6 Sonographic Anatomy and Pathology: Cervical Lymph Nodes

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6.1 Introduction

Lymph nodes are small bean-shaped structures that constitute a major part of the body's immune system [1, 2]. Lymph nodes filter substances that travel through the lymph fluid, and contain lymphocytes (white blood cells) that help the body fight infection and disease. There are hundreds of lymph nodes found throughout the body [1, 3]. They are connected to one another by lymph vessels. Clusters of lymph nodes are found in the neck, axilla (underarm), chest, abdomen, and groin [1–4].

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6.1.1 Basic Anatomy

Normal lymph nodes are small anatomical oval or kidney-shaped structures with a size ranging from 0.1 to 2.5 cm in size. They are surrounded by a thick connective tissue capsule extending with diaphragms inside the lymph nodes covering multiple compartments [1, 3].

The parenchyma of the lymph nodes is distinguished in the cortical, subcortical, and medullary sections. Enclosed areas of the cortical section form the primary follicles containing a large number of B- and T lymphocytes, mononuclear, and macrophages. B lymphocytes produce antibodies, T lymphocytes destroy antigens, and macrophages perform phagocytosis [1, 3, 4].

A small opening in the middle of the glands creates an area rich in fibrous and fatty tissue designated as the hilum. The medullary section surrounds the hilum and is separated from the cortical section by insertion of the transitional

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zone of the subcortex. The blood supplying artery enters through the hilum and the corresponding vein and the lymph nodes exit through it [1–4].

The accessory lymph nodes collect the lymph from the adjacent tissues and centrally discharge into the capsule of the lymph nodes. The transported lymph infiltrates the lymph nodes, which act as "refineries" of blood, destroying germs, viruses, cancer cells, and harmful foreign substances before eventually entering the venous circulation.

The lymph nodes are innervated by autonomic nervous system fibers and their innervation include the capsule, the inner diaphragms, and the smooth muscle of the blood vessels [1–4].

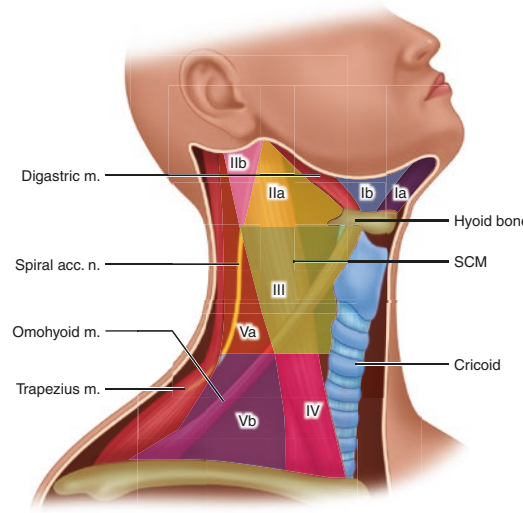

Fig. 6.1 Classification of the neck regions based on lymph node groups. Courtesy of Aikaterini Spanou

6.1.2 Regional and Functional Classification of Lymph Nodes

Based on the older and more recent historical data cervical lymph nodes are classified at least in six different anatomical levels (level I–VI) with different varying subclassifications aiming to the more accurate classification of the pathology, the more detailed surgical planning, and the better programming of the treatment of cervical and even head and neck cancer [5–7].

Figure 6.1 depicts a more current classification of the varying levels and anatomical borders that apply to daily clinical and radiographic treatments, which are analyzed in detail below.

The major lymph node groups of the head region are described together with their topographic location and the structures they drain [5–7].

So basically they are classified according to their drainage and the major divisions are:

- Facial: Skin and mucosa of the eyelids, the nose, the buccal area, the temporal and subtemporal region, and rinopharynx
- Parotid: Skin of the temporal and frontal region. The maxilla, the buccal area, the external acoustic meatus and eardrum, the eyelids, and section of the nose.
- Retroauricular: Side section of the hairy part of the skin behind the ear, the skin at the external acoustic meatus region, and the external ear
- Suboccipital: Posterior section of the hairy part of the head

Cervical lymph nodes are accepted as intermediary stations of the lymph drainage from the head and face lymph nodes groups. They also drain the soft tissues of the region and the organs that are present in the neck area [5, 8, 9]. The most important groups are:

- Submental: Lower lip, tongue tip, gums, and anterior teeth
- Submandibular: Upper and lower lip, intraoral mucosa, tongue, mandible gums, and teeth
- Jugulodigastric: Lingual and pharyngeal tonsils, hard palate, sections of the tongue
- Deep cervical: Larynx, trachea, thyroid gland, parathyroid glands, and upper esophagus
- Supraclavicular: Anterior thoracic wall, armpit region, shoulder, and upper limb
- Superficial cervical lymph nodes are lying on the surface of the sternocleidomastoid muscle, they drain the skin, and the superficial tissues and flow into the deep cervical lymph nodes.

When one is talking about varying levels of classifications, the most frequently followed divisions of the cervical lymph nodes are those

according to the American Academy of Otolaryngology which classifies them as follows:

Level I: Submental and submandibular nodes

- Level Ia: Submental, within the triangular boundary of the anterior belly digastric muscles and the hyoid bone.
- Level Ib: Submandibular triangle—within the boundaries of the anterior belly of the digastric muscle, the stylohyoid muscle, and the body of the mandible.

Level II: Upper jugular nodes (Subdigastric nodes)—around the upper third of the internal jugular vein and adjacent accessory nerve. The upper boundary is the base of the skull and the lower boundary is the inferior border of the hyoid bone. The anterior/medial boundary is the stylohyoid muscle and the posterior/lateral one is the posterior border of the sternocleidomastoid muscle. On imaging, the anterior/medial boundary is the vertical plane of the posterior surface of the submandibular gland.

- Level IIa: Anteriomedial to the vertical plane of the accessory nerve
- Level IIb: Posterolateral to this plane.

Level III: Middle jugular nodes—around the middle third of the internal jugular vein, from the inferior border of the hyoid to the inferior border of the cricoid cartilage. Anteromedially they are bounded by the lateral border of the sternohyoid muscle and posterolaterally by the posterior border of the sternocleidomastoid.

Level IV: Lower jugular nodes—around the lower third of the internal jugular vein from the inferior border of the cricoid to the clavicle, anteromedially by the lateral border of the sternohyoid and posterolaterally by the posterior border of the sternocleidomastoid.

Level V: Posterior triangle nodes—around the lower half of the spinal accessory nerve and the transverse cervical artery, and includes the supraclavicular nodes. The upper boundary is the apex formed by the convergence of the sternocleidomastoid and trapezius muscles, and inferiorly by the clavicle. The anteromedial border is the posterior border of the sternocleidomastoid and the posterolateral border is the anterior border of the trapezius.

- Level VA: Above the horizontal plane formed by the inferior border of the anterior cricoid arch, including the spinal accessory nodes.
- Level VB: Lymph nodes below this plane, including the transverse cervical nodes and supraclavicular nodes (except Virchow's node which is in IV).

Level VI: Anterior compartment nodes—Pretracheal, paratracheal, precricoid (Delphian), and perithyroid nodes, including those on the recurrent laryngeal nerve. The upper border is the hyoid, the lower the suprasternal notch, and the lateral borders the common carotid arteries

The American Joint Committee on Cancer (AJCC) system differs from the above by including Level VII, which is based on the 2002 American Academy system, although the boundaries are defined slightly different [5]

The boundaries are defined as (Superior, Inferior, Anteromedial, Posterolateral)

- Level IA: Symphysis of mandible, Body of hyoid, Anterior belly of the contralateral digastric muscle, Anterior belly of ipsilateral digastric muscle
- Level IB: Body of mandible, Posterior belly of digastric muscle, Anterior belly of digastric muscle, Stylohyoid muscle
- Level IIA: Skull base, Horizontal plane defined by the inferior border of the hyoid bone, The stylohyoid muscle, Vertical plane defined by the spinal accessory nerve
- Level IIB: Skull base, Horizontal plane defined by the inferior body of the hyoid bone, Vertical plane defined by the spinal accessory nerve, Lateral border of the sternocleidomastoid muscle
- Level III: Horizontal plane defined by the inferior body of hyoid, Horizontal plane defined by the inferior border of the cricoid cartilage, Lateral border of the sternohyoid

muscle, Lateral border of the sternocleidomastoid or sensory branches of cervical plexus
- Level IV: Horizontal plane defined by the inferior border of the cricoid cartilage, Clavicle, Lateral border of the sternohyoid muscle, Lateral border of the sternocleidomastoid, or sensory branches of cervical plexus
- Level VA: Apex of the convergence of the sternocleidomastoid and trapezius muscles, Horizontal plane defined by the lower border of the cricoid cartilage, Posterior border of the sternocleidomastoid muscle or sensory branches of cervical plexus, Anterior border of the trapezius muscle
- Level VB: Horizontal plane defined by the lower border of the cricoid cartilage, Clavicle, Posterior border of the sternocleidomastoid muscle, Anterior border of the trapezius muscle
- Level VI: Hyoid bone, Suprasternal notch, Common carotid artery
- Level VII: Suprasternal notch, Innominate artery, Sternum, Trachea, esophagus, and prevertebral fascia

6.2 Cervical Lymph Nodes Pathology

6.2.1 Pathological Swelling of Lymph Nodes Criteria

Normal lymph nodes in healthy individuals are rarely palpable. When they are palpable, they present as small nodular structures that give the impression of sliding at the examiner's fingers. When they are compressed clinically, they give the impression of tension and mild pain [4, 9]. The clinical features of lymph nodes swellings and the type of disease they usually accompany are seen in Table 6.1

Ultrasonographically, normal and reactive lymph nodes are usually found in submandibular, parotid, upper cervical, and posterior triangle regions. On gray-scale sonography, normal and reactive nodes tend to be hypoechoic compared to adjacent muscles, and oval in shape, except for submandibular and parotid nodes, which are usually more rounded. Figure 6.2 depicts a normal cervical lymph node.

Lymph nodes swellings in the head and neck region are usually identified by the patients. The patients usually refer to doctors, for a palpable swelling, painful or not.

The basic clinical characteristics of the pathological swelling of lymph nodes are the following:

- Localized swelling of the soft tissues upon palpation, and in a few cases alterations on the skin color of the area involved in the pathology.
- Single palpable nodule, or multiple in a row, nodules, resembling a pearl necklace. Usually, they are found at the lateral neck borders, with a head-to-tail direction
- Larger and occasionally lobular mass in the event of convergence of multiple nodules, or a nodular group, resulting in the creation of multiple nodules palpable section is often referred to as "block" of lymph nodes.
- Elastic in texture nodes, with free mobility, and sensitivity upon palpation, that often is benign reactive lymph nodes.
- Hard and uncompressed nodules, that present as hard and firm attached often to the regional soft tissues, and the adjacent tissues nodules, without apparent mobility, and painless upon palpation are in the majority of cases malignant in origin.

The major causes of cervical lymph nodes swellings are seen in Table 6.2.

Table 6.1 Lymph nodes clinical characteristics and features according to types of pathology they accompany

Characteristics	Malignant nodes	Benign nodes
Size	>2 cm	<1–2 cm
Texture	Hard, elastic	Soft
Presence (time)	>2 weeks	<2 weeks
Mobility	No	Yes
Adjacent tissues	Attached	Non attached

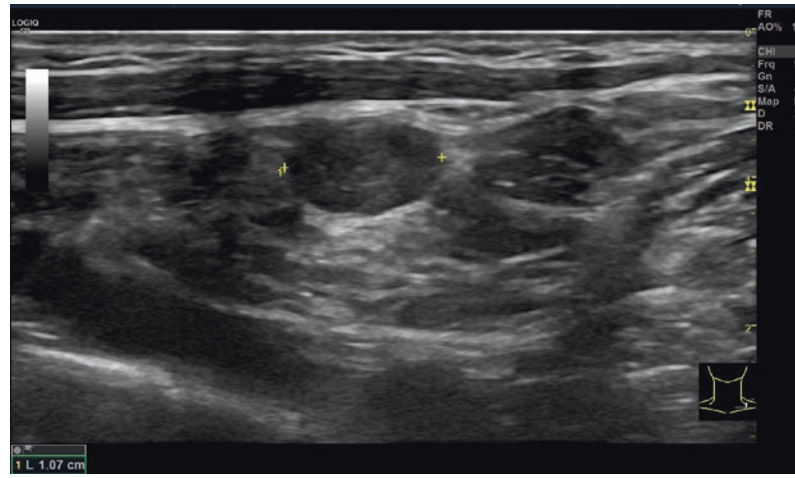

Fig. 6.2 Typical appearance of lymph node, without inflammation, oval shape, and a hilum

Table 6.2 Etiology of lymph nodes neck swelling

Inflammatory causes
Bacterial infections: Streptococcal, staphylococcal, Koch bacilli, etc.
Viruses: Mononucleosis, rhinoviruses, flu, measles, herpes simple type I
Fungal: Candida, Moniliasis
Neoplasma
Primary: Hodgkin and non-Hodgkin lymphomas
Metastatic: Carcinomas of the neck, the upper aerodigestive tract, the thyroid, and salivary glands
Immunological causes
Autoimmune conditions thyroiditis, Behcet syndrome
Immunodeficiency

6.2.2 Ultrasonographic Criteria of Lymph Nodes Pathology

Ultrasonographic control of the head and neck with modern high-frequency probes undoubtedly provides "vivid" high-definition images and offers safer criteria in distinguishing physiological and pathological lymph nodes.

Normal lymph nodes usually have elongated morphology and size not exceeding 1 cm; while, a hypoechoic halo corresponding to the cortex surrounds the ultrasound section of the entry and the medullary complex.

The ultrasonographic findings that characterize swollen and pathological lymph nodes are mentioned [10–12].

In the majority of inflammatory reactive lymph nodes, they appear more rounded and elongated but have a characteristic in many cases halo around them. Benign reactive nodes tend to preserve this shape due to diffuse nodal involvement by pathogens, resulting in diffuse lymphoid proliferation and subsequent cortical widening, while preserving the overall normal shape of the node. Whwn of benignorigin the nodes have been found to have a long-axis diameter at least 2 times the short axis diameter, with a shape index of less than 0.5, corresponding to an oval shape. Typically inflamed lymph nodes are seen and described in Figs. 6.3, 6.4 and 6.5.

The type of inflammation and causes are clearly seen in Table 6.3.

In combination with the patients' history, clinical image, and blood test results, they can be evaluated in the direction of differential diagnosis [13–15]:

- Increase in the size of the lymph nodes with a diameter greater than 1 cm. Regarding the jugulodigastric lymph node, the diameter should not exceed 1.5 cm. the size of a lymph node in the neck may be used for their classification, but this is not without problems due to their anatomical shape (oval/ellipsoid), the node should always be measured in all three planes. A moderate increase in size without alteration of the shape and echo structure of a lymph node is usually due to reactive overfunction.
- "Rounding" of lymph nodes with loss of their normal elongated morphology due to inflam-

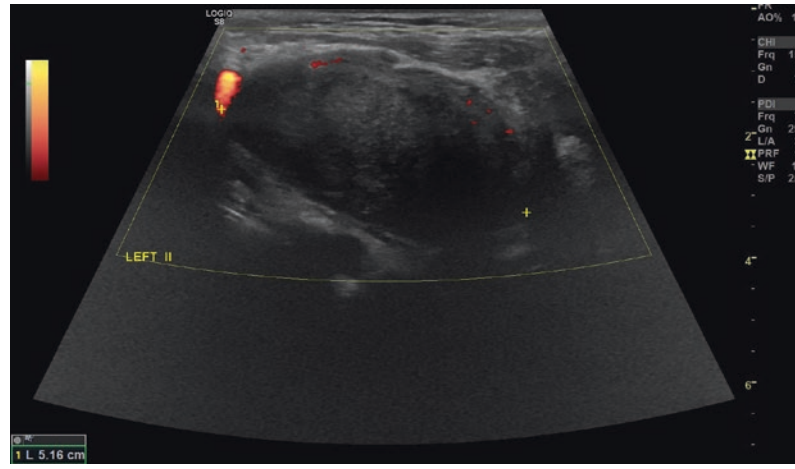

Fig. 6.3 A large lymph node due to inflammation. The node is with ellongated shape and normal texture

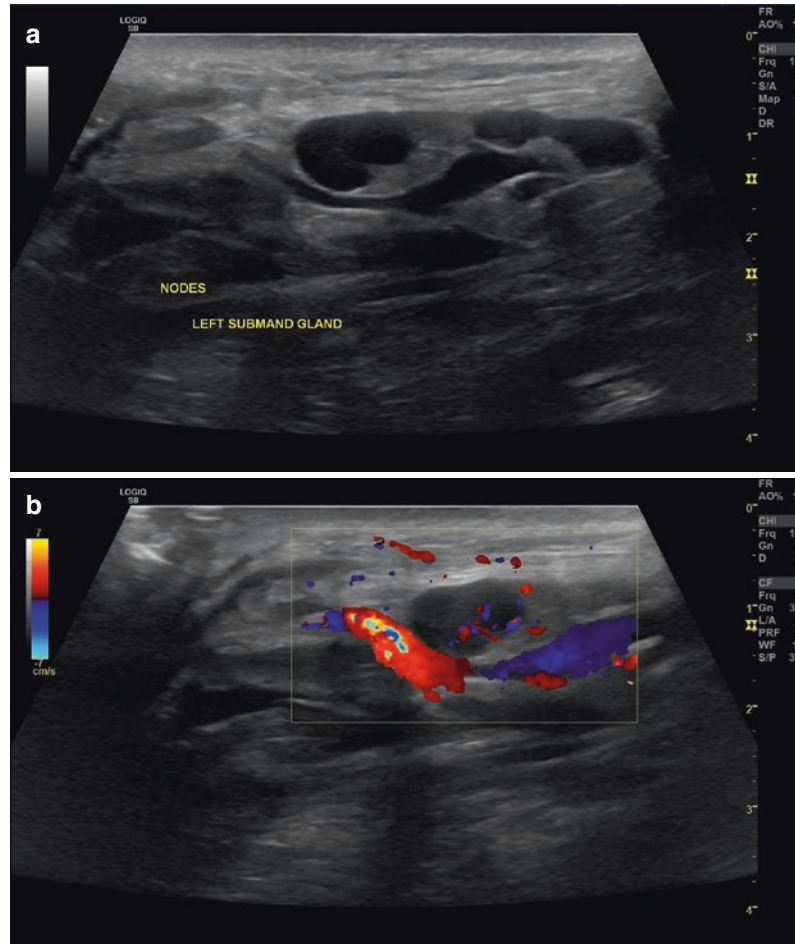

Fig. 6.4 A typically inflamed lymph node. block. Characteristic in the neck region and frequently presenting upon clinical examination. Here is a characteristic appearance with inflammatory response due to infectious mononucleosis

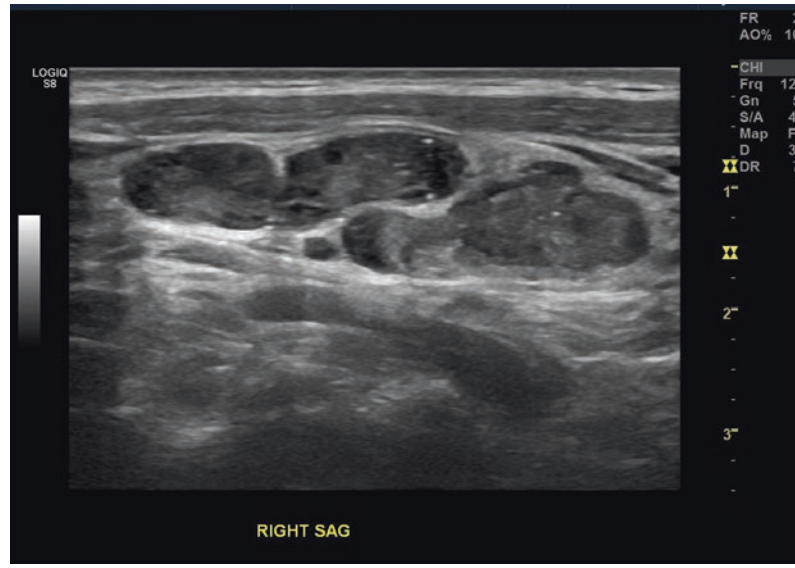

Fig. 6.5 Inflamed reactive lymph nodes of the submandibular region in patient with a tender, painful and palpable lump. The use of Power and Pulse Wave Doppler demonstrates abnormally enlarged nodes with increased vascularity and benign Resistance Index below 0,72

Table 6.3 Ultrasonographic features of nodes based on pathology

inflammatory nodes	• Varying in size, long to short axis ratio ≥2 • Clearly visible lymph node gate
metastatic nodes	• Varying in size, long to short axis ratio <2 • No clear gate imaged, varying vascularity
Primary lymphoma	• Varying in size, long to short axis ratio usually ≤2 • no clear gate imaged,varying echoigenicity, increased vascularity

matory filtration of their parenchyma or an increase in the cell population. The typical rounding of lymph nodes is frequently present in tumor cases as a reactive response initially and as a tumor course directive after. Figure 6.6 shows an extremely enlarged rounded node in the neck of a laryngeal tumor case. Measurable size refers to the reduction of the ratio of diameters of the long-to-short axis below the limit of two (long/short <2/ Solbiati index). Submental lymph nodes are an exception together with most groups of head lymph nodes since they normally exhibit rounded morphology [13, 15] In this rule there are a few exceptions providing a potential pitfall as found in the setting of benign submandibular and parotid nodes, which are often normally round in shape; likewise, tuberculous node

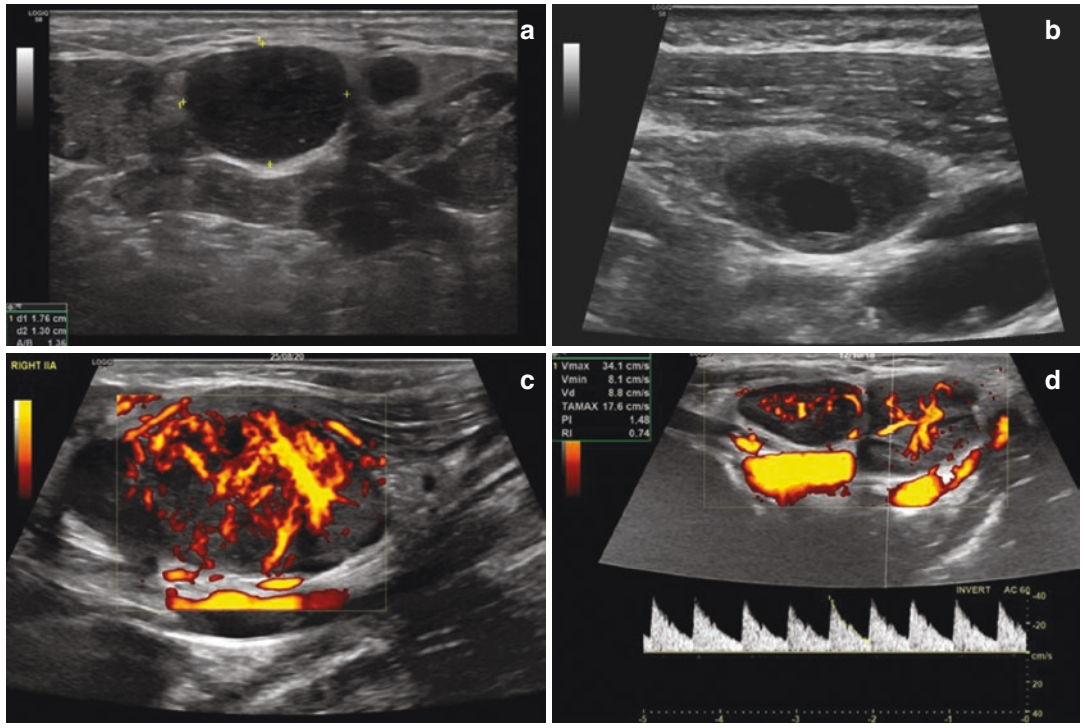

Fig. 6.6 Examples of malignant cervical lymph nodes (**a**) Rounded node with lack of the fatty hilum (**b**) lymph node with anechoic central necrotic like area. (**c**) enlarged node with diffusely increase in the vascularity in the entire parenchymal area (**d**) Acute wave forms with pathological Doppler coloring (Resistance Index >0,72 and Pulsatility Index >1,3)

involvement also tends to be round in shape. Therefore the anatomical and pathological exceptions to the index should be noted.

- In neoplastic lymph nodes, a progressive reduction in size up to and/or even including complete elimination of the nodal hilum is diagnosed due to the replacement of fibroadipose tissue by malignant cells. It is a very important finding, characterized by high sensitivity and low specificity. They typically present with the abovementioned imaging characteristic in lymphoma cases as seen in Fig. 6.7. Similar ultrasonographic images may be observed in benign lymph nodes swellings and in various types of infections such as tuberculosis [10–12].
- Absence of the hyperechoic central structure in the hilar region may be considered as a sign of malignancy (absence of hilar sign).
- Reduction of the echogenicity of lymph nodes and disturbance of their texture in the presence of single or multiple subechoic regions, representing areas of necrosis, melting, or abscesses [19, 20].
- Increased blood perfusion in color Doppler with multiple vascular branches spanning the entire parenchyma, including the periphery of the lymph nodes. In normal and reactive lymph nodes one can depict the nourishing artery and the accompanying vein with small branches that are confined to the area of the node gate and not beyond it [16–18].

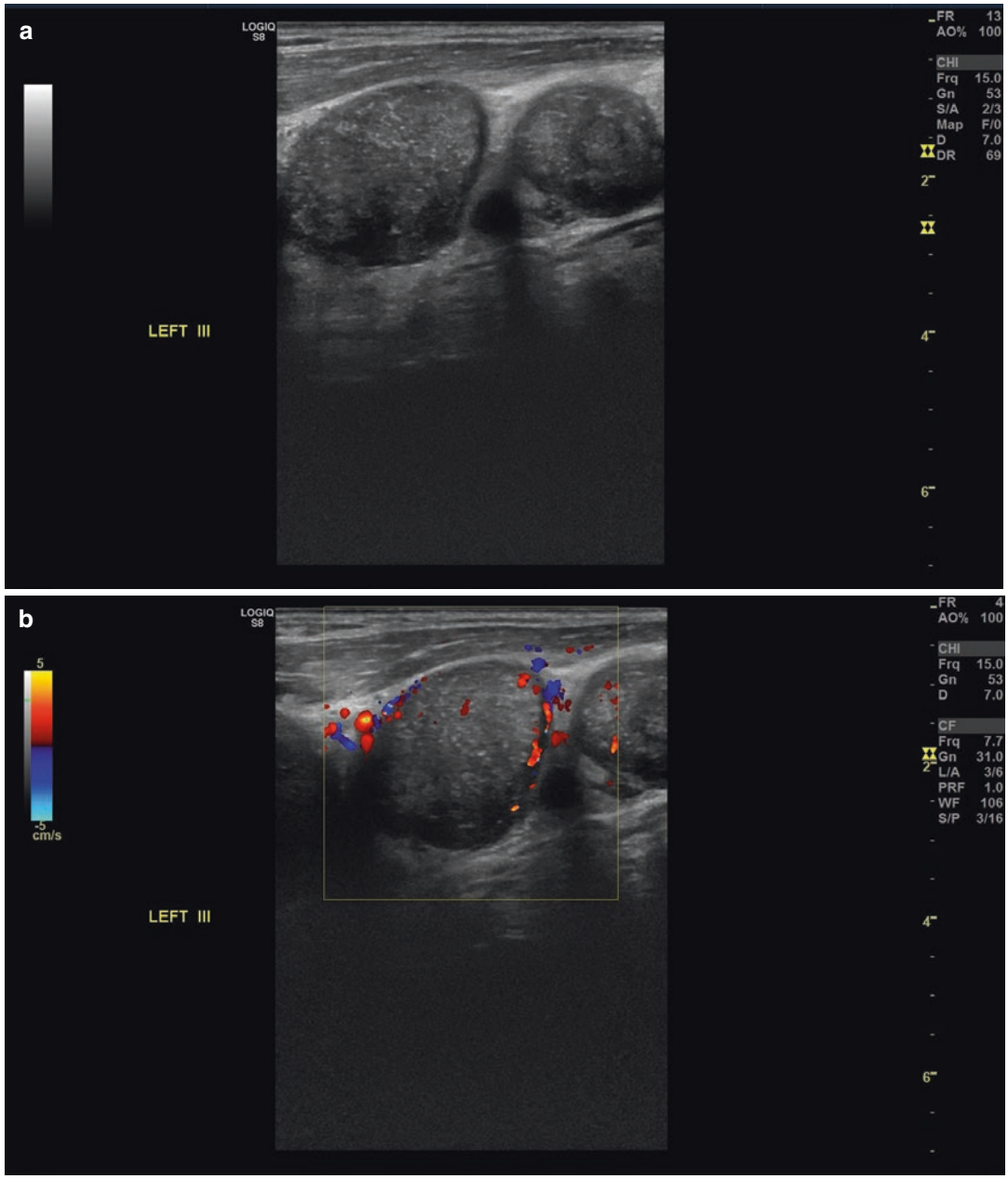

Fig. 6.7 (**a**) Case of a Hodgkin lymphoma with multiple hypoechoic and round shaped nodes. Infiltration of the adjacent fatty tissue is present. (**b**) Same case with peripheral vascularity with the use of color Doppler

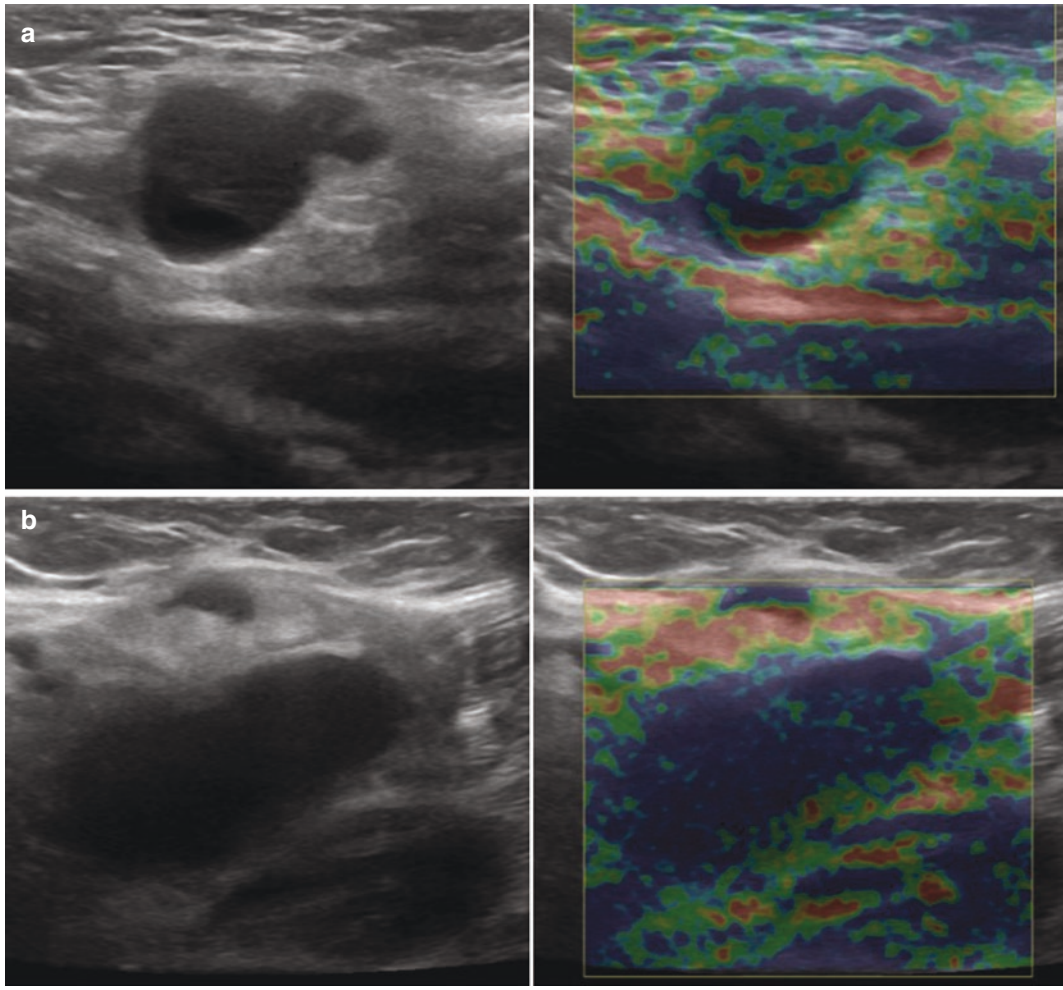

Fig. 6.8 In strain elastography the dark blue color indicates areas of reduced compression of the tissues and the green or red color indicate regions of high elasticity. (**a**) Lymph node with benigh elastographic features and (**b**) Pathological lymph node

- Increase in the resistance index RI bigger than 0.72 and the pulsativity index PI more than 1.3 during examination with the use of Color Doppler. The finding is due to increment of the resistances in the blood circulation caused by the compression of the arteries to the interior of the pathological mostly lymph nodes, and mainly the neoplasmatic ones [19–22].
- High index of rigidity of the pathological lymph nodes, in strain elastography and high units of pressure with the application of shear wave elastography (Fig. 6.8).

Basically, one should always bear in mind the Solbiati index or long-to-short axis ratio which represents the morphology of the nodes and their shape in two dimensions. This index has a cutoff value of 1.5–2 while a node with an index over 2 is highly suspicious for malignancy [15, 21]. Besides the shape and the short to long axis ratio, there are a few other factors one should consider to determine the type of node. These are the presence or absence of the hilum (present in benign lesions), the border type which is irregular in malignant nodes, and thevascularity, since

it has been reported that the use of the vascular pattern in assessing lymph nodes results in a high sensitivity (83%–89%) and specificity (87%–98%) in differentiating malignant from benign nodes [23].

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