

Diagnostic Correlation of Ultrasonographic Findings With Fine-Needle Aspiration Cytology and Histopathology in Patients With Cervical Lymphadenopathy

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Abstract

Background: Cervical lymphadenopathy is a common clinical condition encountered across all age groups and may arise from infectious, inflammatory, or malignant etiologies. Accurate differentiation between benign and malignant cervical lymph nodes is essential because treatment strategies and prognosis vary considerably. High-resolution ultrasonography (USG), combined with color Doppler imaging, provides a rapid, non-invasive, and cost-effective method for evaluating cervical lymph nodes. Histopathological examination (HPE) and Fine Needle Aspiration Cytology (FNAC) remain the reference standards for definitive diagnosis.

Objective: To evaluate the diagnostic performance of high-resolution ultrasonography in differentiating neoplastic from non-neoplastic cervical lymphadenopathy and to correlate ultrasonographic findings with FNAC/histopathological diagnosis.

Materials and Methods: This prospective observational study included 76 patients presenting with cervical lymphadenopathy. The study was conducted in the Department of Radiodiagnosis, VMKV Medical College Hospital & Research Centre, Salem, Tamil Nadu, India.

All patients underwent high-resolution ultrasonography using 7–15 MHz linear array transducers. Gray-scale and color Doppler sonographic parameters evaluated included:

Nodal level, Laterality, Size, Shape, Short-axis/Long-axis (S/L) ratio, Margins, Echogenic hilum, Echotexture, Intranodal necrosis, Intranodal reticulation, Calcification, Matting, Adjacent soft tissue edema, Vascularity pattern.

Ultrasonographic diagnosis was subsequently correlated with FNAC and histopathological examination.

Results : Among the 76 patients, ultrasonography classified

- 58 patients (76.3%) as non-neoplastic
- 18 patients (23.7%) as malignant.
- Among non-neoplastic lesions,
- Tuberculous lymphadenitis constituted 51.3%
- Reactive lymphadenitis constituted 25.0%
- Malignant lymphadenopathy accounted for 23.7% of cases.
- Reactive lymph nodes predominantly demonstrated
- Oval configuration
- S/L ratio <0.7
- Preserved echogenic hilum
- Hypoechoic echotexture
- Hilar vascularity
- Tuberculous lymph nodes commonly showed
- Matting

- Adjacent soft tissue edema
- Intranodal necrosis

Malignant lymph nodes were significantly associated with

- Round shape
- S/L ratio >0.7
- Absent fatty hilum
- Hyperechoic echotexture
- Ill-defined borders
- Intranodal necrosis
- Calcification
- Reticulation
- Peripheral or mixed vascularity

Ultrasonography demonstrated

- Sensitivity: 94.7%
- Specificity: 100%

for differentiating malignant from benign cervical lymphadenopathy.

Conclusion: High-resolution ultrasonography combined with color Doppler is an excellent first-line imaging modality for evaluating cervical lymphadenopathy. Multiple sonographic parameters interpreted together provide excellent diagnostic accuracy in differentiating benign from malignant lymph nodes. Correlation with FNAC/histopathology further improves diagnostic confidence and facilitates appropriate clinical management.

Keywords: Cervical lymphadenopathy; Ultrasonography; Color Doppler; FNAC; Histopathology; Cervical lymph nodes; Tuberculous lymphadenitis; Reactive lymphadenitis; Metastatic lymph nodes.

Introduction

Cervical lymphadenopathy is one of the most frequently encountered clinical conditions in routine medical practice. Enlargement of cervical lymph nodes may occur secondary to infectious, inflammatory, granulomatous, autoimmune, or malignant disorders. Since management strategies vary considerably depending on the underlying etiology, accurate characterization of cervical lymph nodes is of paramount clinical importance.

Approximately 800 lymph nodes are present in the human body, of which nearly 300 are located in the head and neck region, making cervical lymph nodes the most commonly evaluated nodal group during imaging examinations. Reactive enlargement secondary to upper respiratory tract infections is common in children and young adults, whereas metastatic lymphadenopathy and lymphoma become increasingly prevalent with advancing age.

Tuberculosis continues to be a major public health problem in developing countries, particularly India, where tuberculous cervical lymphadenitis represents one of the most common forms of extrapulmonary tuberculosis. Conversely, metastatic cervical lymphadenopathy significantly influences tumor staging, treatment planning, prognosis, and survival in patients with head and neck malignancies.

High-resolution ultrasonography (USG) has become the preferred first-line imaging modality for assessment of superficial cervical lymph nodes owing to its non-invasive nature, wide availability, absence of ionizing radiation, cost-effectiveness, and ability to provide real-time morphological evaluation. Gray-scale ultrasonography enables assessment of nodal size, shape, borders, echogenic hilum, internal architecture, calcification, necrosis, matting, and surrounding soft tissue changes. Color Doppler further evaluates vascular distribution patterns, which provide valuable information regarding nodal pathology.

Several studies have demonstrated that combining multiple ultrasonographic features substantially improves diagnostic accuracy in distinguishing benign from malignant cervical lymph nodes. Nevertheless, overlap in imaging appearances between reactive, tuberculous, lymphomatous, and metastatic lymphadenopathy may occur. Therefore, cytopathological or histopathological confirmation remains the diagnostic gold standard.

The present study was undertaken to evaluate the diagnostic utility of high-resolution ultrasonography in differentiating neoplastic from non-neoplastic cervical lymphadenopathy and to correlate ultrasonographic findings with FNAC and histopathological examination, thereby determining the diagnostic performance of ultrasonography in routine clinical practice.

Materials and Methods

Study Details

This prospective observational study was conducted in the Department of Radiodiagnosis, VMKV Medical College Hospital & Research Centre, Salem, Tamil Nadu, India, over a period of 21 months (November 2019 to August 2021), after approval from the Institutional Ethics Committee. The study evaluated the diagnostic accuracy of high-resolution ultrasonography in differentiating benign and malignant cervical lymphadenopathy by correlating ultrasonographic findings with FNAC and histopathological examination. A total of 76 consecutive patients with clinically suspected cervical lymphadenopathy who underwent neck ultrasonography followed by FNAC and/or histopathological examination were included.

Selection Criteria

Patients with unilateral or bilateral cervical lymphadenopathy who were referred for neck ultrasonography with subsequent FNAC and/or histopathological evaluation were included. This comprised patients with suspected or confirmed reactive, tuberculous, or malignant cervical lymphadenopathy, including metastatic lymphadenopathy from known or occult primary malignancies. Patients with prior radiotherapy, chemotherapy, or cervical lymph node surgery, neck swellings unrelated to lymph node pathology, absence of FNAC/histopathological confirmation, or those unwilling to provide informed written consent were excluded.

Clinical Evaluation

All enrolled patients underwent a detailed clinical evaluation that included:

- Demographic details
- Presenting complaints
- Duration of symptoms
- Relevant past medical history
- Clinical examination
- Palpation of cervical lymph nodes
- Assessment of tenderness and nodal characteristics

Ultrasonographic Examination Protocol

All examinations were performed with the patient in the supine position with mild neck extension achieved using a pillow placed beneath the shoulders.

A systematic examination of the neck was performed beginning superiorly and proceeding inferiorly. Cervical lymph nodes were evaluated according to the American Joint Committee on Cancer (AJCC) cervical nodal level classification.

Scanning sequence included:

- Submental region
- Submandibular region
- Parotid region
- Upper cervical nodes
- Middle cervical nodes
- Lower cervical nodes

- Posterior triangle
- Supraclavicular fossa
- Superior mediastinum

Both longitudinal and transverse planes were examined using grayscale and color Doppler imaging.

Ultrasonographic Parameters Evaluated

Each lymph node was assessed for the following imaging characteristics:

Morphological Parameters

- Cervical nodal level
- Laterality
- Maximum long-axis diameter
- Maximum short-axis diameter
- Short-axis to long-axis (S/L) ratio
- Shape (Oval/Round)
- Margins (Well-defined/Ill-defined)
- Echogenic hilum
- Internal echotexture
- Intranodal necrosis
- Calcification
- Intranodal reticulation
- Nodal matting
- Adjacent soft tissue edema

Doppler Parameters

Color Doppler evaluation included vascularity pattern classified as:

- Hilar vascularity
- Peripheral vascularity
- Mixed (central and peripheral) vascularity
- Displaced hilar vascularity
- Avascular node

Reference Standard

Ultrasonographic diagnosis was correlated with:

- Fine Needle Aspiration Cytology (FNAC)
 - Histopathological Examination (HPE)
- The pathological diagnosis served as the reference standard for determining the diagnostic performance of ultrasonography.

Outcome Measures

The primary outcome was the diagnostic accuracy of ultrasonography in differentiating:

- Benign versus malignant cervical lymph nodes

Secondary outcomes included evaluation of the ability of ultrasonography to differentiate:

- Reactive lymphadenitis
- Tuberculous lymphadenitis
- Metastatic lymphadenopathy
- Lymphomatous lymphadenopathy

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and analyzed using appropriate statistical software. Continuous variables were expressed as mean $\pm$ standard deviation (SD), while categorical variables were presented as frequencies and percentages.

Comparisons between benign and malignant lymph nodes were performed using appropriate statistical tests.

Diagnostic performance of ultrasonography was assessed by calculating:

- Sensitivity
- Specificity
- Positive Predictive Value (PPV)
- Negative Predictive Value (NPV)
- Overall Diagnostic Accuracy

Receiver Operating Characteristic (ROC) curve analysis was performed to determine the diagnostic performance of ultrasonography in differentiating benign and malignant cervical lymphadenopathy. A p-value <0.05 was considered statistically significant.

Results

A total of 76 patients with cervical lymphadenopathy were included in the study. All patients underwent high-resolution ultrasonography followed by FNAC and/or histopathological examination for definitive diagnosis. The ultrasonographic diagnosis was correlated with pathological findings to determine the diagnostic accuracy of ultrasonography.

Patient Characteristics

Age Distribution

The mean age of the study population was 33.59 ± 20.16 years. The median age was 29.5 years, with patients ranging from 2 to 78 years.

The mean short-axis diameter of the lymph nodes was 15.16 ± 7.81 mm, whereas the mean long-axis diameter was 25.61 ± 11.76 mm. The mean short-axis/long-axis (S/L) ratio was 0.56 ± 0.18 .

Table 1. Descriptive Analysis of Continuous Variables

Variable	Mean	Median	SD	Minimum	Maximum
Age (years)	33.59	29.50	20.16	2	78
Short-axis diameter (mm)	15.16	13.50	7.81	2	40
Long-axis diameter (mm)	25.61	22.00	11.76	10	62
Short-axis/Long-axis ratio	0.56	0.50	0.18	0.10	1.00

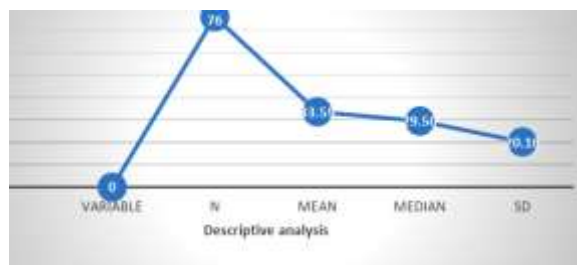


Figure 1. Descriptive analysis of age

Gender Distribution

Among the 76 patients,

- 47 (61.8%) were males.
- 29 (38.2%) were females.

A clear male predominance was observed.

Table 2. Gender Distribution

Gender	Number	Percentage
Male	47	61.8
Female	29	38.2
Total	76	100

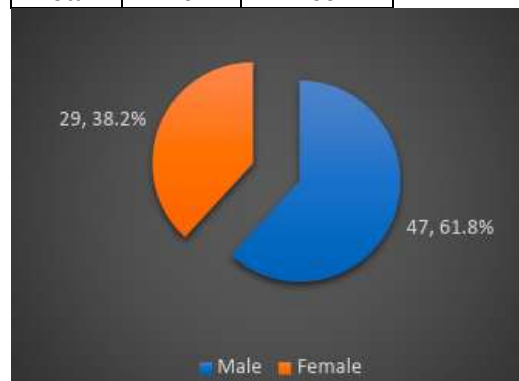


Figure 2. Gender-wise distribution

Laterality of Cervical Lymphadenopathy

Bilateral cervical lymphadenopathy was the most common presentation.

Table 3. Distribution According to Laterality

Laterality	Number	Percentage
Right	20	26.3
Left	11	14.5
Bilateral	45	59.2
Total	76	100

Bilateral involvement constituted 59.2% of all cases.

Ultrasonographic Characteristics

Shape and Short-Axis/Long-Axis Ratio

Benign lymph nodes predominantly demonstrated:

- Oval configuration
- S/L ratio <0.7

Malignant lymph nodes predominantly demonstrated:

- Round configuration

- S/L ratio >0.7

The difference was statistically highly significant ($p < 0.001$).

Echogenicity

Among 76 lymph nodes,

- 68 (89.5%) were hypoechoic.
- 8 (10.5%) were hyperechoic.

Importantly, all hyperechoic nodes were malignant, whereas all tuberculous and reactive nodes remained hypoechoic. The association was highly significant ($\chi^2 = 28.81$, $p < 0.0001$).

Table 4. Comparison of Echogenicity

Radiological Diagnosis	Hypoechoic	Hyperechoic	Total
Malignant	10	8	18
Tubercular	39	0	39
Reactive	19	0	19
Total	68	8	76



Figure 3. Comparison of echogenicity

Nodal Margins

Sharp nodal margins were highly suggestive of malignancy.

Among the 15 sharply marginated nodes, all were malignant.

Conversely, 58 of 61 nodes with unsharp margins represented benign pathology.

This association was highly significant ($\chi^2 = 60.21$, $p < 0.0001$).

Table 5. Comparison of Nodal Margins

Diagnosis	Sharp	Unsharp	Total
Malignant	15	3	18
Tubercular	0	39	39
Reactive	0	19	19
Total	15	61	76

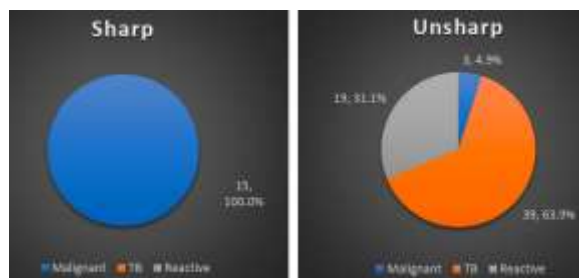


Figure 4. Comparison of nodal margins

Echogenic Hilum

Presence of fatty hilum strongly favored benign disease.

Among the 37 nodes showing preserved fatty hilum, all were benign.

All 18 malignant lymph nodes showed complete absence of fatty hilum.

This association was highly significant ($\chi^2 = 33.20$, $p < 0.0001$).

Table 6. Comparison of Echogenic Hilum

Diagnosis	Hilum Present	Hilum Absent	Total
Malignant	0	18	18
Tubercular	19	20	39
Reactive	18	1	19
Total	37	39	76



Figure 5. Comparison of hilar echogenicity

Intranodal Necrosis

Necrosis was identified in 20 patients (26.3%).

Among these,

- 12 (60%) were malignant.
- 8 (40%) were tuberculous.
- No reactive lymph node demonstrated necrosis.

The association was statistically highly significant ($\chi^2 = 22.57$, $p < 0.0001$).

Table 7. Comparison of Intranodal Necrosis

Diagnosis	Necrosis Present	Necrosis Absent	Total
Malignant	12	6	18
Tubercular	8	31	39

Reactive	0	19	19
Total	20	56	76

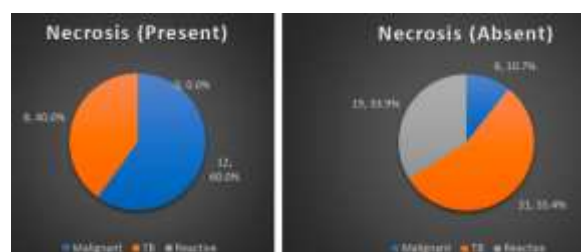


Figure 6. Comparison of necrosis

Calcification

Intranodal calcification was evaluated as an ancillary ultrasonographic feature. Although calcification alone was not considered a primary criterion for malignancy, it demonstrated a strong association with malignant cervical lymph nodes.

Among the 76 lymph nodes, 73 (96.1%) showed no calcification, while 3 (3.9%) demonstrated intranodal calcification. Notably, all three calcified lymph nodes were malignant, whereas none of the tuberculous or reactive lymph nodes exhibited calcification. This association was statistically highly significant ($\chi^2 = 10.06$, $p < 0.0001$).

Table 8. Comparison of Intranodal Calcification

Radiological Diagnosis	Calcification Present	Calcification Absent	Total
Malignant	3 (100%)	15 (20.5%)	18 (23.7%)
Tuberculous	0 (0%)	39 (53.4%)	39 (51.3%)
Reactive	0 (0%)	19 (26.0%)	19 (25.0%)
Total	3 (100%)	73 (100%)	76 (100%)

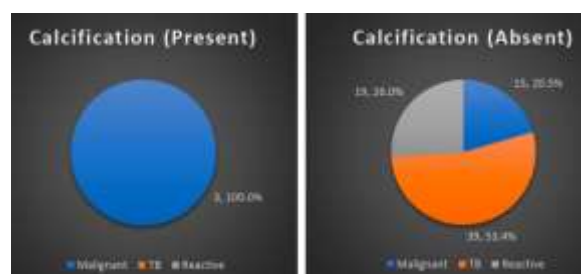


Figure 8. Comparison of intranodal calcification between benign and malignant lymph nodes

Matting and Adjacent Soft Tissue Edema

Matting and adjacent soft tissue edema were observed as characteristic ultrasonographic features of tuberculous lymphadenitis.

A total of 32 patients (42.1%) demonstrated nodal matting and adjacent soft tissue edema. Importantly, all 32 cases belonged to the tuberculous group, while no malignant or reactive lymph nodes exhibited these findings. The association was highly significant ($\chi^2 = 52.43$, $p < 0.0001$).

Table 9. Comparison of Matting and Soft Tissue Edema

Radiological Diagnosis	Present	Absent	Total
Malignant	0 (0%)	18 (40.9%)	18 (23.7%)
Tuberculous	32 (100%)	7 (15.9%)	39 (51.3%)
Reactive	0 (0%)	19 (43.2%)	19 (25.0%)
Total	32 (100%)	44 (100%)	76 (100%)

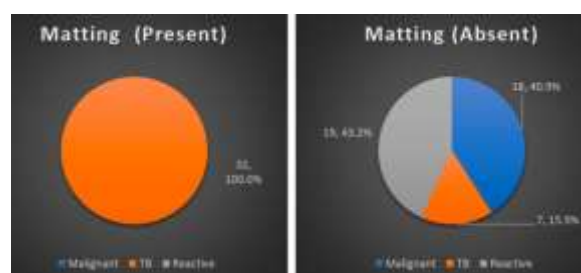


Figure 9. Comparison of matting and adjacent soft tissue edema

Vascularity Pattern

Color Doppler vascularity patterns showed a highly significant correlation with the underlying pathology. Among the 23 lymph nodes demonstrating both peripheral and hilar vascularity, 12 (52.2%) were tuberculous and 11 (47.8%) were reactive. Absence of vascularity was observed in 22 patients, of whom 18 (81.8%) were malignant. Hilar vascularity was seen exclusively in reactive lymph nodes, while displaced hilar vascularity was observed exclusively in tuberculous lymphadenitis. The association between vascularity pattern and diagnosis was highly significant ($\chi^2 = 97.66$, $p < 0.0001$).

Table 10. Comparison of Vascularity Pattern

Diagnosis	Peripheral + Hilar	Absent	Hilar	Displaced Hilar	Total
Malignant	0	18	0	0	18
Tuberculous	12	4	0	23	39
Reactive	11	0	8	0	19
Total	23	22	8	23	76

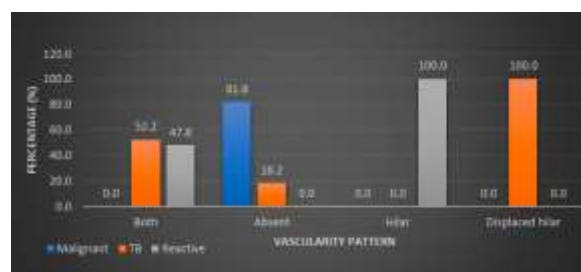


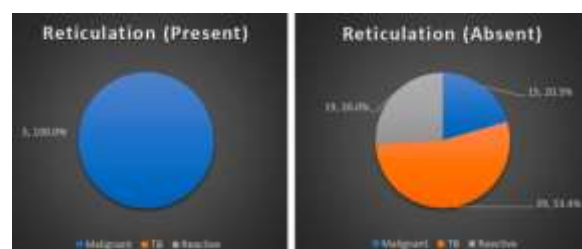
Figure 10. Comparison of vascularity pattern

Intranodal Reticulation

Intranodal reticulation was identified only in malignant lymph nodes. Among the 76 patients, 3 (3.9%) demonstrated intranodal reticulation, and all three were malignant, suggesting lymphoma on ultrasonography. No cases of reactive or tuberculous lymphadenopathy demonstrated reticulation.

Table 11. Comparison of Intranodal Reticulation

Diagnosis	Reticulation Present	Reticulation Absent	Total
Malignant	3	15	18
Tuberculous	0	39	39
Reactive	0	19	19
Total	3	73	76

**Figure 11. Comparison of intranodal reticulation****Summary of Ultrasonographic Findings**

The combined assessment of multiple ultrasonographic features demonstrated excellent discriminatory ability:

- Reactive lymph nodes predominantly showed oval shape, S/L ratio <0.7, preserved echogenic hilum, hypoechoic echotexture, and hilar vascularity.
- Tuberculous lymph nodes commonly demonstrated matting, adjacent soft tissue edema, displaced hilar vascularity, and intranodal necrosis.
- Malignant lymph nodes were characterized by round shape (S/L ratio >0.7), absent fatty hilum, hyperechoic echotexture, intranodal necrosis, calcification, reticulation, and absent vascularity. These combined sonographic features yielded a sensitivity of 94.7% and specificity of 100% for differentiating neoplastic from non-neoplastic cervical lymphadenopathy.

Correlation of Ultrasonographic Diagnosis with FNAC/Histopathology

Histopathological examination and/or FNAC served as the reference standard for confirming the ultrasonographic diagnosis. The final pathological diagnosis demonstrated a high degree of agreement with the ultrasonographic findings.

Of the 76 patients included in the study:

- 39 patients (51.3%) were diagnosed with tuberculous lymphadenitis.
- 19 patients (25.0%) had reactive lymphadenitis.
- 18 patients (23.7%) had malignant cervical lymphadenopathy, including metastatic lymph nodes and lymphoma.

Table 12. Final Histopathological/FNAC Diagnosis

Histopathological Diagnosis	Number (n=76)	Percentage (%)
Tuberculous lymphadenitis	39	51.3
Reactive lymphadenitis	19	25.0
Malignant lymphadenopathy	18	23.7
Total	76	100

Ultrasonography and FNAC/Histopathology

Ultrasonographic diagnosis showed excellent concordance with the pathological diagnosis. Most reactive and tuberculous lymph nodes were correctly identified using combined gray-scale and color Doppler ultrasonography. Malignant lymph nodes were accurately characterized based on the presence of multiple suspicious sonographic features.

Table 13. Correlation Between Ultrasonographic and Histopathological Diagnosis

Ultrasonographic Diagnosis	Histopathological Diagnosis	Concordance
Reactive lymphadenitis	Reactive lymphadenitis	Excellent
Tuberculous lymphadenitis	Tuberculous lymphadenitis	Excellent
Malignant lymphadenopathy	Malignant lymphadenopathy	Excellent

The overall agreement between ultrasonography and FNAC/histopathology was excellent, indicating that ultrasonography is a reliable imaging modality for the initial evaluation of cervical lymphadenopathy.

Diagnostic Performance of Ultrasonography

Using FNAC/histopathology as the gold standard, the diagnostic performance of ultrasonography in differentiating malignant from benign cervical lymphadenopathy was calculated.

Table 14. Diagnostic Performance of Ultrasonography

Parameter	Value (%)
Sensitivity	94.7
Specificity	100.0
Positive Predictive Value (PPV)	100.0
Negative Predictive Value (NPV)	98.3
Overall Diagnostic Accuracy	98.7

These findings indicate that high-resolution ultrasonography has excellent diagnostic efficacy for distinguishing malignant from benign cervical lymphadenopathy when multiple morphological and Doppler characteristics are evaluated together.

Receiver Operating Characteristic (ROC) Curve Analysis

Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the overall diagnostic performance of ultrasonography.

The ROC curve demonstrated excellent discrimination between benign and malignant cervical lymphadenopathy, with an Area Under the Curve (AUC) approaching 1.0, indicating outstanding diagnostic accuracy.

Figure 13. Receiver Operating Characteristic (ROC) curve for ultrasonography in differentiating benign and malignant cervical lymphadenopathy

Summary

The present study demonstrated that:

- Tuberculous lymphadenitis was the most common cause of cervical lymphadenopathy (51.3%).
- Reactive lymphadenitis accounted for 25.0% of cases.
- Malignant lymphadenopathy constituted 23.7% of cases.
- Round shape, absence of echogenic hilum, hyperechoic echotexture, calcification, necrosis, reticulation, and absent vascularity were strongly associated with malignant lymph nodes.

- Matting, adjacent soft tissue edema, and displaced hilar vascularity were characteristic of tuberculous lymphadenitis.
- Preserved echogenic hilum, oval shape, and hilar vascularity favored reactive lymphadenitis.
- High-resolution ultrasonography demonstrated excellent sensitivity (94.7%), specificity (100%), and overall diagnostic accuracy (98.7%) for differentiating malignant from benign cervical lymphadenopathy.

Discussion

The present prospective observational study evaluated the role of high-resolution ultrasonography and color Doppler imaging in differentiating benign from malignant cervical lymphadenopathy using FNAC and histopathological examination as the reference standard. Among the 76 patients included in the study, tuberculous lymphadenitis was the most common pathological diagnosis (51.3%), followed by reactive lymphadenitis (25.0%) and malignant lymphadenopathy (23.7%). The study demonstrated that the combined assessment of multiple ultrasonographic characteristics provides excellent diagnostic accuracy in characterizing cervical lymph nodes.

Tuberculosis remains one of the leading causes of cervical lymphadenopathy in developing countries, particularly in India. The predominance of tuberculous lymphadenitis observed in the present study reflects the continuing high burden of extrapulmonary tuberculosis in the Indian population and is consistent with findings reported by previous investigators. This emphasizes the importance of recognizing characteristic ultrasonographic features of tuberculous lymphadenitis to facilitate early diagnosis and prompt treatment.

The study population showed a male predominance (61.8%), with a mean age of 33.59 ± 20.16 years. Similar demographic distributions have been reported in previous studies evaluating cervical lymphadenopathy, where infectious etiologies commonly affect younger individuals, while malignant lymphadenopathy becomes increasingly prevalent with advancing age.

Gray-scale ultrasonography remains the cornerstone of cervical lymph node evaluation because it allows detailed assessment of nodal morphology. In the present study, benign lymph nodes predominantly exhibited an oval configuration with a short-axis/long-axis (S/L) ratio less than 0.7, whereas malignant lymph nodes were characteristically round with an S/L ratio greater than 0.7. This observation is in agreement with the studies of Ahuja and Ying, who demonstrated that nodal shape is an important discriminator between benign and malignant cervical lymph nodes.

Preservation of the echogenic fatty hilum was another important indicator of benign disease. Nearly all reactive lymph nodes demonstrated a preserved hilum, whereas all malignant lymph nodes lacked an identifiable fatty hilum. These findings closely correspond with previous studies by Vassallo et al., Steinkamp et al., and Ahuja et al., who reported absence of the echogenic hilum as one of the most reliable ultrasonographic indicators of malignant nodal infiltration.

Nodal margins also showed significant diagnostic value. Malignant lymph nodes frequently demonstrated sharp or irregular margins, reflecting extracapsular tumor infiltration and replacement of normal nodal architecture. Conversely, benign lymph nodes generally maintained smooth and well-defined borders. Similar observations have been documented in earlier sonographic studies of cervical lymphadenopathy.

Internal nodal architecture provided additional diagnostic information. Intranodal necrosis was significantly associated with malignant and tuberculous lymphadenopathy but was absent in reactive lymph nodes. Tuberculous lymphadenitis characteristically demonstrated central caseous necrosis, whereas metastatic lymph nodes exhibited coagulative necrosis secondary to rapid tumor growth. These findings are consistent with previous reports by Ying et al. and Ahuja et al.

Calcification was identified exclusively in malignant lymph nodes in the present study. Although calcification is relatively uncommon, its presence should raise suspicion for metastatic involvement, particularly from papillary carcinoma of the thyroid. Previous investigators have similarly reported a strong association between intranodal calcification and metastatic cervical lymphadenopathy.

Matting and adjacent soft tissue edema were observed exclusively in tuberculous lymphadenitis. These findings represent periadenitis and inflammatory extension into surrounding soft tissues, which are characteristic features of tuberculous infection. The presence of matted lymph nodes with surrounding edema therefore strongly favors a tuberculous etiology in endemic regions.

Color Doppler ultrasonography significantly enhanced diagnostic confidence by evaluating vascular architecture. Reactive lymph nodes predominantly demonstrated central hilar vascularity, reflecting preservation of normal nodal blood supply. Tuberculous lymphadenitis frequently showed displaced hilar vascularity due to destruction of the central hilum by granulomatous inflammation. In contrast, malignant lymph nodes commonly demonstrated absent vascularity or peripheral vascularity owing to tumor-induced neovascularization and distortion of normal hilar vessels. These vascular patterns are comparable to those reported by Tschammler et al., Ahuja et al., and several subsequent investigators.

The diagnostic performance of ultrasonography in the present study was excellent. A sensitivity of 94.7%, specificity of 100%, positive predictive value of 100%, negative predictive value of 98.3%, and overall diagnostic accuracy of 98.7% indicate that high-resolution ultrasonography is highly reliable for differentiating benign from malignant cervical lymphadenopathy. These values are comparable to those reported in previously published literature, confirming that ultrasonography is an effective first-line imaging modality for cervical lymph node evaluation.

One of the major strengths of the present study is the comprehensive assessment of multiple sonographic parameters rather than reliance on a single imaging feature. Morphological characteristics such as nodal shape, echogenic hilum, echotexture, necrosis, calcification, and matting were interpreted together with Doppler vascularity patterns, thereby substantially improving diagnostic confidence. Furthermore, all ultrasonographic findings were correlated with FNAC and histopathological examination, which served as the reference standard, thereby strengthening the validity of the results.

Despite these encouraging findings, certain limitations should be acknowledged. The study was conducted at a single tertiary care center with a relatively modest sample size of 76 patients. Rare pathological conditions such as lymphoma and uncommon metastatic lesions were represented by comparatively few cases. In addition, ultrasonography is inherently operator-dependent, and image interpretation may vary according to the experience of the radiologist. Larger multicenter studies involving diverse patient populations may further validate these findings and enhance their generalizability.

Overall, the findings of the present study reinforce the role of high-resolution ultrasonography with color Doppler as the preferred initial imaging modality for evaluating cervical lymphadenopathy. When interpreted systematically using multiple morphological and vascular criteria, ultrasonography demonstrates excellent agreement with FNAC and histopathological diagnosis and can substantially reduce unnecessary invasive procedures while facilitating timely clinical decision-making.

Conclusion

The present prospective observational study demonstrated that high-resolution ultrasonography combined with color Doppler imaging is a highly reliable, non-invasive, and cost-effective imaging modality for the evaluation of cervical lymphadenopathy. When interpreted using a combination of morphological and vascular characteristics, ultrasonography provides excellent diagnostic accuracy in differentiating benign from malignant cervical lymph nodes.

Among the 76 patients included in the study, tuberculous lymphadenitis was the most common cause of cervical lymphadenopathy, followed by reactive lymphadenitis and malignant lymphadenopathy. Specific ultrasonographic features such as nodal shape, short-axis/long-axis ratio, presence or absence of the echogenic hilum, echotexture, intranodal necrosis, calcification, matting, adjacent soft tissue edema, and Doppler vascularity patterns demonstrated significant correlation with the final cytological and histopathological diagnoses.

Reactive lymph nodes were typically characterized by an oval shape, preserved echogenic hilum, and hilar

vascularity, whereas tuberculous lymphadenitis commonly demonstrated matting, adjacent soft tissue edema, displaced hilar vascularity, and intranodal necrosis. Malignant lymph nodes were significantly associated with a round configuration, absent fatty hilum, hyperechoic echotexture, intranodal necrosis, calcification, reticulation, and absent or abnormal vascularity.

Correlation with FNAC and histopathological examination confirmed the excellent diagnostic performance of ultrasonography, with a sensitivity of 94.7%, specificity of 100%, positive predictive value of 100%, negative predictive value of 98.3%, and an overall diagnostic accuracy of 98.7%.

Therefore, high-resolution ultrasonography with color Doppler should be considered the first-line imaging investigation for patients presenting with cervical lymphadenopathy. It provides valuable information for lesion characterization, guides image-guided FNAC or biopsy, assists in treatment planning, and may reduce unnecessary invasive procedures. Histopathological or cytological confirmation, however, remains the gold standard in cases with equivocal imaging findings or strong clinical suspicion of malignancy.

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