Lymphology 10 (1977) 54-61

The Anatomy of Lymph Vessels in Relation to Function

F. Huth, D. Bernhardt

Pathologic Institute, University of Düsseldorf (Chairman: Prof. Dr. H. Meessen)

The essential functions of the lymphatic system are to pick up large molecules, particles and excess fluid and to transport them from the peripheral connective tissue to the venous system. Within normal tissue most of the lymphatics are collapsed, (Fig. 1a). They can, therefore, hardly be differentiated light microscopically from blood capillaries or from septal connective tissue. Various techniques have been used to visualize the lymph vessels within organs and extremities. Retrograde injection of air, indian ink, different proteins and dyes, silver nitrate, mercury, ferritin, acrylic resins etc., often lead to ruptures of the thinwalled and vulnerable lymphatics, there by causing interstitial dye extravasates to be falsely interpreted as lymphatics (*Wutzer* 1834, *Most* 1908, *Bartels* 1909, *Baum* 1928, *Grau* 1943, *Jancso* et al. 1952, *Mori* 1963, *Mori* et al. 1964, *Leak* and *Burke* 1966, *Viragh* et al. 1966, *Bergström* and *Werner* 1966, *Kuprianov* 1969, *Casley-Smith* 1969, *Gerteis* 1972). Injection of lymph-specific dyes such as patent blue as well as different tracer techniques demonstrate sectoral lymph vascular branches but never the complete lymph drainage of tissue or organs. Application of hydrogen peroxide demonstrates the lymph vessels below mesothelial surfaces; total lymphangiography of an organ was not possible with this method (*Magnus* 1922, 1923, *Hass* 1936, *Johnson* and *Blake* 1966; *Johnson* 1969).

In 1939 *Kaiserling* and *Soostmeyer* found a way out of this methodological problem by blocking the lymph flow of an organ like the kidney. This procedure leads to a lymphostasis with dilatation of the lymph vascular branches (Fig. 1b) up to their capillary endings which thus can be seen light microscopically. Other investigators used this method with success in various organs (*Romualdi* et al. 1946, 1947; *Natucci* and *Zaccharini* 1949; *Rusznyak, Földi* and *Szabo* 1957; *Hankiss* 1959; *Aiello* et al. 1960; *Tormene* et al. 1965; *Csillik* and *Földi* 1967; *Huth* et al. 1970; *Földi* 1971; *Stroobandt* et al. 1976; *Lie* et al. 1976; *Huth* et al. 1974, 1976). *Cremer* et al. (1972) modified the method of blocking the lymph outflow by interrupting the thoracic duct.

The possibility of huge dilation of the lymphatics is different from the limited dilatation rate of the blood capillaries (Fig. 2a). Electron microscopy demonstrates that additional properties of lymph capillaries exist in contrast to blood capillaries (*Casley-Smith* 1965, 1967, 1970; *Burke* and *Leak* 1965, 1970; *Huth* 1967, 1968; *Huth* et al. 1970). The thickness of the lymphatic endothelium can vary from 0.1 μ to several micra. In contrast to blood capillaries, the lymphatic endothelium is not enveloped in a continous basal lamina or pericytes (Figs. 1, 2a, b, c, d). Similar to blood vascular endothelium, it contains mitochondria, lysosomes, free ribosomes, a scant endoplasmic reticulum, fine intracytoplasmic muscular filaments, and sometimes numerous microvesicles. The endothelial processes link to each other multiformally: Apposed membranes can be held together by maculae occludentes or adherentes (Fig. 3b). Sometimes the cellular margins are connected by interdigitations (Fig. 3a); in other areas, a close apposition without special cellular protrusions dominates. A specific structure of lymph capillaries is represented by the overlap of endothelial cell processes. The gaps between the overlapping cell processes can separate up to several micra so that complete cells from the interstitium can readily pass the patent junction (Fig. 2b). The patency of the junctions is influenced by another specific structure: *Leak* and *Burke* (1968) were able to demonstrate fine anchoring filaments

emanating from the outer surface of the lymphatic endothelium and extending into the interstitium with its thicker collagen fibrils (Fig. 3b). The overlap of endothelial cells with the possibility of extensive patency and the anchoring filaments maintain the removal of interstitial fluids and corpuscular substances and/or large molecules. Increased interstitial hydrostatic pressure will expand the interstitial space, hereby drawing the collagen fibrils. In this way the intercellular clefts are opened by pulling the filaments attached to the endothelial wall. This adaptive mechanism of lymphatics in response to altered hydrostatic and osmotic interstitial pressure has been proven not only in subcutaneous connective tissue (*Casley-Smith* 1967, *Leak* 1972) but also in other organs such as the kidney, the liver, and the heart (*Huth* 1968; *Huth* et al. 1970, 1976; *Lie* et al. 1976; *Stroobandt* et al. 1976). *Kalima* and *Kalima* (1975) demonstrated different gaps between the overlapping endothelial processes of mesenteric lymphatics. They referred to them as perilymphatic channels. They thought the channels played a significant role in the uptake of liquids or substances into the lymphatics. We saw comparable structures in organ lymphatics (Fig. 2d). *Casley-Smith* used the term prelymphatic for all interstitial spaces which are finally drained by lymphatic vessels. The tremendous dilatation rate of the lymphatics cannot be completely explained by the special connections of the endothelial cellular processes. A further extending capacity such as an intensive folding of the lymphatic endothelium within nonaltered organs or tissues exists (Fig. 2f). In addition, the numerous cellular protrusions of lymphatic endothelial cells (Fig. 1a) must be regarded as a structural reserve for dilation since they disappear during dilation. It was *Casley-Smith* (1967), *Földi* (1972), and *Leak* (1972) who differentiated between the special manner of transpoting fluids, proteins, and lipids via draining lymph vessels and the characteristic submicroscopical structures. Increased interstitial pressure leads to opening of the endothelial junctions while higher pressure inside the vascular lumen presses the

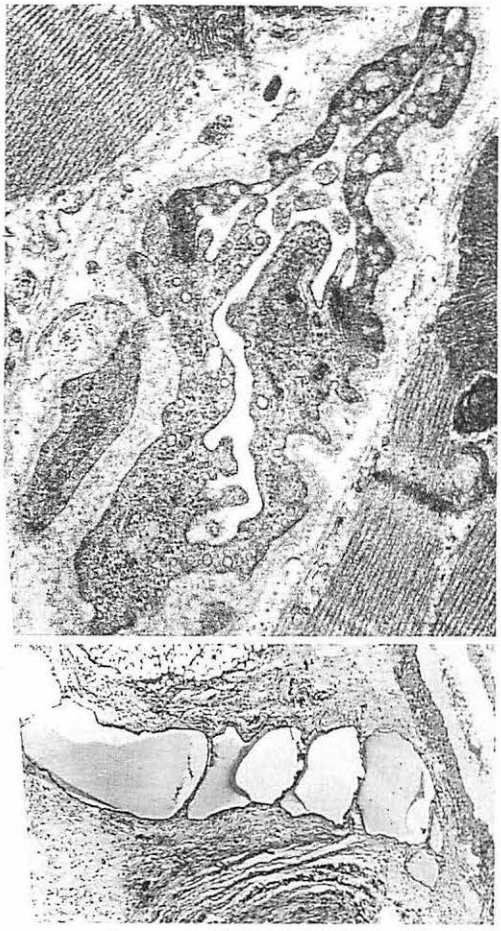


Fig 1a Nearly collapsed lymph capillary of the heart muscle. x 19.120
1b Dilated lymph collecting vessel with valves within the renal hilus, following experimental lymphostasis of the kidney.
22 x, v. Gieson

overlapping cell processes together thus closing the junctions. At this point one could speculate that the peripheral lymph drainage system functions adequately until the endothelial junctions are pulled too far apart and lymph fluid can again escape.

Uptake of particles and fluids into lymphatics from the interstitium can also occur across the endothelium within multiple vesicles (Fig. 3b). The transcellular passage has been elucidated by experiments with different parti-

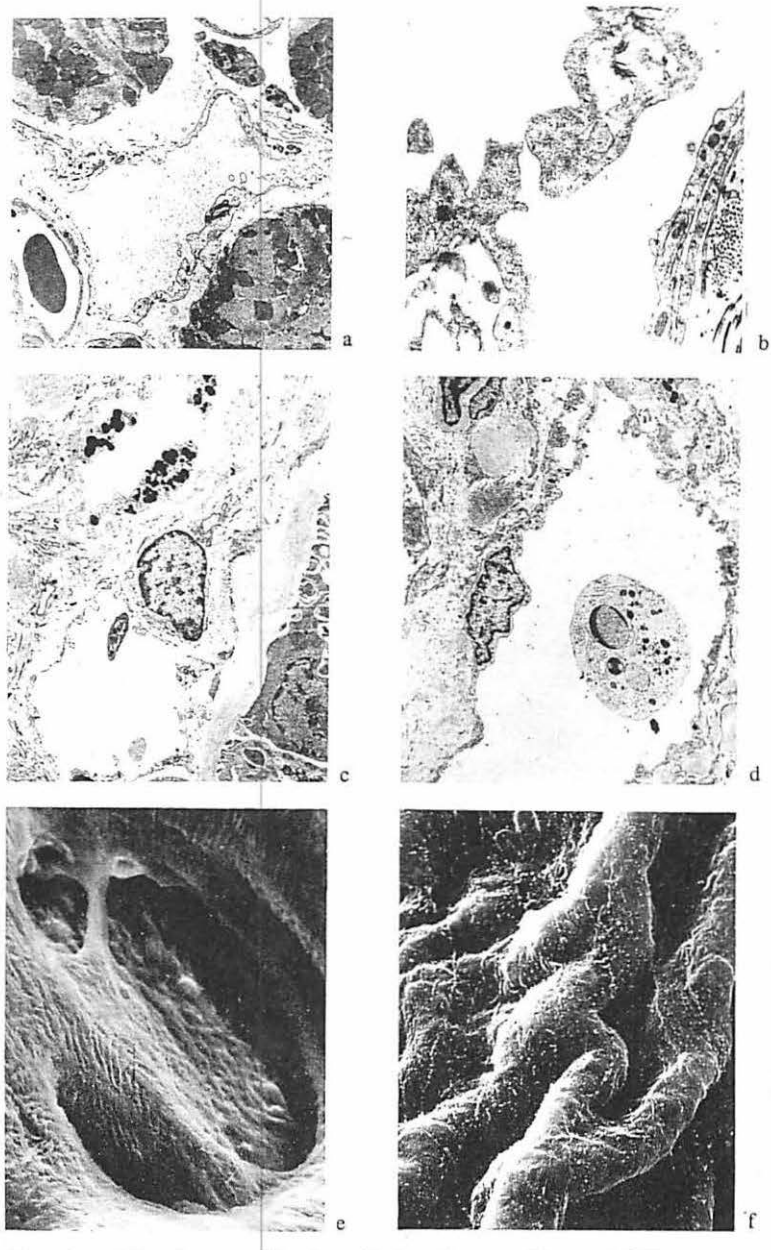
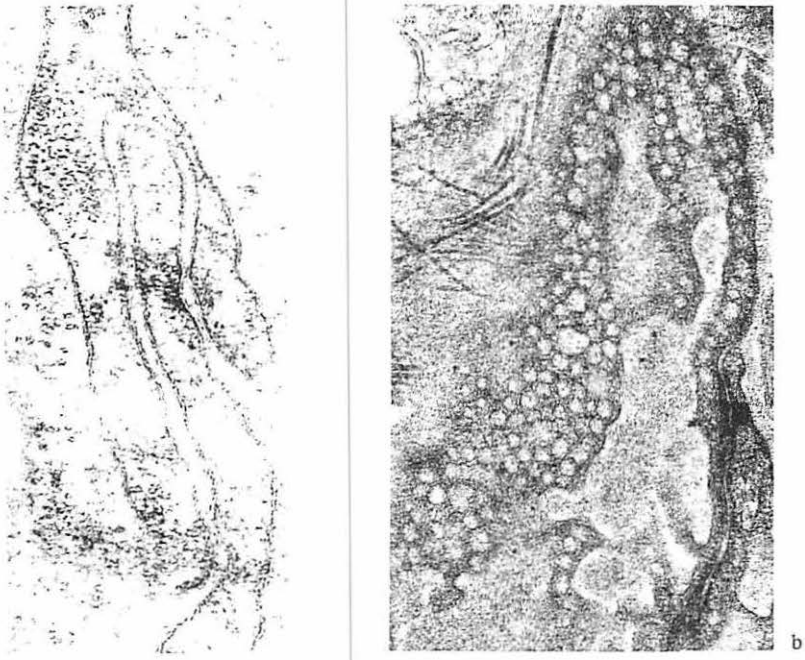
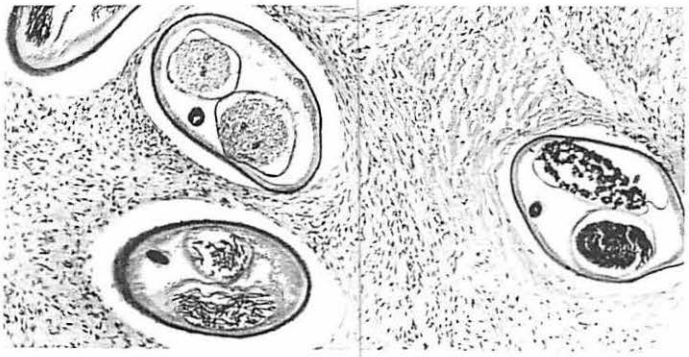


Fig. 2a Dilated lymph capillary between blood capillaries of myocardium. x 3.750
2b Open junction between two endothelial processes of a lymph capillary. x 13.800
2c Dilated lymph capillaries with endothelial siderosomes, following venous congestion. x 4 000
2d Dilated lymph capillary with splitting of an endothelial cell, forming a perilymphatic channel (above). x 3.675
2e "Confluence" of several lymphatics at the inner surface of the chylous cisterna. x 230
2f Top view of lymph vascular endothelium with intensive folding of the endothelial cells. x 600



b



c

Fig. 3a Interdigitation of two endothelial processes in the lymph capillary wall. x 29.500
3b Partly transversally, partly tangentially sectioned lymph capillary with intensive microvesiculation of the endothelium beside the adjacent collagen fibrils and finer filaments. Zonula occludens formed by two endothelial cell processes at the right below. 44.250 x
3c Parasitic lymphangiosis (onchocercosis). HE, 60 x

cles and substances (*Casley-Smith* 1964, 1965, 1968; *Leak* and *Burke* 1966, 1968). The further transport of lymph following its resorption is maintained by valves which can already be observed in smaller lymph-collecting vessels like those of the epicardium or the hilar lymph vessels of different organs (Fig. 1b). Lymph vascular valves differ in size and shape. With the aid of stereomicroscopy and scanning electron microscopy, it has been proven that funnel-like valvular structures dominate (*Lauweryns* 1971). Blood vessels, i.e. veins of comparable size, do not contain valves. The existence of valves, therefore, support the identification of medium-sized lymph vessels. Within the lymph-collecting vessels, not only the valves but also a special wall structure helps to propel the

lymph centripetally. Lymph propulsion by rythmic contractions has been demonstrated experimentally in vivo and in vitro by *Florey* (1927), *Smith* (1949), *Horstmann* (1951, 1959), *Webb* and *Starzl* (1953), *Mislin* (1961, 1963, 1976), *Kinmonth* et al. (1963), *Schipp* and *Schäfer* (1969), *Yoffey* and *Courtice* (1970). The contractability of a lymph vascular segment between two valves with autonomous nerval stimulation enables functional adaptation to the amount of lymph by the number of contractions. Another control mechanism for lymph transport is provided by the wall structure of the chylous cisterna. The lymph vessels running into the chylous cisterna take a helical course within the cisternal wall. This structural property makes it possible to compress the entering lymph vessels during the filling phase of the cisterna. In addition the cisternal lymph vessels have valvular folds at their orifices which can block the afferent vessels during the filling phase (Fig. 2e) (*Lenz* and *Huth* 1976).

Transport of lymph within the lymph trunks, especially in the thoracic duct, is facilitated by the elastic and muscular wall components, by their well-developed valvular apparatus, and probably by the pulsation of the adjacent aorta. Adrenergic nerves have been demonstrated in close contact to muscle cells of the thoracic duct wall (*Wenzel* 1972). A final regulative mechanism for the lymph flow to the venous system is represented by the ductal orifice at the venous angle with its individual variability and its special ductal branching at the venous angle as well as by its special valvular apparatus. The importance of these structures has been emphasized by endoscopic findings (*Seeliger* 1973, 1974).

The lymphatic vascular wall structures and their alterations considerably influence the pathological changes in the interstitium of almost every organ. Only a few examples are mentioned in the context of this article. Brain tissue which does not have its own lymphatic vascular system, can be split by lymphostatic oedema as has been shown experimentally and after human pharyngitis, sinusitis, neck dissection, etc. (*Földi* et al. 1962, 1967). Interstitial cardiac fibrosis and sclerosis of the heart valves in cases without carditis have been correlated with lymphostatic conditions (*Kline* 1964, *Miller* et al. 1960-70, *Goldberg* 1968, *Bullon* and *Huth* 1972). Pulmonary lymphostasis with interstitial fibrosis has been demonstrated after obliteration of lymph vessels in pneumoconiosis as well as primary fibrosis of the lung (*Meessen* 1949, *Vanek* 1954, *Szabo* 1960).

Lymphostatic alterations with lymphangiectasia and enteral protein loss are increasingly being detected with the aid of modern methods of investigation. The importance of lymphatic vascular drainage of the cirrhotic liver and consequently, the dynamic insufficiency of the great lymph trunks in liver cirrhosis with ascites as well as their interdependence have been clarified in the past ten years (*Baggenstoss* and *Cain* 1957; *Baggenstoss* 1960; *Dumont* et al. 1960–1969; *De Benedetti* et al. 1965; *Ludwig* et al. 1968; *C.L.* and *M.H. Witte* et al. 1968, 1969, *Beltz* et al. 1969; *Borchard* et al. 1972).

The special architecture of the peripheral lymphatics in lymph nodes and spleen as well as their role in the spread of blastoma cells has been elucidated by combined scanning and transmission electron microscopy. For the urinary tract, chyluria, for instance following filariasis impressively illustrates the possible importance of this drainage system (Fig. 3c).

A connection between general diseases such as widespread tumorous processes and the lymphostatic symptoms caused by them often remains occult. The lymphovenous pressure gradient and/or the shunt of the fluid into the venous system can be influenced by generalized factors such as venous congestion in heart failure or venous thrombosis. An oedema resulting from such factors can just barely be correlated with lymphostasis.

The sequence of organic diseases involving specific lymph vascular structures ought to be researched further. Finally, attention should be drawn to the fact that the diagnosis of lymphangiomata over against hemangiomata often depends on the evidence of specific lymphvascular features such as valves within smaller vascular lumina.

In summary, the morphology of the lymph vessels not only determines the function of this drainage system but also influences its pathologic reactions.

References

Aiello, R.J., J.F. Enquist, E. Ikezono, B.S. Levowitz: An experimental study of the role of hepatic lymph in the production of ascites. Surg. Gynecol. Obstet. 11 (1960) 77-81

Baggenstoss, A.H., J.C. Cain: The hepatic hilar lymphatics of man; their relation to ascites. New Engl. J. Med. 256 (1957) 531-535

Baggenstoss, A.H.: The relationship of the hepatic hilar lymph vessels of man to ascites. Arch. De Vecchi 31 (1960) 11-19

Bartels, P.: Das Lymphgefäßsystem. In: Bardeleben: Handb. Anat. III. 4, 231-233. Fischer Jena 1909

Baum,H.: Das Lymphgefäßsystem des Pferdes. Springer, Berlin 1928

Becher, H., E. Fischer: Weitere Erfolge mit der Methode der selbsttätigen Luftfüllung. Anat. Anz. 76 (1933) 340-348

Beltz, L., G. Esser, M. Grenzmann: Zur Lymphdynamik bei der portalen Hypertension. Fortschr. Röntgenstr. 111 (1969) 1-21

De Benedetti, M.J., Ph.W. Wright, M.J. Orloff: Dynamics of liver lymph and blood flow in experimental liver disease and ascites. Surgical Forum 16 (1965) 274-276

Borchard, F., H. Borchard, F. Huth: Beitrag zur lymphvasculären Sklerose des Ductus thoracicus. Beitr. Path. Anat. 146 (1972) 145-161

Bullon, A., F. Huth: Fine structure of lymphatics in the myocardium. Lymphology 5 (1972) 42-48

Bergström, K., B. Werner: Proteins in human thoracic duct lymph. Acta chir. scand. 131 (1966) 413-422

Burke, J.F., L.V. Leak: Ultrastructure of lymphatic capillaries during the inflammatory response. J. Cell. Biol. 27 (1965) abstr. 129A-130A

Burke, J.F., L.V. Leak: Lymphatic capillary function in normal and inflammed states. Progress in Lymphology II. Ed. Viamonte et al., pp. 81-85 Thieme, Stuttgart 1970

Casley-Smith, J.R.: Endothelial permeability II. The passage of particles through the lymphatic endothelium of normal and injured ears. Brit. J. exp. Path. 46 (1965) 35-49

Casley-Smith, J.R.: The fine structure, properties and permeability of the lymphatic endothelium. Experientia, Suppl. 14, pp. 19-39 Birkhäuser, Basel, 1967

Casley-Smith, J.R.: The functioning of the lymphatic system under normal and pathological conditions; its dependence on the fine structures and permeabilities of the vessels. In: Progress in Lymphology. pp. 348-359. Thieme, Stuttgart 1967

Casley-Smith, J.R.: How the lymphatic system works. Lymphology 1 (1968) 77-80

Casley-Smith, J.R.: The structure of large lymphatics: How this determines their permeabilities and their ability to transport lymph. Lymphology 2 (1969) 15-25

Casley-Smith, J.R.: How the lymphatic system overcomes the inadequacies of the blood system. In: Progress in Lymphology II. Ed.: Viamonte et al. 51-54, Thieme, Stuttgart 1970

Cremer, H., N. Müller, H. Bechtelsheimer: Morphologische Untersuchungen an Leber und Dünndarm sowie lipidchemische Untersuchungen im Serum nach Unterbindung des Ductus thoracicus bei Ratten. Virchows Arch. Abtl. A, 355 (1972) 309-322

Csillik, B., M. Földi: Experimental lymphostasis: Histochemistry and ultrastructure. Experientia Suppl. 14, pp. 159-168 Birkhäuser, Basel 1967

Dumont, A.E., J.H. Mulholland: Flow rate and composition of thoracic duct lymph in patients with cirrhosis. New Engl. J. Med. 263 (1960) 471-474

Dumont, A.E., J.H. Mulholland: Effects of thoracic duct to esophagus shunt in dogs with congestive heart failure. Comparison with findings in hepatic cirrhosis. New Engl. J. Med. 269 (1963) 949-952

Dumont, A.E.: Liver lymph: a critical component of hepatic cirrhosis. In: Ch. G. Child: The liver and portal hypertension. Vol I (1964) 176-188

Dumont, A.E., J.H. Mulholland: Hepatic lymph in cirrhosis. In: Progress in liver diseases. Vol. II, pp. 427-441. Grune + Stratton, New York-London 1965

Dumont, A.E., M.H. Witte: Significance of excess lymph in the thoracic duct in patients with hepatic cirrhosis. Amer. J. Surg. 112 (1966) 401-406

Dumont, A.E., A. Martelli: X-ray opacification of hepatic lymph nodes following intravenous injection of tantalum dust. Lymphology 2 (1969) 91-95

Florey, H.: Observations on the contractility of lacteals. Part I. J. Physiol. 62 (1927) 267-272

Florey, H.: Observations on the contractility of lacteals. Part II. J. Physiol. 63 (1927) 1-18

Földi, M., E. Csanda, G. Szeghy, L. Varga: Histopathologische Veränderungen im Zentralnervensystem nach Unterbindung der Lymphgefäße und Lymphknoten des Halses beim Hund. Klin. Wschr. 40 (1962) 598

Földi, M., Ö.T. Zoltan, F. Obal, I. Madaraz, L. Lehotai: Die Wirkung der Unterbindung der Lymphgefäße und Lymphknoten des Halses auf das Zentralnervensystem IV. Zschr. ges. exper. Med. 138 (1964) 185-190

Földi, M., B. Csillik, F. Joo, Ö.T. Zoltan: Electron microscopic alterations in the central nervous system in experimental lymphogenic encephalopathy. Angiologica 4 (1967) 50-56

Földi, M., F. Obal, A. Kahan, A. Wagner, E. Csanda, E. Börcsök: Lymphogene Encephalopathie. Acta Paediatr. Acad. Sci. Hung. 8 (1967) 171-204

Földi, M., B. Csillik, Ö.T. Zoltan: Lymphatic drainage of the brain. Experientia 24 (1968) 1283-1287

Földi, M.: Erkrankungen des Lymphgefäßsystems. G. Witzstrock, Baden-Baden, Brüssel 1971

Gerteis, W.: Darstellungsmethoden des Lymphgefäßsystems und praktische Lymphographie. In: Handb. Allg. Path. III/6, pp. 595-636. Springer, Berlin, Heidelberg, New York 1972

Goldberg, G.M.: The involvement of the endocardium as related to subendocardial lymphatics. Amer. J. Path. 52 (1968) 69a

Grau, H.: Das Lymphgefäßsystem. In: Ellenberger-Baum: Handb. Vergl. Anat. d. Haustiere 18. Aufl. Berlin 1943

Hankiss, J.: Kollodiumeinhüllung der Leber zur Untersuchung des Lymphkreislaufs der Leberkapsel. Zschr. Ges. Inn. Med. 14 (1959) 1018

Hass, H.: Die Architektur der Lymphgefäße der Leberkapsel in ihren Beziehungen zur Bindegewebsstruktur und Flüssigkeitsströmung. Virchows Arch. 297 (1936) 384-403

Horstmann, E.: Über die funktionelle Struktur der mesenterialen Lymphgefäße. Morphol. Jahrb. 91 (1951) 483-510

Horstmann, E.: Beobachtungen zur Motorik der Lymphgefäße. Pflügers Arch. ges. Physiol. 269 (1959) 511-519

Hudack, S.S. P.D. McMaster: The lymphatic participation in human cutaneous phenomena. J. exp. Med. 57 (1933) 751-774

Huth, F.: Disk. in: Progress in Lymphology. p. 411 Thieme Stuttgart 1967

Huth, F.: Beiträge zur Orthologie und Pathologie der Lymphgefäße der Nieren. Beitr. Path. Anat. 136 (1968) 341-412

Huth, F., A. Wilde, H.J. Schulten, S. Berger: Morphologische Beiträge zur Pathophysiologie des Lymphgefäßsystems der Leber. Virchows Arch. Abt. A, 351 (1970) 41-67

Huth, F.: Allgemeine Pathologie des Lymphgefäßsystems. In: Handb. Allg. Pathol. Bd. III/6, pp. 457-578. Springer, Berlin - Heidelberg - New York 1972

Huth, F.: Morphologische Aspekte des Lymphgefäßsystems der Leber. Leber, Magen, Darm 4 (1974) 262-273

Huth, F., T.S. Lie, W. Nohl, P. Hülzer, H. Nakano: Morphologische Befunde an den Lebern von Hunden nach experimenteller Lymphostase, Cholestase sowie Lymphostase plus Cholestase mit und ohne Behandlung durch subkutane Injektionen von Cumarin-Troxerutin. Folia Angiol. 24 (1976) 39-51

Johnson, R.A., T.M. Blake: Lymphatics of the heart. Circulation 33 (1966) 137-142

Johnson, R.A.: The lymphatic system of the heart. Lymphology 2 (1969) 95-108

Jossifow, G.M.: Das Lymphgefäßsystem des Menschen. Fischer, Jena 1930

Kaiserling, H., T. Soostmeyer: Die Bedeutung des Nierenlymphgefäßsystems für die Nierenfunktion. Wiener Klin. Wschr. 52 (1939) 1113-1117

Kalima, T.V., S.H. Kalima: The significance of ultrastructural details in blood capillaries and initial lymphatics in regard to intestinal absorption. Abstr. Intern. Congr. Lymphol. Buenos-Aires, Rio de Janeiro 1975, pp. 101-103

Kinmonth, J.B., E.P. Sharpey-Schafer, G.W. Taylor: Spontaneous contractions of lymphatic vessels in man. Lancet 1 (1963) 1425

Kline, I.K.: The relationship between human endocardial fibroelastosis and obstruction of the cardiac lymphatics. Circulation 30 (1964) 728-735

Kuprianov, V.V.: Some features of the initial lymphatic vessels in their interrelation with blood vessels. Acta anat. (Basel) 73 (1969) 69-80

Lauweryns, J.M.: Stereomicroscopic funnel-like architecture of pulmonary lymphatic valves. Lymphology 4 (1971) 125-132

Leak, L.V., J.F. Burke: The passage of electron-opaque tracers across the lymphatic capillary wall. In: Electron Microscopy, Vol. II Biology; pp. 731-732. Maruzen Co. Ltd., Tokyo 1966

Leak, L.V., J.F. Burke: Fine structure of the lymphatic capillary and the adjoining connective tissue area. Amer. J. Anat. 118 (1966) 785-809

Leak, L.V.: The fine structure and function of the lymphatic vascular system. In: Handb. Allg. Pathol. III/6, pp. 149-196. Springer, Berlin – Heidelberg – New York 1972

Lenz, W., F. Huth: Lichtoptische und rasterelektronenmikroskopische Untersuchungen zur Wandstruktur der Cisterna chyli des Menschen. Acta anat. 96 (1976) 259-269

Lie, T.S., W. Nohl, H. Nakano, H. Ebata, F. Huth: Beeinflussung einer Cholestase durch eine Lymphostase der Leber. Folia Angiol. 24 (1976) 59-62

Lie, T.S., W. Nohl, H. Nakano, H. Ebata, F. Huth: Lymphostatische Hepatopathie. Folia Angiol. 24 (1976) 52-58

Ludwig, J., P. Linhart, A.H. Baggenstoss: Hepatic lymph drainage in cirrhosis and congestive heart failure. Arch. Pathol. 86 (1968) 551-562

Ludwig, J., P. Linhart: Lymphvarizen bei Leberzirrhose und Stauungsleber. Verh. Dtsch. Ges. Pathol. 52 (1968) 563-567

Magnus, G.: Darstellung der Lymphwurzeln von serösen Häuten und ihre Bedeutung für die Pathologie. Arch. Klin. Chir. 121 (1922) 128-130

Meessen, H.: Über Lungenzirrhose. Beitr. path. Anat. 110 (1949) 1-14

Miller, A.J., R. Pick, L.N. Katz: Lymphatics of the myocardial pathology produced by chronic cardiac lymphatic obstruction in the dog. Circ. Res. 8 (1960) 941-947

Miller, A.J., R. Pick, L.N. Katz: Lymphatics of the mitral valve of the dog. Circ. Res. 9 (1961) 1005-1009

Miller, A.J., R. Pick, L.N. Katz: Studies on the effect of chronic impairment of cardiac lymph flow in the dog. In: Progress in Lymphology. pp 369-370. Thieme, Stuttgart 1967

Miller, A.J.: Some observations concerning pericardial effusions and their relationship to the venous and lymphatic circulation of the heart. Lymphology 2 (1970) 76-78

Mislin, H.: Zur Funktionsanalyse der Lymphgefäßmotorik. Rev. suisse Zool. 68 (1961) 228-238

Mislin, H.: Experimenteller Nachweis der autochtonen Automatik der Lymphgefäße. Experientia 17 (1961) 29-30

Mislin, H.: Zur Funktionsanalyse des Elektrolymphangiogramms (ELG) bei Mesenterialgefäßen von Meerschweinchen. Verh. Dtsch. Ges. Zool. pp. 543-549. Leipziger Acad. Verlagsanstalt Geest & Portzig KG 1963

Mislin, H.: Active contractility of the lymphangion and coordination of lymphangion chains. Experientia 32 (1976) 820-822

Mori, K.: Morphological observation on the passage of substances through the walls of blood and lymphatic vessels. Acta path. jap. 13 (1963) 208-209

Mori, K., S. Yamada, R. Ohori, M. Takada, T. Naito: Observations in vivo on the extravasation of various dye fluids from the blood vessels into the connective tissue. Okajimas Folia anat. jap. 39 (1964) 277-299

Most, A.: Untersuchungen über die Lymphbahnen an der oberen Thoraxapertur und am Brustkorb. Arch. Anat. Physiol. 1 (1908) 1-30

Natucci, G., C. Zaccarini: Risultati sperimentali e sequele determinate dalla ligatura dei linfatici all'ilo del rene. Riv. Anat. Path. 2 (1949) 639-658

Romualdi, G., O. Linoli: Le alterazioni delle strutture glomerulari nelle nefrosi umano e sperimentali ed il loro significato nella genesi della alterazioni tubulari a gocce jalines. Arch. De Vecchi 8 (1946) 577-622

Romualdi, G., M. Monaci: La nefrosi consecutiva a linfostasi sperimentale e la nefrosi da tossici esogeni nell rene in linfostasi. Arch. De Vecchi 9 (1947) 987-1002

Romualdi, G., M. Monaci: Le modificazioni della funzione dei rene in corso di linfostasi in animali normali e nella ipertrofica vicariante. Arch. De Vecchi 9 (1947) 973-986

Rusznyak, I., M. Földi, G. Szabo: Physiologie und Pathologie des Lymphkreislaufs. Fischer, Jena 1957

Schipp, R., A. Schäfer: Elektronenmikroskopische Untersuchungen zur Chylusbildung und Funktion der Lymphwege in der Darmwand des Säugers. Zool. Anz. Suppl. Bd 33, Verh. Zool. Ges. pp. 407-415 (1969)

Seeliger, K.: Direkte intravaskuläre fibroskopische Lymphoskopie und Ductus thoracicus-Kanülierung. Folia Angiol. XXI (1973) 287-296

Seeliger, K.: Vasculäre Endoskopie der Ductus thoracicus-Einmündung im linken Venenwinkel. Folia Angiol. Suppl. Vol. III (1974) 117-118

Smith, R.O.: Lymphatic contractility: A possible intrinsic mechanism of lymphatic vessels for transport of lymph. J. exp. Med. 90 (1949) 497-509

Stroobandt, R., W. Lenz, G. Jacobs, E. Wiebringhaus, F. Huth, L. Van Der Hauwart: X-ray, light- and electron microscopic investigations of the cardiac lymph vascular system. Folia Angiol. 24 (1976) 63-71

Szabo, G.: Die Bedeutung des Lymphgefäßsystems in der Physiologie und Pathologie. Med. Klin. 55 (1960) 974-977

Tormene, A., O. Zangrando, R. Millini G. Fazzini: Contribution to the study of the lymphatic circulation in organs. Note I: The renal lymphatics. Urol. int. 20 (1965) 305-318

Vanek, J.: Interstitielle nichteitrige Pneumonie. Zentralbl. Pathol. 92 (1954) 405-416

Viragh, S., M. Papp, I. Törö, I. Rusznyak: Cutaneous lymphatic capillaries in dextran – induced oedema of the rat. Brit. J. exp. Path. 47 (1966) 563-567

Webb, R.C., T.E. Starzl: The effect of blood vessel pulsation on lymph pressure in large lymphatics. Bull. Johns Hopk. Hosp. 93 (1953) 401-407

Wutzer, C.W.: Einmündung des Ductus thoracicus in die Vena azygos. Arch. Anat. Physiol. (1834) 311-318

Wenzel, J.: Normale Anatomie des Lymphgefäßsystems. In: Handb. Allg. Pathol. Bd. III/6 pp. 89-148. Springer, Berlin – Heidelberg – New York 1972

Witte, C.L., M.H. Witte, A.E. Dumont, J. Frist, W.R. Cole: Lymph protein in hepatic cirrhosis and experimental hepatic and portal venous hypertension Ann. Surg. 168 (1968) 567-577

Witte, M.H., A.E. Dumont, W.R. Cole, C.L. Witte, K. Kintner: Lymph circulation in hepatic cirrhosis: effect of portocaval shunt. Ann. Int. Med. 70 (1969) 303-310

Witte, M.H., C.L. Witte: Influence of mechanical factors on ascites formation in hepatic cirrhosis. Lymphology 2 (1969) 89-91

Yoffey, J.M., F.C. Courtice: Lymphatics, lymph and the lymphomyeloid complex. London, Acad. Press. 1970

F. Huth, Patholog. Institut, Univ. Düsseldorf, Moorenstr. 5, 4000 Düsseldorf