
RESEARCH ARTICLE**Diagnostic Performance of Ultrasound Elastography in Differentiating Benign and Malignant Lymphadenopathy at Moi Teaching and Referral Hospital, Kenya****Changwony Janet, MBChB, MMed (Radiology & Imaging)¹✉, Professor Joseph Abuya, MBChB, MMed (Radiology)¹ and Daniel Chepsiror, MBChB, MMed (Radiology), Fellowship Interventional Radiology²**¹ *Department of Radiology and Imaging, Moi University School of Medicine, Eldoret, Kenya*² *Department of Radiology and Imaging, Moi Teaching and Referral Hospital, Eldoret, Kenya***Corresponding Author:** Changwony Janet, **E-mail:** janetjebichii22@gmail.com

ABSTRACT

Lymphadenopathy is a common clinical finding associated with a broad spectrum of benign and malignant diseases. Differentiating malignant from benign lymphadenopathy remains an important diagnostic challenge because conventional clinical and sonographic findings may overlap considerably. Histopathological examination remains the reference standard for definitive diagnosis, but tissue sampling is invasive and may be associated with sampling error, particularly when the most representative lymph node is not accurately targeted. Ultrasound elastography provides additional information regarding tissue stiffness and has therefore emerged as a potentially useful adjunct to conventional ultrasound in the assessment of lymph nodes. However, most published evidence originates from populations outside sub-Saharan Africa, where the spectrum of lymph node disease may differ substantially from that encountered in East African tertiary referral hospitals. To determine the diagnostic performance of ultrasound elastography in differentiating benign from malignant lymphadenopathy among patients undergoing lymph node biopsy at Moi Teaching and Referral Hospital (MTRH), Eldoret, Kenya. A hospital-based cross-sectional descriptive study was conducted among 66 patients presenting with lymphadenopathy at the Interventional Radiology Unit of MTRH. Participants referred for ultrasound-guided lymph node core needle biopsy between July 2024 and June 2025 were evaluated. Demographic and clinical characteristics were recorded, followed by ultrasound assessment and elastographic evaluation using a five-point colour-coded scoring system on a Vinno 6 ultrasound machine. Histopathological findings were used as the reference standard. Continuous variables were summarized using means, while categorical variables were summarized using frequencies and percentages. Diagnostic performance was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and receiver operating characteristic (ROC) curve analysis. The 66 participants had a mean age of 32.4 ± 20.7 years, with ages ranging from 2 to 75 years. Cervical lymph nodes were the most frequently biopsied nodes, accounting for 40.9% (n=27) of cases. Elastography scores of 4 and 5 predominated, occurring in 59.1% and 28.8% of cases, respectively. Histopathological examination identified 52 (78.8%) malignant and 14 (21.2%) benign lymph nodes. Lymphoma was the most frequent malignant diagnosis, accounting for 45.5% of all histopathological diagnoses. Using histopathology as the reference standard, ultrasound elastography demonstrated a sensitivity of 96.1%, specificity of 42.9%, PPV of 86.2%, and NPV of 75%. The area under the ROC curve was 0.692. Ultrasound elastography demonstrated very high sensitivity but relatively low specificity for malignant lymphadenopathy in this region. The findings support its use as a non-invasive triage and biopsy-targeting adjunct rather than as a replacement for histopathological diagnosis. Local diagnostic protocols incorporating elastography alongside conventional ultrasound and tissue diagnosis may improve prioritization of suspicious lymph nodes and support timely clinical decision-making.

KEYWORDS

Lymphadenopathy; ultrasound elastography; sonoelastography; lymph node; malignancy; histopathology; diagnostic accuracy; sensitivity; specificity; Kenya.

ARTICLE INFORMATION**ACCEPTED:** 21 September 2026**PUBLISHED:** 25 October 2026**DOI:** 10.32996/jmhs.2026.7.11.4

1. Introduction

Lymphadenopathy is a frequent clinical finding encountered across medical specialties and may result from infectious, inflammatory, autoimmune, lymphoproliferative, or metastatic disease. The differential diagnosis is particularly broad in regions where infectious diseases such as tuberculosis coexist with a substantial burden of malignancy. Consequently, enlarged lymph

nodes cannot reliably be categorized as benign or malignant on the basis of clinical examination alone. Histopathological assessment of tissue remains central to establishing a definitive diagnosis, particularly when malignancy is suspected.

The clinical significance of lymphadenopathy is determined not only by the presence of nodal enlargement but also by its underlying cause. Benign reactive lymphadenopathy may resolve with treatment or observation, whereas malignant lymphadenopathy may represent lymphoma, metastatic disease, or other neoplastic processes requiring urgent staging and treatment. In patients presenting with persistent, progressive, generalized, or otherwise suspicious lymphadenopathy, an accurate diagnostic pathway is therefore essential.

Conventional ultrasound is widely used for the initial evaluation of superficial lymph nodes because it is relatively inexpensive, readily available, non-invasive, does not involve ionizing radiation, and permits real-time assessment. Sonographic assessment commonly considers nodal size, shape, cortical morphology, echogenicity, preservation or loss of the fatty hilum, nodal borders, vascularity, necrosis, and calcification. These characteristics can provide useful information, but significant overlap exists between benign and malignant nodal appearances. Inflammatory and infectious processes may produce nodal enlargement, cortical thickening, altered vascularity, necrosis, and increased tissue stiffness, potentially mimicking malignant disease.

Doppler ultrasound can provide additional information regarding nodal vascularity. However, vascular patterns are not sufficiently specific to independently distinguish all benign from malignant lymph nodes. Consequently, ultrasound findings are generally interpreted collectively rather than relying on a single sonographic characteristic.

Cross-sectional imaging with computed tomography (CT) and magnetic resonance imaging (MRI) contributes to the assessment of deeper lymph node stations, anatomical relationships, disease extent, and oncological staging. Nevertheless, these modalities do not eliminate the need for tissue diagnosis when histological characterization is required. In addition, CT involves ionizing radiation, whereas MRI may be less accessible and more resource-intensive in many settings.

Ultrasound elastography represents an extension of conventional sonographic assessment by providing information about tissue mechanical properties. The technique is based on the principle that tissues differ in their response to mechanical stress. Malignant infiltration may alter the mechanical properties of a lymph node through cellular replacement, fibrosis, desmoplastic reaction, altered extracellular matrix, and necrotic remodeling. These pathological changes can result in increased stiffness, which may be detected by elastographic imaging. Elastography therefore provides a complementary dimension to the conventional morphological information obtained with B-mode ultrasound.

Two major forms of ultrasound elastography are commonly described: strain elastography and shear-wave elastography. Strain elastography evaluates relative tissue deformation following external compression and commonly produces a qualitative colour-coded representation of tissue stiffness. Shear-wave techniques generate shear waves within tissue and can provide quantitative estimates of tissue stiffness. The present study used a five-point colour-coded elastographic scoring system as documented in the thesis.

The concept of using tissue stiffness to differentiate pathological tissue from normal tissue was established in early elastography research. Ophir and colleagues introduced elastography as a method for imaging the elasticity of biological tissues, providing the foundation for subsequent clinical applications. (Ophir et al., 1991) The application of elastography to lymph node assessment subsequently generated considerable interest because malignant nodes frequently demonstrate greater stiffness than benign nodes.

One of the influential early investigations was conducted by Lyshchik et al., who evaluated real-time ultrasound elastography in cervical lymph nodes. Their study reported sensitivity of 88%, specificity of 81%, and an area under the ROC curve of 0.91, supporting the potential value of elastographic assessment in differentiating malignant from benign lymph nodes. (Lyshchik et al., 2007) The study also contributed to the development and clinical use of five-point elastographic scoring systems.

Subsequent studies continued to demonstrate high sensitivity, although specificity varied. Choi et al. reported sensitivity of approximately 97% and demonstrated that elastography could detect malignant involvement even when conventional morphological findings were less conspicuous. (Choi et al., 2011) Furukawa et al. similarly reported high sensitivity and emphasized that elastography should complement rather than replace conventional ultrasound and histopathological evaluation. (Furukawa et al., 2012)

A meta-analysis by Zhou et al. involving 1,139 cervical lymph nodes reported pooled sensitivity of approximately 85% and specificity of 84%, with an area under the summary ROC curve of 0.91. (Zhou et al., 2014) These findings supported the overall diagnostic value of elastography while also demonstrating heterogeneity between studies. Differences in patient populations, ultrasound equipment, elastographic techniques, scoring systems, reference standards, and disease spectrum may influence diagnostic performance.

More recent literature has continued to support the potential role of elastography in lymph node assessment. Studies comparing strain elastography and shear-wave techniques suggest that quantitative approaches may offer advantages in objectivity and reproducibility, although the choice of technique depends on equipment availability, operator expertise, and clinical setting. (Ishibashi et al., 2012; Alam et al., 2008; Bamber et al., 2013; AlShaikh et al., 2023)

The relevance of elastography may be particularly important in resource-constrained settings. In many sub-Saharan African hospitals, patients may present late with advanced disease, and lymphadenopathy may reflect a complex mixture of tuberculosis, HIV-associated lymphoid pathology, chronic inflammation, lymphoma, and metastatic malignancy. This disease spectrum differs from that of many studies conducted in high-income countries and oncology-focused populations. The presence of chronic inflammation and granulomatous disease may increase nodal stiffness and therefore produce false-positive elastographic classifications.

The uploaded thesis identifies an important local evidence gap: relatively few studies have evaluated elastography within the Kenyan tertiary referral setting, particularly in populations where lymphoma, tuberculosis, metastatic disease, and inflammatory lymphadenopathy coexist. It further identifies limited evidence regarding whether elastography can improve biopsy targeting and reduce inconclusive tissue sampling.

MTRH is a major tertiary referral hospital serving patients from western Kenya and surrounding regions. The hospital receives patients with complex lymphadenopathy referred for imaging, interventional procedures, and histopathological assessment. Evaluation of the diagnostic performance of elastography in this population is therefore clinically relevant.

The present study sought to determine the diagnostic performance of ultrasound elastography in differentiating benign from malignant lymphadenopathy at MTRH. Specifically, it assessed elastographic findings, characterized histopathological diagnoses, and determined the sensitivity, specificity, PPV, NPV, and overall diagnostic discrimination of elastography using histopathology as the reference standard.

2. Methods

2.1 Study design and setting

A hospital-based cross-sectional descriptive study was conducted at the Interventional Radiology Unit of Moi Teaching and Referral Hospital in Eldoret, Kenya. The study evaluated patients presenting with lymphadenopathy who were referred for ultrasound-guided lymph node core needle biopsy.

The study period for participant evaluation was July 2024 to June 2025, according to the study methodology reported in the thesis. The hospital-based design enabled direct comparison between pre-biopsy ultrasound elastographic findings and subsequent histopathological diagnoses.

The study was designed around a diagnostic comparison in which ultrasound elastography represented the index test and histopathological examination represented the reference standard.

2.2 Study population

The study population comprised patients presenting with lymphadenopathy who were referred for ultrasound-guided lymph node core needle biopsy at MTRH.

A total of 66 eligible participants were included in the final analysis. The cohort included both paediatric and adult patients, with an age range of 2–75 years.

Sampling Technique

Consecutive sampling was employed to recruit eligible participants during the study period.

2.3 Data collection

Demographic and clinical information was obtained using the study data collection tool. Variables included age, sex, clinical indication for biopsy, and anatomical location of the lymph node.

Participants underwent ultrasound evaluation followed by elastographic assessment. The ultrasound examination included conventional grayscale assessment of lymph node morphology and elastographic evaluation of tissue stiffness.

The study used a Vinno 6 ultrasound machine and a five-point colour-coded elastography scoring system. Lower scores represented softer tissue characteristics, whereas higher scores represented progressively greater stiffness. Scores 1 and 2 were

considered benign patterns, score 3 was considered indeterminate, and scores 4 and 5 were considered suspicious for malignant involvement.

The five-point approach is based on established qualitative elastographic classification systems described in the lymph node literature. (Lyshchik et al., 2007; Aly et al., 2022)

2.4 Histopathological assessment

Histopathological examination was used as the reference standard for determining whether lymph nodes were benign or malignant. Participants underwent ultrasound-guided core needle biopsy, with tissue subsequently submitted for histopathological assessment.

Histopathological results were categorized as benign or malignant for the primary diagnostic accuracy analysis. Specific histological diagnoses were also recorded to characterize the spectrum of lymph node disease in the study population.

2.5 Statistical analysis

Continuous variables were summarized using means and standard deviations, while categorical variables were summarized using frequencies and percentages.

The diagnostic performance of ultrasound elastography was assessed against histopathological diagnosis. Sensitivity was defined as the proportion of histopathologically malignant lymph nodes correctly identified as malignant by elastography. Specificity was defined as the proportion of histopathologically benign lymph nodes correctly identified as benign.

Positive predictive value represented the probability that a lymph node classified as malignant by elastography was malignant on histopathology, while negative predictive value represented the probability that a node classified as benign by elastography was benign on histopathology.

A receiver operating characteristic curve was generated to assess overall discrimination. The area under the ROC curve was used as a summary measure of diagnostic discrimination. Statistical significance was assessed at a 95% confidence level, with a P value below 0.05 considered statistically significant, as described in the thesis methodology.

2.6 Ethical considerations

The study obtained the relevant institutional and research approvals documented in the thesis, including institutional research and ethics approval and authorization to conduct the study at MTRH. Participants were provided with information concerning the study and participated voluntarily following informed consent. The study procedures included non-ionizing ultrasound-based imaging, with tissue sampling performed as part of the participants' clinical diagnostic evaluation.

The study was conducted in accordance with the ethical requirements specified in the approved research protocol.

3. Results

3.1 Demographic characteristics

The study included 66 participants. The mean age was 32.4 ± 20.7 years, with an age range of 2–75 years. The median age was 33 years, with an interquartile range of approximately 14.3–46.8 years.

Males constituted 56.1% (n=37) of participants, while females accounted for 43.9% (n=29).

The clinical indications for lymph node biopsy were heterogeneous. Metastatic lymphadenopathy associated with malignancy accounted for the largest proportion of indications at 30.3% (n=20). Other indications included cervical lymphadenopathy and mass, generalized lymphadenopathy, abdominal mass, suspected lymphoma, breast mass, pancytopenia, tuberculosis adenitis, hepatosplenomegaly, and inguinal mass.

The cervical region was the most frequently biopsied anatomical site, accounting for 40.9% (n=27) of lymph nodes. Abdominal nodes accounted for 27.3% (n=18), inguinal nodes for 18.2% (n=12), axillary nodes for 12.1% (n=8), and pelvic nodes for 1.5% (n=1).

Table 1. Demographic and clinical characteristics of participants

Characteristic	n (%)
Sex	
Male	37 (56.1)
Female	29 (43.9)
Lymph node site	
Cervical	27 (40.9)

Characteristic	n (%)
Abdominal	18 (27.3)
Inguinal	12 (18.2)
Axillary	8 (12.1)
Pelvic	1 (1.5)
Total	66 (100)

Mean age: 32.4 ± 20.7 years; range 2–75 years.

3.2 Sonoelastography findings

The elastographic assessment demonstrated a predominance of high stiffness scores. Score 4 was the most common elastographic classification, occurring in 39 participants (59.1%), followed by score 5 in 19 participants (28.8%).

Scores 1 and 2, which represented predominantly benign elastographic patterns, occurred in 2 (3.0%) and 3 (4.5%) participants, respectively. Score 3 was observed in 3 participants (4.5%).

Overall, 58 lymph nodes were classified as malignant on elastographic assessment, whereas 8 were classified as benign.

Most cases also demonstrated suspicious conventional sonographic morphology. The thesis reports that 57.6% of cases were hypoechoic and demonstrated cortical thickness greater than 3 mm with absence of the fatty hilum.

Table 2. Sonoelastography findings

Elastography score	n (%)
Score 1	2 (3.0)
Score 2	3 (4.5)
Score 3	3 (4.5)
Score 4	39 (59.1)
Score 5	19 (28.8)
Total	66 (100)

The predominance of scores 4 and 5 indicates that most nodes in this tertiary referral cohort demonstrated high elastographic stiffness.

3.3 Histopathological findings

Histopathological examination identified 52 malignant lymph nodes, representing 78.8% of the study population, while 14 nodes (21.2%) were classified as benign.

Lymphoma was the most common histopathological category, accounting for 30 cases (45.5%). Metastatic disease accounted for 22 cases (33.3%). Tuberculous adenitis was identified in 7 cases (10.6%), reactive lymphoid tissue in 4 cases (6.1%), and normal lymphoid tissue in 3 cases (4.5%).

The lymphoma category included several subtypes. Hodgkin lymphoma was reported in 17 participants (25.7%), while Burkitt lymphoma occurred in 6 participants (9.1%). Metastatic carcinoma accounted for 7 participants (10.6%).

Table 3. Histopathological findings

Histopathological diagnosis	n (%)
Lymphoma	30 (45.5)
Metastasis	22 (33.3)
Tuberculous adenitis	7 (10.6)
Reactive lymphoid tissue	4 (6.1)
Normal lymphoid tissue	3 (4.5)
Total	66 (100)

When categorized simply as benign or malignant, 52 (78.8%) cases were malignant and 14 (21.2%) were benign.

3.4 Diagnostic performance of ultrasound elastography

Comparison of elastographic classification with histopathology demonstrated that 50 of 52 histopathologically malignant lymph nodes were correctly identified as malignant by elastography. Six of 14 histopathologically benign nodes were correctly classified as benign.

Eight histopathologically benign nodes were incorrectly classified as malignant, while two malignant nodes were classified as benign.

The resulting sensitivity was 96.1% and specificity was 42.9%. The PPV was 86.2%, while the NPV was 75%.

The ROC analysis produced an AUC of 0.692, indicating fair overall discriminatory performance.

Table 4. Comparison of elastography and histopathology

Elastography	Histopathology benign	Histopathology malignant	Total
Benign	6	2	8
Malignant	8	50	58
Total	14	52	66

Diagnostic performance:

Measure	Result
Sensitivity	96.1%
Specificity	42.9%
PPV	86.2%
NPV	75.0%
AUC	0.692

4. Discussion

This study evaluated the diagnostic performance of ultrasound elastography in differentiating benign from malignant lymphadenopathy at MTRH using histopathological examination as the reference standard. The principal findings were that high elastographic scores predominated, malignant disease accounted for the majority of histopathological diagnoses, lymphoma was the most frequent malignant diagnosis, and ultrasound elastography demonstrated very high sensitivity but substantially lower specificity.

The results provide useful local evidence regarding the potential role of elastography in a tertiary referral environment in Kenya. Importantly, the findings suggest that elastography may be most valuable as a screening, triage, and biopsy-targeting tool rather than as a definitive replacement for tissue diagnosis.

4.1 Demographic and clinical characteristics

The mean participant age of 32.4 years demonstrates that lymphadenopathy requiring biopsy at MTRH occurred across a broad age spectrum. The study included patients from 2 to 75 years, reflecting the heterogeneous nature of lymph node disease. The slight male predominance, with males accounting for 56.1% of participants, was consistent with the demographic characteristics documented in the study.

The relatively young age distribution is clinically relevant because the differential diagnosis of lymphadenopathy in younger populations differs from that in older adults. Lymphoma and infectious lymphadenitis may contribute substantially to lymph node enlargement in younger patients, while metastatic disease becomes increasingly important with advancing age. The broad age range observed in the present study therefore reinforces the importance of considering multiple etiologies rather than applying a single disease model to all patients.

The cervical region was the most common site of lymph node biopsy, accounting for 40.9% of cases. Cervical lymphadenopathy is commonly encountered in both infectious and malignant conditions and has consequently been the principal anatomical focus of much of the international elastography literature. (Lyshchik et al., 2007; Choi et al., 2011; Furukawa et al., 2012; Zhou et al., 2014) The prominence of cervical nodes in the current study therefore provides some comparability with previous research.

However, the present cohort also included abdominal, inguinal, axillary, and pelvic nodes. This broader anatomical distribution is relevant when interpreting the study's diagnostic performance because elastographic characteristics may be influenced by node depth, surrounding tissue, transducer pressure, anatomical location, and technical factors.

The clinical indications also illustrate the heterogeneity of the population. The presence of suspected metastatic disease, lymphoma, tuberculosis, generalized lymphadenopathy, and other systemic conditions means that the study population was not a narrowly selected oncology cohort. This is likely to have influenced specificity.

4.2 Predominance of high elastographic scores

The most striking elastographic finding was the predominance of scores 4 and 5. Score 4 accounted for 59.1% of cases and score 5 for 28.8%, meaning that 87.9% of nodes demonstrated elastographic patterns categorized as malignant or highly suspicious.

This finding is broadly consistent with the histopathological results, in which 78.8% of nodes were malignant. The high proportion of high elastographic scores therefore reflects, at least in part, the high prevalence of malignancy within the study cohort.

The association between high elastographic stiffness and malignant lymph node involvement has been reported repeatedly in the literature. Lyshchik et al. demonstrated that malignant cervical nodes were significantly more likely to exhibit high elastographic scores and reported an AUC of 0.91. (Lyshchik et al., 2007) Choi et al. similarly found that elastography was highly sensitive for

metastatic cervical lymph nodes. (Choi et al., 2011) Furukawa et al. reported comparable high sensitivity and emphasized that increased stiffness should be interpreted alongside other sonographic characteristics. (Furukawa et al., 2012)

The biological basis for increased stiffness in malignant lymph nodes is plausible. Malignant infiltration may replace normal lymphoid architecture with tumour cells, fibrous stroma and desmoplastic tissue. Necrosis and architectural remodeling may further alter the mechanical properties of the node. These pathological changes may result in reduced tissue deformability and therefore a predominantly hard elastographic appearance.

However, increased stiffness is not specific to malignancy. Fibrosis, granulomatous inflammation, chronic infection and other inflammatory processes can also increase tissue stiffness. This is particularly important in settings where tuberculosis and chronic inflammatory diseases are common. The relatively low specificity observed in the present study is therefore clinically meaningful.

4.3 Histopathological spectrum

Histopathology demonstrated that 78.8% of nodes were malignant, with lymphoma representing the largest diagnostic category at 45.5%. Metastatic disease accounted for 33.3%, while tuberculous adenitis, reactive lymphoid tissue and normal lymphoid tissue accounted for the remainder.

The high proportion of lymphoma is notable. Lymphoma can present with generalized or localized lymphadenopathy and may produce enlarged, relatively homogeneous lymph nodes. In contrast to some metastatic nodes, lymphoma may not always exhibit the classic sonographic characteristics associated with metastatic disease. The presence of lymphoma as the leading malignant diagnosis therefore emphasizes the need for diagnostic methods capable of evaluating more than nodal size alone.

The substantial proportion of metastatic disease also reflects the role of MTRH as a tertiary referral centre. Patients with known or suspected malignancy may be referred for definitive tissue diagnosis and staging.

The presence of tuberculous adenitis in 10.6% of the study population is particularly relevant to interpretation of the elastography results. Tuberculosis can produce necrotic, matted, inflamed and fibrotic lymph nodes. These pathological characteristics may increase tissue stiffness and produce elastographic appearances that overlap with malignancy.

This provides a plausible explanation for the lower specificity observed in this study compared with several international studies. The thesis similarly identifies the complex disease spectrum of sub-Saharan African referral populations as an important contextual difference.

4.4 Sensitivity

Ultrasound elastography demonstrated a sensitivity of 96.1%, correctly identifying 50 of the 52 malignant lymph nodes.

This was the strongest diagnostic characteristic observed in the study. The finding is broadly consistent with the high sensitivity reported by several previous investigators. Lyshchik et al. reported sensitivity of 88%, (Lyshchik et al., 2007) Choi et al. reported approximately 97%, (Choi et al., 2011) and Furukawa et al. reported approximately 94%. (Furukawa et al., 2012)

The high sensitivity has important clinical implications. A highly sensitive test can be useful when the clinical objective is to identify patients who are unlikely to have malignant disease when the test is negative, although the NPV must also be interpreted in relation to disease prevalence.

In the present study, only two malignant nodes were classified as benign by elastography. This represents a relatively small number of false-negative classifications. From a clinical perspective, avoiding missed malignancy is particularly important in a tertiary referral setting because delayed diagnosis may result in delayed staging and treatment.

However, the high sensitivity should not be interpreted as evidence that elastography can replace histopathology. Sensitivity describes the ability of the test to identify disease; it does not establish histological subtype or definitively establish malignancy. A lymph node that is highly suspicious on elastography still requires appropriate clinical and pathological correlation.

4.5 Specificity

Specificity was 42.9%, considerably lower than sensitivity. Eight of 14 benign nodes were classified as malignant by elastography.

This is an important finding and represents the principal limitation of elastography in the present study. A specificity of 42.9% indicates that stiffness alone was not sufficiently reliable for confidently excluding benign pathology when a node appeared hard.

The result differs substantially from several international studies. Lyshchik et al. reported specificity of 81%, while Zhou et al. reported pooled specificity of approximately 84%. (Lyshchik et al., 2007; Zhou et al., 2014) The thesis also compares the present result with other studies reporting higher specificity.

Several factors may explain this discrepancy.

First, the underlying disease spectrum differs. Many early elastography studies were performed predominantly among patients with metastatic cervical disease or in oncology-focused populations. The MTRH population included tuberculosis, inflammatory disease, lymphoma and metastatic disease. Chronic inflammation and fibrosis may increase tissue stiffness, producing false-positive elastographic classifications.

Second, qualitative elastographic scoring is inherently dependent on interpretation. Colour-based assessment requires the operator to determine the predominant elastographic pattern. Mixed lesions may therefore be difficult to categorize consistently. The thesis identifies pattern 3 and mixed stiffness patterns as particular areas of diagnostic uncertainty.

Third, technical factors may influence elastographic assessment. Strain-based techniques depend on the interaction between transducer pressure, tissue depth, lesion characteristics and operator technique. Such factors may contribute to variability between examinations.

Fourth, the relatively small number of benign cases in the study means that specificity is estimated from only 14 histopathologically benign nodes. Consequently, a relatively small number of false-positive results can substantially influence the calculated specificity.

4.6 Positive and negative predictive values

The PPV of 86.2% indicates that most nodes classified as malignant by elastography were confirmed to be malignant on histopathology. However, because the study population had a high prevalence of malignancy, the PPV should not automatically be generalized to populations with lower disease prevalence.

The NPV was 75%. Although this provides some reassurance when elastography classifies a node as benign, it is not sufficiently high to justify using elastography alone to exclude malignancy in a patient with significant clinical suspicion.

This distinction is important when translating diagnostic research into clinical practice. Predictive values are influenced by disease prevalence, whereas sensitivity and specificity are intrinsic characteristics of the test under the study conditions. The high prevalence of malignancy in this tertiary referral population likely contributed to the relatively high PPV.

4.7 Overall diagnostic discrimination

The AUC of 0.692 indicates fair overall discriminatory performance. The AUC is particularly informative because it summarizes the ability of the test to discriminate between malignant and benign cases across thresholds.

The current AUC was lower than values reported in several earlier studies, including the AUC of 0.91 reported by Lyshchik et al. and approximately 0.89 reported by Choi et al. (Lyshchik et al., 2007; Choi et al., 2011)

The lower AUC in the current study may reflect the heterogeneous nature of the MTRH population. A diagnostic test generally performs differently when applied to a population with a wider range of disease processes. In particular, benign inflammatory and granulomatous lymph nodes may overlap substantially with malignant nodes in terms of stiffness.

The result also reinforces the importance of avoiding an interpretation in which a high elastographic score is treated as synonymous with malignancy. Elastography provides information about mechanical properties, whereas malignancy is a histopathological diagnosis.

4.8 Comparison with conventional ultrasound

Conventional B-mode ultrasound remains fundamental to lymph node assessment. Characteristics such as shape, cortical thickness, fatty hilum, echogenicity, margins, necrosis and vascularity provide important structural information. However, none of these findings should necessarily be interpreted in isolation.

The thesis reports that many participants demonstrated suspicious grayscale characteristics, including hypoechogenicity, increased cortical thickness and absence of the hilum.

Elastography adds information about tissue stiffness. The combination of morphology and mechanical properties may therefore provide a more comprehensive assessment than either approach alone.

This multimodal approach is consistent with the literature. Furukawa et al. emphasized that elastography should complement conventional B-mode and Doppler findings rather than function as an independent diagnostic test. (Furukawa et al., 2012) The practical value of elastography may therefore lie in identifying the most suspicious node among multiple enlarged nodes or in supporting a decision to proceed with tissue sampling.

4.9 Implications for biopsy targeting

One of the potentially important clinical applications of elastography is selection of the most suspicious lymph node for biopsy.

In patients with multiple enlarged lymph nodes, not every node will necessarily provide the same diagnostic yield. Sampling an inappropriate or less representative node may result in inadequate or inconclusive pathology. Elastography could potentially help identify areas of increased stiffness and therefore prioritize nodes for tissue sampling.

This application is particularly relevant in resource-limited settings because repeated biopsies increase costs, delay diagnosis, and impose additional procedural burden on patients.

However, the present study did not directly measure biopsy yield, repeat biopsy rates, time to diagnosis, or the proportion of inconclusive pathology results. Therefore, these potential benefits should be regarded as hypotheses for future research rather than demonstrated outcomes of this study.

The thesis identifies this as an important research gap, noting that relatively few studies have examined whether elastography improves core needle biopsy yield or reduces repeat procedures.

4.10 Relevance to the Kenyan and sub-Saharan African setting

The results have particular relevance to the Kenyan healthcare context because lymphadenopathy occurs against a complex background of infectious and malignant disease.

Tuberculosis, HIV-associated lymphadenopathy, chronic inflammatory conditions, lymphoma and metastatic malignancy may coexist within the same healthcare environment. This can make differentiation between benign and malignant lymphadenopathy more challenging than in populations where the differential diagnosis is narrower.

The high sensitivity observed in the current study suggests that elastography may be valuable for identifying patients who require further investigation. However, the relatively low specificity demonstrates that local disease patterns may reduce the ability of stiffness-based assessment to confidently distinguish benign from malignant disease.

Consequently, implementation should emphasize elastography as an adjunct rather than a standalone diagnostic test.

4.11 Clinical interpretation

The findings support a practical diagnostic pathway in which elastography is incorporated into conventional ultrasound assessment.

A node demonstrating low elastographic stiffness and benign morphological features may have a lower probability of malignancy, but clinical context remains important. A node with high stiffness, suspicious morphology, or both should be considered for histopathological confirmation.

In patients with multiple nodes, elastography may assist in prioritizing the most suspicious target for image-guided biopsy. However, the final decision should incorporate clinical presentation, anatomical site, conventional ultrasound findings, laboratory investigations, and the indication for biopsy.

The study therefore supports an integrated approach rather than replacement of tissue diagnosis.

4.12 Strengths

An important strength of the study is the use of histopathological examination as the reference standard. This allowed direct assessment of elastography against definitive tissue diagnosis.

A further strength was inclusion of patients with a broad spectrum of lymph node pathology. This provides a more realistic representation of the diagnostic challenges encountered in a tertiary referral hospital than would a narrowly selected oncology cohort.

The study also provides local data from Kenya, where evidence regarding lymph node elastography remains comparatively limited.

4.13 Limitations

The study was conducted at a single tertiary referral centre and included patients referred for imaging and biopsy. The cohort therefore represents a selected population with clinically significant or suspicious lymphadenopathy rather than the general population. The thesis identifies this selection bias as an important limitation and notes that the findings may not be directly generalizable to community populations.

The sample size was relatively small, with only 66 participants. In particular, the number of benign cases was limited to 14. This may have contributed to instability in estimates of specificity and predictive values.

The qualitative nature of the elastographic scoring system may also introduce interobserver variability. Interpretation of colour patterns can be influenced by operator experience and technical factors.

In addition, the study included lymph nodes from several anatomical sites. Differences in node depth, tissue environment and technical accessibility may introduce heterogeneity in elastographic measurements.

The study was also conducted in a high-prevalence referral population. Predictive values observed in this population may therefore differ substantially from those in primary-care or community settings.

Finally, although the study demonstrates diagnostic performance, it does not directly establish whether use of elastography reduces the number of biopsies, improves biopsy adequacy, decreases repeat procedures, reduces diagnostic delay, or improves patient outcomes.

5. Conclusion

Ultrasound elastography demonstrated high sensitivity for detecting malignant lymphadenopathy among patients evaluated at MTRH. The majority of lymph nodes demonstrated high elastographic scores, particularly scores 4 and 5, and histopathological examination identified malignancy in 78.8% of the study population.

Lymphoma was the most frequent malignant diagnosis, followed by metastatic disease. Tuberculous adenitis and other benign lymphoid conditions represented important alternative causes of lymphadenopathy.

Compared with histopathology, ultrasound elastography demonstrated sensitivity of 96.1%, specificity of 42.9%, PPV of 86.2%, NPV of 75%, and an AUC of 0.692.

The combination of very high sensitivity and relatively low specificity indicates that elastography is more suitable as a **screening, triage, and biopsy-targeting adjunct** than as a definitive diagnostic test. High stiffness should be regarded as a marker of suspicion rather than definitive proof of malignancy.

Histopathological examination remains necessary when malignancy is suspected, particularly because benign inflammatory and granulomatous processes can also produce increased tissue stiffness.

6. Recommendations

Sonoelastography should be integrated into routine lymph node assessment as a non-invasive triaging tool. Sonoelastography findings can be incorporated into comprehensive diagnostic guidelines that integrate both elastography and histopathological results in the evaluation of lymphadenopathy. Establishing such protocols would help standardize the assessment of lymph nodes, improve diagnostic accuracy—especially in distinguishing benign from malignant lesions—and support timely clinical decision-making. Additionally, the integration of elastography into image-guided tissue sampling techniques, particularly elastography-guided core needle biopsy by interventional radiologist, may further enhance diagnostic yield. It can serve as a triage tool—guiding sonographers and clinicians which patients require urgent biopsy or further oncological evaluation. In resource-limited settings like Moi Teaching and Referral Hospital (MTRH), where access to histopathology may be delayed, utilizing elastography as a first-line, non-invasive screening tool could optimize patient management and streamline the diagnostic workflow.

Ethical Approval

Ethical approval was obtained from the Institutional Research and Ethics Committee (IREC) of Moi University and Moi Teaching and Referral Hospital. Approval was also **sought from the National Commission for Science, Technology and Innovation (NACOSTI)** to conduct the study. Written informed consent was obtained from all participants.

Funding: Pending author confirmation.

Conflicts of Interest:

The authors declare no conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

References

- Abd-Elmageed, M. K., Ibrahim, S. G., & Zawawi, M. S. E. E. (2023). Diagnostic accuracy of B-mode, Doppler ultrasound, strain elastography, and 2D shear wave elastography in differentiation between benign and malignant lymphadenopathy. *Egypt J Radiol Nucl Med.*, 54(1), 136.
- Afolabi, A. O., Afolabi, E. R., Salami, A. A., & Adesina, O. A. (2015). Pattern of lymphadenopathy on fine needle aspiration cytology in HIV-positive patients. *Niger Med J.*, 56(6), 374-377.

- Ahmad, S., Akhtar, S., Akhtar, K., Naseem, S., & Mansoor, T. (2012). Cervical lymphadenopathy: a clinicopathological study. *J Pak Med Assoc.*, 62(6), 582-585.
- Ahn, J. E., Lee, J. H., Yi, J. S., Shong, Y. K., Hong, S. J., Lee, D. H. et al. (2008). Diagnostic accuracy of CT and ultrasonography for evaluating metastatic cervical lymph nodes in patients with thyroid cancer. *World J Surg.*, 32, 1552-1558.
- Ahn, B. C. et al. (n.d.). Evaluation of cervical lymphadenopathy using ultrasound and elastographic techniques. [Reference details should be verified against the original indexed publication before journal submission.].
- Ahuja, A. T., & Ying, M. (2005). Sonographic evaluation of cervical lymph nodes. *AJR Am J Roentgenol.*, 184, 1691-1699.
- Alam, F., Naito, K., Horiguchi, J., Fukuda, H., Tachikake, T., & Ito, K. (2008). Accuracy of sonographic elastography in the differential diagnosis of enlarged cervical lymph nodes: comparison with conventional B-mode sonography. *AJR Am J Roentgenol.*, 191(2), 604-610.
- Allin, D., David, S., Jacob, A., Mir, N., Giles, A., & Gibbins, N. (2017). Use of core biopsy in diagnosing cervical lymphadenopathy: a viable alternative to surgical excisional biopsy of lymph nodes? *Ann R Coll Surg Engl.*, 99(3), 242-244.
- AlShaikh, R. A., Aldaoud, K. M., & Abdelrahman, H. (2023). Role of elastography in the evaluation of lymph nodes: is it a game changer? *Insights Imaging.*, 14(1), 65.
- Aly, A. A., Farouk, O. M., & Khaled, A. A. (2022). Strain elastography and ARFI imaging in the evaluation of enlarged lymph nodes. *Pol J Radiol.*, 87:e1-e10.
- Antel, K., Louw, V. J., Maartens, G., Oosthuizen, J., Chetty, D., & Verburch, E. (2020). Diagnosing lymphoma in the shadow of an epidemic: lessons learned from the diagnostic challenges posed by the dual tuberculosis and HIV epidemics. *Leuk Lymphoma.*, 61(14), 3417-3421.
- Bakr, M. M., Abdel-Wanis, M. E., & Alshami, M. (2021). Diagnostic performance of strain elastography in cervical lymphadenopathy. *Egypt J Radiol Nucl Med.*, 52(1), 42.
- Bamber, J., Cosgrove, D., Dietrich, C. F., Fromageau, J., Bojunga, J., Calliada, F. et al. (2013). EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 1: basic principles and technology. *Ultraschall Med.*, 34(2), 169-184.
- Bazemore, A. W., & Smucker, D. R. (2002). Lymphadenopathy and malignancy. *Am Fam Physician.*, 66(11), 2103-2110.
- Choi, Y. J., Lee, J. H., Lim, H. K., Kim, S. Y., Han, B. K., Ko, E. Y. et al. (2011). A comparison of ultrasound elastography with conventional ultrasound for the diagnosis of cervical lymph node metastasis in patients with thyroid cancer. *J Ultrasound Med.*, 30(3), 353-359.
- Furukawa, M. K., & Furukawa, M. (2012). Diagnosis of cervical lymph node metastasis of head and neck squamous cell cancer using ultrasound elastography. *Med Ultrason.*, 14(2), 85-91.
- International Committee of Medical Journal Editors (2026). Recommendations for the conduct, reporting, editing, and publication of scholarly work in medical journals. Updated January.
- Ishibashi, N., Yamagata, K., Sasaki, H., Tominaga, M., Hayashi, K., Takahashi, H. et al. (2012). A novel method for evaluation of cervical lymph nodes using real-time tissue elastography. *Eur Radiol.*, 22, 1412-1419.
- Lyshchik, A., Higashi, T., Asato, R., Tanaka, S., Ito, J., Mai, J. J. et al. (2007). Cervical lymph node metastases: diagnosis at sonoelastography—initial experience. *Radiology.*, 243(1), 258-267.
- Mohseni, S., Shojaiefard, A., Khorgami, Z., Alinejad, S., Ghorbani, A., & Ghafouri, A. (2014). Peripheral lymphadenopathy: approach and diagnostic tools. *Iran J Med Sci.*, 39(2), 158-170.
- Mwanda, W. O., Othieno-Abinya, N. A., & Oduor, C. I. (2004). Clinical characteristics of Burkitt's lymphoma in Kenya. *East Afr Med J.*, 81(3), 124-130.
- Ngwenga, T., Matarira, H. T., & Chikwasha, V. (2019). Histopathological analysis of lymph node biopsies performed at a central hospital in Zimbabwe. *BMC Res Notes.*, 12, 652.
- Nowicki, A., & Dobruch-Sobczak, K. (2016). Introduction to ultrasound elastography. *J Ultrason.*, 16(65), 113-124.
- Olu-Eddo, A. N., & Omoti, C. E. (2011). The challenge of lymphadenopathy in African adults: a histopathologic study of 373 lymph node biopsies. *J Chin Clin Med.*, 6(3), 143-147.
- Ophir, J., Céspedes, I., Ponnekanti, H., Yazdi, Y., & Li, X. (1991). Elastography: a quantitative method for imaging the elasticity of biological tissues. *Ultrason Imaging.*, 13(2), 111-134.
- Otieno, J. A., Ahmed, M., & Othieno, R. (2012). Pattern of lymphadenopathy in adult Kenyans. *East Afr Med J.*, 89(10), 320-325.
- Zhou, J., Zhan, W. W., Chang, C., Zhang, X. H., Zhang, Y. F., Fu, Z. et al. (2014). Elastography for the diagnosis of cervical lymph nodes: a meta-analysis. *Eur J Radiol.*, 83(10), 1705-1712.
- Öztürk, S., Akın, L., & Yıldırım, Z. (2021). Cervical lymphadenopathy in children: predictors of malignancy in a cohort of 501 patients. *Turk J Pediatr.*, 63(2), 250-258.