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Diagnostic imaging of the lymphatic system

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The lymphatic system is involved in most disease processes, and imaging of the lymphatic system can provide important information about type and severity of the patient’s disease. The lymphatic system can be divided into a vascular and a cellular component.

The vascular system includes lymph capillaries, lymph vessels, and collecting ducts. The vascular lymphatic system has mainly transport function in addition to the venous part of the vascular system. They remove interstitial fluid from tissues, absorb and transport fatty acids and fats as chyle from the digestive system, they transport white blood cells between the lymph nodes and bones, and carry antigen-presenting cells to the lymph nodes where an immune response is stimulated. The lymphatic capillaries are transparent and the lymph they carry is clear everywhere except in the intestinal villi, where the absorbed and transported emulsified fat or chyle makes the lymph appear milky. These intestinal lymphatic capillaries are known as lacteals.

Interstitial fluid enters the lymph capillaries and flows slowly towards the heart via lymphatic ducts. Fluid is transported via peristalsis of the lymph vessels or passive compression from surrounding tissues such as musculature. The thoracic duct collects the lymph fluid from almost the entire body and connects to the general circulation via jugular vein or cranial vena cava. The thoracic duct is the continuation of the cisterna chyli after it courses through the aortic hiatus at the diaphragm.

The cisterna chyli is the only portion of the normal vascular lymphatic system that can be seen on diagnostic imaging studies without the use of contrast media. The cisterna chyli is normally seen on cross-sectional imaging such as computed tomography (CT) or magnetic resonance imaging (MRI) and should not be confused with pathological conditions. It is displayed as one or multiple tubular structure running alongside the aorta. The cisterna chyli may enhance after contrast medium administration.

To investigate the anatomy of the lymph vessels and possible abnormalities, a lymphangiogram has to be performed in most cases. The most common indications are lymphedema, or chylothorax.

Lymphangiography is performed by injecting iodinated contrast medium into a lymph node, or a lymph vessel. With the wide availability of ultrasound, ultrasound-guided lymph node injections are most commonly performed. Both the popliteal and mesenteric lymph nodes are usually accessible for injections; if possible, the popliteal lymph node is preferred in our practice as no injection into a body cavity is needed. The hair over the lymph node is clipped and the skin is aseptically prepared. A 25 gauge needle is then inserted under ultrasound guidance into the center of the lymph node, followed by very slow injection of iodinated contrast medium through an extension set at a dose of 0.5 ml/kg in dogs, at a total dose of 1.5ml in cats. Immediately following injection radiographs or if available, CT images of the limb, abdomen and thorax are acquired to evaluate transportation of the lymph fluid. If the distal extremity is to be examined, a lymph vessel has to be directly cannulated for good delineation of the lymphatics. Feeding a fatty meal before the study enlarges the lymph vessels. Then, 0.5 – 1.5 ml of a dilute vegetable dye such as patent blue (2-3%) or Evans Blue (2-3%) is injected interdigitally, subcutaneously or intradermally. The dorsal metatarsal or metacarpal region is then surgically exposed and a blue stained lymphatic vessel is isolated. Lastly, the lymphatic vessel is cannulated with a 25 to 27 gauge needle and 2 to 20 ml of iodinated contrast medium are infused by hand or through an infusion pump and radiographs or CT images are obtained.

CT is the preferred imaging method for lymphangiography, since it has higher contrast resolution and cross-sectional imaging avoids obscuring smaller lymph vessels by the ribcage or other superimposed structures.

Lymphoscintigraphy is an alternative, noninvasive and safe method. However, it requires availability of a gamma camera and is therefore not commonly used. Lymphoscintigraphy involves subcutaneous injection of the radioactive substance, technetium-99m, coupled to sulphur colloid or albumin. The radioactive particles are then imaged as they pass through the lymphatic system, and draining lymph nodes can be visualized. The disadvantage of this method is that the spatial resolution is poor.

The cellular component of the lymphatic system consists of lymph nodes, and aggregations of lymph tissue in other organs such as the gastrointestinal tract, thymus, and the spleen.

Lymph nodes are located in peri-articular fat stores, the mediastinum and mesentery, and adjacent to many larger blood vessels. Each lymph node consists of a capsule containing elastic and smooth muscle fibers, and an internal...
framework consisting of septa and trabeculae. Microscopically, each node is made up of a central medulla, which contains cords of lymphocytes and small sinuses, and an outer cortex containing lymphatic nodules or follicles. There are no lymph vessels in the brain and spinal cord or within skeletal muscles; however, mucous membranes and the skin are richly supplied with lymph vessels. The spleen, thymus, and bone marrow also contain lymphoid tissue, although the latter primarily forms erythrocytes and leukocytes rather than lymphocytes. Afferent lymph vessels enter the lymph node at the capsule (afferent = arriving). Efferent (= leaving) lymph vessels leave the node at the hilus. The hilus is also the entrance for the venous and arterial blood supply of the lymph node.

The lymph nodes are primarily involved in immune responses. When infectious agents appear in the drainage area of a lymph node, they stimulate hyperplasia of the lymph node with an increase in numbers of macrophages and reticulocytes. The lymph node enlargement leads to stretching of the capsule which can be painful. Lymph nodes also act as filters for other cells such as tumor cells. Tumor cells carried in the lymph may become trapped in the lymph nodes where they are phagocytosed and destroyed or initiate a metastatic lesion. If metastatic tumor cells are not filtered out by the lymph nodes, they enter the circulation and lead to hematogeneous metastatic spread.

All diagnostic imaging modalities can be used to investigate the lymph nodes to some degree. Radiography is the least sensitive method to detect lymph node enlargement, or lymphomegaly. On radiographs, normal and only mildly enlarged lymph nodes are not typically seen, only if they are surrounded by a fair amount of fat as for example the popliteal lymph node. Advanced lymphomegaly will lead to a mass effect with displacement of adjacent structures, for example ventral displacement of the descending colon and rectum in the case of sublumbar lymphomegaly.

Ultrasound is the most commonly used imaging method to assess lymph nodes. Normal lymph nodes should be spindle-shaped, slender and have an echogenicity very similar to the surrounding fat. The capsule should be smooth and hyperechoic. Occasionally, a hyperechoic hilus can be seen. Most lymph nodes are only a few millimeters wide, reliable reference values are not available. When comparing lymph node size, the width is more reliable than the length, as it is often difficult to have the entire length of a lymph node in the same image plane resulting in measurement errors. More important than the measurements however is the sonographic appearance of the lymph node, typically abnormal lymph nodes become more hypoechoic compared to the surrounding fat and become rounded rather than elongated. Doppler examination of the lymph nodes or contrast enhanced ultrasound can be performed to evaluate the blood flow and vascular architecture of the lymph node. Tumor infiltrates for example may lead to compression of blood vessels, or increased vascular supply which can be visualized with contrast enhanced ultrasound. Normal abdominal lymph nodes have a resistive index (RI) <0.65 and a pulsatility index (PI) of <1.45 whereas metastatic lymph nodes often have an elevated RI and PI.

Head and neck lymph nodes as well as intrathoracic lymph nodes are more commonly investigated with computed tomography (CT) and magnetic resonance (MR) imaging as the skull as well as the ribcage and air-filled lungs limit accessibility for ultrasound imaging. Normal lymph nodes on CT and MR are smooth in outline, have uniform density or signal intensity, and typically enhance strongly and uniformly after contrast medium administration. Normal thoracic lymph nodes, if visible at all, typically are less than 5mm in thickness whereas head and neck lymph nodes should be less than 10mm in thickness.

In most cases, fine needle aspiration will be necessary to determine if a lymph node is normal or abnormal, and if it is reactive or neoplastic. Fine needle aspiration under ultrasound guidance should only be performed by ultrasonographers experienced in this technique. Lymph nodes, even if enlarged, are still relatively small structures that are mobile in the surrounding fat and closely associated with large vessels.