*Clinical Radiology* (2003) **58**: 359–366
doi:10.1016/S0009-9260(02)00585-8, available online at www.sciencedirect.com

# Review

# Sonography of Neck Lymph Nodes. Part II: Abnormal Lymph Nodes

A. AHUJA*, M. YING†

*Department of Diagnostic Radiology and Organ Imaging and †Department of Optometry and Radiography, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Prince of Wales Hospital, Shatin, New Territories, Hong Kong SAR, People's Republic of China

Received: 16 July 2002 Revised: 13 November 2002 Accepted: 20 November 2002

**Assessment of cervical lymph nodes is essential for patients with head and neck carcinomas, and ultrasound is a useful imaging technique. Sonographic features that help distinguish between the causes of neck lymphadenopathy, including grey scale and Doppler features, are discussed. In addition to the distribution and location of nodes, the useful grey-scale features are: size, shape, internal architecture, intranodal necrosis, absence of hilar structure and calcification. The useful Doppler features are: distribution of vascularity and intranodal resistance. Ancillary features such as oedema of soft tissue and nodal matting are particularly helpful to identify tuberculous nodes.** Ahuja, A., Ying, M. (2003). *Clinical Radiology* **58**: 359–366.



**Key words:** ultrasound, cervical lymph nodes, metastases, lymphoma, tuberculosis.

## INTRODUCTION

Evaluation of cervical nodes is an important procedure for patients with head and neck carcinomas because it assesses the prognosis of the patients and helps to select appropriate treatment [1–5]. Regardless of the primary tumour, the presence of a metastatic node reduces the 5-year survival rate by 50%, and the presence of another metastatic node on the contralateral side further reduces the survival rate to 25% [6]. Metastatic nodes are site-specific [7], and nodal metastasis of a particular head and neck cancer in an unexpected level indicates that the neoplasm is more biologically aggressive [8]. Cervical lymph nodes are also common sites of involvement of lymphoma in the head and neck [9–11].

Tuberculous lymphadenitis remains a diagnostic dilemma and lymph nodes in the head and neck regions are common sites of this infection [12,13]. Tuberculous lymphadenitis is common in underdeveloped countries, and with the spread of acquired immune deficiency syndrome (AIDS), tuberculous lymphadenitis is now frequently encountered in developed countries [14,15]. Although the incidence of AIDS-related tuberculous lymphadenitis is increasing, it may also be found in patients without AIDS.

The role of high-resolution ultrasound in assessment of cervical lymph nodes is well established, and grey-scale ultrasound is widely used to assess cervical nodes for their number, site, size, nodal boundary, hilum, matting, adjacent soft tissue oedema and other internal nodal echo patterns [7,16–21]. With the use of colour Doppler sonography (CDS), the amount of information that can be obtained during an ultrasound examination of cervical lymph nodes has increased. However, when CDS was initially applied in the assessment of cervical lymphadenopathy, its value in daily practice was often doubted because of inconsistent results and disagreement on methodology [22,23]. With the development of technology and the introduction of power Doppler sonography, assessment of the vascularity of lymph nodes by ultrasound has become more accurate [24–28]. In comparison with CDS, power Doppler sonography is more sensitive in detection of structures with low volume flow of fluid, and is less dependent on the direction of flow [29,30]. Therefore, power Doppler sonography is more

Guarantors of study: Drs Anil Ahuja and M. Ying. Author for correspondence: Dr Anil Ahuja, Department of Diagnostic Radiology and Organ Imaging, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Prince of Wales Hospital, Shatin, New Territories, Hong Kong SAR, People's Republic of China. Tel: +852-2632-2290; Fax: +852-2636-0012; E-mail: aniltahuja@cuhk.edu.hk

0009-9260/03/$30.00/0

accurate in the assessment of small vessels, such as those found in lymph nodes.

## SONOGRAPHIC CRITERIA FOR IDENTIFICATION OF ABNORMAL CERVICAL NODES

### Distribution

Metastatic lymph nodes in the neck are site-specific, and this specific distribution helps to identify metastases and assists tumour staging. Also, if the primary tumour is not identified, the pattern of distribution of metastatic nodes may suggest a primary location [7,8,10,31,32]. Table 1 summarizes the distribution of metastatic nodes from different primary tumours and the distribution of non-Hodgkin's lymphomatous and tuberculous nodes [3,7,10,11,16,18,31–50]. In our experience the infraclavicular primaries that metastasize to the neck included lung, breast, cervix and oesophagus (in decreasing order of frequency) [7,18,31,46]. These were also the common primaries to involve the neck in other reports [34–39].

### Size

Size of lymph nodes was used previously as an indicator of malignancy [51]. Different cut-off points of nodal size (maximal short axis axial diameter) to differentiate malignant from benign nodes have been reported previously (5, 8 and 10 mm) [52–54]. Van den Brekel *et al*. [55] suggested that the optimal size criterion for ultrasound assessment of cervical metastatic nodes varies with the patient population, and the most acceptable size criterion in minimal axial diameter for the patient population selected randomly is 9 mm for subdigastric nodes, and 8 mm for other cervical nodes. In their subsequent study, they reported that a minimum axial diameter of 7 mm for level II (upper internal jugular chain nodes) and 6 mm for the rest of the neck revealed the optimal compromise between sensitivity and specificity in necks without palpable metastases. Using nodal size as the assessment criterion, one should note that when a lower cut-off point of nodal size is used, the sensitivity in differentiating malignant from benign nodes increases, whilst the specificity decreases [56]. A higher cut-off point yields higher specificity and lower sensitivity.

In patients with a known primary tumour, an increase in nodal size on serial examinations may suggest metastatic involvement. Also, serial change in size of malignant nodes is useful in monitoring patient response to treatment.

Size cannot be used as an absolute criterion, as inflammatory nodes can be as large as malignant nodes, whilst malignancy can be found in small nodes. It has been reported also that lymph nodes in the upper neck, including those in the submandibular and subdigastric region, tend to be larger than those in the lower neck [8,10,44,57].

### Shape

Metastatic (Fig. 1), lymphomatous (Hodgkin's or non-Hodgkin's) and tuberculous nodes commonly appear as round lesions, whereas normal or reactive nodes are usually oval, or flat [4,5,16,18,58–60]. Nodal enlargement by the infiltrating tumour is not uniform in different parts of the lymph node, and this changes the shape from oval to round [4,5]. Eccentric cortical hypertrophy is another useful sign to identify malignant nodes, and it indicates focal intranodal tumour infiltration [4].

### Nodal Border

Malignant nodes (including metastases and lymphoma) tend to have sharp borders, whereas benign nodes usually have unsharp borders [53]. The high incidence of sharp borders in malignant nodes is believed to be due to the infiltrating tumour cells replacing the normal intranodal lymphoid tissues causing an increase in the acoustic impedance difference between the lymph nodes and surrounding tissues [53,61]. The reduced fatty infiltration may also result in a greater difference in acoustic impedance between the lymph nodes and surrounding tissues leading to a sharp nodal border [53].

Unsharp borders are also common in tuberculous nodes because of oedema or active inflammation of the surrounding soft tissues (periadenitis).

In our experience, we have found that sharpness of nodal border does not help in differentiating malignant from benign nodes. However, proven malignant nodes with unsharp borders indicate extracapsular spread, which helps in assessing the prognosis of patients.

**Table 1 – Common locations of metastatic, lymphomatous and tuberculous nodes in the neck**

| | Commonly involved nodal groups |
|---|---|
| Metastases from oropharynx, hypopharynx, larynx carcinomas | Internal jugular chain |
| Metastases from oral cavity carcinomas | Submandibular |
| | Upper cervical |
| Metastases from infraclavicular carcinomas | Supraclavicular fossa |
| | Posterior triangle |
| Metastases from nasopharyngeal carcinoma | Upper cervical |
| | Posterior triangle |
| Metastases from papillary carcinoma of the thyroid | Internal jugular chain |
| Non-Hodgkin's lymphoma | Submandibular |
| | Upper cervical |
| | Posterior triangle |
| Tuberculosis | Supraclavicular fossa |
| | Posterior triangle |

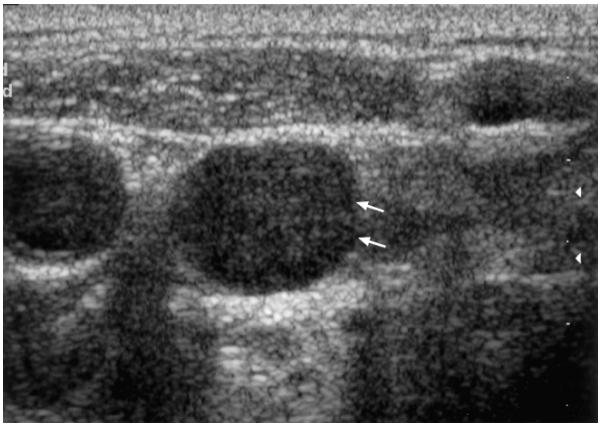

Fig. 1 – Sonogram showing a transverse scan of a round, hypoechoic metastatic node (arrows). Note the echogenic hilus is absent in the lymph node.

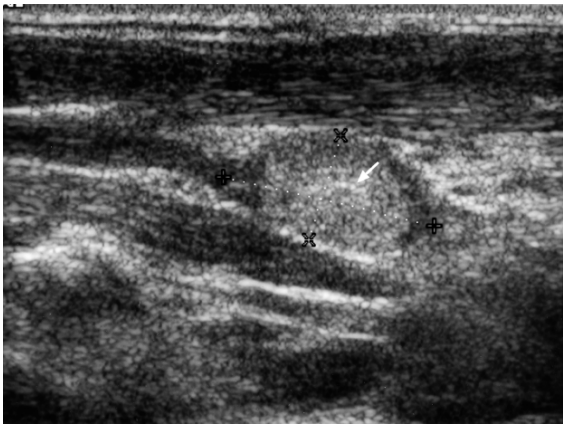

Fig. 2 – Sonogram showing a longitudinal scan of a hyperechoic metastatic node from papillary carcinoma of the thyroid (calipers). Note the punctate calcification within the lymph node which is common in metastases from papillary carcinoma of the thyroid.

## Echogenic Hilus

The presence of a central echogenic hilus within lymph nodes is usually considered as a sign of benignity [54,59,60,62]. Solbiati *et al*. [54] found that only 4% of metastatic nodes showed an echogenic hilus, and Rubaltelli *et al*. [62] and Vassallo *et al*. [4] noted that 84 to 92% of benign nodes have an echogenic hilus. However, Vassallo *et al*. [4] have also reported that 51.5% of metastatic nodes have an echogenic hilus. Although the echogenic hilus is a manifestation of the normal anatomy of lymph nodes, it is also possible to see it in early nodal malignancy, because the medullary lymphatic sinuses have not been sufficiently disrupted to eradicate it [63].

In our previous studies, we found that metastatic (69–95%) (Fig. 1), lymphomatous (72–73%) and tuberculous (76–86%) nodes tended to have an absent hilus, whereas normal nodes usually had an echogenic hilus (75–100%) [7,16,18,41,46,64]. However, as an echogenic hilus can be found in normal and abnormal nodes, the presence/absence of an echogenic hilus should not be the sole criterion in assessment of cervical nodes.

## Echogenicity

Metastatic nodes are usually hypoechoic when compared to the adjacent muscles (Fig. 1) [7,18,65]. However, metastatic nodes from papillary carcinoma of the thyroid tended to be hyperechoic (Fig. 2) [7,41]. This is due to the deposition of thyroglobulin, which is produced in the papillary carcinoma of the thyroid, within the lymph nodes. Therefore, when hyperechoic nodes were detected, sonologists should look at the thyroid for a primary tumour.

Tuberculous nodes are predominantly hypoechoic which may be related to the high incidence of intranodal cystic necrosis [7,16,18].

Lymphomatous nodes were previously reported to have a "pseudocytic" appearance, hypoechoic with posterior enhancement [20,46]. However, with the use of newer transducers, lymphomatous nodes demonstrate intranodal reticulation (Fig. 3) and the pseudocystic appearance is less likely to be seen [17].

## Calcification

Nodal calcification in metastatic nodes is generally rare, but it is common in metastatic nodes from papillary carcinoma (Fig. 2) and medullary carcinoma of the thyroid [6–8,41,51]. It has been reported that about 50–69% of metastatic nodes from papillary carcinoma of the thyroid showed intranodal calcification, and the calcification is usually fine or punctate, peripherally located and may show fine threads of acoustic shadowing with a high-resolution transducer [7,41]. Intranodal calcification may also be found in metastatic nodes from medullary carcinoma of the thyroid but the incidence is relatively lower. Gooding [51] found that when a medullary thyroid carcinoma has been previously resected, recurrent cervical lymph nodes usually have calcification.

Calcification may be also found in other irradiated

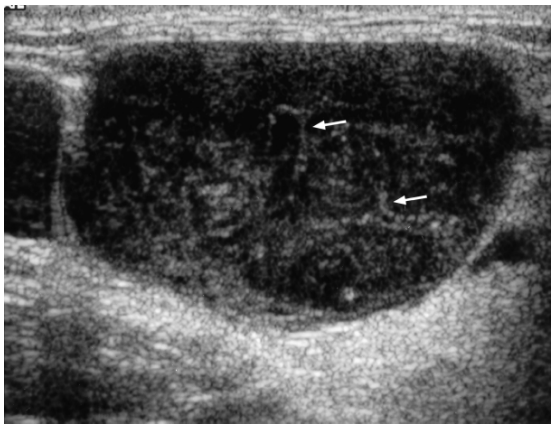

Fig. 3 – Sonogram showing a lymphomatous node with intranodal reticulation (micronodular pattern) (arrows).

metastatic lymph nodes but it is rare [6,8,66], and may also develop in lymph nodes after chemotherapy.

## Intranodal Necrosis

Nodal necrosis is a late event in tumour invasion of lymph nodes [8], and it may appear as a cystic area (cystic necrosis) or an echogenic area (coagulation necrosis). Cystic necrosis appears as an echolucent area within the lymph nodes (Fig. 4), and is commonly found in metastatic nodes from squamous cell carcinoma [44,68,69], tuberculous nodes [4,7,16,18,63] and metastatic nodes from papillary carcinoma of the thyroid [7,41]. Lymph nodes with cystic necrosis or coagulation necrosis, regardless of the nodal size, must be considered abnormal. Coagulation necrosis is an uncommon sign and appears as an echogenic focus within the lymph nodes on ultrasound, and may be found in both malignant and inflammatory nodes [62,67].

## Ancillary Features

Ancillary features that help to evaluate cervical lymphadenopathy with ultrasound are matting (Fig. 5) and adjacent soft tissue oedema (Fig. 6). Matting of lymph nodes is common in tuberculous lymphadenitis [7,16,18,48,70–72], and is believed to be due to the perinodal inflammatory reaction (periadenitis) [70]. As matting of lymph nodes is common in tuberculosis, it is a useful feature in distinguishing tuberculosis from other diseases.

Metastatic and granulomatous lymph nodes may produce adjacent soft tissue oedema either due to tumour infiltration or as an inflammatory response to adjacent disease [10,37]. In our previous studies, adjacent soft tissue oedema was found in 38–49% of tuberculous nodes, whereas it was not common in metastatic and lymphomatous nodes [7,16,18].

One should be aware that soft tissue oedema and nodal matting may also be seen in patients with previous radiation therapy of the neck [73]. In patients without previous radiation therapy, the presence of soft tissue oedema and nodal matting are highly suggestive of tuberculosis.

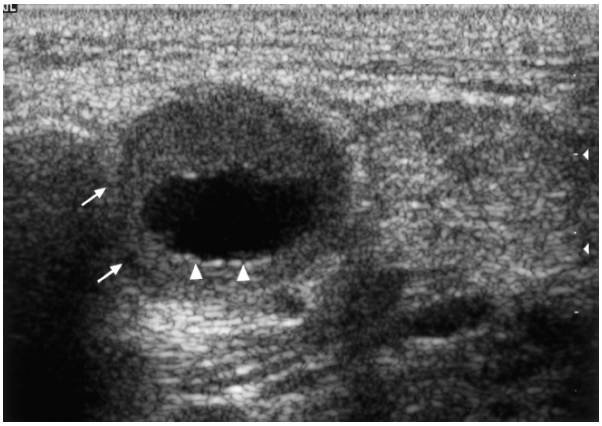

Fig. 4 – Sonogram of a metastatic node (arrows) with intranodal cystic necrosis (arrowheads).

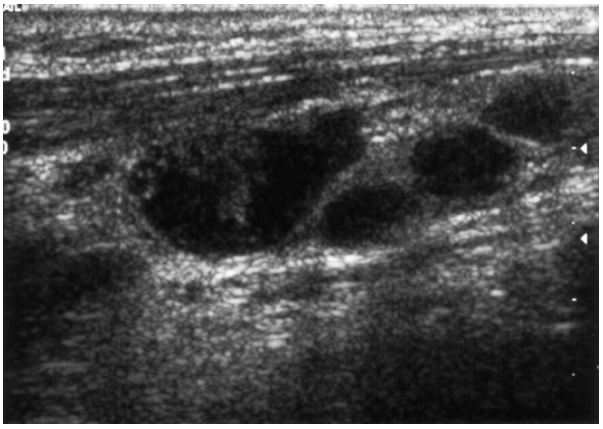

Fig. 5 – Longitudinal sonogram showing matting of multiple lymph nodes in the posterior triangle.

## Vascular Pattern

Normal and reactive lymph nodes tend to show hilar vascularity or appear apparently avascular [74–81]. However, metastatic nodes tend to have peripheral (Fig. 7) or mixed (presence of both peripheral and hilar) (Fig. 8) vascularity [24–28,76,80,82], and mixed vascularity is also common in lymphomatous nodes [25,26,82]. Unlike metastatic nodes, peripheral vascularity alone is less common in lymphoma. Therefore, we believe that the presence of peripheral vascularity, regardless of the presence of hilar vascularity or not, is highly suggestive of malignancy. The vascular changes in malignant nodes are thought to be related to tumour angiogenesis and the associated desmoplastic reaction or recruitment of capsular vessels [24,25,28,83].

Using PDS to demonstrate the vascular pattern of lymph nodes results in high sensitivity (83–89%) and specificity (87–98%) in distinguishing metastatic from reactive nodes [24,28].

The vascular pattern of tuberculous nodes varies on Doppler sonography, and simulates both benign and malignant conditions [60,84]. Peripheral vascularity was found in 31% of

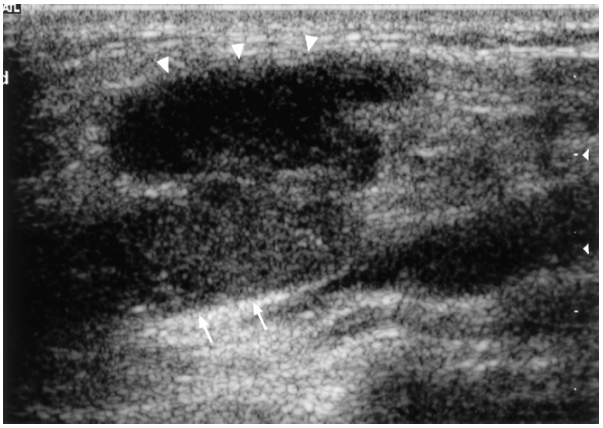

Fig. 6 – Sonogram of a hypoechoic node with ill-defined borders (arrows). Note the hypoechoic area adjacent to the lymph node (arrowheads) which indicates soft tissue oedema.

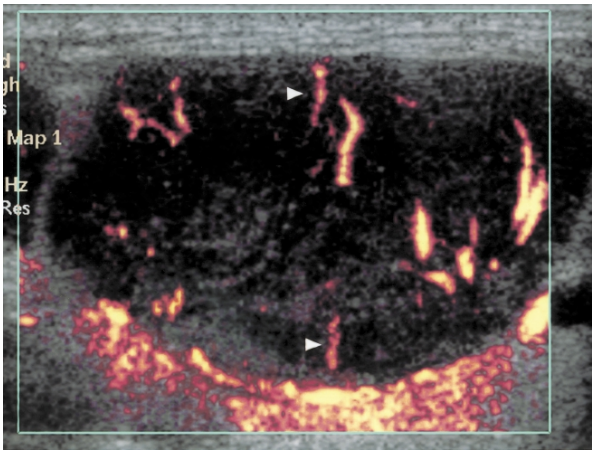


Fig. 7 – Power Doppler sonogram of a malignant node with peripheral vascularity (arrowheads).

tuberculous nodes [84]. Apparent avascularity was also found in tuberculous nodes (19%) [84], and may be related to the extensive intranodal cystic necrosis of tuberculous nodes, which destroys the blood vessels of the lymph nodes. Apparent avascularity of tuberculous nodes may also reflect later stages of the disease where healing has begun and fibrosis and hyalinization cause compression and obliteration of intranodal vessels [85]. Displaced vascularity was also common (81%) in tuberculous nodes which is also related to the high incidence of intranodal cystic necrosis of tuberculosis which displaces the vessels (Fig. 9). Since displaced vascularity is not found in normal nodes and relatively uncommon in other pathological nodes, it is a useful Doppler feature in classifying tuberculous nodes.

### Vascular Resistance

The role of vascular resistance parameters (resistivity index, RI; pulsatility index, PI) in distinguishing malignant from benign nodes is controversial, thus limiting the role of RI and PI in routine clinical practice. It has been reported that the RI and PI of reactive lymph nodes is lower than that of metastatic lymph nodes [23,25,28,74,83]. However, Adibelli *et al*. [77] found that there was no significant difference in RI and PI between benign and malignant nodes.

Steinkamp *et al*. [83] suggested that the optimal cut-off for RI and PI in distinguishing reactive and metastatic nodes were 0.8 and 1.6, with a sensitivity of 80 and 94%, respectively, and a specificity of 94 and 97%, respectively. Our previous study [80] found that the optimal cut-off for RI and PI in differentiating reactive from metastatic nodes from nasopharyngeal carcinoma (frequently seen in Cantonese Chinese) were 0.7 and 1.4 with a sensitivity of 86 and 80%, respectively, and a specificity of 70 and 86%, respectively.

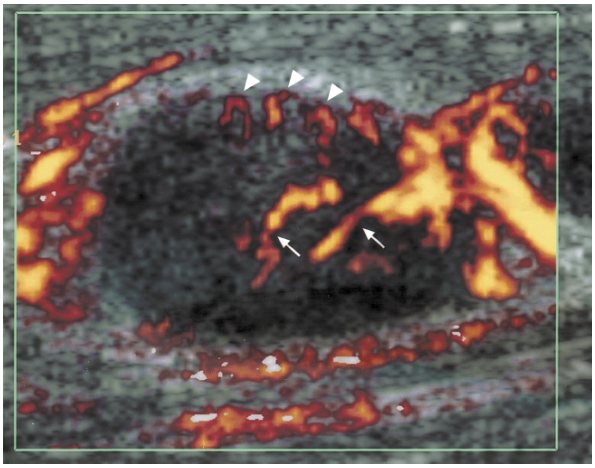

Fig. 8 – Power Doppler sonogram of a malignant node with both hilar (arrows) and peripheral (arrowheads) vascularity.

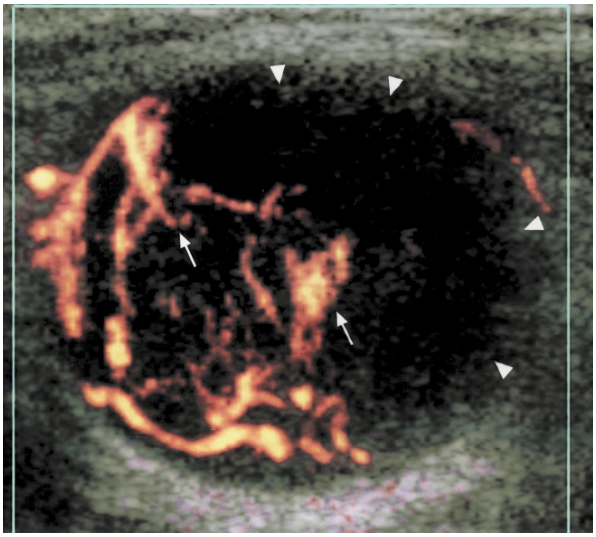

Fig. 9 – Power Doppler sonogram of a tuberculous node with displaced vascularity (arrows). Note the hypoechoic area within the lymph node (arrowheads) indicating intranodal cystic necrosis which displaces the vessels.

## CONTRAST-ENHANCED DOPPLER SONOGRAPHY

It has been suggested that contrast-enhanced CDS improves the diagnostic accuracy by better assessment of characteristic vascular patterns of cervical nodes [86,87]. There are drawbacks to introducing contrast agents in Doppler sonography. It has been found that the measured blood flow velocity of the middle cerebral artery increased substantially after the administration of contrast agent [88] and similar findings have been reported in contrast-enhanced Doppler sonography of cervical lymph nodes [74]. The measured blood flow velocity of metastatic and reactive nodes increased substantially in association with a decrease in vascular resistance (RI and PI) after the introduction of contrast agent [74]. Therefore, this effect should be considered in the assessment of cervical lymphadenopathy, when contrast agents are administered. The duration of contrast-enhancement in Doppler sonography is

short (less than 5 min in hepatic haemangiomas) [89], limiting the examination time, and patients may have to undergo more than one dose of contrast agent. Further studies are necessary before the role of contrast-enhanced Doppler sonography of neck nodes is established in routine clinical practice.

## ULTRASOUND-GUIDED FINE-NEEDLE ASPIRATION CYTOLOGY (FNAC)

Some centres may prefer ultrasound-guided FNAC which provides cytological diagnosis. Ultrasound-guided FNAC has been shown to be an accurate method in evaluation of cervical lymphadenopathy with a high sensitivity (89–98%), specificity (95–98%) and accuracy (95–97%) [90,91]. This technique provides more accurate information than blinded FNAC, and influences the indications for therapeutic and elective treatment [92].

It has been reported that ultrasound-guided FNAC can correctly stage the cervical lymph nodes in 93% of the patients with head and neck carcinoma [90].

In patients with N0 head and neck cancer, it has been found that ultrasound-guided FNAC has the risk of 18% of missing occult metastases [93]. Therefore, ultrasound-guided FNAC is useful in the follow-up examination of the neck after tumour excision, and serial examinations should be performed if no elective treatment of neck is undertaken [93].

## REFERENCES


1 Baatenburg de Jong RJ, Rongen RJ, De Jong PC, *et al*. Screening for lymph nodes in the neck with ultrasound. *Clin Otolaryngol*, 1988;13: 5–9.
2 Baatenburg de Jong RJ, Rongen RJ, Lameris JS, *et al*. Metastatic neck disease. Palpation vs ultrasound examination. *Arch Otolaryngol Head Neck Surg*, 1989;115:689–690.
3 Ishii JI, Amagasa T, Tachibana T, *et al*. US and CT evaluation of cervical lymph node metastasis from oral cancer. *J Cranio-Max-Fac Surg*, 1991;19:123–127.
4 Vassallo P, Wernecke K, Roos N, Peters PE. Differentiation of benign from malignant superficial lymphadenopathy: the role of high-resolution US. *Radiology*, 1992;183:215–220.
5 Vassallo P, Edel G, Roos N, *et al*. In-vitro high-resolution ultrasonography of benign and malignant lymph nodes. A sonographic-pathologic correlation. *Invest Radiol*, 1993;28:698–705.
6 Som PM. Detection of metastasis in cervical lymph nodes: CT and MR criteria and differential diagnosis. *AJR Am J Roentgenol*, 1992;158: 961–969.
7 Ahuja A, Ying M, King W, Metreweli C. A practical approach to ultrasound of cervical lymph nodes. *J Laryngol Otol*, 1997;111: 245–256.
8 Som PM. Lymph nodes of the neck. *Radiology*, 1987;165:593–600.
9 Bragg DG. Radiology of the lymphomas. *Curr Probl Diagn Radiol*, 1987;16:183–206.
10 Swartz JD, Yussen PS, Popky GL. Imaging of the neck: nodal disease. *Crit Rev Diagn Imaging*, 1991;31:413–469.
11 Lee YY, Van Tassel P, Nauert C, *et al*. Lymphomas of the head and neck: CT findings at initial presentation. *AJR Am J Roentgenol*, 1987; 149:575–581.
12 Ishikawa H, Hyo Y, Ono T. Tuberculous submandibular lymphadenitis. *J Oral Maxillofac Surg*, 1982;40:302–305.
13 Qizilbash AH, Young JEM. Lymph nodes. In *Guides to clinical aspiration biopsy: head and neck*. New-York: Igaku-Shoin, 1988; 117–203.
14 Radin DR. Intraabdominal *Mycobacterium tuberculosis* vs *Mycobacterium avium-intracellulare* infections in patients with AIDS: distinction based on CT findings. *AJR Am J Roentgenol*, 1991;156:487–491.
15 Shapiro AL, Pincus RL. Fine-needle aspiration of diffuse cervical lymphadenopathy in patients with acquired immunodeficiency syndrome. *Otolaryngol Head Neck Surg*, 1991;105:419–421.
16 Ahuja A, Ying M, Evans R, *et al*. The application of ultrasound criteria for malignancy in differentiating tuberculous cervical adenitis from metastatic nasopharyngeal carcinoma. *Clin Radiol*, 1995;50:391–395.
17 Ahuja AT, Ying M, Yuen HY, Metreweli C. Pseudocystic appearance of non-Hodgkin's lymphomatous nodes: an infrequent finding with high-resolution transducers. *Clin Radiol*, 2001;56:111–115.
18 Ying M, Ahuja AT, Evans R, *et al*. Cervical lymphadenopathy: sonographic differentiation between tuberculous nodes and nodal metastases from non-head and neck carcinomas. *J Clin Ultrasound*, 1998;26:383–389.
19 van den Brekel MW, Stel HV, Castelijns JA, *et al.* Cervical lymph node metastasis: assessment of radiologic criteria. *Radiology*, 1990;177: 379–384.
20 Bruneton JN, Normand F, Balu-Maestro C, *et al.* Lymphomatous superficial lymph nodes: US detection. *Radiology*, 1987;165:233–235.
21 Bruneton JN, Roux P, Caramella E, *et al*. Ear, nose, and throat cancer: ultrasound diagnosis of metastasis to cervical lymph nodes. *Radiology*, 1984;152:771–773.
22 Chang DB, Yuan A, Yu CJ, *et al*. Differentiation of benign and malignant cervical lymph nodes with color Doppler sonography. *AJR Am J Roentgenol*, 1994;162:965–968.
23 Choi MY, Lee JW, Jang KJ. Distinction between benign and malignant causes of cervical, axillary, and inguinal lymphadenopathy: value of Doppler spectral waveform analysis. *AJR Am J Roentgenol*, 1995;165: 981–984.
24 Ariji Y, Kimura Y, Hayashi N, *et al.* Power Doppler sonography of cervical lymph nodes in patients with head and neck cancer. *AJNR Am J Neuroradiol*, 1998;19:303–307.
25 Na DG, Lim HK, Byun HS, *et al*. Differential diagnosis of cervical lymphadenopathy: usefulness of color Doppler sonography. *AJR Am J Roentgenol*, 1997;168:1311–1316.
26 Steinkamp HJ, Mueffelmann M, Bock JC, *et al*. Differential diagnosis of lymph node lesions: a semiquantitative approach with colour Doppler ultrasound. *Br J Radiol*, 1998;71:828–833.
27 Wu CH, Hsu MM, Chang YL, Hsieh FJ. Vascular pathology of malignant cervical lymphadenopathy: qualitative and quantitative assessment with power Doppler ultrasound. *Cancer*, 1998;83: 1189–1196.
28 Wu CH, Chang YL, Hsu WC, *et al*. Usefulness of Doppler spectral analysis and power Doppler sonography in the differentiation of cervical lymphadenopathies. *AJR Am J Roentgenol*, 1998;171: 503–509.
29 Jeffrey RB, Ralls PW. Color and power Doppler sonography. A teaching file. In *Principles, pitfalls, and practical hints*, Philadelphia: Lippincott Raven, 1998; 18.
30 Rubin JM, Bude RO, Carson PL, *et al*. Power Doppler US: a potentially useful alternative to mean frequency-based color Doppler US. *Radiology*, 1994;190:853–856.
31 Ahuja A, Ying M. Grey-scale sonography in assessment of cervical lymphadenopathy: review of sonographic appearances and features that may help a beginner. *Br J Oral Maxillofac Surg*, 2000;38:451–459.
32 Lindberg R. Distribution of cervical lymph node metastases from squamous cell carcinoma of the upper respiratory and digestive tracts. *Cancer*, 1972;29:1446–1449.
33 Komisar A. Treatment of the node negative neck. In Vogl SE ed. *Head and Neck Cancer*. New York: Churchill Livingstone, 1988; 19–30.
34 van Overhagen H, Lameris JS, Berger MY, *et al.* Supraclavicular lymph node metastases in carcinoma of the esophagus and gastroesophageal junction: assessment with CT, US, and US-guided fine-needle aspiration biopsy. *Radiology*, 1991;179:155–158.
35 van Overhagen H, Lameris JS, Zonderland HM, *et al*. Ultrasound and ultrasound-guided fine needle aspiration biopsy of supraclavicular lymph nodes in patients with esophageal carcinoma. *Cancer*, 1991;67: 585–587.
36 Van Overhagen H, Lameris JS, Berger MY, *et al.* Improved assessment of supraclavicular and abdominal metastases in oesophageal and gastro-oesophageal junction carcinoma with the combination of ultrasound and computed tomography. *Br J Radiol*, 1993;66:203–208.

37 Sugama Y, Kitamura S. Ultrasonographic evaluation of neck and supraclavicular lymph nodes metastasized from lung cancer. *Intern Med*, 1992;31:160–164.
38 Yao ZH, Wu AR. Supraclavicular lymph node metastasis from carcinoma of the uterine cervix after radiotherapy—analysis of 219 patients. *Chung Hua Chung Liu Tsa Chih*, 1988;10:230–232.
39 Kiricuta IC, Willner J, Kolbl O, Bohndorf W. The prognostic significance of the supraclavicular lymph node metastases in breast cancer patients. *Int J Radiat Oncol Biol Phys*, 1994;28:387–393.
40 Cervin JR, Silverman JF, Loggie BW, Geisinger KR. Virchow's node revisited. Analysis with clinicopathologic correlation of 152 fine-needle aspiration biopsies of supraclavicular lymph nodes. *Arch Pathol Lab Med*, 1995;119:727–730.
41 Ahuja AT, Chow L, Chick W, *et al*. Metastatic cervical nodes in papillary carcinoma of the thyroid: ultrasound and histological correlation. *Clin Radiol*, 1995;50:229–331.
42 Attie JN, Setzin M, Klein I. Thyroid carcinoma presenting as an enlarged cervical lymph node. *Am J Surg*, 1993;166:428–430.
43 De Jong SA, Demeter JG, Jarosz H, *et al*. Primary papillary thyroid carcinoma presenting as cervical lymphadenopathy: the operative approach to the lateral aberrant thyroid. *Am Surg*, 1993;59:172–176.
44 DePena CA, Van Tassel P, Lee YY. Lymphoma of the head and neck. *Radiol Clin North Am*, 1990;28:723–743.
45 Ishii J, Fujii E, Suzuki H, *et al*. Ultrasonic diagnosis of oral and neck malignant lymphoma. *Bull Tokyo Med Dent Univ*, 1992;39:63–69.
46 Ahuja A, Ying M, Yang WT, *et al*. The use of sonography in differentiating cervical lymphomatous lymph nodes from cervical metastatic lymph nodes. *Clin Radiol*, 1996;51:186–190.
47 Appling D, Miller RH. Mycobacterium cervical lymphadenopathy: 1981 update. *Laryngoscope*, 1981;91:1259–1266.
48 Reede DL, Bergeron RT. Cervical tuberculous adenitis: CT manifestations. *Radiology*, 1985;154:701–704.
49 Reede DL, Som PM. Lymph nodes. In Som PM, Bergeron RT eds. *Head and Neck Imaging*. St. Louis: Mosby Year Book, Inc, 1991; 558–577.
50 Keusters D, Van de Heyning P, Claes J, *et al*. Cervical tuberculosis. Differential diagnosis and CT imaging. *Acta Otorhinolaryngol Belg*, 1987;41:958–964.
51 Gooding GA. Malignant carotid invasion: sonographic diagnosis. *ORL J Otorhinolaryngol Relat Spec*, 1993;55:263–272.
52 Hajek PC, Salomonowitz E, Turk R, *et al*. Lymph nodes of the neck: evaluation with US. *Radiology*, 1986;158:739–742.
53 Shozushima M, Suzuki M, Nakasima T, *et al*. Ultrasound diagnosis of lymph node metastasis in head and neck cancer. *Dentomaxillofac Radiol*, 1990;19:165–170.
54 Solbiati L, Rizzatto G, Bellotti E, *et al*. High-resoultion sonography of cervical lymph nodes in head and neck cancer: criteria for differentiation of reactive versus malignant nodes. *Radiology*, 1988; 169(Suppl. P):113.
55 Bruneton JN, Balu-Maestro C, Marcy PY, *et al*. Very high frequency (13 MHz) ultrasonographic examination of the normal neck: detection of normal lymph nodes and thyroid nodules. *J Ultrasound Med*, 1994; 13:87–90.
56 van den Brekel MW, Castelijns JA, Stel HV, *et al*. Modern imaging techniques and ultrasound-guided aspiration cytology for the assessment of neck node metastases: a prospective comparative study. *Eur Arch Otorhinolaryngol*, 1993;250:11–17.
57 Ying M, Ahuja A, Metreweli C. Diagnostic accuracy of sonographic criteria for evaluation of cervical lymphadenopathy. *J Ultrasound Med*, 1998;17:437–445.
58 Tohnosu N, Onoda S, Isono K. Ultrasonographic evaluation of cervical lymph node metastases in esophageal cancer with special reference to the relationship between the short to long axis ratio (S/L) and the cancer content. *J Clin Ultrasound*, 1989;17:101–106.
59 Solbiati L, Cioffi V, Ballarati E. Ultrasonography of the neck. *Radiol Clin North Am*, 1992;30:941–954.
60 Papakonstantinou O, Bakantaki A, Paspalaki P, *et al*. High-resolution and color Doppler ultrasonography of cervical lymphadenopathy in children. *Acta Radiol*, 2001;42:470–476.
61 Ishii J, Amagasa T, Tachibana T, *et al*. Ultrasonic evaluation of cervical lymph node metastasis of squamous cell carcinoma in oral cavity. *Bull Tokyo Med Dent Univ*, 1989;36:63–67.
62 Rubaltelli L, Proto E, Salmaso R, *et al*. Sonography of abnormal lymph nodes in vitro: correlation of sonographic and histologic findings. *Am J Roentgenol*, 1990;155:1241–1244.
63 Evans RM, Ahuja A, Metreweli C. The linear echogenic hilus in cervical lymphadenopathy—a sign of benignity or malignancy? *Clin Radiol*, 1993;47:262–264.
64 Ying M, Ahuja A, Brook F, *et al*. Sonographic appearance and distribution of normal cervical lymph nodes in a Chinese population. *J Ultrasound Med*, 1996;15:431–436.
65 Chang DB, Yang PC, Luh KT, *et al.* Ultrasonic evaluation of cervical lymphadenopathy. *J Formosan Med Assoc*, 1990;88:286–292.
66. Bruneton JN, Normand F. Cervical lymph nodes. In Bruneton JN ed. *Ultrasonography of the Neck*. Berlin: Springer-Verlag, 1987; 81–92.
67 Sakai F, Kiyono K, Sone S, *et al.* Ultrasonic evaluation of cervical metastatic lymphadenopathy. *J Ultrasound Med*, 1988;7:305–310.
68 Mancuso AA, Harnsberger HR, Muraki AS, Stevens MH. Computed tomography of cervical and retropharyngeal lymph nodes: normal anatomy, variants of normal, and applications in staging head and neck cancer. Part II: pathology. *Radiology*, 1983;148:715–723.
69 Olsen WL, Jeffrey RB, Jr, Sooy CD, *et al*. Lesions of the head and neck in patients with AIDS: CT and MR findings. *AJR Am J Roentgenol*, 1988;151:785–790.
70 Pombo F, Rodriguez E, Mato J, *et al*. Patterns of contrast enhancement of tuberculous lymph nodes demonstrated by computed tomography. *Clin Radiol*, 1992;46:13–17.
71 Patel MP, Adler L, Alexander LL. The value of CT scanning in the diagnosis of tuberculous lymphadenitis of the neck. *Comput Radiol*, 1984;8:21–23.
72 Newcombe J. Tuberculosis: tuberculous glands in the neck. *Br J Hosp Med*, 1979;22:553–555.
73 Ahuja A, Ying M, Leung SF, Metreweli C. The sonographic appearance and significance of cervical metastatic nodes following radiotherapy for nasopharyngaeal carcinoma. *Clin Radiol*, 1996;51:698–701.
74 Maurer J, Willam C, Schroeder R, *et al.* Evaluation of metastases and reactive lymph nodes in Doppler sonography using an ultrasound contrast enhancer. *Invest Radiol*, 1997;32:441–446.
75 Dragoni F, Cartoni C, Pescarmona E, *et al.* The role of high resolution pulsed and color Doppler ultrasound in the differential diagnosis of benign and malignant lymphadenopathy: results of multivariate analysis. *Cancer*, 1999;85:2485–2490.
76 Wu CH, Shih JC, Chang YL, *et al*. Two-dimensional and three-dimensional power Doppler sonographic classification of vascular patterns in cervical lymphadenopathies. *J Ultrasound Med*, 1998;17: 459–464.
77 Adibelli ZH, Unal G, Gul E, *et al*. Differentiation of benign and malignant cervical lymph nodes: value of B-mode and color Doppler sonography. *Eur J Radiol*, 1998;28:230–234.
78 Tschammler A, Ott G, Schang T, *et al*. Lymphadenopathy: differentiation of benign from malignant disease—color Doppler US assessment of intranodal angioarchitecture. *Radiology*, 1998;208: 117–123.
79 Ying M, Ahuja A, Brook F, Metreweli C. Power Doppler sonography of normal cervical lymph nodes. *J Ultrasound Med*, 2000;19:511–517.
80 Ahuja AT, Ying M, Ho SS, Metreweli C. Distribution of intranodal vessels in differentiating benign from metastatic neck nodes. *Clin Radiol*, 2001;56:197–201.
81 Sakaguchi T, Yamashita Y, Katahira K, *et al.* Differential diagnosis of small round cervical lymph nodes: comparison of power Doppler US with contrast-enhanced CT and pathologic results. *Radiat Med*, 2001; 19:119–125.
82 Steinkamp HJ, Teichgraber UK, Mueffelmann M, *et al*. Differential diagnosis of lymph node lesions. A semiquantitative approach with power Doppler sonography. *Invest Radiol*, 1999;34:509–515.
83 Steinkamp HJ, Maurer J, Cornehl M, *et al*. Recurrent cervical lymphadenopathy: differential diagnosis with color-duplex sonography. *Eur Arch Otorhinolaryngol*, 1994;251:404–409.
84 Ahuja A, Ying M, Yuen YH, Metreweli C. Power Doppler sonography to differentiate tuberculous cervical lymphadenopathy from nasopharyngeal carcinoma. *AJNR Am J Neuroradiol*, 2001;22:735–740.
85 Ioachim HL. Metastatic nasopharyngeal carcinoma. In *Lymph Node Pathology*, Second edn. Philadelphia: J.B. Lippincott Company, 1994; 613–618.
86 Willam C, Maurer J, Schroeder R, *et al.* Assessment of vascularity in

reactive lymph nodes by means of D-galactose contrast-enhanced Doppler sonography. *Invest Radiol*, 1998;33:146–152.
87 Moritz JD, Ludwig A, Oestmann JW. Contrast-enhanced color Doppler sonography for evaluation of enlarged cervical lymph nodes in head and neck tumors. *AJR Am J Roentgenol*, 2000;174:1279–1284.
88 Khan HG, Gailloud P, Bude RO, *et al.* The effect of contrast material on transcranial Doppler evaluation of normal middle cerebral artery peak systolic velocity. *AJNR Am J Neuroradiol*, 2000;21:386–390.
89 Kim TK, Han JK, Kim AY, Choi BI. Limitations of characterization of hepatic hemangiomas using a sonographic contrast agent (Levovist) and power Doppler ultrasonography. *J Ultrasound Med*, 1999;18:737–743.
90 Knappe M, Louw M, Gregor RT. Ultrasonography-guided fine-needle aspiration for the assessment of cervical metastases. *Arch Otolaryngol Head Neck Surg*, 2000;126:1091–1096.
91 Baatenburg de Jong RJ, Rongen RJ, Verwoerd CD, *et al*. Ultrasound-guided fine-needle aspiration biopsy of neck nodes. *Arch Otolaryngol Head Neck Surg*, 1991;117:402–404.
92 Robinson IA, Cozens NJ. Does a joint ultrasound guided cytology clinic optimize the cytological evaluation of head and neck masses? *Clin Radiol*, 1999;54:312–316.
93 van den Brekel MW, Reitsma LC, Quak JJ, *et al.* Sonographically guided aspiration cytology of neck nodes for selection of treatment and follow-up in patients with N0 head and neck cancer. *AJNR Am J Neuroradiol*, 1999;20:1727–1731.