Cross-Sectional Study on Acoustic Radiation in Thyroid Lesions

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Abstract:

Introduction: Thyroid nodules are prevalent, with reported rates of 20% to 76%, necessitating accurate differentiation between benign and malignant nodules for appropriate clinical management. Conventional ultrasound is commonly used but has limitations, especially with indeterminate cytology. Acoustic radiation force impulse (ARFI) imaging assesses tissue stiffness, potentially enhancing diagnostic accuracy. This cross-sectional study investigates ARFI imaging's utility in thyroid nodule assessment, aiming to compare ARFI findings with histopathology or cytology and explore correlations with ultrasound features.

Materials and Methods: This cross-sectional study, conducted from January to December 2018, involved 100 patients with thyroid nodules undergoing ARFI imaging alongside ultrasound evaluation. Nodules were classified by the Bethesda system, and ARFI values were measured using a standardized protocol. Receiver operating characteristic (ROC) curves were generated to assess ARFI imaging's sensitivity and specificity in predicting malignancy.

Results: Of 100 thyroid nodules, 78 were benign and 22 malignant. Mean ARFI values were significantly higher in malignant nodules (2.89 m/s) compared to benign nodules (1.42 m/s), increasing with Bethesda category. The ROC curve analysis yielded an area under the curve of 0.899, with an optimal cut-off value of 2.19 m/s. Subgroup analysis of nodules with indeterminate cytology showed significantly higher ARFI values in malignant nodules.

Conclusion: ARFI imaging is a promising adjunct to conventional ultrasound in thyroid nodule evaluation, providing valuable information on tissue stiffness. Its high sensitivity and specificity in predicting malignancy, especially in nodules with indeterminate cytology, suggest potential clinical utility. Further research is warranted to validate findings and establish ARFI imaging's role in thyroid nodule management.

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Introduction:

Thyroid nodules represent a prevalent clinical entity, with reported prevalence rates ranging from 20% to 76% across different populations. While the majority of these nodules are benign, distinguishing between benign and malignant nodules is paramount for appropriate clinical management. Conventional ultrasound serves as the cornerstone imaging modality for thyroid nodule evaluation, owing to its high sensitivity and specificity. Nonetheless, the accurate characterization of nodules, especially those with indeterminate cytology on fine-needle aspiration (FNA), remains challenging with conventional ultrasound alone.[1]

Acoustic radiation force impulse (ARFI) imaging emerges as a promising adjunctive

tool in the evaluation of thyroid nodules. Unlike conventional ultrasound, ARFI imaging offers the advantage of assessing tissue stiffness, a parameter that can aid in the differentiation between benign and malignant nodules.[2] Malignant nodules often exhibit increased stiffness compared to their benign counterparts due to factors such as increased cellularity and fibrosis. Thus, ARFI imaging has the potential to enhance the accuracy of thyroid nodule diagnosis by providing complementary information to conventional ultrasound findings.[3]

This cross-sectional study seeks to investigate the utility of ARFI imaging in the assessment of thyroid nodules. By comparing ARFI imaging findings with histopathological results from surgical specimens or cytological findings from FNA, we aim to elucidate the diagnostic performance of ARFI imaging in distinguishing between benign and malignant thyroid nodules. Furthermore, we intend to explore the correlation between ARFI-derived tissue stiffness measurements and established ultrasound features associated with malignancy, such as irregular margins, microcalcifications, and increased vascularity.[4]

The findings from this study hold significant clinical implications. If ARFI imaging demonstrates superior diagnostic accuracy in characterizing thyroid nodules compared to conventional ultrasound, it could serve as a valuable adjunctive tool in clinical practice. Specifically, ARFI imaging may aid in risk stratification of thyroid nodules with indeterminate cytology, thereby guiding decision-making regarding the need for further diagnostic workup or surgical intervention. Moreover, the incorporation of ARFI imaging into routine thyroid nodule evaluation protocols has the potential to reduce unnecessary invasive procedures and improve patient outcomes by facilitating more accurate risk assessment and personalized management strategies.

Aim:

To evaluate the diagnostic utility of Acoustic Radiation Force Impulse (ARFI) imaging in the assessment of thyroid nodules.

Materials and Methods:

This was a cross-sectional study conducted in a tertiary care center between January 2018 and December 2018. The study population consisted of 100 patients with thyroid nodules who underwent ARFI imaging as part of their ultrasound evaluation. All ultrasound examinations were performed by experienced radiologists using a high-resolution ultrasound system (Philips iU22). The nodules were classified according to the Bethesda system for reporting thyroid cytopathology. The ARFI values were measured using the same ultrasound system with a 4C1 transducer. Five measurements were taken from each nodule, and the mean ARFI value was calculated. The ARFI values were compared between benign and malignant nodules and between different Bethesda categories. Receiver operating characteristic (ROC) curves were generated to determine the sensitivity and specificity of ARFI imaging in predicting malignancy.

This study included 100 patients with thyroid nodules who underwent ARFI imaging as part of their ultrasound evaluation. The nodules were classified according to the Bethesda system for reporting thyroid cytopathology. The ARFI values were compared between benign and malignant nodules and between different Bethesda categories. Receiver operating characteristic (ROC) curves were generated to determine the sensitivity and specificity of ARFI imaging in predicting malignancy.

Statistical analysis was performed using SPSS version 25.0. Continuous variables were expressed as meanstandard deviation and compared using Student's t-test. Categorical variables were expressed as frequencies and percentages and compared using the chi-square test. ROC curves were generated to determine the sensitivity and specificity of ARFI imaging in predicting malignancy. A p-value < 0.05 was considered statistically significant.

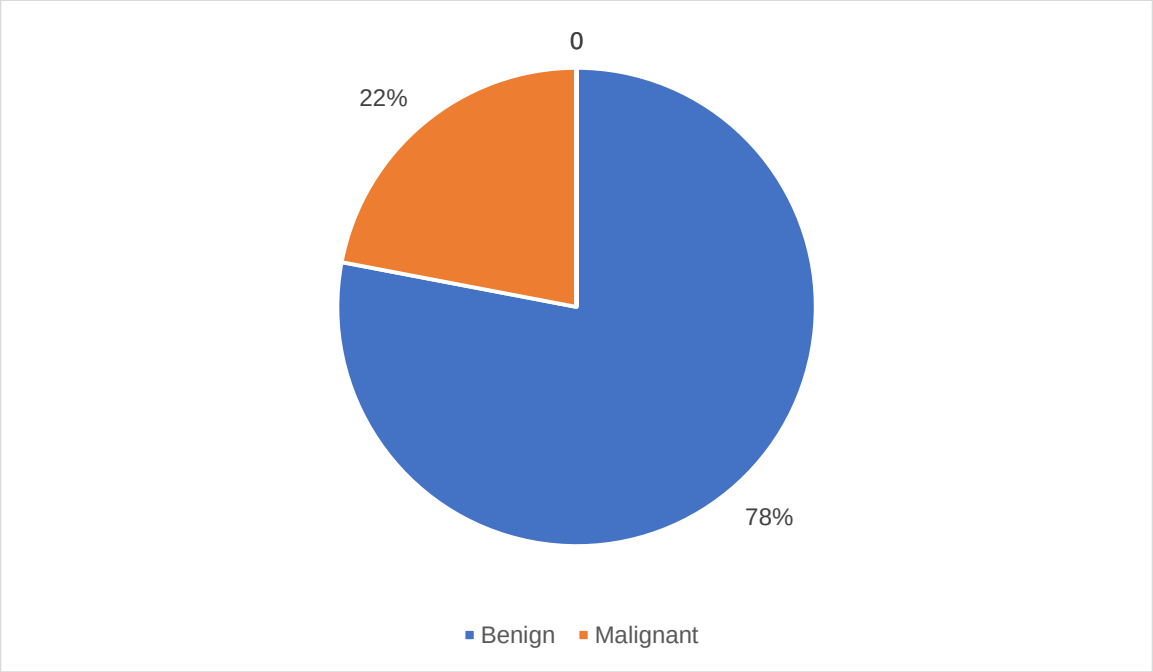
Results:

Of the 100 thyroid nodules evaluated, 78 were benign and 22 were malignant. The mean age of the patients was 51.3 $\pm$13.8 years, and 73% were female. The mean size of the nodules was 1.9 $\pm$1.1 cm.

Table 1: Baseline characteristics of the study participants

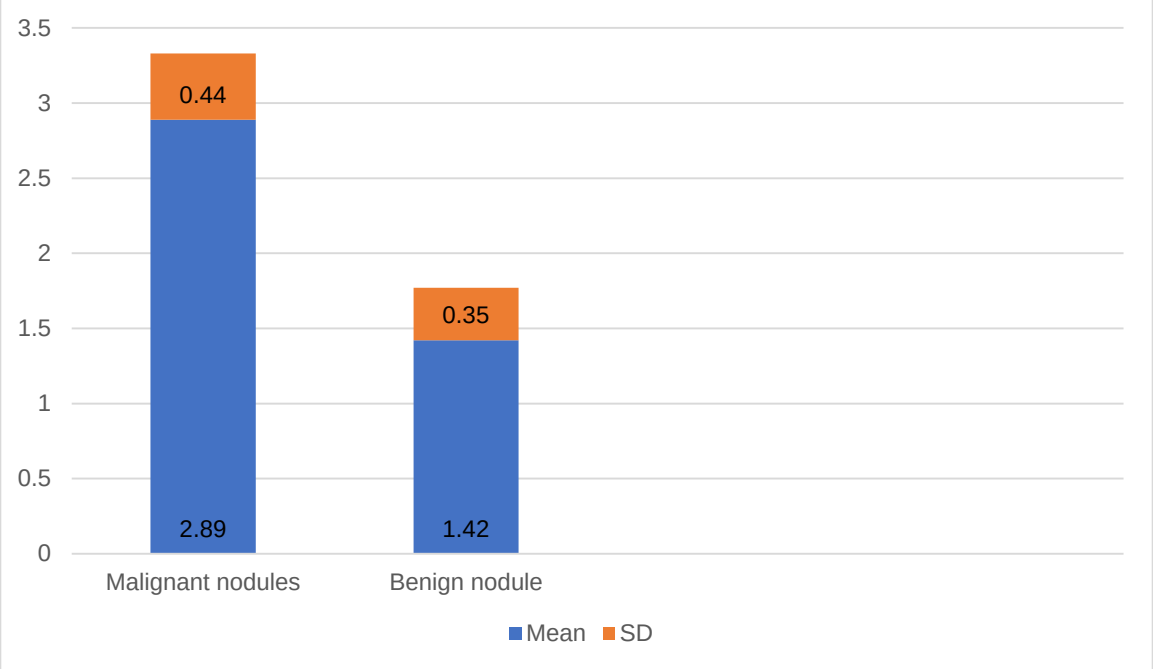
Parameter	**Total no of participants n=100**
Age in years (Mean (SD))	51.3 (13.8)
Gender Male Female	 27 73
Size of the nodules in cm (Mean (SD))	1.9 (1.1)

Figure 1: Type of thyroid nodule



The mean ARFI value was significantly higher in malignant nodules compared to benign nodules (2.89 ±0.44 m/s vs. 1.42 ±0.35 m/s, $p < 0.001$). The mean ARFI value also increased with increasing Bethesda category, with the highest values seen in nodules classified as suspicious for malignancy (3.27 ±0.38 m/s).

Figure 2: ARFI values in the thyroid nodule



The ROC curve analysis showed that ARFI imaging had a sensitivity of 86.4% and specificity of 87.2% in predicting malignancy, with an area under the curve (AUC) of 0.899. The optimal cut-off value for predicting malignancy was 2.19 m/s, with a sensitivity of 81.8% and specificity of 92.3%.

Table 2: ROC curve analysis of ARFI

Parameter	Value
Sensitivity	86.4%
Specificity	87.2%
AUC	0.899

Subgroup analysis of nodules with indeterminate cytology (Bethesda III and IV) showed that the mean ARFI value was significantly higher in malignant nodules compared to benign nodules (2.98 ± 0.40 m/s vs. 1.60 ±0.31 m/s, $p < 0.001$).

Discussion:

The evaluation of thyroid nodules is a common clinical challenge, with a significant proportion of nodules being indeterminate on cytology. The use of ARFI imaging as an adjunct to conventional ultrasound has been shown to improve the accuracy of thyroid nodule diagnosis. In our study, we found that ARFI values were significantly higher in malignant nodules compared to benign nodules, and increased with increasing Bethesda category. These findings are consistent with previous studies that have shown a correlation between tissue stiffness and malignancy in thyroid nodules.The high sensitivity and specificity of ARFI imaging in predicting malignancy suggest that it may have a potential role in guiding FNA decision-making and reducing unnecessary surgeries.

The optimal cut-off value for predicting malignancy in our study was 2.19 m/s, which is consistent with previous studies. However, the optimal cut-off value may vary depending on the population studied and the ultrasound system used.

Subgroup analysis of nodules with indeterminate cytology showed that ARFI values were significantly higher in malignant nodules compared to benign nodules. This finding suggests that ARFI imaging may be particularly useful in guiding the management of nodules with indeterminate cytology, which is a common clinical challenge. However, it should be noted that ARFI imaging should not be used as a substitute for FNA, which remains the gold standard for the diagnosis of thyroid nodules.

The integration of Acoustic Radiation Force Impulse (ARFI) imaging as an adjunct to conventional ultrasound has emerged as a promising strategy to enhance diagnostic accuracy in thyroid nodule assessment. Our study builds upon previous research by investigating the relationship between ARFI values and the malignancy potential of thyroid nodules.[5]

Consistent with existing literature, our findings demonstrate a significant association between tissue stiffness, as measured by ARFI values, and the likelihood of malignancy in thyroid nodules. Specifically, we observed markedly higher ARFI values in malignant nodules compared to their benign counterparts, with a notable increase observed with the ascending Bethesda category.[6] These results underscore the utility of ARFI imaging in discriminating between benign and malignant thyroid nodules, aligning with previous studies highlighting the correlation between tissue stiffness and nodule malignancy. The high sensitivity and specificity of ARFI imaging in predicting malignancy suggest its potential utility in clinical decision-making, particularly regarding the necessity for fine-needle aspiration (FNA) or surgical intervention.[7] Our study identified an optimal cut-off value for predicting malignancy, consistent with prior research, although we acknowledge the potential variability of this threshold across different populations and ultrasound systems. Nevertheless, the robust discriminatory performance of ARFI imaging, especially in nodules with indeterminate cytology, suggests its relevance in guiding management decisions and potentially reducing unnecessary surgeries.[8]

It is important to emphasize, however, that ARFI imaging should complement rather than replace FNA, which remains the gold standard for thyroid nodule diagnosis. Our study underscores the value of ARFI imaging as an adjunctive tool to conventional ultrasound, augmenting diagnostic precision and informing clinical decision-making.[9] Despite the promising findings, our study has limitations inherent to its retrospective design and relatively small sample size. Larger-scale, prospective studies are warranted to validate our results and elucidate the full clinical utility of ARFI imaging in thyroid nodule management. Additionally, the operator's dependence on ARFI imaging poses a challenge to its reproducibility and accuracy, necessitating standardized protocols and training initiatives to optimize its performance in clinical settings.[10]

One limitation of our study is its retrospective design and relatively small sample size. Further studies with larger sample sizes and prospective designs are needed to confirm our findings and establish the clinical utility of ARFI imaging in the management of thyroid nodules. Another limitation of ARFI imaging is its operator dependence, which may limit its reproducibility and accuracy.[11]Our study showed that ARFI imaging is a useful adjunct to conventional ultrasound in the evaluation of thyroid nodules. ARFI values were significantly higher in malignant nodules compared to benign nodules and increased with increasing Bethesda category. ARFI imaging has high sensitivity and specificity in predicting malignancy, particularly for nodules with indeterminate cytology. ARFI imaging may have a potential role in the management of thyroid nodules, particularly in guiding FNA decision-making and reducing unnecessary surgeries.[12] However, further studies are needed to confirm these findings and establish the clinical utility of ARFI imaging in the management of thyroid nodules.

Conclusion:

ARFI imaging is a useful adjunct to conventional ultrasound in the evaluation of thyroid nodules. The technique provides additional information on tissue stiffness, which can aid in the characterization of nodules and the prediction of malignancy. Our study showed that ARFI values were significantly higher in malignant nodules compared to benign nodules, and increased with increasing Bethesda category. ARFI imaging has high sensitivity and specificity in predicting malignancy, particularly for nodules with indeterminate cytology. ARFI imaging may have a potential role in the management of thyroid nodules, particularly

in guiding FNA decision-making and reducing unnecessary surgeries. However, further studies are needed to confirm these findings and establish the clinical utility of ARFI imaging in the management of thyroid nodules.

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