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Techniques in Vascular and Interventional Radiology

Novel Lymphatic Imaging Techniques

Yoav Dori, MD, PhD

The lymphatic system plays an important role in immune regulation, transport of metabolites, and fluid balance. The key circulatory role of the lymphatic system is to transport fluid from tissue back into the venous system via lymphovenous connections. Despite the centuries-old recognition of this key role, there has been poor understanding of lymphatic flow pathophysiology because of a lack of a simple reliable noninvasive clinical lymphatic imaging method. This lack of clinical imaging has limited the treatment options for patients with lymphatic flow disorders. Recent development of noncontrast magnetic resonance (MR) lymphangiogram and dynamic contrast MR lymphangiography make it possible to visualize central lymphatic anatomy and flow dynamics with high spatial and temporal resolution. Dynamic contrast MR lymphangiography has provided insight into understanding the pathophysiology of several pulmonary lymphatic flow disorders and provides guidance for interventional procedures. Another important development has been intranodal lymphangiogram, which has now replaced pedal lymphangiogram as the main lymphatic interventional modality, and which provides quick and reliable access to the central lymphatic ducts for interventional procedures. These new techniques have led to a resurgence in interest in the lymphatic system and the development of new treatments for patients with lymphatic flow disorders.
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Pedal and Intranodal Lymphangiography

Lymphatic flow disorders can involve peripheral lymphatic channels or the central lymphatic system, which includes the thoracic duct (TD), cisterna chyli, and their tributaries. Traditionally, the main imaging technique for central lymphatic for diagnosis and interventional lymphatic procedures has been pedal lymphangiography (PL). This technique involved exposure of small lymphatic ducts in the dorsum of the foot, which were then cannulated, followed by injection of an oily contrast agent (Lipiodol, Guerbet LLC, Bloomington, IN) that would track its way up the legs and into the central lymphatic ducts.[1] PL is invasive, time consuming, and challenging, which made it a significant barrier for most practitioners. Intranodal lymphangiography has now replaced PL as the new method for central lymphangiography.[2,3] This technique involves cannulation of lymph nodes in the groin with thin needles followed by injection of an oily contrast agent that is allowed to proceed up the central lymphatic conducting vessels. Intranodal lymphangiography is faster, less complicated, and has a higher success rate than PL, making it feasible to perform lymphatic procedures in most centers.

Noncontrast Magnetic Resonance Lymphangiography

Noncontrast T2-weighted magnetic resonance (MR) lymphangiography has been described as a noninvasive MR technique that depicts central and peripheral lymphatic system with good spatial resolution.[4-8] T2 imaging exploits the differences in T2-weighted signal intensity between fluid-filled structures and adjacent soft tissue so that slow-moving nonbloody fluids produce high T2 signal. This technique is able to visualize parts of the anatomy of the peripheral lymphatic system in patients with lymphedema, and with lymphatic malformations, as well as segments of the central lymphatic anatomy, including the TD in disease states such as liver cirrhosis.[7,9-11] This technique has also

Division of Cardiology, HUP/CHOP Center for Lymphatic Imaging and Interventions, Children's Hospital of Philadelphia, Philadelphia, PA.
Address reprint requests to Division of Cardiology, HUP/CHOP Center for Lymphatic Imaging and Interventions, Children's Hospital of Philadelphia, 34th Str, Civic Center Blvd, Philadelphia, PA 19104. E-mail: doriy@email.chop.edu

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been used to demonstrate patterns of abnormal lymphatic anatomy in patients with single ventricle physiology.[12] The main limitations to noncontrast T2 imaging are that it does not provide information about lymphatic flow and the lack of a contrast agent makes it difficult to visualize small lymphatic ducts. Consequently, its use in diagnostic and interventional lymphangiography is limited.

Pedal Lymphoscintigraphy

Intradermal pedal lymphoscintigraphy has been used as a screening tool for disorders of both the central and peripheral lymphatic systems. In addition to anatomical information, lymphoscintigraphy is able to demonstrate regions of abnormal lymphatic perfusion. This additional flow information is key for an understanding of the pathophysiology of certain lymphatic flow disorders.[13,14] Improved anatomical localization with SPECT-CT has overcome the relatively poor spatial resolution inherent to scintigraphy. Despite this improved anatomical localization with SPECT-CT, the spatial resolution of this modality is not conducive to guiding lymphatic interventional procedures (PL is further discussed in a later section of this issue).

Dynamic Contrast-Enhanced MR Lymphangiography

There are 2 types of contrast MR lymphatic imaging techniques: and they are imaging of the extremities and imaging of the central lymphatic system. Multiple techniques have been described for extremity imaging including gadolinium injected intradermally or subcutaneously. Intradermal injected gadolinium-based contrast material has been shown to be absorbed readily into the lymphatic vessels. This technique has been used to delineate lymphatic abnormalities in patients with lymphedema as well as to demonstrate the central lymphatic anatomy in animal models.[10,15-17] However, intradermal contrast injection does not provide sufficient information for imaging of the central lymphatic channels because of dilution of the contrast material leading to poor enhancement of deeper structures.

Dynamic contrast MR lymphangiography (DCMRL) is a new technique, which alleviates this dilution problem by bypassing the lower extremity lymphatics leading to fast and reliable enhancement of the central lymphatic ducts. In addition, this technique shows both static anatomy as well as dynamic flow with good temporal and spatial resolution.[18-20] This new modality is quickly becoming the modality of choice for both diagnostic purposes as well as for preprocedural interventional planning. DCMRL is a safe procedure that can be performed in any age group in all patient populations as long as the patient does not have a contraindication for an MR imaging (MRI) study.

Current indications for DCMRL include as follows:

(1) Nontraumatic lymphatic leak such as chylothorax, chylous ascites, chylopericardium, or chylurea.
(2) Complicated traumatic lymphatic leaks where the source of the leak cannot be visualized with conventional lymphangiography.
(3) Suspected lymphatic complications of lymphatic disorders such as Kaposiform lymphangiomatosis, generalized lymphatic anomaly, Gorham disease.
(4) Plastic bronchitis or other unspecified pulmonary disease of unclear etiology where the lymphatic system could be suspected to play a role in the disease process.
(5) Congenital lymphatic flow disorders such as congenital lymphatic dysplasia, neonatal chylothorax, and neonatal chylous ascites.
(6) Suspected secondary lymphatic flow abnormalities, such as ascites or chylothorax, due to systemic disease such as heart failure or liver cirrhosis.

Absolute contraindications to DCRML are the same as for any conventional MRI and include presence of some implantable electric and electronic devices such as pacemakers with epicardial leads. Relative contraindications include correctable coagulopathy and claustrophobia.

DCMRL Technique

Lymph node access, which requires proper needle placement, is done using ultrasound and fluoroscopy guidance. Consequently, DCMRL procedures are started in a fluoroscopy suite or in a suite with available ultrasound and c-ARM. After properly positioning the patient on the table, an inguinal lymph node is directly accessed under ultrasound guidance with a 25-gauge spinal needle connected to a 3 mL syringe via a short connector tubing (BD Medical, Franklin Lakes, NJ)[3] (Fig. 1). The needle tip is

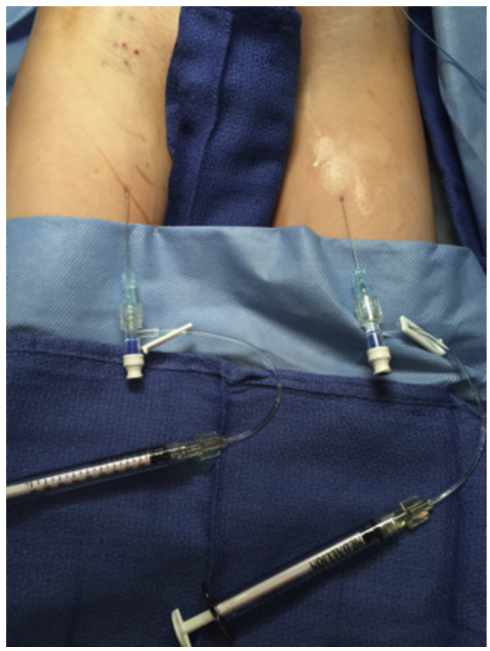

Figure 1 A 25-gauge 3.5 cm spinal needles placed in bilateral inguinal LN's before DCMRL. (Color version of figure is available online.)