thickened skin may deter patients from adhering to treatment regimens. Cumbersome application processes, discomfort, or concerns about skin integrity may lead to non-compliance, undermining the long-term success of therapy [84].

To address these challenges, clinicians may employ strategies to enhance the ease of application and effectiveness of decompressive therapy on thickened skin. Some of the ways which it can be done is by taking advanced pre-treatment measures such as skin moisturization, softening agents, or gentle massage can help improve skin pliability, facilitating the application of compression bandages or garments. Clinicians may also utilize specialized bandaging techniques or materials designed to accommodate thickened skin and promote optimal compression distribution. These may include multi-layer bandaging systems, custom-made compression garments, or alternative compression modalities such as intermittent pneumatic compression. Finally Providing patients with thorough education on proper application techniques, skin care practices, and the importance of adherence can empower them to overcome challenges associated with thickened skin and optimize treatment outcomes.

By addressing the ease of application on thickened skin, clinicians can enhance the effectiveness of decompressive therapy for lymphedema management, improve patient comfort, and promote long-term adherence to treatment regimens.

3.2. Tissue compliance: Tissue compliance, particularly with regard to skin thickness, plays a significant role in determining the success of decompressive therapy for lymphedema. Skin thickness affects tissue pliability and elasticity, which can influence the effectiveness of therapeutic interventions such as compression therapy and manual lymphatic drainage (MLD) in reducing limb swelling and improving lymphatic function. Skin thickness influences the ability of compression garments to exert adequate pressure on the underlying tissues and lymphatic vessels. Thicker skin may require higher compression pressures to achieve optimal lymphatic drainage and fluid reduction. Inadequate compression due to skin thickness limitations may result in suboptimal treatment outcomes and reduced efficacy of compression therapy in managing lymphedema [85] Partsch et al.. Skin thickness also affects the feasibility and effectiveness of manual techniques used in MLD. Thicker skin may present greater resistance to manual manipulation, making it challenging to mobilize lymph fluid and promote drainage. Additionally, excessive pressure or friction during MLD in individuals with thicker skin may lead to discomfort, skin irritation, or injury, compromising treatment adherence and efficacy [86,87]. Understanding the influence of skin thickness on tissue compliance is essential for tailoring decompressive therapy approaches to individual patient characteristics. Healthcare providers may need to adjust compression garment selection, compression bandaging techniques, or MLD protocols based on skin thickness measurements to ensure adequate tissue mobilization and lymphatic drainage. Strategies to improve tissue compliance, such as soft tissue mobilization, scar massage, or skin hydration, may also be incorporated into treatment plans to enhance treatment outcomes [88]. Regular assessment of skin thickness and tissue compliance is important for monitoring treatment progress and adjusting therapeutic interventions as needed. Changes in skin thickness over time may indicate alterations in tissue pliability and lymphatic function, providing valuable insights into treatment response and guiding adjustments to therapy. Multidisciplinary collaboration among healthcare providers, including lymphedema specialists, physiotherapists, and dermatologists, may be necessary to optimize treatment approaches and address skin-related concerns in lymphedema management [89] Czerniec et al. By considering these factors and implementing tailored treatment approaches,

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healthcare providers can optimize treatment outcomes and improve quality of life for individuals living with lymphedema.

3.3. Risk of complications: Skin thickness is a crucial factor influencing the success of decompressive therapy for lymphedema, as it can affect treatment outcomes and the risk of complications. Variations in skin thickness may predispose individuals to certain complications during therapy, potentially impacting treatment efficacy and patient outcomes. Thickened skin in individuals with lymphedema may be more susceptible to irritation, chafing, or damage from compression garments or bandaging. Excessive pressure or friction on the skin due to inadequate fitting or prolonged wear of compression garments can lead to skin breakdown, ulceration, or dermatitis, compromising treatment adherence and effectiveness [25] (Czerniec et al. Thickened skin associated with lymphedema may impair the skin's natural barrier function, making it more susceptible to bacterial or fungal infections. Compromised lymphatic drainage and impaired immune function in the affected limb further increase the risk of cellulitis, lymphangitis, or other infectious complications, requiring prompt medical intervention and potentially interrupting therapy [90]. Thicker skin in individuals with lymphedema may pose challenges in wound healing, particularly in cases of skin breakdown or ulceration. Impaired tissue perfusion, reduced oxygenation, and compromised immune function in the affected limb can delay wound healing, prolonging recovery time and hindering treatment progress. Wound care strategies tailored to the unique needs of individuals with lymphedema are essential to optimize healing and prevent further complications [91]. Skin thickness can influence treatment adherence and patient comfort during decompressive therapy for lymphedema. Individuals with thicker skin may experience discomfort, restriction of movement, or difficulty donning compression garments, leading to reduced compliance with treatment recommendations. Addressing skin-related concerns, optimizing garment fit, and providing supportive care can help enhance treatment adherence and improve patient comfort [92,93]. To address these issues healthcare providers should assess skin characteristics, monitor for signs of skin-related complications, and implement preventive measures to minimize risks and optimize treatment efficacy.

3.4. Lymphatic drainage: Skin thickness can significantly influence the success of decompressive therapy for lymphedema by affecting lymphatic drainage, which plays a crucial role in managing fluid accumulation and reducing limb swelling. Variations in skin thickness can impact lymphatic function and fluid dynamics, influencing treatment outcomes and the effectiveness of therapeutic interventions. Skin thickness may affect the capacity of lymphatic vessels to transport lymph fluid from the interstitial spaces back into the circulation. Thicker skin may pose greater resistance to lymphatic flow, impairing the drainage of excess fluid from the affected limb and contributing to lymphedema progression. Reduced lymphatic transport capacity due to thicker skin can hinder the effectiveness of decompressive therapy in alleviating limb swelling and improving tissue health [61] Scallan et al. Effective lymphatic drainage is essential for optimizing the benefits of compression therapy, a cornerstone of lymphedema management. Compression garments or bandaging exert external pressure on the tissues, promoting lymphatic uptake and enhancing fluid movement towards the lymphatic collectors. Thicker skin may impede the transmission of compression forces to deeper tissues, limiting the efficacy of compression therapy in reducing limb volume and maintaining lymphatic function [94] Partsch et al. Manual techniques such as MLD aim to stimulate lymphatic vessels and enhance lymphatic drainage, facilitating the removal of protein-rich fluid from the interstitial spaces. Thicker skin may present greater resistance to manual manipulation, making it challenging to mobilize lymph fluid and promote drainage. Adequate pressure and precise technique are essential to overcome skin resistance and achieve optimal lymphatic transport during MLD sessions [95]. Advanced lymphedema therapies, such as pneumatic compression devices or low-level laser therapy, may complement decompressive therapy by promoting lymphatic drainage and reducing tissue fibrosis. These modalities target lymphatic vessels and surrounding tissues, aiming to improve lymphatic function and fluid clearance. However, the effectiveness of adjunctive therapies may be influenced by skin thickness and tissue compliance, highlighting the importance of individualized treatment approaches [96]. Therefore skin thickness can impact lymphatic drainage

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and fluid dynamics, influencing the success of decompressive therapy for lymphedema. Understanding the interplay between skin characteristics and lymphatic function is essential for optimizing treatment outcomes and improving quality of life for individuals living with lymphedema.

3.5. Response to treatment: The response to treatment in lymphedema management is influenced by various factors, including skin thickness, which can impact the success of decompressive therapy. Skin thickness affects tissue compliance, lymphatic drainage, and the effectiveness of therapeutic interventions, ultimately shaping treatment outcomes and patient satisfaction. Skin thickness may influence treatment adherence and patient compliance with decompressive therapy. Individuals with thicker skin may experience discomfort, restricted mobility, or difficulty donning compression garments, leading to reduced adherence to treatment recommendations. Poor treatment adherence can compromise treatment efficacy and hinder the achievement of optimal outcomes [25] Czerniec et al. Skin thickness can affect lymphatic drainage and fluid dynamics, which are essential for reducing limb swelling and improving tissue health in lymphedema. Thicker skin may impede lymphatic vessel function and hinder the removal of excess fluid from the interstitial spaces, limiting the effectiveness of decompressive therapy. Response to treatment may be influenced by the degree of tissue compliance and the ability to mobilize lymph fluid effectively [61] Scallan et al. Response to treatment serves as a predictor for the success of decompressive therapy in lymphedema management. Patients who demonstrate favorable responses, such as reductions in limb volume, improvements in symptoms, and enhanced functional status, are more likely to achieve long-term treatment goals and maintain optimal outcomes. Monitoring treatment response allows healthcare providers to adjust therapeutic interventions and optimize treatment approaches based on individual patient needs [97] Damstra et al. Understanding the relationship between skin thickness and treatment response is essential for tailoring decompressive therapy approaches to individual patient characteristics. Healthcare providers may need to adjust treatment protocols, compression garment selection, or manual techniques based on skin thickness measurements and treatment progress. Personalizing treatment plans according to patient-specific factors can enhance treatment efficacy and improve patient satisfaction [98]. By considering skin characteristics and their impact on treatment outcomes, healthcare providers can optimize treatment approaches, improve treatment adherence, and enhance overall patient care.

However, some evidences show that skin thickness does not affect the success of decompressive therapy. Perez et al. showed that increased skin thickness due to biophysical alterations in lymphedema does not affect the success of decompressive therapy. This is inferred from the consistent increase in subcutaneous tissue thickness and echogenicity across various measurements, indicating fibrosis without differing outcomes between affected and unaffected limbs [99]. In other study published by Yoshida et al. the study study highlights that skin thickness does not directly influence the success of decompressive therapy such as liposuction followed by compression therapy. Instead, the stability and level of compression applied postoperatively are critical for a successful outcome in lymphedema treatment [100]. According to the review by Forte et al. successful management of lymphedema through lipoaspiration and controlled compressive therapy does not specifically depend on skin thickness. The main factor is the continuation of compressive therapy to maintain reduced limb volume and other benefits such as improved skin blood flow and decreased infection incidence [101]. In another study by Lanza et al. the authors show that the success of decompressive therapy, measured by limb volume reduction and quality of life improvement, is more influenced by the frequency and method of treatment rather than skin thickness. The absence of direct correlation between skin thickness and therapeutic response underscores that other factors, such as treatment adherence and protocol, play a more significant role [102]. In a study conducted by Can et al. eventough the study supports that while skin thickness might alter due to lymphedema, its impact on the efficacy of decompressive therapies like compression alone is less significant compared to other factors such as patient adherence and proper application of compression therapy [47]. A report published by Tidhar et al. indicates that effective self-management and adherence to prescribed compression therapies can lead to significant edema volume reduction, regardless of skin

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thickness changes in lymphedema. The focus is on patient independence and adherence to therapy rather than physiological changes such as increased skin thickness [103].

While skin thickness can be a consideration in lymphedema management, it is just one of several factors that healthcare providers take into account when planning and implementing decompressive therapy. Individualized assessment, including evaluation of skin condition, tissue characteristics, and overall patient health, is necessary to tailor treatment approaches and optimize outcomes for each patient with lymphedema. Additionally, close monitoring and ongoing adjustments to the treatment plan may be needed to address changes in skin thickness and other factors over time.

4. Influence of Fat Layer Thickness on the Success of Decompressive Therapy of Lymphedema

The thickness of the fat layer can indeed influence the success of decompressive therapy for lymphedema.

4.1. Impact on Compression Therapy: The thickness of the fat layer affects the distribution of external pressure exerted by compression garments or bandaging. In individuals with thicker fat layers, achieving adequate pressure to promote lymphatic drainage and reduce limb swelling may be more challenging. Compression therapy relies on consistent pressure to facilitate fluid movement and maintain tissue health. Thicker fat layers may require customized compression garments or specialized bandaging techniques to ensure optimal compression and treatment efficacy [94] Partsch et al. Many different factors contribute to the success of the compression therapy. Some of them are outlined in this review. One is optimal Pressure Distribution where compression effectiveness relies on consistent pressure to promote lymphatic drainage, reduce limb swelling, and prevent fluid accumulation. Thicker fat layers may require customized compression garments or specialized bandaging techniques to ensure optimal pressure distribution and treatment efficacy [104]. The other factor which can influence the success of of decompressive therapy in lymphedema is to improve lymphatic transport. Compression therapy aims to improve lymphatic transport by enhancing the uptake of lymph fluid into lymphatic vessels and promoting fluid movement towards the lymphatic collectors. Thicker fat layers can impede lymphatic flow and hinder the effectiveness of compression therapy in facilitating fluid clearance. Compression garments or bandages must exert sufficient pressure to overcome tissue resistance and stimulate lymphatic transport in individuals with thicker fat layers. Tailoring compression protocols based on adipose tissue thickness is essential for optimizing lymphatic function and treatment outcomes [105]. It is also important here to address tissue compliance as the thickness of the fat layer influences tissue compliance, which refers to the ability of tissues to expand and contract in response to external pressure. Thicker fat layers may exhibit reduced tissue compliance, making it challenging to achieve adequate compression and maintain therapeutic efficacy. Compression garments or bandages must effectively compress the underlying tissues without causing discomfort or restricting mobility. Adjusting compression parameters and garment selection based on adipose tissue thickness can enhance treatment effectiveness and improve patient comfort [2]. The other very important factor is Enhancing Treatment Adherence. The effectiveness of compression therapy is closely linked to treatment adherence and patient satisfaction. Individuals with thicker fat layers may experience difficulty donning compression garments or bandages, leading to reduced compliance with treatment recommendations. Healthcare providers should assess adipose tissue thickness and provide education and support to address barriers to treatment adherence. Customized compression solutions and patient-centered care strategies can enhance treatment effectiveness and improve outcomes in individuals with lymphedema [106].

In summary, the thickness of the fat layer influences the effectiveness of compression therapy in lymphedema management by affecting pressure distribution, lymphatic transport, tissue compliance, and treatment adherence. Tailoring compression protocols to address adipose tissue thickness is essential for optimizing treatment outcomes and improving quality of life for individuals living with lymphedema.

4.2. Role in Lymphatic Drainage: The fat layer contributes to tissue compliance and influences lymphatic drainage dynamics. Excessive adipose tissue can compress lymphatic vessels and impede

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lymphatic flow, exacerbating fluid accumulation and lymphedema progression. Thicker fat layers may hinder the effectiveness of decompressive therapy by restricting lymphatic transport and limiting the removal of excess fluid from the interstitial spaces. Addressing adipose tissue thickness is essential for optimizing lymphatic drainage and enhancing treatment outcomes in individuals with lymphedema [61] Scallan et al. The thickness of the fat layer significantly influences fluid distribution in lymphedema management, impacting the dynamics of fluid accumulation, lymphatic transport, and treatment efficacy. In many ways. In individuals with thicker fat layers, lymphatic vessels may encounter increased resistance to fluid uptake, leading to impaired lymphatic transport and exacerbation of fluid accumulation in the affected limb. This impediment to lymphatic drainage contributes to the progression of lymphedema and challenges in managing fluid distribution effectively [106]. It can also pose challenges in compression therapy. Thicker fat layers pose challenges in achieving optimal compression during therapy, which is essential for promoting lymphatic drainage and reducing limb swelling. Compression garments or bandages may struggle to exert sufficient pressure on the underlying tissues, particularly in areas with thicker fat deposits. Inadequate compression due to adipose tissue thickness limitations may result in uneven fluid distribution, suboptimal treatment outcomes, and difficulty in maintaining therapeutic efficacy [107]. Thick fat layer can have profound impact on tissue Compliance. Adipose tissue thickness influences tissue compliance, affecting the ability of tissues to accommodate changes in fluid volume and respond to external pressure. Thicker fat layers may exhibit reduced tissue compliance, making it challenging to redistribute fluid effectively and achieve desired treatment goals. Decreased tissue compliance can contribute to persistent swelling, tissue fibrosis, and functional impairment, highlighting the importance of addressing adipose tissue thickness in lymphedema management [108]. Considering the thickness of the fat layer is crucial for tailoring treatment approaches and optimizing fluid distribution in lymphedema management. Healthcare providers should assess adipose tissue thickness and customize treatment plans to address individual patient characteristics. Strategies to enhance lymphatic drainage, such as manual lymphatic drainage (MLD), pneumatic compression therapy, or adjunctive modalities, may be employed to overcome fluid distribution challenges and improve treatment outcomes [109]. Overall the thickness of the fat layer influences fluid distribution in lymphedema management by impacting lymphatic drainage, compression therapy efficacy, tissue compliance, and treatment tailoring considerations. Understanding the interplay between adipose tissue thickness and fluid dynamics is essential for optimizing treatment strategies and improving outcomes for individuals living with lymphedema.

4.3. Challenges in Manual Techniques: Manual lymphatic drainage (MLD), a key component of decompressive therapy, may encounter challenges in individuals with thicker fat layers. Manipulating lymph fluid through manual techniques requires precise pressure and technique to penetrate deeper tissues and stimulate lymphatic vessels. Thicker fat layers may necessitate modifications to MLD protocols or the use of adjunctive therapies to enhance lymphatic transport and facilitate fluid clearance. Tailoring treatment approaches based on adipose tissue thickness is essential for optimizing treatment efficacy and improving patient outcomes [110]. There are many different ways the fat layer can impact MLD. It can effect the Penetration Depth. The thickness of the fat layer impacts the ability of manual techniques to penetrate deeper tissues and stimulate lymphatic vessels effectively. In individuals with thicker fat layers, achieving sufficient penetration depth during MLD sessions may be challenging. The increased distance between the skin surface and underlying lymphatic vessels can hinder the transmission of manual pressure and diminish the effectiveness of lymphatic drainage techniques. Adjustments in pressure intensity or technique may be necessary to overcome adipose tissue thickness limitations and optimize treatment outcomes [111]. The other way fat layer thickness can pose pose problem is by challenging fluid Mobilization. Thicker fat layers present obstacles in mobilizing lymph fluid and promoting fluid movement towards the lymphatic collectors. Manual techniques rely on precise pressure and rhythmic movements to stimulate lymphatic vessels and facilitate fluid clearance. In individuals with thicker fat layers, the resistance encountered by manual manipulation may impede fluid mobilization and compromise treatment efficacy. Strategies to enhance tissue compliance and overcome adipose tissue thickness

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barriers are essential for improving the response to manual techniques in lymphedema management [112]. Thick fat layer can have impact on Treatment Duration. The response to manual techniques may be influenced by the duration and frequency of treatment sessions, which can vary based on adipose tissue thickness and treatment goals. Individuals with thicker fat layers may require longer treatment durations or more frequent sessions to achieve comparable lymphatic drainage outcomes. Healthcare providers should consider adipose tissue thickness when planning treatment regimens and adjust session parameters accordingly to optimize treatment response and patient satisfaction [113]. To address the above problems tailoring Techniques to individual Patient needs to be adopted. Adapting manual techniques to address adipose tissue thickness is essential for tailoring treatment approaches and optimizing treatment outcomes in lymphedema management. Healthcare providers may employ modified MLD protocols, alternative manual techniques, or adjunctive therapies to enhance lymphatic drainage and overcome adipose tissue thickness limitations. Personalizing treatment plans based on individual patient characteristics ensures that manual techniques are applied effectively and contribute to improved fluid distribution, symptom relief, and functional improvement [114]. Healthcare providers should assess adipose tissue thickness, along with other patient-specific factors, to tailor treatment plans and select appropriate interventions. Customized compression garments, targeted manual techniques, and adjunctive therapies can be implemented to address adipose tissue thickness and enhance lymphatic function, ultimately improving treatment success and patient satisfaction [115]. Understanding the interplay between adipose tissue thickness and treatment efficacy is essential for optimizing manual lymphatic drainage and enhancing outcomes for individuals living with lymphedema.

4.4. Surgical considerations: The thickness of the fat layer can significantly influence surgical considerations in lymphedema management, impacting surgical planning, procedural feasibility, and treatment outcomes. Thicker fat layers present challenges in surgical accessibility and exposure, particularly in procedures aimed at lymphatic vessel reconstruction or debulking. Surgeons may encounter difficulty in visualizing and accessing lymphatic structures or performing tissue excision in individuals with thicker fat layers. Adequate exposure and access to target tissues are essential for performing surgical interventions effectively and minimizing intraoperative complications. Thicker fat layers may necessitate modifications to surgical techniques or the use of adjunctive approaches to optimize surgical outcomes [116]. Thick fat layer thickness will also increase the risk of surgical complications, including wound healing issues, infection, and tissue necrosis. In individuals with lymphedema and thicker fat layers, compromised tissue vascularity and lymphatic dysfunction may impair wound healing processes and predispose to postoperative complications. Surgeons must carefully evaluate adipose tissue thickness and patient-specific risk factors when planning surgical interventions to minimize the risk of adverse outcomes and optimize patient safety [117].

The success of surgical interventions in lymphedema management is also effected by the thickness of fat layer. Procedures such as lymphaticovenous anastomosis (LVA) or lymph node transfer aim to improve lymphatic drainage and reduce limb swelling. Thicker fat layers may pose challenges in achieving optimal lymphatic vessel identification, anastomosis creation, or lymph node transplantation, potentially compromising the effectiveness of surgical treatments. Preoperative assessment of adipose tissue thickness is essential for predicting surgical feasibility and optimizing treatment outcomes [42]. Considering the thickness of the fat layer is crucial for patient selection and counseling regarding surgical options in lymphedema management. Individuals with thicker fat layers may require alternative surgical approaches or adjunctive therapies to achieve desirable outcomes. Surgeons should discuss the potential benefits, risks, and limitations of surgical interventions with patients, taking into account adipose tissue thickness and individual treatment goals. Patient education and informed decision-making are essential for ensuring realistic expectations and maximizing patient satisfaction with surgical outcomes [118]. Understanding the implications of adipose tissue thickness on surgical interventions is essential for optimizing treatment strategies and improving outcomes for individuals living with lymphedema.

4.5. Adherence to treatment: Individuals with thicker fat layers may experience challenges in donning compression garments due to the increased difficulty in fitting tight-fitting garments over

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the affected limb. The process of donning compression garments may be time-consuming and physically demanding, particularly if the fat layer thickness restricts mobility or flexibility. These difficulties can discourage patients from consistently wearing compression garments as prescribed, leading to non-adherence to treatment recommendations [119]. Thicker fat layers can exacerbate discomfort and skin irritation associated with wearing compression garments, as the increased pressure exerted by the garments may cause discomfort or pain. Individuals with thicker fat layers may be more prone to developing pressure sores, chafing, or skin irritation beneath compression garments, leading to discomfort and reduced adherence to treatment protocols. Addressing issues related to garment fit and comfort is essential for promoting treatment adherence and minimizing patient discomfort [120]. The presence of thicker fat layers can also limit access to the affected limb for self-care activities, such as skin care, manual lymphatic drainage (MLD), or bandaging. Difficulty accessing the affected limb may hinder patients' ability to perform essential components of their treatment regimen, resulting in suboptimal treatment adherence. Healthcare providers should assess adipose tissue thickness and provide education and support to help patients overcome barriers to self-care activities and promote treatment adherence [121]. Thicker fat layers may contribute to negative body image perceptions and psychological distress in individuals with lymphedema. Feelings of embarrassment, self-consciousness, or dissatisfaction with body appearance may influence treatment adherence by affecting patients' motivation to engage in self-care activities or wear compression garments regularly. Addressing psychological factors and providing psychosocial support are essential for promoting treatment adherence and improving patient well-being in lymphedema management [122]. Understanding the impact of adipose tissue thickness on treatment adherence is essential for developing patient-centered treatment approaches and optimizing outcomes for individuals living with lymphedema.

Overall, while the thickness of the fat layer can pose challenges in lymphedema management, healthcare providers can adapt treatment strategies to accommodate individual patient needs and optimize outcomes. This may involve a combination of compression therapy, manual techniques, exercise, skincare, and, in some cases, surgical interventions tailored to the specific characteristics of each patient's condition.

5. Conclusions

Lymphedema, a debilitating condition marked by the accumulation of lymphatic fluid and subsequent swelling, can significantly impair an individual's quality of life and functional capacity. The comprehensive management of lymphedema through decongestive therapy, which combines manual lymphatic drainage, compression therapy, skin care, and exercise, is essential for mitigating the physical and psychological burdens of the disease.

The efficacy of decongestive therapy largely hinges on several critical factors. Early diagnosis and the timely initiation of therapy play pivotal roles in preventing the progression of lymphedema to its more severe, often irreversible stages. Adherence to a meticulously tailored therapeutic regimen that includes all components of complete decongestive therapy is crucial for achieving optimal outcomes.

Moreover, recent research has illuminated the significant influence of both skin and adipose tissue characteristics on the success of decongestive therapy. Increased skin thickness and a higher volume of adipose tissue have been identified as factors that can diminish the effectiveness of traditional decongestive methods, necessitating adjustments in therapy that may include more advanced techniques such as surgical interventions or specialized compression protocols.

In conclusion, managing lymphedema effectively requires a nuanced approach that considers the individual characteristics of the lymphedema and the patient. Successful outcomes are most likely when therapy is personalized, initiated early, and diligently followed, with adaptations made as necessary to address the specific challenges posed by the physical properties of affected tissues. Continued research into the predictors of therapeutic success and the impacts of tissue characteristics will further enhance our ability to provide targeted and effective interventions for those suffering from lymphedema.

 doi:10.20944/preprints202410.0506.v1

Conflict of Interest: Non Declared.

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