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# Prognostic value of ultrasound and doppler imaging in the diagnosis and treatment of peripheral tuberculous lymphadenitis

Anvarova Ekaterina Vladimirovna *

*Tashkent Medical Academy, Republican Specialized Scientific and Practical Medical Center of Phthisiology and Pulmonology, Assistant of the Department of Phthisiology and Pulmonology.*

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## Abstract

**Background:** Tuberculous lymphadenitis, a common form of extrapulmonary tuberculosis, poses diagnostic challenges due to its nonspecific clinical presentation. Traditional methods often require invasive procedures for confirmation, underscoring the need for reliable noninvasive techniques. Ultrasonography (US), Doppler imaging, and elastography have emerged as potential diagnostic tools for evaluating lymph node pathology, enabling detailed assessment of tissue characteristics and vascularization.

**Objective:** This study aims to evaluate the diagnostic accuracy and clinical value of combining ultrasonography, Doppler imaging, and elastography in the noninvasive diagnosis and management of peripheral tuberculous lymphadenitis.

**Methods:** A total of 160 patients suspected of having tuberculous lymphadenitis underwent ultrasonography, Doppler imaging, and elastography. Documented ultrasonographic characteristics included lymph node size, central necrosis, and hypoechoic areas. Doppler imaging assessed vascularization, while elastography provided strain ratios to measure tissue stiffness, distinguishing between purulent and fibrotic lymph nodes. Diagnostic accuracy was assessed using sensitivity, specificity, and area under the ROC curve (AUC), with microbiological confirmation as the gold standard.

**Results:** Ultrasonography identified abnormal lymph nodes in 90% of cases, with central necrosis observed in 60.6% of cases. Doppler imaging revealed increased peripheral vascularization in 72% of cases, while elastography identified necrotic (low stiffness) and fibrotic (high stiffness) nodes in 67.2% and 10.6% of cases, respectively. The combined modalities achieved a sensitivity of 93%, specificity of 88%, and an AUC of 0.92, indicating excellent diagnostic performance. Microbiological confirmation was achieved in 88.7% of cases.

**Conclusions:** The integration of ultrasonography, Doppler imaging, and elastography provides a highly accurate, noninvasive approach for diagnosing tuberculous lymphadenitis, reducing the need for invasive procedures. This multimodal approach holds significant potential for improving diagnostic workflows, particularly in resource-limited settings, and guiding clinical management by distinguishing between active and chronic disease stages.

**Keywords:** Tuberculous lymphadenitis; Ultrasonography; Doppler imaging; Elastography; Noninvasive diagnosis; Extrapulmonary tuberculosis

## 1. Introduction

Tuberculosis (TB) remains a significant global health challenge, with millions of new cases reported annually. While pulmonary tuberculosis (PTB) dominates TB diagnoses, extrapulmonary tuberculosis (EPTB) is becoming increasingly

* Corresponding author: Anvarova Ekaterina Vladimirovna

prevalent, particularly among immunocompromised populations. Tuberculous lymphadenitis, the most common manifestation of EPTB, frequently affects peripheral lymph nodes, presenting unique diagnostic challenges due to its nonspecific clinical features and similarity to other causes of lymphadenopathy. These challenges necessitate the development and implementation of more accurate, noninvasive diagnostic methods [1, 2].

Traditional diagnostic methods for TB, such as sputum microscopy and culture, are largely limited to identifying pulmonary forms of the disease. Histopathological examination of lymph node biopsies remains the gold standard for diagnosing tuberculous lymphadenitis; however, these procedures are invasive, time-consuming, and often unavailable in resource-limited settings. This creates an urgent need for noninvasive, reliable diagnostic tools that can enhance the detection of tuberculous lymphadenitis and inform treatment strategies [3, 4].

Ultrasound (US) imaging has emerged as a promising noninvasive modality for evaluating lymph node abnormalities, providing real-time visualization of lymph node size, structure, and internal architecture. Doppler ultrasonography further enhances the diagnostic process by allowing the assessment of blood flow within lymph nodes, which is often altered in tuberculous infections. Despite its widespread use in evaluating lymphadenopathies of various etiologies, the specific application of ultrasound in diagnosing tuberculous lymphadenitis remains underexplored [5, 6].

Elastography, a relatively new imaging technique, adds another level of diagnostic precision by measuring tissue stiffness. This method is particularly valuable for differentiating purulent (soft, fluid-filled) from fibrotic (dense, hardened) lymph nodes, which are hallmark features of tuberculous infection. Combining elastography with conventional US and Doppler imaging offers a comprehensive, noninvasive approach to diagnosing tuberculous lymphadenitis, potentially reducing the need for biopsy and improving patient outcomes [7, 8].

This study aims to evaluate the prognostic value of ultrasound, Doppler imaging, and elastography in the diagnosis and management of peripheral tuberculous lymphadenitis. By integrating these imaging modalities, we aim to establish a reliable, noninvasive diagnostic protocol that enhances clinical decision-making, reduces dependence on invasive procedures, and contributes to better TB management, particularly in resource-constrained settings [9, 10].

## 2. Material and methods

### 2.1. Study Design

This study was conducted as a prospective observational analysis to evaluate the diagnostic and prognostic value of ultrasonography (US), Doppler imaging, and elastography in diagnosing and managing tuberculous lymphadenitis. The research was carried out at a tertiary care medical center specializing in infectious diseases from January 2023 to June 2024. Ethical approval was obtained from the institutional review board, and informed consent was secured from all participants.

### 2.2. Study Population

The study included 160 patients aged 18–65 years with clinically suspected or confirmed tuberculous lymphadenitis. Inclusion criteria involved patients presenting with peripheral lymphadenopathy suspected to be of tuberculous origin, based on clinical signs and symptoms (fever, night sweats, weight loss, and enlarged lymph nodes). Patients with other causes of lymphadenopathy (e.g., lymphoma, metastatic cancer) were excluded. All participants underwent a comprehensive diagnostic evaluation, including US, Doppler imaging, and elastography.

### 2.3. Ultrasound and Doppler Imaging

Ultrasound imaging was performed using a high-resolution ultrasound system (Philips iU22) equipped with a linear transducer of 7.5–10 MHz. Assessed sonographic parameters included lymph node size, shape, echotexture, presence of central necrosis, and the cortex-to-medulla ratio. Lymph nodes were categorized as normal, reactive, or pathological based on these parameters.

Subsequently, Doppler imaging was used to evaluate lymph node vascularization. Blood flow assessment included color Doppler and spectral Doppler analysis. Lymph nodes with increased peripheral or central vascularization were classified as suggestive of active inflammation, while avascular or hypovascular nodes were considered more likely to represent fibrotic changes or chronic infection.

### 2.4. Elastography

Elastography was employed to measure tissue stiffness in lymph nodes, providing additional data on their consistency. Elastographic assessment was performed using the Hitachi HI VISION Preirus system with a 9–4 MHz linear array probe. Measurements were expressed as strain ratios between the lymph node and adjacent soft tissues. Lymph nodes with high strain ratios (indicating greater stiffness) were classified as fibrotic, while those with low strain ratios (indicating reduced stiffness) were classified as suggestive of purulent or necrotic processes.

### 2.5. Microbiological Confirmation

To confirm imaging findings, all patients underwent fine-needle aspiration cytology (FNAC) or excisional biopsy for histopathological and microbiological analysis. Samples were stained for acid-fast bacilli (AFB) and tested using GeneXpert MTB/RIF and mycobacterial culture. These results were used as the gold standard for confirming the presence of *Mycobacterium tuberculosis*.

### 2.6. Statistical Analysis

Statistical analysis was performed using SPSS version 26.0. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for US, Doppler imaging, and elastography relative to the gold standard (biopsy and microbiological confirmation). The diagnostic accuracy of each modality was compared using receiver operating characteristic (ROC) curve analysis. A p-value <0.05 was considered statistically significant.

The aim of this study is to develop a reliable noninvasive approach to diagnosing tuberculous lymphadenitis, reducing reliance on invasive procedures and improving clinical decision-making.

## 3. Results

### 3.1. Diagnostic Findings from Ultrasound, Doppler Imaging, and Elastography

In this study, 160 patients with suspected tuberculous lymphadenitis were evaluated using a combination of ultrasonography (US), Doppler imaging, and elastography. Comprehensive results are summarized in **Table 1**, which highlights the key findings from these diagnostic modalities.

**Table 1** Summary of Ultrasound, Doppler Imaging, and Elastography Results in Patients with Tuberculous Lymphadenitis

| Characteristic | Ultrasound Findings | Doppler Findings | Elastography Strain Ratio | Number of Patients (%) | Clinical Interpretation |
|---|---|---|---|---|---|
| Enlarged lymph nodes (≥2 cm) | 132 (82.5%) | 120 (75%) | N/A | 144 (90%) | Suggests active inflammation |
| Central necrosis | 97 (60.6%) | N/A | N/A | 97 (60.6%) | Indicates necrotic processes |
| Peripheral vascularization | N/A | 115 (72%) | N/A | 115 (72%) | Active inflammatory processes |
| Avascular/hypovascular nodes | N/A | 45 (28%) | N/A | 45 (28%) | Associated with chronic fibrosis |
| Hypoechoic or anechoic areas | 107 (66.9%) | N/A | N/A | 107 (66.9%) | Necrosis or purulent content |
| Low stiffness (purulent) | N/A | N/A | 1.0–1.5 | 107 (67.2%) | Necrotic or purulent lymph nodes |
| Moderate stiffness | N/A | N/A | 1.6–2.5 | 36 (22.5%) | Early fibrotic changes |

| | | | | | |
|---|---|---|---|---|---|
| High stiffness (fibrotic) | N/A | N/A | >2.6 | 17 (10.6%) | Chronic fibrotic lymph nodes |

Table 1 consolidates key diagnostic data from US, Doppler imaging, and elastography, providing a clear overview of results, including the percentage of patients with enlarged lymph nodes, necrotic changes, vascular patterns, and elastography strain ratios. This detailed table facilitates a thorough comparison of imaging findings and their clinical interpretation.

### 3.2. Findings from Ultrasound and Doppler Imaging

Ultrasound identified abnormal lymph nodes in 144 patients (90%), with 82.5% exhibiting significant enlargement (≥2 cm in diameter). Central necrosis was observed in 60.6% of cases, a key ultrasonographic feature indicative of tuberculous lymphadenitis. Hypoechoic or anechoic areas were present in 66.9% of patients, suggesting necrotic or purulent content within the lymph nodes.

Doppler imaging revealed increased peripheral vascularization in 72% of cases, consistent with active inflammation. Avascular or hypovascular nodes, typically associated with fibrotic or chronic changes, were identified in 28% of patients. These findings underscore the role of Doppler imaging in evaluating vascular patterns indicative of the inflammatory activity within lymph nodes.

### 3.3. Findings from Elastography

Elastography provided additional diagnostic value by differentiating necrotic/purulent and fibrotic lymph nodes based on tissue stiffness. Elastographic strain ratios indicated that 67.2% of patients had lymph nodes with low stiffness (strain ratio: 1.0–1.5), corresponding to necrotic or purulent processes. Moderate stiffness (strain ratio: 1.6–2.5) was observed in 22.5% of patients, indicative of early fibrotic changes, while high stiffness (strain ratio >2.6), associated with chronic fibrosis, was found in 10.6% of patients.

### 3.4. Diagnostic Accuracy of Imaging Modalities

The combined use of ultrasonography, Doppler imaging, and elastography significantly improved diagnostic accuracy. Ultrasound alone demonstrated a sensitivity of 84% and specificity of 75%. The addition of Doppler imaging increased sensitivity to 90% and specificity to 82%. The inclusion of elastography further enhanced diagnostic performance, achieving a sensitivity of 93% and specificity of 88%.

Overall diagnostic accuracy, measured by the area under the receiver operating characteristic (ROC) curve, was 0.92 for the combined use of ultrasonography, Doppler imaging, and elastography. This high accuracy suggests that these noninvasive imaging methods can reliably reduce the need for invasive diagnostic procedures such as biopsy, particularly in resource-limited settings.

### 3.5. Microbiological Confirmation

Microbiological confirmation of tuberculous lymphadenitis was obtained in 142 patients (88.7%) using GeneXpert MTB/RIF and mycobacterial culture. In 18 cases (11.3%), despite negative microbiological results, imaging findings, along with clinical assessment, strongly suggested a diagnosis of tuberculous lymphadenitis. These cases highlight the utility of advanced imaging modalities when microbiological confirmation is not feasible.

## 4. Discussion

This study highlights the significant diagnostic value of integrating ultrasonography, Doppler imaging, and elastography for the noninvasive evaluation of tuberculous lymphadenitis. The inclusion of these modalities achieved high diagnostic accuracy, with a sensitivity of 93% and specificity of 88% for the combined approach. This suggests that this multimodal method can reduce the need for invasive procedures. These findings align with a growing body of research emphasizing the importance of noninvasive diagnostics in managing tuberculosis, particularly extrapulmonary forms such as lymphadenitis [1, 2].

### 4.1. Clinical Significance of Ultrasound and Doppler Imaging

Ultrasound alone proved effective in detecting features characteristic of tuberculous lymphadenitis, including enlarged lymph nodes, central necrosis, and hypoechoic areas indicative of necrotic or purulent processes. These findings are consistent with previous studies underscoring the utility of ultrasound in differentiating tuberculous lymphadenopathy from other types [3, 4]. However, ultrasound alone has limitations, particularly in distinguishing between active and chronic lymphadenopathy.

The addition of Doppler imaging provided crucial information on vascularization, aiding in the assessment of inflammatory activity. Studies have shown that peripheral vascularization detected via Doppler imaging correlates with active inflammatory processes in tuberculous lymph nodes, potentially guiding the identification of nodes requiring immediate intervention [5, 6].

In this study, Doppler imaging revealed increased peripheral vascularization in 72% of cases, confirming its role in assessing inflammatory activity within lymph nodes. These results align with the findings of Sharma et al., who demonstrated that Doppler imaging significantly enhances diagnostic value when evaluating lymphadenopathies of infectious origin [7]. By identifying hypervascular patterns, Doppler imaging enables more targeted and precise diagnostics, reducing the likelihood of unnecessary invasive procedures.

### 4.2. Role of Elastography in Differential Diagnosis

Elastography emerged as an especially valuable tool in this study, providing an effective means of differentiating purulent and fibrotic lymph nodes. By assessing tissue stiffness through strain ratios, elastography offered insights into the internal structure of lymph nodes, with low stiffness indicating necrotic processes and high stiffness associated with chronic fibrotic changes. These findings align with previous studies emphasizing elastography's potential in differentiating benign from malignant lymphadenopathies by evaluating tissue stiffness [8, 9].

Our study builds on this research by demonstrating the application of elastography specifically in tuberculous lymphadenitis, where it plays a key role in distinguishing between active and chronic disease phases. Results showed that 67.2% of patients had lymph nodes with low stiffness, indicating necrotic or purulent changes, while 10.6% exhibited nodes with high stiffness, suggestive of fibrotic changes. This ability to distinguish active lymphadenopathy from chronic forms is critical for treatment decision-making. Necrotic lymph nodes typically signal active infection requiring immediate anti-tuberculosis therapy, whereas fibrotic nodes indicate chronic or resolved disease, suggesting that aggressive intervention may not be necessary. These findings are consistent with Chen et al., who reported that elastography aids in staging lymphadenopathy for effective treatment planning [10].

### 4.3. Comparison with Existing Literature

The high diagnostic accuracy observed in this study, as evidenced by the area under the ROC curve (AUC) of 0.92, aligns well with similar studies confirming the effectiveness of multimodal imaging approaches. For example, prior studies have demonstrated moderate diagnostic accuracy for ultrasound and Doppler imaging individually; however, their combination with elastography yields significantly improved results. Wang et al. reported that integrating Doppler and elastographic diagnostics enhances accuracy in assessing lymphadenopathies, a finding corroborated by the increased sensitivity and specificity observed in this study [11, 12].

While previous research emphasized elastography's role in differentiating benign from malignant lymphadenopathies, its use in tuberculous lymphadenitis has been less explored. This study fills that gap, providing evidence that elastography combined with ultrasound and Doppler imaging is particularly useful in distinguishing inflammatory from chronic fibrotic stages of lymphadenitis. These findings expand the current literature and provide a foundation for future research into similar multimodal approaches for other infectious and inflammatory conditions affecting lymph nodes.

### *Limitations*

Despite promising results, several limitations of this study should be acknowledged. First, the availability of advanced imaging techniques such as Doppler imaging and elastography may be limited in certain resource-constrained settings, potentially restricting the generalizability of these findings. These imaging modalities require specialized equipment and trained personnel, posing challenges for widespread implementation, particularly in low-resource healthcare regions.

Moreover, although the study demonstrated high diagnostic accuracy, microbiological confirmation was not achieved in 11.3% of cases, highlighting the importance of integrating imaging results with clinical and microbiological data to ensure diagnostic precision.

Another limitation is the study's focus on tuberculous lymphadenitis without evaluating the broader applicability of these imaging modalities for other forms of extrapulmonary tuberculosis or infectious causes of lymphadenopathy. Future studies should address these limitations by assessing the utility of ultrasound, Doppler imaging, and elastography in other forms of tuberculosis and infectious diseases affecting lymph nodes.

### 4.4. Future Directions

Future research should focus on expanding the application of this multimodal imaging approach to other forms of extrapulmonary tuberculosis and other infectious and inflammatory conditions affecting the lymphatic system. Studies should evaluate the cost-effectiveness of implementing these technologies in resource-limited settings, where reducing reliance on invasive procedures may be particularly beneficial. Additionally, longitudinal studies could explore the role of these imaging modalities in monitoring treatment response and detecting disease recurrence in tuberculosis patients, offering insights into the long-term utility of this approach.

## 5. Conclusion

This study demonstrates the diagnostic potential of combining ultrasonography, Doppler imaging, and elastography for the noninvasive evaluation of tuberculous lymphadenitis. The multimodal approach achieved high diagnostic accuracy, significantly reducing the need for invasive procedures and enhancing diagnostic reliability. These findings hold promise for improving diagnostic workflows, particularly in resource-limited settings, by offering safer and more effective means of diagnosing tuberculous lymphadenitis. Future research should continue to validate and expand the application of this diagnostic strategy to other forms of tuberculosis and related infectious and inflammatory diseases affecting the lymphatic system.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The author declares no conflict of interest.

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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