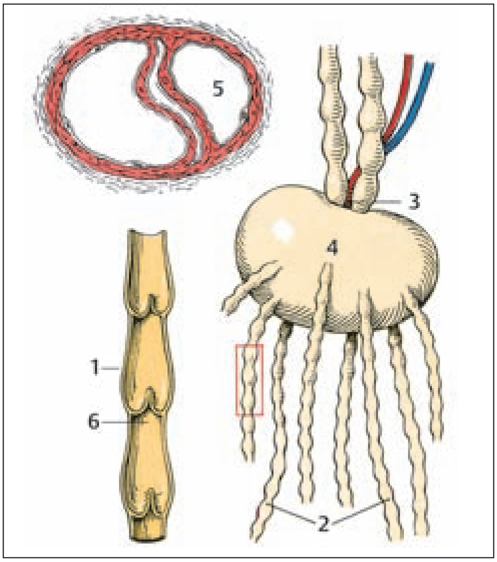


Figure 1–4 Lymph collectors. 1. Lymph collector; 2. Afferent lymph collector to lymph node; 3. Efferent lymph collector from lymph node; 4. Lymph node; 5. Cross section through a lymph collector in the area of the valves; 6. Lymph angion.

It is postulated that the main purpose of pre-collectors is the transport of lymph fluid from the capillaries to lymph collectors. Due to the capillary-like wall structure in some areas, pre-collectors are able to absorb lymphatic loads. This is why these vessels are also referred to in some literature as part of the initial lymphatics.

Lymph Collectors

Lymph collectors transport lymph fluid to the lymph nodes and the lymphatic trunks. The diameter of collectors varies between 0.1 and 0.6 mm; their walls are structured similarly to those of veins and consist of three distinct layers. The inner layer (intima) consists of endothelial cells and a basal membrane, the medium layer (media) contains a network of smooth musculature, and collagen tissue is present in the outer layer (adventitia).

Collectors contain valves, which, as in venous vessels, allow the flow of fluid in one direction only (proximal). The interval between the valves is irregular and varies between 6 and 20 mm (up to 10 cm in larger trunks). The segment of a collector located between a proximal and a distal pair of valves is called *lymph angion* (Fig. 1–4). The media in valvular areas of lymph collectors contains less smooth musculature than the angion area. Lymph angions have an autonomic contraction frequency of ~10 to 12 contractions per minute at rest (*lymphangiomotoricity*).

In healthy lymph collectors, the proximal valve is open during the systole, whereas the distal valve is closed; in the diastole, the opposite is the case. This permits directional flow of lymph fluid from distal to proximal angions. In lymphangiectasia (dilation) with valvular insufficiency, the lymph flow may reverse into distal lymph angions (*lymphatic reflux*).

Lymph collectors have the ability to react to an increase in lymph formation with an increase in contraction frequency. The increase in lymph fluid entering the lymph angion will cause a stretch on the wall of the angion, which in turn results in an increase in lymphangiomotoricity (*lymphatic safety factor*; see also Chapter 2, Safety Factor of the Lymphatic System).

Other factors that may influence lymphangiomotoricity are external stretch on the lymph angion wall (e.g., manual lymph drainage), temperature, activity of muscle and joint pumps, diaphragmatic breathing, pulsation of adjacent arteries, and certain tissue hormones. Stimulation of the local sympathetic tone may also increase the pulsation frequency of lymph collectors.

As stated earlier, the superficial and deep lymph collectors can be differentiated. The transport vessels of the superficial lymphatic system are embedded in the subcutaneous fatty layer of the skin and follow a fairly straight path within their drainage areas toward the lymph nodes, whereas the collectors belonging to the deep and organ systems follow the anatomy of larger blood vessels and organ vessels, respectively.

Lymph collectors are responsible for draining lymphatic loads from certain body areas, called *tributary or drainage areas.* Most drainage areas of the superficial lymphatic system are subdivided into *lymphatic territories*.

Lymphatic territories consist of several collectors that are responsible for the drainage of the

Lymph capillaries → Precollectors → Collectors → Lymph nodes → Trunks → Venous angles

Figure 1–5 The pattern of lymphatic return to the venous system.

same body area. All collectors in a lymphatic territory transport lymph fluid into the same group of lymph nodes (regional lymph nodes). Lymphatic territories are separated by *lymphatic watersheds* (see discussion later in this chapter). Traversing toward the lymph nodes, collectors on the extremities parallel the watersheds, whereas collectors on the trunk tend to originate at the watersheds.

Connections between lymph collectors belonging to the same territory (*intraterritorial lympho-lymphatic anastomoses*) are frequent and important to ensure sufficient return of the lymph fluid from peripheral areas. Connections between lymph collectors of adjacent territories are much less frequent. These interterritorial anastomoses vary depending on location (see discussion later in this chapter).

Lymphatic Trunks

These vessels show the same wall structure as lymph collectors, but generally they contain a more developed muscle structure in the media. Lymphatic trunks, as lymph collectors, are innervated by the sympathetic nervous system. Intralymphatic valves have the same structure and passive function as in collectors.

> Lymph collectors transport the lymph fluid from the superficial, deep, and organ systems to the lymphatic trunks, which then forward the lymph to the venous angles (Fig. 1–5).

Lumbar Trunks. The left and right lumbar trunks are responsible for the drainage of the lower extremities, the lower body quadrants, and the external genitalia (Figs. 1–6, 1–7, 1–8). Both lumbar trunks, together with the gastrointestinal trunk (which brings lymph fluid from the stomach and digestive system, the liver, and the pancreas), form the *cisterna chyli* (Figs. 1–7, 1–8). Chylous lymph fluid from the digestive system is mixed with the transparent lymph fluid from various other tissues (described in Superfical Layer and Deep Layer, later) in the cisterna chyli. The location of this saclike reservoir varies but is usually between the vertebral levels T11 and L2 (anterior); it is between 3 and 8 cm long, and its width varies between 0.5 and 1.5 cm.

Thoracic Duct. The thoracic duct originates together with the cisterna chyli and represents the largest lymph trunk in the body. The length varies between 36 and 45 cm, its width between 1 and 5 mm. Its origin is located between the peritoneum and the vertebral column and varies, as with the cisterna chyli, between T11 and L2 (Figs. 1–7, 1–8). On its way to the venous angle, the thoracic duct

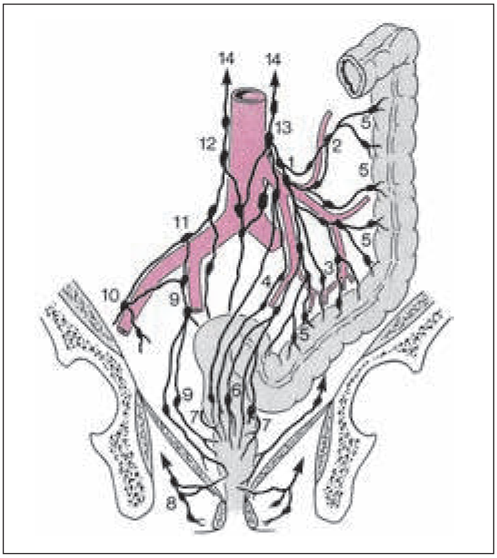


Figure 1–6 Lymphatic drainage of distal colon and rectum (anterior view). 1. Inferior mesenteric lymph nodes; 2. Left colic lymph nodes; 3. Sigmoid lymph nodes; 4. Superior rectal lymph nodes; 5. Paracolic lymph nodes; 6. Pararectal lymph nodes; 7. Lymphatic vessels draining to sacral lymph nodes; 8. Lymph nodes in the ischioanal fossa with drainage to the superficial inguinal lymph nodes; 9. Internal pelvic lymph nodes; 10. External pelvic lymph nodes; 11. Common pelvic lymph nodes; 12. Right lumbar lymph nodes; 13. Left lumbar lymph nodes; 14. Left and right lumbar trunks.

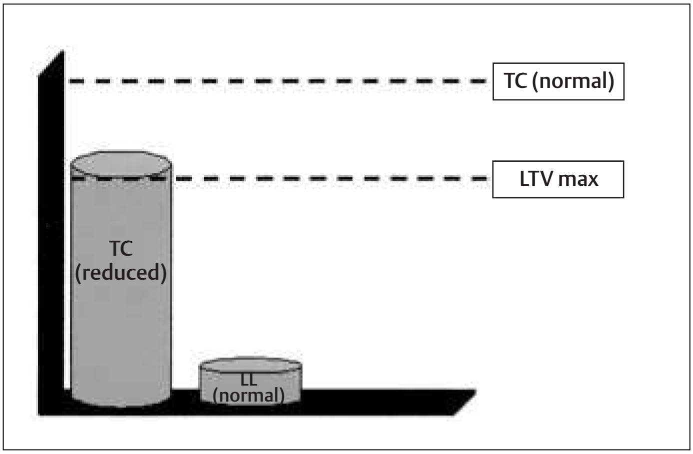


Figure 3–1 Reduced transport capacity in the subclinical stage of lymphedema. LL, lymphatic loads or lymph volume; LTV, lymph time volume (TC = LTV_{max}); TC, transport capacity of the lymphatic system.

Fibrosis of the inguinal lymph nodes (Kinmonth syndrome) presents an additional cause for the onset of primary lymphedema. The fibrotic changes primarily affect the capsular and trabecular area of the involved lymph nodes. This may affect lymph transport in the afferent lymph collectors.

With the understanding of basic lymphatic system physiology, it becomes evident that the transport capacity of the lymphatic system in all the abnormalities listed above is reduced (Fig. 3–1). As discussed in Chapter 2, lymphedema occurs if the transport capacity of the lymphatic system falls below the normal amount of lymphatic loads.

Although the developmental abnormalities are present at birth, lymphedema may develop at some point later in life. It may not develop at all as long as the (reduced) transport capacity of the lymphatic system is sufficient enough to manage the lymphatic loads. Primary lymphedema is often classified by the age of the patient at the onset of swelling.

Congenital lymphedema is clinically evident at birth or within the first 2 years of life. A subgroup of patients with congenital lymphedema has a familial pattern of inheritance, which is termed Milroy's disease. If primary lymphedema presents after birth but before the age of 35, it is called *lymphedema praecox*, which is the most common form of primary lymphedema and most often arises during puberty or pregnancy. *Lymphedema tarda* is relatively rare and develops after the age of 35.

Primary lymphedema almost exclusively affects the lower extremity (unilateral and bilateral) and involves mostly females. The swelling usually starts at the foot and ankle and gradually involves the remainder of the extremity. It may occur without any known impetus or may develop after minor trauma (insect bites, injections, sprains, strains, burns, cuts), infections, or immobility. These triggering factors produce additional stress to the already impaired lymphatic system, resulting in mechanical insufficiency (Fig. 3–2).

Secondary Lymphedema

The mechanical insufficiency present in secondary lymphedema is caused by a known insult to the lymphatic system.

> Most common causes for secondary lymphedema include surgery and radiation, trauma, infection, malignant tumors, immobility, and chronic venous insufficiencies.

Lymphedema may also be self-induced.

Surgery and radiation: As outlined earlier, this is by far the most common cause for secondary lymphedema in the United States. Surgical procedures in cancer therapy commonly include the removal (dissection) of lymph nodes. The goal of these procedures is to eliminate the cancer cells and to save the patient's life.

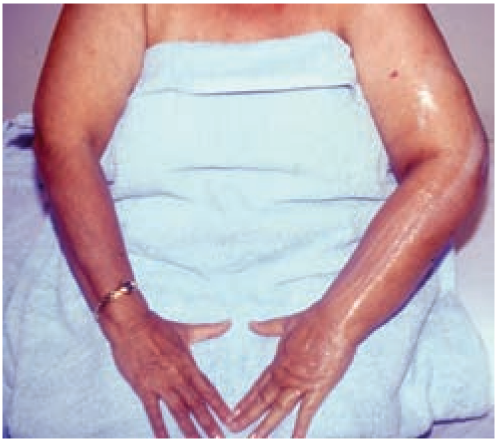
A side effect in lymph node dissection is the disruption in the lymph transport. If the remaining lymphatics are unable to manage the lymphatic load, secondary lymphedema will develop.

In the early years of breast cancer surgery, *radical mastectomy* was the only option available for patients. Radical mastectomy includes the removal of the entire mammary gland, the axillary lymph nodes, and the pectoralis muscles under the breast. Although common in the past, radical mastectomy is now rarely performed and is recommended only if the cancer cells have spread to the muscles under the mammary gland. *Modified radical mastectomy* is now more commonly performed. This procedure includes the removal of the breast and part of the axillary lymph nodes. In certain forms of breast cancer, a *simple* or *total mastectomy* is performed, in which only the mammary gland, but not the axillary lymph nodes, is removed.

Today, many women with breast cancer are given the choice between mastectomy and *lumpectomy*. In lumpectomy, also referred to as breast-conserving surgery, only the part of the mammary gland containing the malignant tumor and some of the normal surrounding tissue are removed. Most women after breast surgery, especially after lumpectomy, receive radiation treatments (Fig. 3–3).

Sentinel lymph node biopsy, a relatively new technique, was developed to determine if cancer cells have spread to the axillary nodes and trunks, without having to perform a traditional axillary lymph node dissection during which, on average, ~10 to 15 axillary lymph nodes are removed. A sentinel lymph node

Figure 3–2 Primary lymphedema of the left lower extremity.



A

B

Figure 3–3 A. Secondary lymphedema of the left upper extremity. B. Secondary lymphedema of the left upper extremity following bilateral mastectomy.

Figure 5–13 Drainage areas for the upper extremity.

Figure 5–14 Thumb circles on the palm (ulnar bundle).

5. Manipulation of the lateral aspect of the upper arm
   Pump technique, with the hand closer to the patient's head on the lateral upper arm in several placements from the lateral epicondyle toward the acromion. The other hand holds the patient's arm in a comfortable and elevated position.
   Combination of pump technique and stationary circle (alternating hands) on the lateral aspect of the upper arm, beginning at the lateral epicondyle in several hand placements toward the olecranon
6. Manipulation of the antecubital fossa
   Thumb circles (one hand or alternating) covering the antecubital fossa from ~2 inches below to ~2 inches above. Several pathways are applied to cover the antecubital fossa from distal to proximal. This area can also be treated using stationary circles with the palmar surfaces of the fingers.
7. Manipulation of the forearm
   Scoop techniques with one hand on the anterior and posterior aspect of the forearm between the wrist and the elbow. To manipulate both aspects with the same hand, the patient's forearm is rotated in pronation and supination, respectively. The other hand holds the patient's arm at the wrist in a comfortable and elevated position.
   Combination of pump technique and stationary circles between the wrist and the elbow to cover the patient's anterior and posterior aspects of the forearm
   The patient's forearm is rotated in pronation and supination, respectively, to cover both surfaces.
8. Manipulation of the dorsum of the hand and wrist
   Thumb circles (one thumb or alternating) over dorsum of the hand and posterior wrist, starting on the metacarpophalangeal joints, ending at the styloid processes
9. Manipulation of the palmar aspect of the hand and the anterior wrist (Fig. 5–14)
   Thumb circles (one thumb or alternating) in the palm, following the ulnar and radial bundle from the center of the palm toward the ulnar and radial edges of the hand (following the path of the collectors)
10. Manipulation of the fingers
   Combination of thumb/finger circles on each individual finger from the distal to the proximal ends

11. Rework
    Appropriate techniques are used (depending on the patient's condition) covering specific parts of the limb or the entire extremity to increase lymph angiomotoricity
12. Final effleurage (as in 2)

Lower Extremity

Selected indications: postsurgical (joint replacement, etc.) and post-traumatic swellings (including edema caused by immobility due to partial or complete paralysis); chronic venous insufficiency stages II and III (phlebolymphostatic edema); lipedema; part of the treatment sequence for primary lymphedema of the genitalia; part of the treatment for cyclic idiopathic edema; general increase in lymph circulation, or to achieve a common soothing effect by decreasing sympathetic activity

Pretreatment: lateral neck (abbreviated; see lateral neck sequence, steps 1–3), abdomen

Anterior leg

Patient in supine position, with the leg slightly abducted and externally rotated; therapist on the patient's involved side:

1. Manipulation of the inguinal lymph nodes
   Stationary circles with both hands at the same time, with the working phase directed toward the inguinal ligament; three hand placements in the medial femoral triangle (Fig. 5–15)
   First hand placement: the upper hand lies parallel to the inguinal ligament (the fifth metacarpophalangeal joint is aligned with the patient's ASIS), the lower hand is positioned diagonally to the upper hand (with the fingertips touching the inguinal ligament).
   Second hand placement: the same hand positions are applied on the medial thigh (medial aspect of the femoral triangle).
   Third placement: both hands lie parallel on the medial aspect of the thigh (sagittal plane) to address the lymph nodes located in the distal apex of the medial femoral triangle.
2. Effleurage, two or three times covering the entire leg

Figure 5–15 Stationary circles on the inguinal lymph nodes (second hand placement).

Figure 5–16 Drainage areas for the anterior lower extremity.

3. Manipulation of the anterior thigh
   Alternating pump techniques following the rectus femoris muscle between the base of the patella and the ASIS
4. Manipulation of the anterior and lateral thigh

bag. Mild liquid detergents may be used, such as Ivory and Dreft (powder detergents or Woolite should not be used). Bandages can be dried on air setting or delicate setting in the dryer. The bandages may lose their elasticity after several applications; washing restores the memory of the braided cotton fibers needed for the working pressure.

During the evaluation, the clinician determines the quantity of materials needed for the application of the compression bandages during the decongestive phase of the therapy. To ensure successful intervention, adequate supplies have to be on hand before treatment starts. The treatment center either keeps a sufficient quantity of compression materials in stock, or the patients themselves are responsible to order the materials needed from a distributor before the initial treatment. Approximate stock quantities for lymphedema treatment centers are listed in Chapter 6 (6.2)

The life of short- and medium-stretch bandages can be considerably extended by using two sets, one to wear and one to wash (the manufacturers recommend to replace the bandages every 3 months if used daily).

Upper Extremity Bandaging

Recommended materials to apply a compression bandage on the upper extremity during the decongestive phase of CDT (phase 1) are listed below. The quantities listed below represent two sets of compression bandages:

- 1 Bottle of skin lotion
- 1 Box of stockinette (tubular bandage) in the appropriate size
- 1–2 boxes (20 individual rolls in a box) of gauze bandages (4 or 6 cm width)
- 4–6 synthetic nonwoven padding bandages (10 cm) or 2 Rosidal Soft foam bandages (10 cm)
- 2 short-stretch bandages (6 cm), or 2 short-stretch bandages (4 cm, for smaller hands)
- 2 short-stretch bandages (8 cm)
- 4–6 short-stretch bandages (10 cm)
- 2 short-stretch bandages (12 cm)
  Tape to secure the bandages
- If necessary: 1 sheet of soft foam (about 0.25–9nch thickness)
- If necessary: 1 sheet of Komprex or 1 roll of soft foam rubber

Application

Generally, bandages are applied with an even pre-stretch of ~30 to 40% and an overlap of ~50 to 70%. The patient should be in the sitting position.

Skin care: Wash and bathe the skin, then apply the appropriate lotion thoroughly.

Stockinette: The tubular bandage should be cut to a length that allows for an overlap of ~5 inches on the proximal end of the extremity. This overlap is used to extend over and cover the complete compression bandage on the proximal border to protect it from axillar perspiration. A hole is cut for the thumb on the distal end (Fig. 5–27).

Finger bandages: The patient's fingers are spread slightly, and the hand is in pronation. A bolster should be placed under the elbow to support the patient's arm.

Start the first gauze bandage with a loose anchor turn around the wrist (Fig. 5–28), then proceed over the dorsum of the hand to the little finger (or the thumb). The fingers should be bandaged with light pressure from the distal to the proximal ends with ~50% overlap. The fingertips are not covered. Leave the finger over the dorsum of the hand toward the wrist, apply a half turn (complete anchoring turns should be always avoided) around the wrist, and proceed to bandage the remaining fingers in the same fashion (Fig. 5–29). The borders of the gauze bandage should not slide or roll in on the distal and proximal ends of the fingers. One and a half to two gauze bandages are typically necessary to bandage all fingers. Any unused part of the second gauze bandage should be wrapped spirally (not circular) around the forearm.

Upon completion, the fingertips should be checked for proper circulation. The bandages should not slide over the knuckles when the patient makes a fist, and no skin area over the fingers should be visible.

Padding materials: Nonwoven synthetic padding (Artiflex, Rosidal) or soft foam rolls

Figure 5–27 Application of stockinette.

Figure 5–28 Application of gauze bandages on the fingers.

Figure 5–29 Application of gauze bandages on the fingers; fingertips remain unbandaged.

(Rosidal Soft) are used to pad the hand and arm. A hole is cut for the thumb (Fig. 5–30); the padding bandage is secured around the wrist with a circular turn. The hand is then padded down to the knuckles using two to four circular turns, with the padding bandage folded in half (Fig. 5–31). The padding bandage then proceeds in the proximal direction to cover the forearm and upper arm. The cubital fossa is protected with extra layers of padding (Fig. 5–32). Two rolls of padding bandages typically are used for an upper extremity (Fig. 5–33).