



Ultrasound Pattern Recognition to Evaluate Lymph Nodes in the Neck: A Pictorial Review

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Abstract

Background and Objective: Evaluation of cervical lymphadenopathy is a frequent clinical challenge. High-frequency ultrasound (US) equipped with B-mode and Colour/Power Doppler capabilities serves as the primary non-invasive modality to differentiate benign, infective, inflammatory, and malignant cervical lymph nodes. This pictorial review aims to synthesize classic sonographic patterns, detail diagnostic metrics and cut-offs, address imaging pitfalls, and provide a comprehensive diagnostic roadmap for head and neck ultrasonography.

Narrative Scope and Search Strategy: A literature search of PubMed and MEDLINE databases (up to 2026) was performed using search terms including "Neck Ultrasound", "Cervical Lymphadenopathy", "Ultrasonography, Doppler", and "Lymph Nodes". Key diagnostic studies evaluating sensitivity, specificity, and Doppler characteristics were reviewed along with representative clinical case studies.

Findings and Conclusion: Key ultrasound features—including long-to-short axis ratio (L/S), fatty hilum integrity, cortical thickness, margin definition, and vascular flow patterns—allow reliable differentiation across nodal pathologies. While classical patterns exist (e.g., central hilar vascularity in benign/reactive nodes vs. chaotic peripheral vascularity and microcalcifications in metastatic malignancy), overlapping features necessitate US-guided Fine Needle Aspiration Cytology (FNAC) or core-needle biopsy for definitive histopathological confirmation.

Keywords: Neck Ultrasound; Cervical Lymphadenopathy; Pattern Recognition; Head and Neck Imaging; Fine-Needle Aspiration Cytology; Differential Diagnosis

Abbreviations

CEUS: Contrast-Enhanced Ultrasound; CT: Computed Tomography; FNAC: Fine-Needle Aspiration Cytology; KFD: Kikuchi-Fujimoto Disease; L/S: Long-to-Short Axis Ratio; MRI: Magnetic Resonance Imaging; PI: Pulsatility Index; RI: Resistive Index; SCC: Squamous Cell Carcinoma; TB: Tuberculosis; US: Ultrasound.

Introduction

The neck houses a vast network of lymph nodes, with specific anatomical zones classified globally into standard levels to guide clinical staging and therapeutic intent [1,2]. Clinical presentation of cervical lymphadenopathy frequently prompts referral for urgent diagnostic evaluation. Although cross-sectional modalities such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) were historically favoured for mapping deep spaces and delineating adjacent macrovascular invasion [3,4], high-frequency linear transducers (7–15 MHz) have firmly established ultrasound (US) as the definitive first-line imaging modality for superficial neck structures.

Ultrasound offers distinct advantages: it is readily available, cost-effective, free of ionizing radiation, uniquely suited for both paediatric and adult populations, and highly feasible for bedside evaluation in bedridden or intensive care unit (ICU) patients. Crucially, real-time ultrasound guidance allows precise needle placement during fine-needle aspiration cytology (FNAC) or core-needle biopsy, ensuring excellent cellular or core tissue yield while minimizing pass complications [5,6].

Depending on etiology, cervical lymph nodes manifest highly diverse sonographic patterns across benign, reactive, infective, inflammatory, and malignant spectrums. This review details these multi-parametric patterns, presents objective quantitative metrics, highlights major diagnostic overlaps, and outlines key imaging pitfalls.

Diagnostic metrics and cut-off values

To move beyond subjective qualitative descriptions, key ultrasound features are quantified using standardized diagnostic metrics and cut-off indices:

- **Long-to-Short Axis (L/S) Ratio:** An L/S ratio > 2.0 indicates an oval/elongated morphology, strongly associated with

benign or reactive processes (sensitivity ~85%, specificity ~80%) [7,8]. Conversely, an L/S ratio < 2.0 signifies a rounded geometry, characteristic of malignant transformation, lymphomatous expansion, or nodal metastases [9,10].

- **Cortical Thickness and Eccentricity:** Normal cortical thickness is uniform and typically < 3 mm [11]. Asymmetric, focal, or eccentric cortical widening is a high-specificity marker (> 88%) for early tumour infiltration or localized reactive response [12].
- **Fatty Hilum Integrity:** The presence of an intact, echogenic central fatty hilum is a hallmark of benign nodes [13]. Displacement, compression, or complete erasure of the hilum carries a high positive predictive value for malignancy or advanced suppurative necrosis [7].
- **Resistive Index (RI) and Pulsatility Index (PI):** Spectral Doppler flow in malignant nodes often exhibits significantly elevated resistance ($\{RI\} > 0.80$), $\{PI\} > 1.60$) due to tumour neovascularization and mechanical vessel compression, whereas benign nodes typically show low-resistance hilar flow ($\{RI\} < 0.70$) [14].
- **Neovascularization and vessel compression,** whereas benign nodes typically show low-resistance flow ($\{RI\} < 0.70$) (Herman., *et al.* 101-04).

Sonographic patterns by etiology

Normal and benign lymph nodes

Benign nodes comprise normal anatomical nodes and reactive lymphoid hyperplasia. Common locations include submandibular, parotid, upper cervical, and posterior triangle regions.

Key ultrasound features:

- **Morphology:** Oval or reniform (kidney-shaped) with an L/S ratio > 2.0 [15].
- **Margins:** Smooth, well-defined capsule clearly delineated from adjacent soft tissue layers.
- **Architecture:** Echogenic central medulla/hilum with a thin, uniform hypoechoic cortex, where cortical thickness does not exceed medullary thickness.
- **Vascularity:** Colour/Power Doppler demonstrates orderly, central hilar vascularity with symmetrical tree-like branching extending toward the periphery [7] (Figures 1 and 2; Figures 3 and 4).

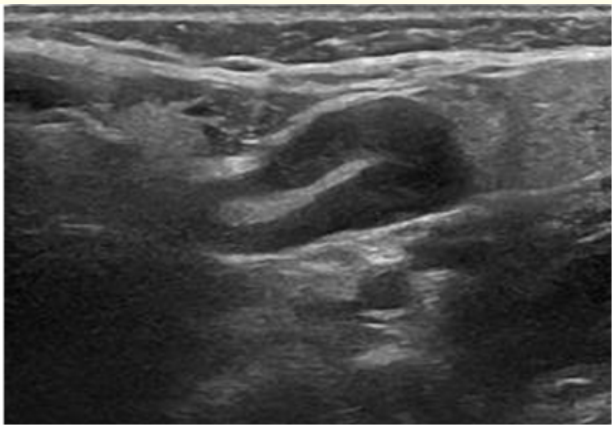


Figure 1: B-mode longitudinal sonogram of a normal right cervical lymph node showing an oval shape, well-defined capsule, thin cortex, and prominent echogenic central fatty hilum.

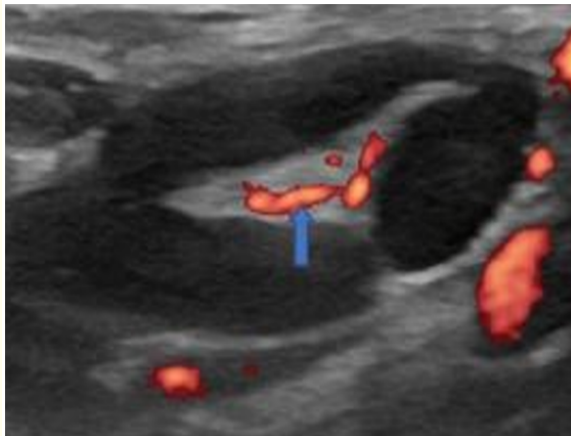
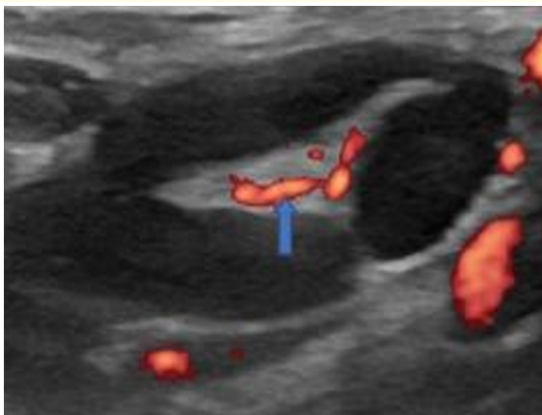


Figure 2: Colour Doppler image demonstrating normal, solitary central hilar vascularity radiating symmetrically within a benign lymph node (arrow).



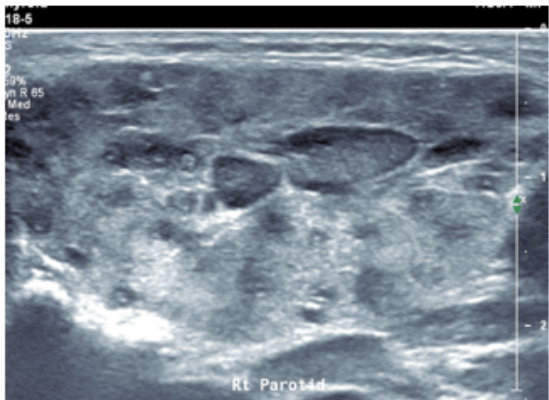
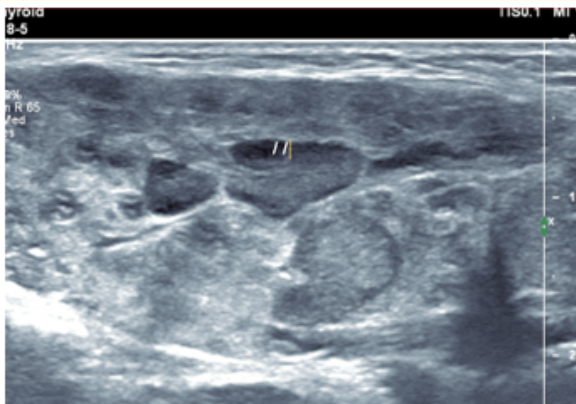
Figures 3 and 4: Gray-scale ultrasound images of a 9-month-old infant presenting with benign lymphoid hyperplasia involving bilateral parotid glands.

Acute bacterial and suppurative lymphadenitis

Acute bacterial infections trigger intense immune reactivity and severe hyperaemia, which may rapidly progress to suppurative adenitis and localized abscess formation [16].

Key ultrasound features

- **Uncomplicated Bacterial Adenitis:** Nodes remain oval (L/S > 2.0) with marked hilar hyperaemia on Colour Doppler and mild-to-moderate perinodal soft tissue oedema.
- **Suppurative Adenitis and Abscess:** Loss or severe distortion of the fatty hilum with focal intra-nodal anechoic/hypoechoic fluid collections representing pus or liquefactive necrosis.
- **Perinodal Changes:** Irregular, thickened capsule with surrounding hyperechoic soft tissue stranding reflecting cellulitis.
- **Vascularity:** Peripheral rim hyperaemia on Doppler imaging, with a complete absence of flow signals within internal necrotic or fluid-filled pockets. Node matting (conglomeration of adjacent nodes) may occur (Figures 5 and 6).



Figures 5 and 6: B-mode ultrasound images demonstrating suppurative cervical lymphadenitis with intranodal abscess formation secondary to acute bacterial infection.

Chronic granulomatous infections

Tuberculosis (TB) lymphadenitis

Cervical tuberculous lymphadenopathy (scrofula) is highly prevalent in endemic regions [17].

Sonographic features

- **Central Caseous Necrosis:** Marked hypoechoic or intranodal cystic liquefaction areas [18].
- **Nodal Matting:** Multiple nodes clumped together by soft tissue peri-adenitis to form conglomerate masses.
- **Hilum and Margins:** Complete loss of the fatty hilum, often with frank capsular disruption extending into cold abscesses. Intranodal coarse micro/macro-calcifications may be noted in chronic or treated phases.
- **Vascularity:** Displacement of normal hilar vessels, demonstrating peripheral or completely avascular patterns (Figures 7 and 8/9 and 10).

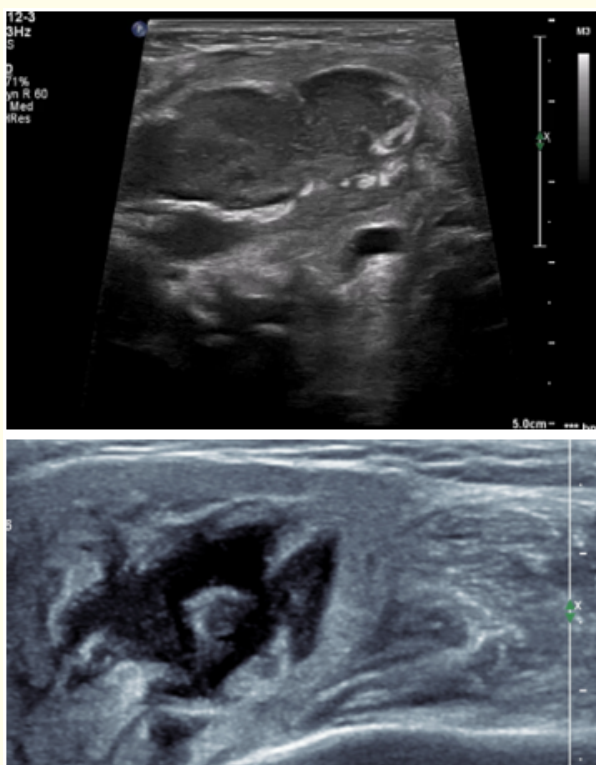


Figure 7: Gray-scale sonogram showing matted hypoechoic tuberculous cervical lymph nodes with perilesional soft tissue stranding.

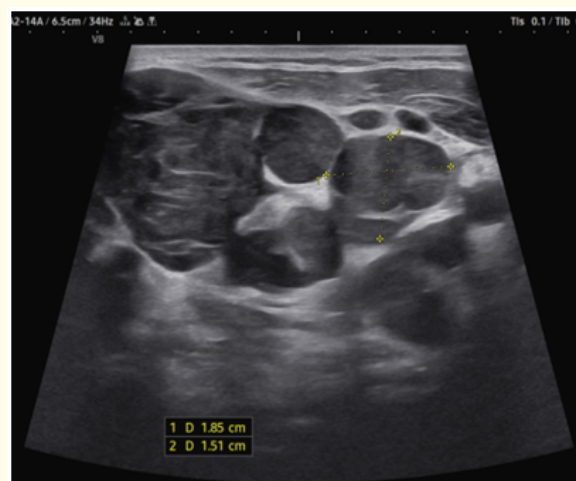


Figure 8: B-mode image of a tuberculous lymph node demonstrating extensive central caseous necrosis.



Figures 9 and 10: Ultrasound images demonstrating a cold abscess collection (arrows) located within the suprasternal space, secondary to tuberculous infection.

Sarcoidosis

Cervical nodal sarcoidosis is an inflammatory granulomatous process that often manifests bilaterally [19].

Sonographic features

- **Morphology and Stiffness:** Nodes are often multiple, enlarged, well-circumscribed, and exhibit increased tissue stiffness on shear-wave or strain elastography [20].

- **Internal Architecture:** Hypoechoic texturing with preserved or distorted hilum, occasionally showing internal septations. Associated involvement of the salivary glands (predominantly parotid) may occur.
- **Contrast-Enhanced Ultrasound (CEUS):** CEUS aids in evaluating non-perfused micro-granulomatous zones, assisting in differentiating sarcoidosis from tuberculous necrosis or lymphoma (Figures 11 – A/B/C).

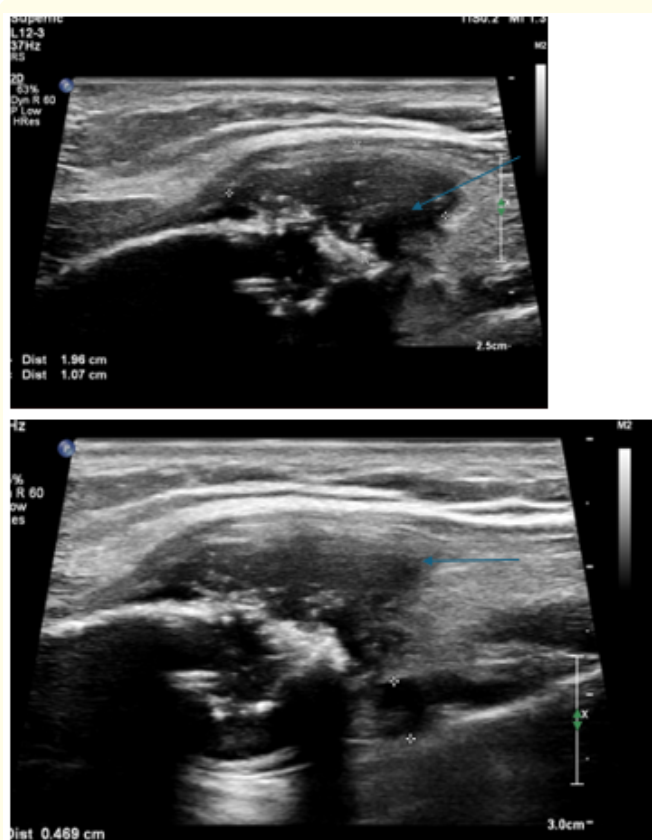


Figure 11: Biopsy-proven cervical sarcoidosis: (A) B-mode ultrasound showing enlarged hypoechoic lymph node with internal septations; (B) Colour Doppler evaluation showing displaced vascularity; (C) Photomicrograph showing characteristic non-caseating epithelioid granulomas (H&E, $\times 200$).

Fungal and atypical lymphadenitis

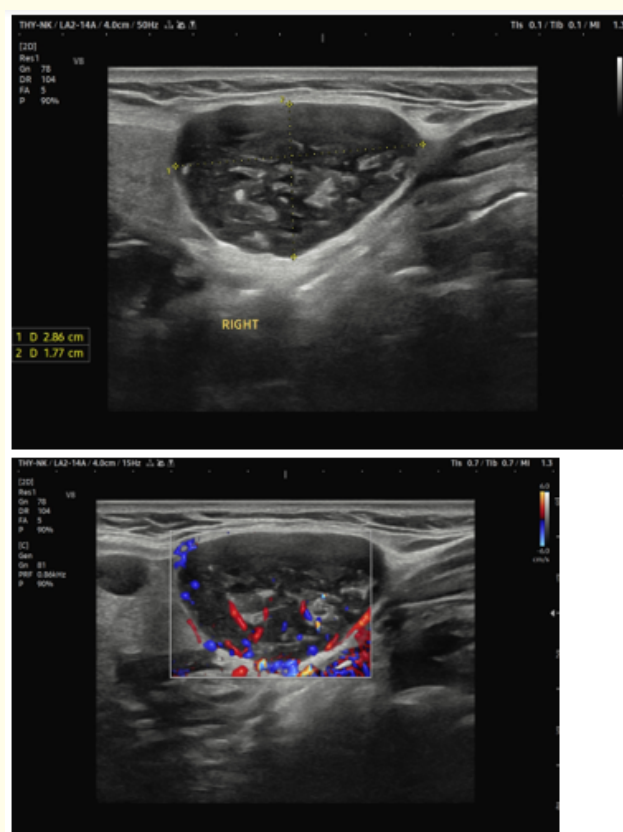
Fungal nodal infections mimic tuberculous and neoplastic processes with extensive necrosis and matting; definitive diagnosis relies on US-guided FNAC/core biopsy with fungal staining and culture [5].

Histiocytic necrotizing lymphadenitis (Kikuchi-Fujimoto Disease)

Kikuchi-Fujimoto disease (KFD) is a self-limiting inflammatory lymphadenopathy predominantly affecting young adults (< 40 years) [21].

Sonographic features

- **Cluster and Matting:** Multiple small-to-medium oval nodes clustered in posterior triangle or deep cervical chains, often displaying prominent perinodal hyperechoic stranding [22].
- **Hilum and Cortex:** Hypoechoic nodes with asymmetric cortical widening, but with a preserved central fatty hilum [23].
- **Vascularity:** Predominantly central hilar vascularity without chaotic or peripheral vessel invasion.
- **Necrosis:** Focal hypoechoic internal necrosis may be present, typically less extensive than in tuberculous adenitis (Figures 12 – A- C and D).



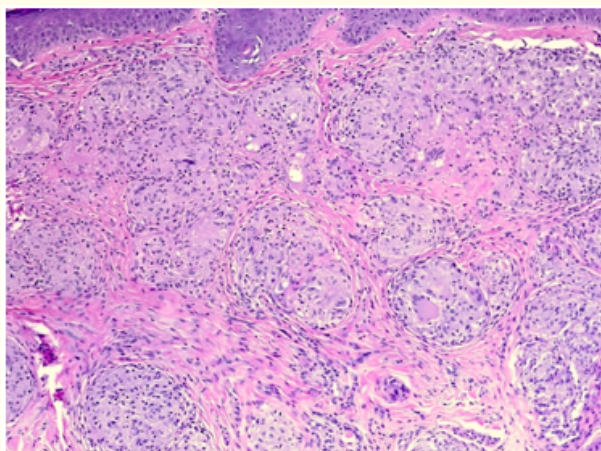


Figure 12: Histologically proven Kikuchi-Fujimoto disease: (A–C) B-mode sonograms showing multiple clustered hypoechoic ovoid nodes with preserved fatty hilum and perinodal stranding; (D) Histopathological slide demonstrating focal coagulative necrosis with abundant crescentic histiocytes.

Malignant and metastatic lymph nodes

Primary lymphoproliferative disorders (lymphoma) and cervical metastases (frequently secondary to head and neck squamous cell carcinoma or thyroid carcinomas) show distinct sonographic features [24,25]. Screening for metastatic disease also requires keeping watch for occult clinical manifestations, such as “skip metastases,” where tumour cells bypass the proximal nodal levels to settle directly in lower chains (Levels III/IV) [26].

Sonographic features

- **Round Morphology:** Eccentric enlargement reducing the L/S ratio to < 2.0 .
- **Loss of Fatty Hilum:** Complete obliteration, displacement, or destruction of the central hilum.
- **Cortical and Texture Alterations:** Asymmetric cortical thickening, markedly hypoechoic and heterogeneous internal architecture [27].

Special markers

- **Microcalcifications:** Punctate hyperechoic foci characteristic of metastatic papillary thyroid carcinoma (correlating with psammoma bodies) [28].
- **Intranodal Cystic Necrosis:** Common in squamous cell carcinoma metastases and papillary thyroid carcinoma.

- **Extracapsular Spread:** Irregular, blurred borders indicating tumour breach through the nodal capsule into adjacent soft tissues.
- **Doppler Characteristics:** Peripheral, penetrating, or chaotic vascularity entering through the capsule rather than the hilum, accompanied by high-resistance spectral parameters (Figures 13/14/15/16/17 and 18).

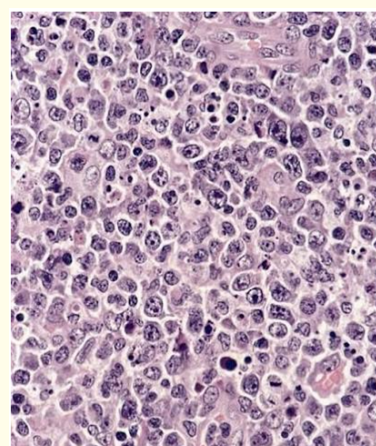
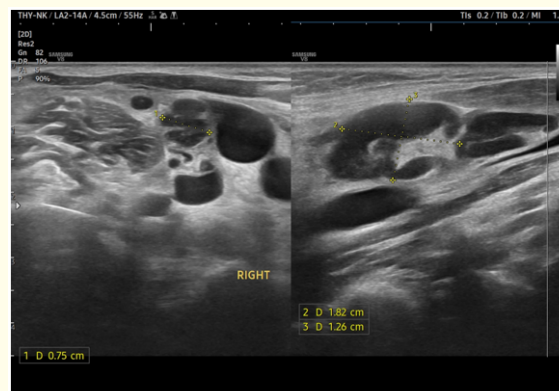
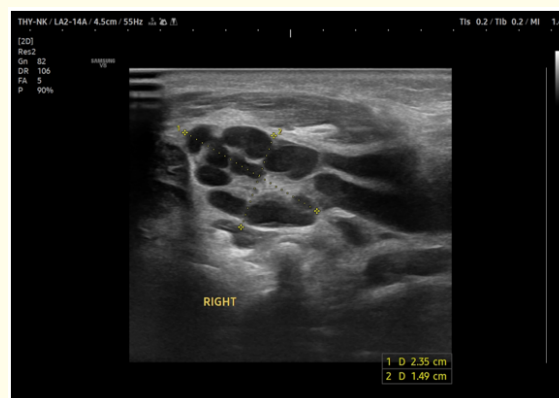


Figure 13: Cervical nodal metastasis from carcinoma larynx: (A) B-mode sonogram showing rounded hypoechoic mass with complete obliteration of fatty hilum; (B) Colour Doppler image exhibiting chaotic, disorganized peripheral vascularity.

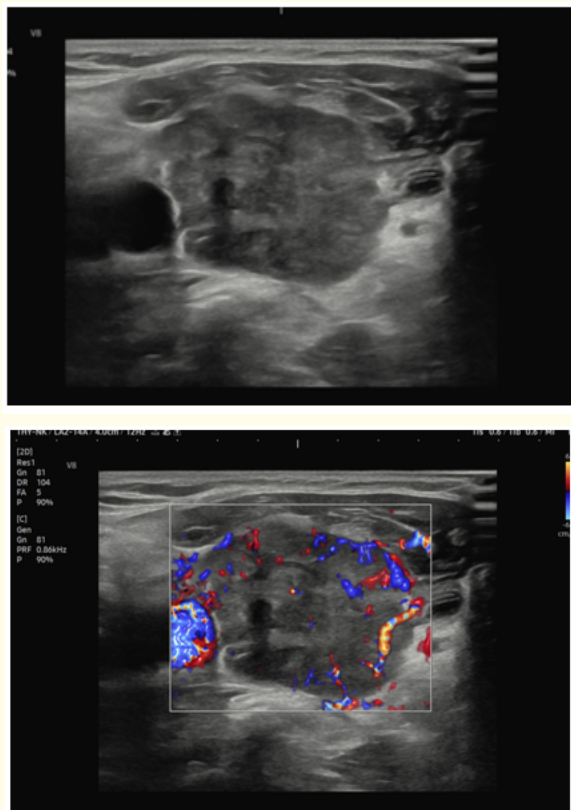


Figure 14: Primary buccal squamous cell carcinoma (SCC): (A, B) High-frequency linear and intraoral ultrasound demonstrating primary buccal tumour; (arrow) (C) Metastatic submandibular lymph node; (D) Histopathology confirming well-differentiated SCC with keratin pearl formation.

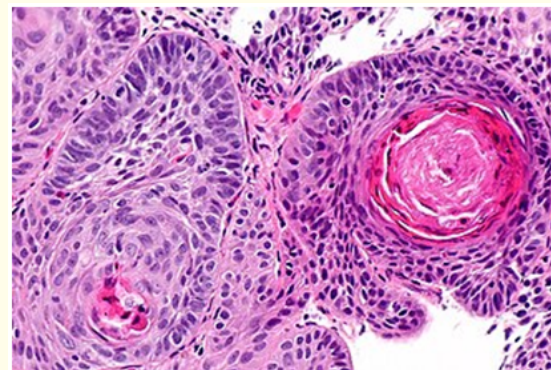
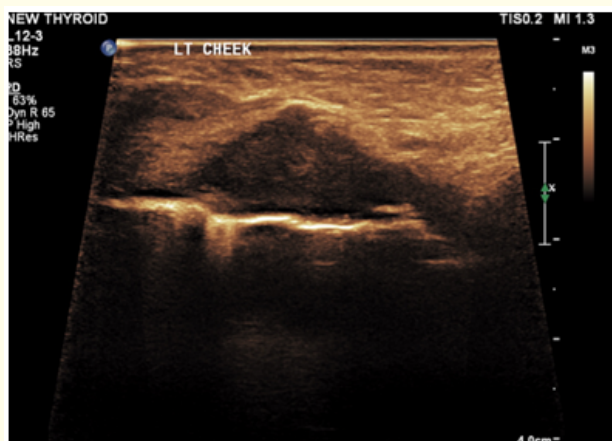


Figure 15: Correlative MRI scan complementing high-resolution ultrasound diagnosis of deep cervical nodal metastasis (mass pointed in arrows).



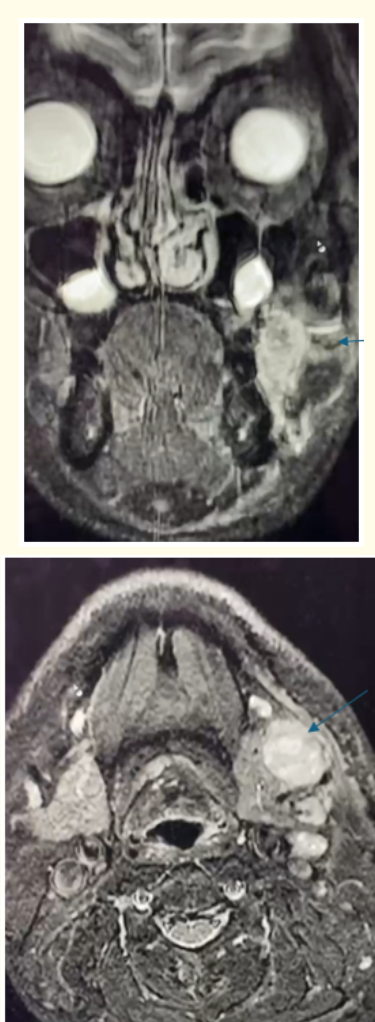


Figure 16: Gray-scale ultrasound showing a malignant lymph node with complete loss of normal architecture.

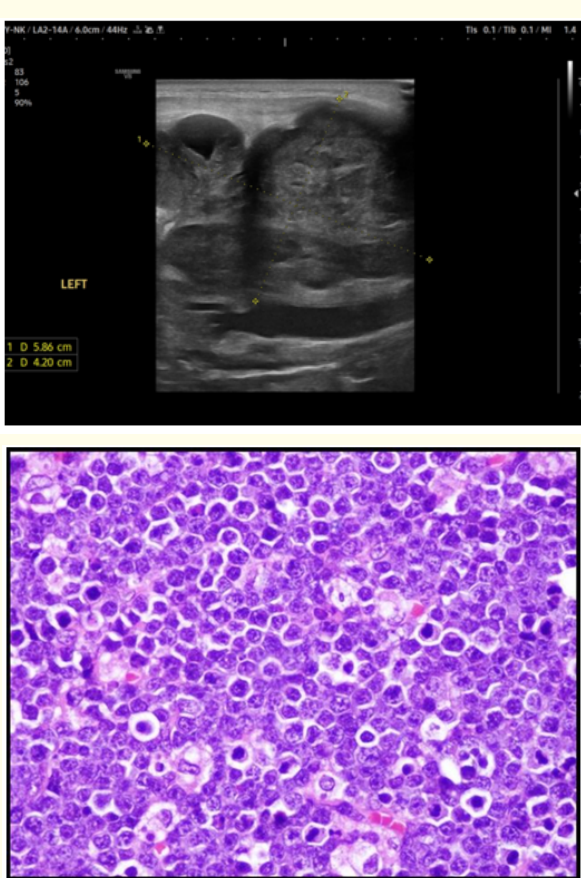


Figure 18: (A) and (B) Metastatic papillary thyroid carcinoma node exhibiting characteristic punctate hyperechoic microcalcification. (arrow) (C) Histopathological section displaying diagnostic psammoma bodies.

Discussion

Comparative analysis

Systematic assessment of nodal shape, margins, fatty hilum, internal echotexture, and vascular orientation provides a highly structured framework for evaluating cervical lymphadenopathy. Table 1 summarizes the primary differential criteria across common nodal pathologies.

Diagnostic overlaps and pitfalls

- **Tuberculosis vs. Metastasis:** Both conditions can present with rounded, matted, hypoechoic nodes with central necrosis and peripheral vascularity (Ahuja., *et al.* “Power Doppler” 735-40). Clinical history, tuberculin testing/GeneXpert, and core biopsy are critical for differentiation.
- **Kikuchi-Fujimoto vs. Lymphoma:** KFD nodes mimic low-grade lymphoma on B-mode ultrasound due to markedly hypoechoic and heterogenous internal architecture and clustering (Lo., *et al.* 1817-20). Preservation of central hilar

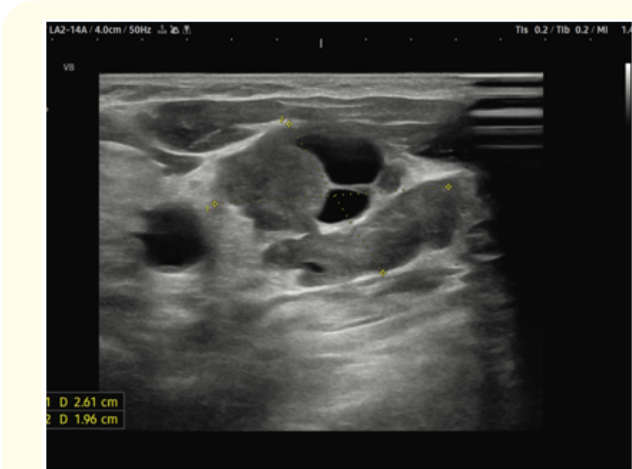
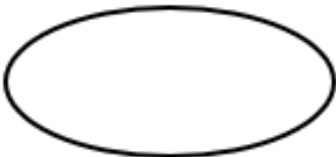
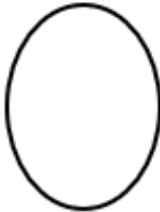
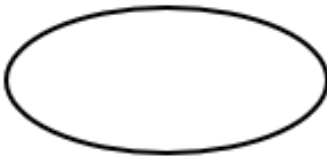
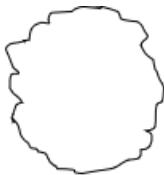


Figure 17: Primary Hodgkin Lymphoma: (A) B-mode image showing a large rounded, pseudo cystic hypoechoic nodal mass; (B) Histopathological section displaying diagnostic Reed-Sternberg cells.

Feature	Normal/Reactive	Acute Suppurative	Tuberculous	Kikuchi-Fujimoto	Malignant/Metastatic
Shape (\$L/\$\$ Ratio)	Oval (\$> 2.0\$)	Oval to Round	Oval or Conglomerate	Ovoid/Small (\$> 2.0\$)	Round (\$< 2.0\$)
Margins	Smooth, well-defined	Irregular/Perinodal oedema	Ill-defined/Matted	Perinodal stranding	Irregular/Extracapsular
Fatty Hilum	Preserved and visible	Severely distorted/Lost	Lost/Effaced	Preserved	Absent or destroyed
Cortex/Echotexture	Thin, uniform hypochoic	Anechoic/hypochoic fluid	Heterogeneous/Caseous	Hypochoic widening	Heterogeneous/Thickened
Doppler Pattern	Central hilar flow only	Peripheral hyperaemia/Avulsion	Peripheral/Displaced	Central hilar vascularity	Peripheral, chaotic, disorganized
Special Features	Symmetrical tree branching	Liquefactive abscess	Cold abscess, calcification	Cluster pattern, self-limiting	Microcalcifications, necrosis

Table 1: Differential Sonographic Features Across Cervical Nodal Pathologies.

Diagrammatic representation	Normal lymphnode	Malignant lymphnode
Shape	 (Wide)	 (Oval)
Margins	 (Regular)	 (Irregular)
Echotexture	 (Echogenic Fatty Hilum And Hypochoic Cortex)	 (Solid Hypochoic)

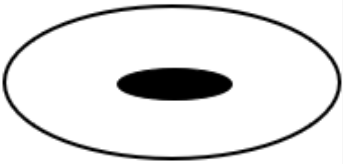
Hilum	 (Central well preserved)	 (Displaced/destroyed)
Colour Doppler	 (Central hilar flow)	 (Chaotic vascularity)

Table a

vascularity and clinical presence of tender lymphadenopathy in young patients favours KFD, but histology remains necessary.

- Reactive Hyperplasia in Submandibular Nodes:** Submandibular lymph nodes normally exhibit lower L/S ratios (< 2.0) and mild cortical widening due to constant oral reactivity, leading to false-positive malignancy classifications if evaluated strictly by shape metrics (Ahuja and Ying 1691-99).

Inter-observer variability and technical considerations

Ultrasound evaluation is operator-dependent. Subjective interpretation of hilum loss, marginal irregularity, and low-flow colour Doppler signals introduces inter-observer variance. Standardized gain settings, low pulse repetition frequencies (PRF) for microvascular flow, and standardized multiplanar measurement protocols are essential to minimize diagnostic discordance.

Limitations

This pictorial review is qualitative and instructional in nature. While diagnostic performance ranges are cited from published literature, institutional variations in ultrasound equipment resolution and operator expertise may influence prospective diagnostic accuracy.

Conclusion

High-frequency B-mode ultrasound integrated with Colour and Power Doppler imaging provides an essential, non-invasive diagnostic framework for evaluating cervical lymphadenopathy. Systemic assessment of nodal shape, hilum preservation, cortical thickness, internal echotexture, and vascular orientation facilitates accurate pattern recognition across benign, infective, inflammatory, and malignant etiologies. In cases of overlapping sonographic features, real-time ultrasound-guided FNAC or core-needle biopsy remains the definitive modality for establishing an accurate histopathological diagnosis.

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Ethics Approval and Patient Consent

Informed consent for publication of clinical details, anonymized ultrasound images, and histopathological photographs was obtained from all patients (or their legal guardians in paediatric cases) prior to manuscript compilation.

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Conflict of Interest

The authors declare no competing financial or non-financial interests.

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