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Lymphedema

Role of Truncal Clearance as a Therapy Component

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Lymphedema is increasingly being seen in patients receiving home health care and throughout the general population. Substantial risks of complications are associated with failure to recognize its presence, worsening of the condition and the use of inadequate or incomplete therapy. Therapeutic truncal clearance as a component of therapy is universally accepted by professional therapists as being essential, but often rejected by third-party payers. This therapeutic component is based on sound physiological principles, but there has not been, nor will there likely be, peer-reviewed testing because it is deemed unethical to subject patients to therapy without its use. We believe that if the physiological basis for this therapy were more widely understood, its absolute need would be better recognized. Thus, our goal is to describe those lymphatic system features that directly impact lymphedema development and complications emphasizing the role of and scientific basis for truncal clearance as an essential treatment component.

Keywords: *lymphedema; cancer complications; lymphedema therapy; lymphedema management; breast cancer*

Lymphedema is the accumulation of excessive amounts of fluid containing a high protein concentration in tissues. Primary lymphedema arises from genetic disorders that may cause congenital lymphedema manifest at birth or by 2 years of age (Ersek, Danese, & Howard, 1966; Fonkalsrud, 1969), lymphedema praecox manifest at puberty (Saliba, Sawyer, Sawyer, & Sawyer, 1963), or lymphedema tarda manifest later in life but usually before age 35 (Majeski, 1986). Secondary lymphedema is acquired as a complication of conditions including surgery and/or radiation treatment for breast cancer, gynecological and prostate surgery, and melanoma. In developing countries, the major cause is microfilaria-related infections.

A literature review regarding lymphedema incidence and/or prevalence indicates for the primary form a prevalence of 1.15/100,000 in persons younger than 20 years of age, with primary forms accounting for 8% to 28% of non-cancer-related lymphedema (Rockson & Rivera, 2008). For cancer-related forms of lymphedema, incidence depends on the specific diagnosis, anatomical location, surgical procedure, and use of radiotherapy. Reported incidence estimates range from 5% for sentinel node biopsy done in relation to breast cancer exploration to 49% associated with surgical and radiation treatment for cervical cancer (Rockson & Rivera, 2008).

Lymphedema is a chronic condition and presents significant challenges to patients, health care providers, and the health management system. This problem is not new. Nearly 100 years ago, breast cancer treatment

> in about one-sixth of cases produces lymphedema of the corresponding arm from obstruction of the lymph-vessels, and the same condition commonly ensues upon the thorough removal of the axillary nodes. On an average, these patients survive less than a year, and generally suffer great pain, as well as almost total incapacity of the limb, from interference with joint movement and the heavy burden of the water-logged member. (Gerish, 1913, p. 233)

Throughout the intervening years, survival rates have improved significantly, but the duration that affected persons must cope with the lymphedematous burden has also increased. Patient education and lymphedema treatment has improved, reducing the lymphedematous burden somewhat. Encouragingly, recent research into early detection of incipient lymphedema holds the promise of earlier treatment to lessen the lymphedema burden further.

However, in part because nonpractitioners and third party payers lack familiarity with lymphatic system features and the dependence of therapy on these features, it is not always easy for these groups to appreciate the need for the various therapeutic components. The potential unintended consequence is to limit availability of therapy components. Thus, although they have a sound physiological basis, the consequences may not be well documented.

Of particular relevance is the concept and practice of treating the core (truncal) lymphatics as a major treatment component. The essence of this concept is that treatment must first be directed at lymphatic territories, such as the trunk, so that they are adequately prepared to receive lymph from subsequently treated lymphedematous regions such as the arm or leg. Treating truncal lymphatics is also needed in the presence of often unrecognized acute truncal edema. This truncal clearance or decongestion approach makes intuitive sense to most intensively trained practitioners. Beyond textbook descriptions of the rationale for its use (Foldi, Foldi, & Kubik, 2003), however, there has been little discussion of how the lymphatic system's physical, anatomical, and physiological features combine to lay the basis for this truncal clearance approach, although previous discourse in this journal has opened important discussion about lymphedema therapy (Korosec, 2004).

Failure to recognize the importance of treating the truncal lymphatics may be associated with significant risk to the patient and poor overall outcomes. Some stakeholders, including third party payers and others, look for substantial clinical trials to demonstrate the need and effectiveness of truncal treatment. However, the importance of core decongestion is so rooted in scientific understanding of lymphatics that it is unethical to conduct such a study:

> To direct fluid towards the groin or axilla of a lymphedematous limb without decongesting the truncal quadrants first, especially if the regional lymph nodes have been removed or are diseased, defies an understanding of basic anatomy and physiology. (M. Foeldi, 1994, p. 5)

Because of the clinical importance of this issue, the main goal of this communication is to describe those lymphatic system features that most directly affect lymphedema development and complications emphasizing preparatory truncal clearance as an essential treatment component. The aim is to provide a basis from which health care management and clinical practice judgments can be made in an informed manner based on our current understanding of the principles underlying the lymphedematous condition. This information will also help us understand newly emerging lymphedema detection and therapeutic methods and strategies in clinical practice.

Overview of the Physiological Basis of Lymph Formation and Its Transport

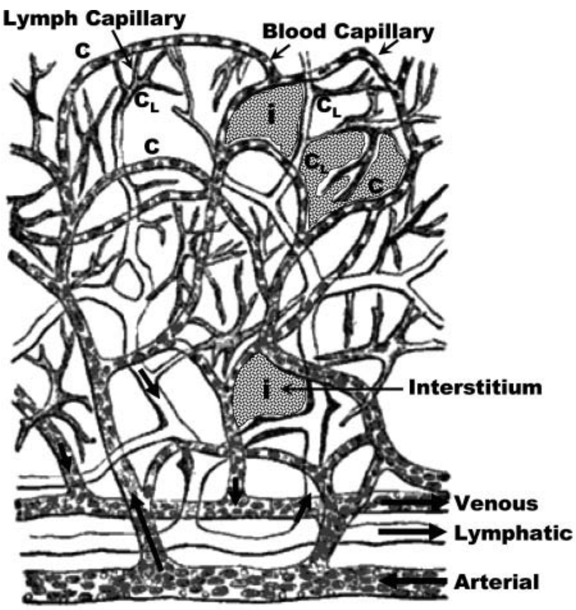
The significance of truncal clearance cannot be adequately appreciated without referring to certain underlying principles governing lymph fluid formation and transport within and out of lymphatic pathways. The purpose of this section is to elucidate the features of fluid balance, lymphatic overload, and anatomical pathways. Details of their relationship to lymphedema treatment are discussed in the following section.

Fluid Balance

Body tissues receive nourishment and have waste products removed through an interaction between blood circulatory and lymphatic systems. The initial complex vessel network is illustrated in Figure 1, and the situation for a single blood capillary and lymphatic capillary is illustrated in Figure 2.

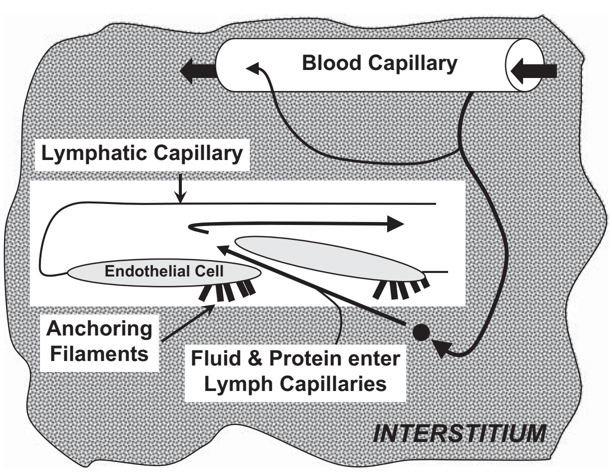
Blood pumped by the heart moves through decreasingly smaller arteries (A) until it reaches blood capillaries (C), whereupon oxygen and other nutrients move across the capillary wall to supply cells and tissues. In this process, fluids also move into the tissue spaces, collectively called the interstitial space or the interstitium (I). In addition, waste products residing in the interstitium are transferred to blood capillaries, and most of the filtered fluid is reabsorbed. Capillary blood then flows into small collecting venules that converge to form larger and larger veins (V) that finally return the blood to the heart. The action of the lymphatic system in this overall process is to remove excess fluid from the interstitium, as well as proteins, cellular debris, viruses, and bacteria. This process begins with fluids, leaked proteins, and other substances in the interstitium entering into lymphatic capillaries (C_L) that abound and surround blood capillaries. These lymph capillaries unite with others to form a network of wider vessels that serve as a regional tissue drainage system (L). As regional lymph vessels

Figure 1
Schema of Regional Vascular and Lymphatic Networks



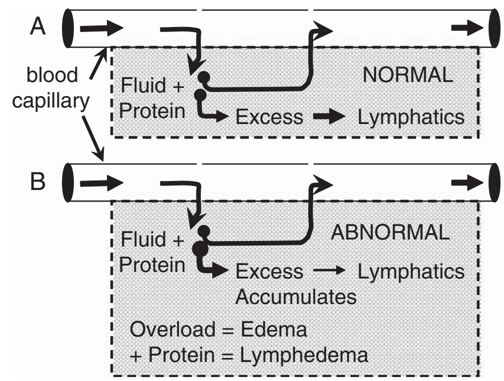
Note: Arteries (A) supply blood to blood capillaries (C). Excess fluids entering the interstitial space (I) are taken up by the lymphatic capillaries (C_L) and removed via the network of lymphatic vessels (L). Blood is returned via the network of venous vessels (V).
Source: Adapted from Kirkes (1857).

Figure 2
Relationship of Blood Capillaries to Lymphatic Capillaries



Note: Fluid and cellular uptake into lymphatic capillaries depends on movement of material through openings between adjacent endothelial cells that compose the lymphatic capillary wall. Increased fluid pressure in the interstitium promotes opening of these interendothelial cell junctions.

Figure 3
Fluid and Protein Accumulation in the Interstitial Space



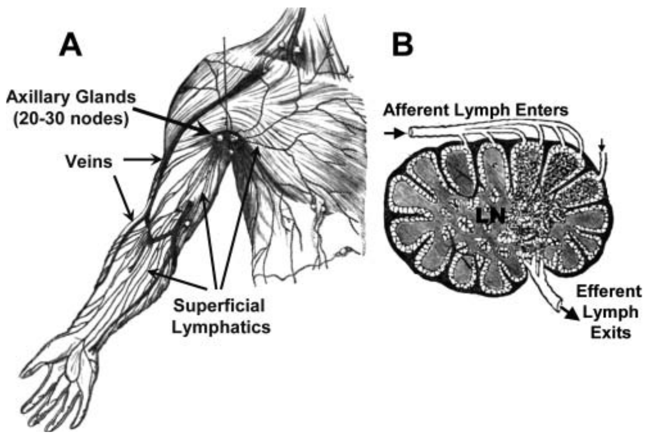
Note: If the combined capacities of capillary reabsorption and lymphatic drainage are exceeded, fluid accumulates, causing edema. If the protein concentration also rises because of inadequate lymphatic drainage, then lymphedema results.

become larger, they follow a path similar to veins and resemble them in structure with the presence of numerous one-way valves. Ultimately, lymphatic vessels carrying drainage fluid and its contents (lymph) combine and empty into large veins in the thorax via the thoracic duct that connects to an opening in the junction of the left internal jugular and subclavian veins and also via a corresponding smaller trunk that drains into the corresponding part on the right side.

Overload

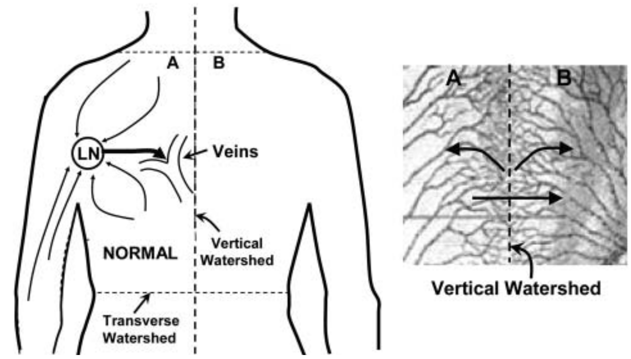
The amount of fluid and other substances, such as protein, that remain or accumulate within the interstitium depends on how much enters from blood capillaries into the interstitium in relation to how much is removed from the interstitium by reabsorption into blood capillaries and via lymphatic drainage. Although some fluid can be reabsorbed by capillaries as illustrated in Figure 3a, macromolecules such as protein and cellular debris cannot, so their removal is entirely dependent on lymphatic function. Excess tissue fluid (edema) accumulates if the balance between interstitial fluid formation exceeds its removal rate because of the combined actions of reabsorption into blood capillaries and lymphatic drainage (Figure 3b). Imbalances also can occur if the net flux of fluid from blood capillaries increases or lymphatic drainage decreases. Untoward increases in capillary blood pressure, derangements of the capillary wall, and decreases in the blood's protein concentration all cause edema. If there is a dysfunction of lymphatic drainage (for example, because

Figure 4
Diagram of Drainage Toward and Through Axillary Lymph Nodes



Note: A. Overview of superficial lymphatics draining toward the axillary nodes. Modified from Anatomy (1901). B. View of lymph fluid entering and leaving a node. Removal of a node prevents the afferent lymph to continue on its normal course to be collected back into the venous system. Modified from Kimber (1902, p. 147).

Figure 5
Schematic Overview of Main Elements for Lymph Drainage of the Right Arm



Note: LN represents axillary lymph nodes. A and B correspond to the ipsilateral and contralateral quadrants, respectively, on either side of the vertical watershed. The inset shows a more detailed depiction of a portion of the myriad of lymphatic vessels that are bounded by the watershed. Lymph normally drains away from this area into nodes in the corresponding quadrant. However, lymph flow can be directed across the watershed into the contralateral quadrant with proper applied therapy, as depicted by the arrow from A to B.

of removal of lymph nodes or radiation that injures lymphatic vessels), then in addition to a build up of interstitial fluid, there is also an increase in protein and other substances in the interstitium, resulting in the condition described as lymphedema. The increase in protein concentration in the interstitium acts as a "magnet" because of osmotic forces and causes more fluid to enter and remain in the interstitial space.

Pathways

The lymphatic system consists of an enormous number of lymphatic vessels, punctuated with lymph glands (nodes) that course through the body in association with blood vessels. The ultimate movement of lymph through these vessels is directed toward specific entry points into the venous system. To introduce this aspect, we first briefly consider lymphatic drainage of the right arm.

Under normal healthy conditions, axillary lymph nodes receive most of the lymph fluid from the upper extremity (see Figure 4a) via superficial and deep lymphatic channels and also from the ipsilateral quadrant of the trunk via multiple pathways (Foldi & Foldi, 1991). Some lymph drainage from the upper extremity also passes through the supraclavicular and infraclavicular nodes, bypassing the axillary nodes (Weissleder & Schuchhardt, 1997). Lymph enters lymph nodes (LN) via afferent channels and exits the lymph nodes via efferent channels (see Figure 4b). It is collected by lymphatic vessels that join major trunks to empty into the venous system via junctions within the venous angle as schematized in Figure 5.

If one or more axillary nodes are removed as part of breast cancer treatment, then the ability of upper extremity lymphatic channels and all trunk tributaries of the relevant quadrant to move lymph out of their respective territories are reduced. This reduction depends on the number of lymph nodes removed, their prior share of the overall drainage load, and other effects associated with the surgery and therapeutic radiation. Subsequent effects depend on the extent of lymphatic channels with direct connections to the venous system (Edwards & Kinmonth, 1969), the presence of anastomotic lymph collectors connecting the affected quadrant to the contralateral axillary and supraclavicular nodes, and differences of upper extremity lymph flow features that may affect subsequent arm lymphedema patterns (Modi et al., 2005; Stanton et al., 2003). If, the reduction in lymph drainage capacity is large, the stage is set for development of lymphedema.

Physiological Basis of Truncal Clearance in Lymphedema Therapy

The effectiveness of lymphedema therapy depends on stimulating lymphatic flow in a way that facilitates lymph movement through alternative pathways so that lymph fluid is moved from lymphedematous regions circumventing damaged or obliterated normal pathways. Key to effective therapy is the recognition and thoughtful use of the underlying physiological processes, anatomical features, and physical principles governing the lymphatic system. Treating truncal lymphatics when providing lymphedema therapy is consistent with these processes, features, and principles. Four basic features need to be elaborated on to illustrate the necessity for truncal clearance and the need for a more comprehensive treatment of the lymphatic system, rather than limiting therapy to affected limb(s). These are (a) lymphatic territories and watersheds, (b) lymphatic vessel contractility, (c) associated dynamic pressures, and (d) overall lymph flow determinants.

(a) Lymphatic Regions and Watersheds

Lymphatic tributary regions or territories are separated by lymphatic watersheds. The term *watershed* is borrowed from hydrology, where it can be thought of as a drainage basin usually bounded by ridges of higher ground. Although lymphatic watersheds are not true anatomical structures, their dividing lines delineate the direction of lymph flow. As diagramed in Figure 5, there are two main horizontal watersheds of the trunk. The lower horizontal or transverse watershed starts approximately at the umbilicus and travels around the ribs to about the second lumbar vertebrae. The upper horizontal watershed separates the neck and shoulder territories from the territories of the arm and thorax. The vertical or sagittal watershed divides the trunk into halves, running along the body's central axis. The result is four trunk quadrants: right and left upper quadrants and right and left lower quadrants. These watersheds are not insurmountable, as interconnected small lymphatics, containing no valves, cover the whole body and bridge these divider lines (M. Foeldi & Strossenreuter, 2005). These interconnections are illustrated in the inset of Figure 5. The bridges allow lymph from an ineffective quadrant to be redirected to a healthy quadrant. Groups of connecting lymphatic channels crossing watersheds form a natural communication between regions and are called anastomoses. For example, the axilloaxillary anastomosis connects the right and left axilla both anteriorly and posteriorly. The axilloinguinal anastomosis connects axillary and inguinal lymph nodes on the same side of the body.

In a healthy lymphatic system, lymph on one side of the watershed preferentially drains to its regional lymph nodes. If the regional nodes are damaged or obstructed, treatment aims to open and dilate anastomosis or connective channels between territories crossing the watersheds, allowing lymph to be directed to adjacent normally functioning territories. However,

> a premature sudden increase of the lymphatic load in these watersheds without preparation is to be avoided; otherwise, an iatrogenic dynamic insufficiency of these lymphatics with trapped edema is likely to be triggered. (M. Foeldi & Strossenreuter, 2005, p. 27)

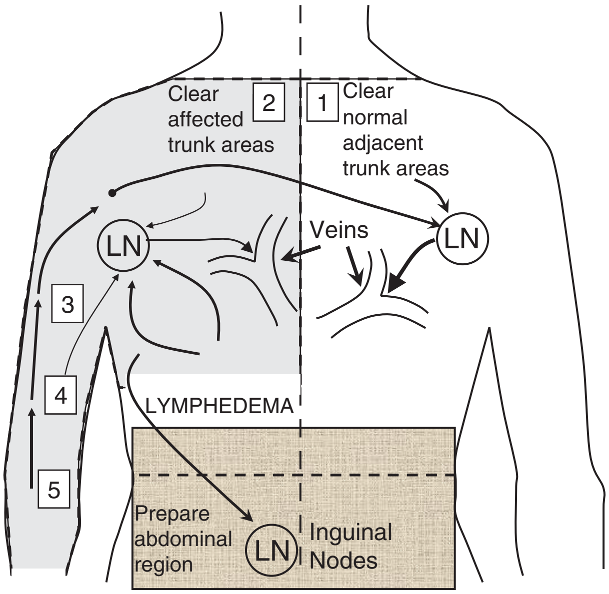
Thus, decongestion of the lymphostatic trunk quadrant allows lymph to pass through dilated tissue channels and remaining unaffected lymphatics from the limb, first into the ipsilateral and then into the contralateral trunk quadrant, as schematically shown in Figure 6. Lymph fluid can then be moved across watersheds from the lymphostatic quadrant into tissue spaces of the normal quadrant, where it enters lymphatic capillaries. This preliminary clearance enables movement of edema fluid from the root of the swollen limb, across the ipsilateral quadrant and the watersheds into the healthy quadrants. Such treatment of the contralateral normal trunk quadrant of a patient with postmastectomy lymphedema was reported to cause an immediate increase in the speed of lymphatic transport and the pull of proteins from the lymphostatic quadrant and limb as shown by isotope lymphography (Pecking et al., 1988). Thus, stimulation of truncal lymphatics plays an important role in lymph transport out of the limb.

(b) Lymphatic Contractility

The intrinsic contractility of lymphatic vessels and the pressure within contracting vessels that is generated helps to propel lymph centrally (Pippard & Roddie, 1987). An operant physiological consideration for truncal treatment is that stimulation of these lymphatics augments normal intrinsic contractile activity (Bridenbaugh, Gashev, & Zawieja, 2003; von der Weid & Zawieja, 2004; Zhang, Gashev, Zawieja, Lane, & Davis, 2007), which is known to promote lymph movement and lymphatic drainage. A resulting direct physical effect that has been attributed to this process is the drawing away of lymph from the affected truncal region because of a combination of Bernoulli-like effects (Foldi et al., 2003) and reductions in both volume and pressure within the lymphatic network of the normal adjacent quadrants:

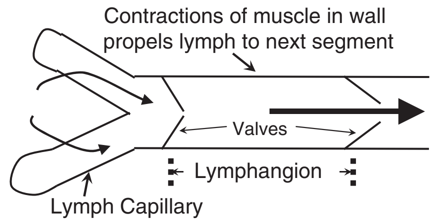
> The first goal of this special massage technique, commenced over the contralateral quadrant of the trunk free of lymphostasis, is to increase lymphatic contractility in these normal lymphatics. These

Figure 6
Schematized Depiction of Truncal-Limb Treatment Pattern



Note: The numbers suggest the sequential order in which applied therapeutic decongestion or clearance is most appropriate and effective. The main emphasis is on preparing the truncal regions prior to treating the affected limb. The physiological basis for this approach is discussed in detail within the text.

Figure 7
Depiction of a Collecting Lymphatic Vessel



Note: Lymph entering lymphatic capillaries is collected by vessels that have smooth muscle in their wall and are segmented along their length by valves. Contraction of the smooth muscle causes intrasegment pressure to rise, thereby moving lymph forward into the next segment. Partial emptying of a lymphangion reduces its pressure during the muscle relaxation phase, thereby facilitating lymph entry into it in preparation for the next contraction phase. Contraction strength and frequency are enhanced during lymphatic therapeutic maneuvers.

> lymphatics now start to drain the lymphostatic quadrant across the lymphatic watershed. (E. Foeldi, Foeldi, & Clodius, 1989, p. 513)

Because many collecting vessels have segments (lymphangions) that are bounded on each end by valves (see Figure 7), contraction of the muscle in their walls raises internal pressure and propels lymph forward into the next lymphangion, resulting in a unidirectional peristaltic-like flow from collector to collector with lymph ultimately draining into the venous system. The partial emptying of contracting lymphagions also makes it easier for the lymph from lymph capillaries and other contracting lymphangions to enter the now relaxed lymphatic collector. Such intrinsic contractions of collecting vessels (lymphomotoricity) are essential for normal lymph propulsion and depend on the amount of lymph fluid in these collectors (Mortimer, 1998). The greater the stretch (or lymph volume received), the greater the contraction force and frequency (Lasinski, 1998) and, by extension, the greater the lymph flow. Although a variety of factors can affect contraction strength and frequency, including nerve stimulation, skeletal muscle contraction, temperature, adjacent artery pulsations, and changes in abdominal and thoracic pressure during breathing (Kelly, 2002; Olszewski, 2002), it is primarily the manipulation of the truncal or limb lymphatics that is the operative mechanism in the therapeutic situation.

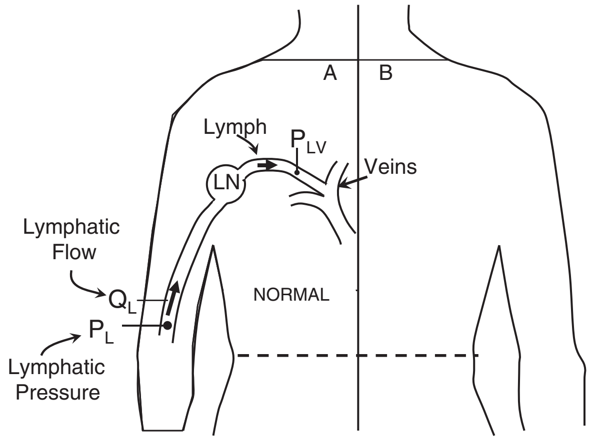
(c) Lymphatic Pressures

From a physical viewpoint, lymph movement within and then out of the various lymphatic territories is mainly determined by (a) normal contractile activity of lymphatic vessels, (b) the associated dynamic pressures that are developed, and (c) the resistance to lymph flow attributable to the overall network of lymphatic vessels and nodes. Pressures, in turn, depend on distension of smooth muscle within vessel walls and are therefore influenced by their lymph volume or load. Volume and pressure in lymphatic vessels are not independent, but each can play different roles in facilitating lymph uptake and movement. It is instructive to separate the process conceptually into two interacting components: one that determines and facilitates movement of lymph fluid into cleared areas and one that determines and facilitates movement within and then out of these cleared regions, ultimately emptying into the venous circulation.

(d) Lymph Flow Determinants as Affected by Truncal Clearance

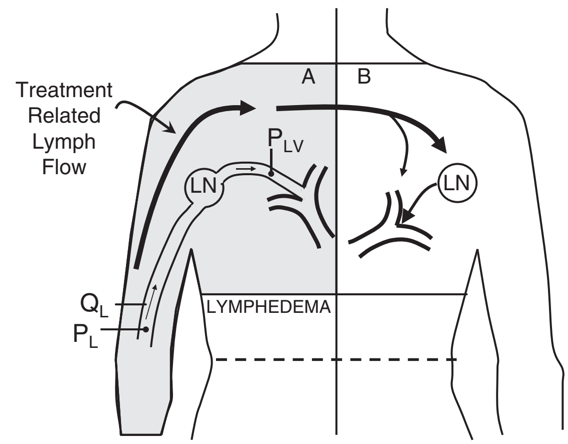
We focus first on normal lymph transport from a limb to and through lymph nodes and within lymph collectors and conduits terminating at junctions with the venous system (see Figure 8). In principle, there are

Figure 8
Main Physical Determinants of Normal Lymph Flow From the Arm



Note: P_L is the dynamic propulsive pressure developed by contracting lymphatic vessels, and P_{LV} is the pressure in the network of lymphatic vessels linking the nodes to the venous system. The lymph flow (Q_L) depends on the difference between P_L and P_{LV} and on the resistance of the entire lymphatic pathway between arm and venous junction.

Figure 9
Pathways and Changes Associated With Therapy in a Prepared Truncal Region



Note: Normal flow pathways are reduced or absent. Truncal clearance reduces P_{LV} in ipsilateral (A) and contralateral (B) quadrants and augments normal lymphatic vessel pumping actions. Treatment related lymph flow is thus optimized. See text for further discussion.

three major physical factors that affect this process: (a) The dynamic propulsive pressure developed by contracting lymphatic vessels located within the limb (P_L), (b) the resistance to lymph flow between the limb and venous junction (R_L), and (c) the pressure in the network of lymphatic vessels linking the nodes to the venous system (P_{LV}). These factors determine the flow of lymph (Q_L) from the limb as described by following functional relationship:

$$Q_L \sim (P_L - P_{LV}) / R_L. \quad (1)$$

This relationship compactly states that the lymph flow is proportional to the difference in the intralymphatic pressures between the regions (P_L – P_{LV}) divided by the resistance of the lymphatic network that lies between them. In the lymphedematous condition, lymph movement out of lymphedematous regions is reduced because of at least two contributing factors (see Figure 9). The most widely recognized factor is an increase in R_L, the resistance to lymph flow. For example, in breast cancer–related lymphedema (BCRL), node removal and injury experienced by lymphatic vessels and tissues cause the increase in R_L. A less well recognized factor is the alteration in P_L: the pressure developed in lymphatic vessels within lymphedematous regions. Recent work has shown that maximum dynamic pressures achievable by the lymphatic network within lymphedematous arms are significantly reduced in BCRL (Modi et al., 2007). The combined effects of increased resistance to lymph flow from affected regions and reduced contractile lymphatic pump function can physically account for part of the resultant diminished normal lymph flow, but there are additional factors.

Examination of the defining relationship (1) reveals that the reduction in lymph flow associated with the lymphedematous condition is accounted for by changes in each of its principal determinants: a decrease in lymphatic driving pressure for flow (P_L), an increase in the truncal collecting vessel pressure (P_{VL}), and an increase in the resistance to lymph flow (R_L) associated with node removal and lymphatic vessel injury when radiation treatment is superimposed. Viewed in this context, the importance and basis for preparatory truncal clearance in lymphedema treatment is consistent with all governing physical principles. It facilitates lymph flow through remaining pathways by reducing pressure (P_{LV}) in these lymphatic channels and promoting lymphomotor activity. In this manner, it improves conditions for lymph transport to ipsilateral and contralateral truncal regions and then through available alternate pathways.

This composite analysis emphasizes the major concept of this communication: that treatment should always begin with a thorough truncal clearance phase. In simplistic terms, its fundamental role is to reduce volume and pressure within those lymphatic vessels that will subsequently collect lymph fluid drained from lymphedematous tissue regions and move it into the venous system. Conceptually, the prepared normal truncal region serves as a conduit for the adjacent affected quadrant, and the prepared affected truncal region serves as a conduit for the lymphedematous arm.

Turning Principles Into Practice

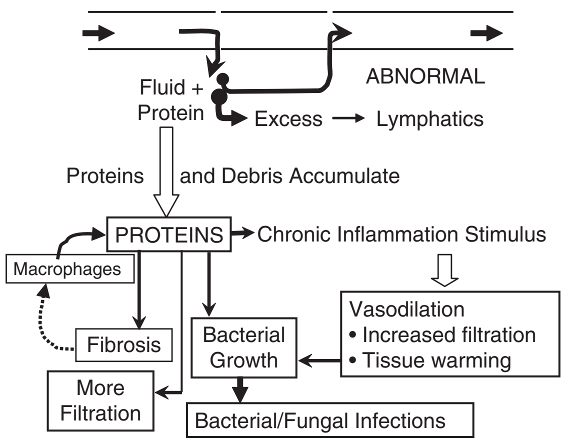
From the forgoing discussion, it is evident that principles governing lymphatic function support treatment of truncal lymphatics in addition to that of the obviously affected limb. This therapy component has been embraced in the lymphedema treatment community, and professional lymphedema therapists consistently employ truncal clearing techniques as part of their comprehensive therapy, which includes manual lymphatic drainage (MLD), a well-accepted treatment sequence. Based on the anatomy and physiology of the lymphatic system, MLD truncal clearance, as partially schematized in Figure 6, occurs proximally first in both contralateral and ipsilateral truncal quadrants of the torso, then in the proximal limb, and only thereafter from the distal to proximal portion of the edematous extremity (E. Foeldi et al., 1989). Although treatment of the trunk has long been a standard MLD process, there are no randomized clinical trials comparing MLD with and without truncal decongestion. Despite this lack of evidence, truncal treatment is well established as a necessary component to effective lymphedema therapy.

Advances in lymphatic therapy have been slow, and until recently, the only means to provide truncal clearance was with MLD therapy. A new technology designed for home use that recognizes that optimal lymphatic drainage encompasses treatment of the truncal lymphatics, providing proximal decongestion in addition to limb therapy, is an advance that has shown promise. The Flexitouch system is an advanced pneumatic device that consists of an electronic controller and garments designed for both upper and lower extremity application and treatment. This device was developed consistent with the anatomy and physiology of the lymphatic system and incorporates truncal treatment. The device programming provides for treatment of the contralateral trunk and, in the case of upper extremity treatment, the chest also prior to draining the ipsilateral truncal quadrant and affected extremity. The garments are designed with narrow and curved chambers covering the trunk and chest (for upper extremity treatment) regions. With a design based on the governing physiological principles of the lymphatic system discussed earlier, this device applies light, variable, directional pressure to the trunk and affected limb using multichambered, inflatable, and stretchable garments. The inflation/deflation cycle applies a brief stretch against the skin in the desired direction stimulating lymphatic flow. In this way, it uses lymphatic anastomoses to direct lymph fluid along existing anatomical pathways from areas where flow is deficient to normally functioning regions. Pressures developed with this system are markedly different than older generation compression pumps (Mayrovitz, 2007b), and preliminary results have indicated its effectiveness (Wilburn, Wilburn, & Rockson, 2006) and acceptance (Ridner, McMahon, Dietrich, & Hoy, 2008) by patients.

A significant challenge faced by new therapeutic approaches like the Flexitouch device is the desire for robust clinical evidence supporting efficacy. In lymphedema treatment, such evidence has been lacking. There are no published studies that confirm the need for truncal treatment in MLD and no published studies isolating the efficacy of the chest and truncal therapy components of the Flexitouch device. Despite a lack of evidence, the necessity of truncal treatment for effective lymphatic treatment is well established and recognized in standard treatment provided to patients in clinics and firmly rooted in fundamental principles.

Other approaches have focused on using various noninvasive physical modalities as adjunctive treatment methods, mainly employed during initial treatment phases. These include therapies in the form of radio frequency stimulation (Mayrovitz, Sims, & Macdonald, 2002), microwave therapy (Gan, Li, Cai, & Chang, 1996), and low-light-level laser therapy (Carati, Anderson, Gannon, & Piller, 2003; Kaviani, Fateh, Yousefi Nooraie, Alinagizadeh, & Ataie-Fashtami, 2006; Piller & Thelander, 1998). However, these methods do not appear to be gaining widespread acceptance or usage yet.

Figure 10
Depiction of Some Lymphedema-Related Pathways Causing Complications



Note: Accumulation of protein, cellular debris, and other materials in the interstitial space sets the stage for increased edema, fibrosis, and infection.

Risks Associated With Ineffective Treatment

Lymphedema resulting from surgery and/or radiotherapy for breast cancer, gynecological or prostate surgery, melanoma, and other conditions that affect lymphatic function is a major complication. This chronic condition grows worse without treatment (Casley-Smith, 1995). Its impact, whether in the upper or lower extremities, is multidimensional and may include chronic pain, severe mobility limitations, predisposition to serious limb infections, weight gain, loss of self-esteem, and depression.

Physiological changes arise that can inhibit normal functioning. Accumulation of protein, debris, and cellular fragments in the interstitium triggers several continuing negative processes (see Figure 10). Accumulating proteins act to pull more fluid out of capillaries and into the interstitium, thereby further increasing tissue edema. As time passes, the accumulated proteins, together with connective tissue changes, cause tissue hardening, a condition called fibrosis. Cells (macrophages) that normally clean up debris in the interstitium are inhibited by fibrosis, and the interstitium suffers other progressive derangements. In addition, accumulated protein and other substances act as stimuli for chronic inflammation accompanied by increased capillary blood pressure and flow caused by widening (vasodilation) of small blood vessels supplying the area. This increased pressure causes more fluid accumulation and tissue warming, which, combined with the bacterial growth stimuli of protein, creates an infection-ripe environment. Thus, the stage is set for a vicious cycle of worsening symptoms and progressive complications.

Failure to treat the truncal lymphatics in addition to the lymphedematous extremity is associated with significant risks to the patient, including (a) development of a fibrous band at the proximal limb that further impedes lymphatic drainage out of the limb and (b) development of new areas of edema in the truncal quadrant adjacent to the affected limb, including swelling of the chest, axilla, back, abdomen, and genitalia. Development of these conditions present new treatment challenges as well as further debilitation for the patient.

Truncal edema presents its own set of complications. Lack of effective treatment of the truncal region may result in pain in the back, chest, shoulder, or breast, worsening neuropathic pain of the fingers and infection. Pain may be localized or may radiate across the chest, trunk, or back. In addition, significant body changes may lead to emotional distress and altered body image.

An additional aspect of truncal treatment should be mentioned. Lymphedema is seldom confined to just the limb that is obviously swollen; in many cases, the lymphedema extends into the adjacent body quadrants. Truncal lymphedema may be more difficult to diagnose as it often presents differently than lymphedema in an extremity. Swelling of the trunk many not initially be observed and instead may present as pain, tenderness, and a sense of fullness and hotness. Patients may also report discomfort with movement and difficulty performing activities of daily living. These additional facts further emphasize the vital need for adjacent body parts (truncal lymphatics) to be treated in addition to the obviously affected lymphedematous extremity.

Effective lifelong treatment of the affected limb and trunk is necessary to reduce the risk of serious complications such as recurrent infections, reduced range of motion, pain, and fibrosis. Complications of lymphedema, whether in the limb or trunk, require careful monitoring to minimize symptom progression and worsening debilitating impacts on a patient's ability to participate successfully in activities of daily living.

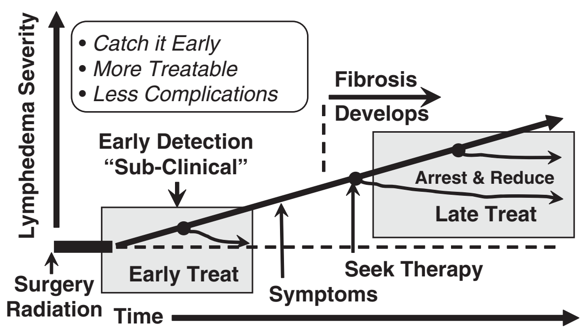
Early Detection of Lymphedema

Although current lymphedema therapy is useful to help prevent the condition's progression and sometimes to partially reverse significant lymphedema already present, in the long run, early detection of subclinical lymphedema and early treatment offer the best approaches to

Table 1
Common Initial Symptoms of Lymphedema

Feeling of limb heaviness or clumsiness
Feeling like a ball is stuck in the armpit
Tingling or numbness
A ring or watch gets tighter
Skin feels "tight"
Bra fits tighter
Diminished flexibility
Limb more easily fatigued
Visual swelling

Figure 11
Early Detection of Lymphedema as an Important Health Management Goal



minimizing a patient's lifelong burden. In the case of BCRL, preventive measures (Ridner, 2006) that women at risk for lymphedema can take are sometimes made known to them by their treating physician, but many patients do not practice these or, if they do, they are often done on an inconsistent basis. Furthermore, women often will not present themselves for therapy until frank swelling and other manifestations of the evolving lymphedema are already present (see Table 1). Absence of consistent preventative measures and late application of therapy are significant problems, as once lymphedema is established and chronic, available therapy and subsequent containment measures are less effective.

This situation could be improved if patients were offered a better and earlier prediction (see Figure 11) of their specific risk of developing lymphedema. For example, as of now, this team can say to a woman who is at-risk for lymphedema because of her breast cancer treatment that lymphedema occurs in somewhere between one and two women out of five. What one would like to say is that based on your specific measurements, there is or is not an early indication of pending lymphedema development. A patient with a positive indication will likely be more motivated to use early preventative measures, some of which may be cumbersome or inconvenient and be more inclined to seek therapy at an earlier stage. Thus, professionals need to assess pending lymphedema in persons who are at risk for this condition more objectively.

There are two promising methods that may allow early, preclinical detection of insipient lymphedema: One uses a bioimpedance principle, and the other uses tissue dielectric constant measurements. Because it is likely that these methods will come into more routine use, it would be useful for health care workers, including home health practitioners, to have some familiarity and basic understanding of these methods, their principles, and their differences. The following offers a brief overview and some key literature references.

Bioimpedance

Because of the relatively higher electrical conductivity of water relative to most tissues, tissues containing increased amounts of water will experience a reduced electrical resistance. In theory then, changes in tissue electrical resistance may detect either changes in tissue water or be used as an indicator of abnormally elevated amounts of water. This change in electrical resistance, associated with changes in tissue water, forms the primary basis for use of the bioimpedance method in the assessment of lymphedematous limbs. In application, electrodes are strategically placed to measure limb electrical impedance (Cornish, Jacobs, Thomas, & Ward, 1999) using a sophisticated multifrequency approach (Cornish, Ward, Thomas, Jebb, & Elia, 1996). Research indicates that this multifrequency method may be useful in unilateral and bilateral lymphedema (Cornish, Thomas, Ward, Hirst, & Bunce, 2002). A commercial device that uses a single frequency is currently available. It is potentially useful for assessing limb lymphedema but not useful for assessing local changes in tissue water or changes in other body areas that are edematous or are at risk for developing lymphedema. A method suitable for determining local tissue water is what the tissue dielectric constant method offers.

Tissue Dielectric Constant Method

An increase in the relative amount of water also alters other electrical features of the tissue. One of these is the tissue dielectric constant, which is related to the tissue's electrical capacitance. The dielectric constant of water is about 78.5, whereas other tissue components have lesser values. Thus, if relative water content increases the composite tissue, dielectric constant increases (Alanen, Lahtinen, & Nuutinen, 1998; Nuutinen, Ikaheimo, & Lahtinen, 2004; Nuutinen et al., 1998; Petaja, Nuutinen, Uusaro, Lahtinen, & Ruokonen, 2003; Stuchly, Athey, Samaras, & Taylor, 1982). In simplified terms, this is the basis for assessing local water. A commercial device is currently available, and a number of recent research studies have been done demonstrating its utility (Mayrovitz, 2007a; Mayrovitz, Brown-Cross, & Washington, 2007; Mayrovitz, Davey, & Shapiro, 2008a, 2008b).

Implications for Home Health Care Practice

In the United States and other developed countries, lymphedema most often occurs as a secondary complication of cancer treatment. At the top of the list is breast cancer, followed by prostate and gynecological cancers and a growing incidence of melanoma. The National Cancer Institute estimates that 12.7% of women born today in the United States will be diagnosed with breast cancer. Since lymphedema occurs in about 30% of female breast cancer survivors (Box, Reul-Hirche, Bullock-Saxton, & Furnival, 2002; Erickson, Pearson, Ganz, Adams, & Kahn, 2001), lymphedema represents a huge patient and health care burden.

As improvements in cancer treatments extend life expectancies, there is likely to be a corresponding increase in the number of patients diagnosed with lymphedema. Of all individuals with cancer, 60% are 65 years of age and older (Medicare eligible) and represent 70.5% of the patients receiving home health care in the United States. The increased pressure to reduce cost by providing more care in community and home-based settings means that home health providers will encounter a greater number of lymphedema patients.

In the continuum of care for a lymphedema patient, the challenge of home maintenance is significant. Although patients are instructed in techniques and therapy to continue their care at home, only 50% are able to manage their condition successfully on a long-term basis. As explained earlier, the risks of poor treatment or no treatment at all are great. Thus, although home health providers are generally not trained to manage lymphedema, it is important that they be familiar with the signs and symptoms to detect exacerbations of lymphedematous changes so that serious and costly complications can be minimized. They should also have some understanding of the underlying causes and complications of the lymphedematous condition, the basic principles on which both acute and home maintenance phase therapies are based, and new technologies for treatment. We have tried in this communication to provide an appropriate background and to highlight the importance of truncal clearance as an essential element of therapy.

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