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Techniques in Vascular and Interventional Radiology

Lymphatic Anatomy

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Recent development of new lymphatic imaging and intervention techniques, such as intranodal lymphangiogram, dynamic contrast enhanced magnetic resonance lymphangiography and lymphatic embolization, have resulted in the resurgence of interest in the lymphatic anatomy. The lymphatic system is a continuous maze of interlacing vessels and lymph nodes and is extremely complex and variable. This presents a significant challenge for interpretation of imaging and performance of interventions on this system. There is an embryological reason for this complexity and variability; the lymphatic system sprouts off of primordia from several locations in the body, which later fuse together at different stages of development of the embryo. The lymphatic system can be divided in three distinct parts: soft tissue lymphatics, intestinal lymphatics, and liver lymphatics. Liver and intestinal lymphatics generate approximately 80% of the body lymph and are functionally the most important parts of the lymphatic system. However, their normal anatomy and pathological changes are relatively unknown. In this chapter we will explore the anatomy of these three systems relevant to lymphatic imaging and interventions.

KEYWORDS Lymphatic, Anatomy, Embryology

Compared with vascular, the lymphatic system anatomy is extremely complex and variable. Most of the lymphatic vessels are very small and together with lymphnodes they create a maze of interlacing vessels. For that reason, classical anatomical research methods, such as continuous dissection and corrosion casting, are hindered. In spite of that, since Greek times scientists and physicians have tried to explore the structure and function of these small vessels filled with colorless and milky fluid. However, not until the Renaissance era, in 1552, is Eustachius credited as being the first to discover and name this milky colored duct "Vena albathoracis" after observing it during a horse dissection. However, it was GasparoAselli (1581-1626), a professor of anatomy and surgery in Pavia, who was the first to observe "lacteal vessels," while dissecting a dog after a heavy meal, tracing them from the gut to the mesentery. Later, Bartholinus (1653) understood the connection between different parts of the lymphatic system and Rudbeck during the same time first described the lymphatic vessels on the liver surface. The famous French anatomist Rouviere published the most extensive anatomical description of the lymphatic system in 1938.

The lymphatic system consists of at least the following 3 distinct parts: soft tissue lymphatic system, intestinal lymphatic system, and liver lymphatic system.[1-4] All 3 systems communicate with each other and eventually coalesce together at the level of the cisterna chyli and continue in the thorax as the thoracic duct (TD). As an analogy, the thoracic duct represents the trunk of an inverted lymphatic tree a simple approximation represents a reverse tree where the thoracic duct represents the trunk. The terminal drainage of lymphatic fluid is the venous system via lympho-venous connections. The main lympho-venous connection is between the thoracic duct and junction of the left subclavian and internal jugular veins (Fig. 1). While multiple other normal lympho-venous connections exist in the body (Fig. 2), it should be noted that functional or anatomic occlusion of downstream lymphatic vessels can result in opening of new, pathologic lympho-venous connections, which can become clinically relevant[5].

The core function of the lymphatic system is collection of excess interstitial fluid from the soft tissues with eventual return to the venous system. However, the

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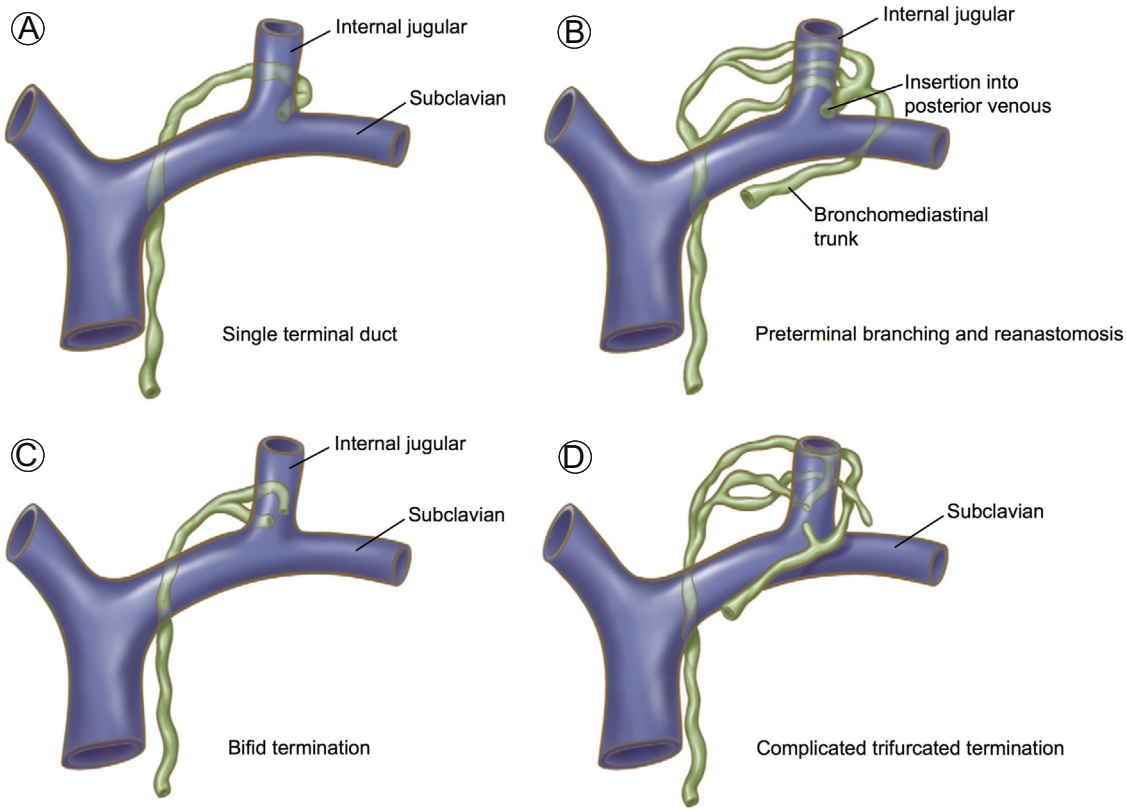

Figure 1 Illustration of variations in termination of the thoracic duct: (A) typical termination of the thoracic duct (single terminal duct), (B) preterminal branching and reanastomosis of the thoracic duct, (C) bifid termination, and (D) complicated trifurcated termination. (Reprinted with permission from Hematti and Mehran.[18]) (Color version of figure is available online.)

lymphatics also These three systems not only drain different part of the body, but perform other important functions in addition to removal of the excessive interstitial fluid. The intestinal lymphatics system actively participates in absorption of dietary fats, and and the liver lymphatics system delivers liver-producedhepatic proteins into the systemic circulation. The clinical presentation of lymphatic flow abnormalities in these lymphatic systems is completely highly different variable, and rangesincluding from lymphedema due tofrom soft tissue lymphatic obstruction of the soft tissue lymphatic toand liver lymphorrhea and chylous ascites from lymphatic leakage, such as liver lymphorea and chylous leaks.

The core function of the lymphatic system is collecting the residual interstitial fluid from the soft tissue and delivering it back into veins through lympho-venous connections. The main lympho-venous connection is between the thoracic duct and junction of the left subclavian and jugular veins (Fig. 1). However, there are multiple other lympho-venous connections at different levels of the body (Fig. 2).[5] More importantly, functional or anatomical occlusion of the lymphatic vessels downstream can result in opening of new lympho-venous connections, resulting in changes that can become relevant under some clinical scenarios.

The imaging anatomy of extremity, pelvic, lumbar, and central (cisterna chyli and thoracic duct) lymphatic systems is well known and has been described based ondemonstrated with conventional lymphangiogram and, more recently, lower extremity Magnetic resonance lymphangiography[6-8]. Traditionally, abdominal and pelvic lymphatic anatomy has been more extensively studied with lymphangiograms to delineate lymph node involvement in the setting of malignancy. While radiologists often neglected this system. it is more recently gaining more attention as intranodal lymphangiogram and glue embolization are becoming new diagnostic and treatment options for patients with chylous ascites and lymphocele (Hur S, Shin JH, Lee IJ, et al. Early experience in the management of postoperative lymphatic leakage using lipiodol lymphangiography and adjunctive glue embolization. J Vasc Interv Radiol 27:1177–1186.e1, 2016; Baek Y, Won JH, Chang SJ, et al. Lymphatic embolization for the treatment of pelvic lymphoceles: preliminary experience in five patients. J Vasc Interv Radiol 27:1170–1176, 2016). Despite these advances, the anatomy of the liver and intestinal lymphatics remain relatively unknown, due to absence of clinical imaging techniques. Since they combine to produce approximately 80% of the body's lymph, understanding the anatomy and pathology of these two particular systems is far more important than any other lymphatic system. Furthermore, lymphatic flow in these systems can increase tenfold during certain pathological conditions, significantly affecting fluid exchange