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REVIEW ARTICLE

Assessment of thyroid nodules using elastography and scintigraphy: review of literature.

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INTRODUCTION

Thyroid nodules are prevalent worldwide, impacting a substantial segment of the populace, frequently exhibiting no clinical manifestations. It is essential to diagnose thyroid nodules as soon as possible in order to distinguish between those that need to be treated medically and those that don't. As a result, it is now critical to develop and use cutting-edge, non-invasive diagnostic techniques for thyroid nodules **[1].**

Thyroid nodules come in a wide variety of forms and represent several different pathologies. Nonetheless, a significant portion of thyroid nodules—roughly 10%—may be cancerous. Most cases of thyroid cancer are caused by these malignant nodules, which are frequently diagnosed as papillary, follicular, or medullary thyroid cancer **[2].**

The ability to distinguish between benign and malignant nodules is essential for both clinical decision-making and patient care. Although fine-needle aspiration cytology (FNAC) is still a useful diagnostic technique for evaluating thyroid nodules, it is an invasive process with uncertain outcomes. The investigation of advanced imaging techniques has been prompted by the urgent need for precise, non-invasive, and affordable diagnostic instruments. Two of these methods are the subject of this review: Both scintigraphy and elastography **[3].**

THYROID NODULES

A growth (lump) in the thyroid gland is called a thyroid nodule. A thyroid nodule is a distinct lesion inside the thyroid gland, according to the American Thyroid Association (ATA). It can be distinguished radiologically from the thyroid parenchyma around it **[4].**

Nodules can be solid, cystic, solitary, or multiple. Thyroid gland nodules are a common occurrence and can be found by physical examination in 5% to 7% of adult individuals. Nonetheless, among patients without a prior diagnosis of thyroid disease, autopsy data have revealed a 50% prevalence of thyroid nodules larger than one centimeter **[5].**

Thyroid nodules are clinically significant because they may represent thyroid cancer in 4.0% to 6.5% of cases, even though more than 90% of detected nodules are benign lesions with no clinical significance **[6].**

ETIOLOGY

Thyroid nodules can indicate a wide range of conditions, from benign to malignant, with varying clinical courses, including indolent and aggressive. The dominant nodule within a multinodular goiter is represented by about 23% of solitary nodules **[6].**

It is well known that ionizing radiation increases the risk of thyroid nodules, both benign and malignant. Thyroid nodules may occur in this population at a 2% yearly rate. It has been reported that palpable nodules on previously irradiated thyroid glands have a 20% to 50% malignancy incidence **[7].**

The most common thyroid nodule, a colloid nodule, is an adenomatous benign neoplasm with no increased risk of malignancy. Although many follicular adenomas are benign, they are similar to follicular carcinomas in certain ways **[8].**

EPIDEMIOLOGY

The population under evaluation and the screening procedure both affect prevalence. Age, gender, iron deficiency, and thyroid radiation history all increase the risk of thyroid nodules **[9].**

Physical examination by itself may reveal a 5% to 7% prevalence of thyroid nodules in the adult population. In this same population, ultrasound reveals a prevalence of 20% to 76%, which is consistent with autopsy results **[10].**

Fig (1). Comparison of thyroid nodule prevalence across various age groups **[11].**

EVALUATION

Thyroid stimulating hormone (TSH) levels, physical examinations, thyroid ultrasounds to characterize the nodule, and history taking should all be part of the initial evaluation for patients who have a thyroid nodule. TSH measurement by itself might be able to identify mild thyroid dysfunction **[12].**

Serum markers, cytology by fine-needle aspiration (FNA), genetic markers, immunohistochemical markers, and various imaging modalities—ultrasonography being the most common, but also MRI, CT, elastography, and 18FDG-PET scans—are all part of the diagnostic workup **[2].**

Thyroid ultrasound (US) is a crucial imaging modality for the assessment of thyroid nodules. It may identify lesions as small as 2 mm and offers details on dimensions, structure, and parenchymal alterations. To prevent the needless use of invasive procedures, irregular margins, hypo echogenicity, taller-than-wide shape, and increased vascularity, it is frequently used to distinguish between benign and malignant lesions **[13].**

FNA is the most economical diagnostic method for evaluating thyroid nodules when combined with the US. It serves as the foundation for thyroid nodule evaluation **[14].**

Based on the patient's history, clinical results, and US findings, an individual risk-stratification should be used to determine whether to perform FNA. When there are multiple suspicious US characteristics, cervical lymphadenopathy, or a high-risk history, nodules smaller than one centimeter are biopsied.

Diagnostic Procedures in Thyroid Nodule Evaluation: Elastography and Scintigraphy

Diagnostic techniques such as scintigraphy and elastography are indispensable instruments in the medical field, each with a unique function in evaluating a range of medical conditions. Tissue elasticity is assessed by elastography, whereas scintigraphy uses radioactive tracers for functional imaging. We examine these diagnostic methods, their approaches, and their uses in this conversation **[15].**

A new diagnostic technique called elastography measures the speed at which shear waves travel or the amount that tissue deforms when compressed to assess tissue stiffness. It can help distinguish benign from malignant lesions and offers more details about the nodule's elasticity. Elastography provides a real-time, non-invasive evaluation of tissue properties **[16].**

Scintigraphy: Thyroid nodule function is evaluated by scintigraphy, such as radioactive iodine scintigraphy. By using radioactive tracers, nodules can be categorized as "hot," "warm," or "cold" according to how well they can concentrate and hold onto radioactive iodine. Scintigraphy provides functional insights to enhance structural imaging **[17].**

I. Elastography: Evaluating Tissue Elasticity

A diagnostic imaging method called elastography gauges a tissue's elasticity or stiffness. It is mainly used to evaluate diseases like thyroid nodules, breast cancers, and liver fibrosis that alter tissue texture. Two primary categories of elastography exist:

1. Shear Wave Elastography:

- Technique: In shear wave elastography, mechanical shear waves are created inside the tissue, and the speed at which these waves travel is directly proportional to the stiffness of the tissue.

- Applications: Thyroid nodules, breast lesions, and liver fibrosis are all frequently diagnosed with shear wave elastography **[18].**

2. Strain Elastography:

- Technique: When external pressure is applied to tissue, strain elastography measures the resulting deformation. Tissue elasticity is revealed by the greater deformation of softer tissues relative to harder tissues.

- Applications*:* Strain elastography is frequently employed in the assessment of musculoskeletal disorders, thyroid function, and breast imaging **[19].**

II. Scintigraphy: Functional Imaging with Radioactive Tracers

Utilizing radioactive tracers, also known as radiopharmaceuticals, scintigraphy, also known as nuclear medicine imaging, produces functional images of internal organs and tissues. It is employed to assess organ function and diagnose a range of illnesses **[20].**

Thyroid nodule evaluation frequently involves the use of scintigraphy with technetium and iodine. Thyroid scintigraphy, also called thyroid uptake scan, is the specific method that is employed. In thyroid scintigraphy, a radioactive tracer is injected and absorbed by the thyroid gland. When it comes to thyroid nodules, the scan's goal is to evaluate the nodule's function and identify whether it's functioning (hot), non-functioning (cold), or indeterminate **[21].**

In thyroid scintigraphy, technetium-99m (Tc-99m) is frequently utilized as the radioactive tracer. Its availability and appropriate physical characteristics make it the preferred option. You can give Tc-99m pertechnetate intravenously or orally. After the tracer is absorbed by the thyroid tissue, pictures of the tracer's distribution inside the thyroid gland are produced using a gamma camera or detector **[22].**

The tracer is evenly distributed across the thyroid gland in a healthy thyroid. If a thyroid nodule is found, its purpose may differ. On a scan, a functioning (hot) nodule shows up as a localized area of increased radioactive uptake because it absorbs more tracer than the thyroid tissue around it. In areas of reduced or absent radioactive uptake, non-functioning (cold) nodules are visible because they do not absorb the tracer. When measured against the surrounding thyroid tissue, the uptake of indeterminate nodules is intermediate **[23].**

IV. Patient Preparation and Safety

Elastography:

There are usually no dietary or medication restrictions associated with patient preparation for elastography. Most patients find the procedure to be safe because it is painless and non-invasive. It is essential to let the healthcare provider know about any allergies, illnesses, or pregnancy before the test **[24].**

Scintigraphy:

Since scintigraphy uses radioactive tracers, precautions for patient safety are crucial. Depending on the kind of scintigraphy used, patients might have to fast or adhere to certain dietary guidelines prior to the examination. It is essential to let the healthcare provider know if you are allergic to something, pregnant, or nursing **[25].**

Elastography methods – strain elastography

To perform strain elastography, an external compression that causes the adjacent tissue to distort parallel to the direction of the deformation force or endogenous stress—such as the movement of a vascular beam—is necessary. Repetitive motions are recorded. When compared to elastic tissue, stiff tissue deforms less and moves less. The elastic images are added using the standard 2B mode, and a color map with red representing soft tissue and blue representing hard issues is displayed. This qualitative assessment varies depending on the manufacturer: in the Toshiba machines, it is presented as a single image that represents the mean relative anelasticity strain over a time loop that is predefined by the examiner, or in parallel with 2B images superimposed to the grey scale images, at a refresh rate equal to that of the grey scale = real-time elastography (RTE), provided by Hitachi Systems **[26].**

Fig (2). Siemens apparatus. Greyscale image on the left US: solid thyroid nodule, longitudinal section. The strain elastography image on the right shows a hard thyroid nodule in red color on a blue-green-red convention map **[27].**

Additionally, it enables a semiquantitative measurement by comparing the nodule's tissue strain in the Region of interest (ROI) to that of the surrounding healthy tissue, with an automatic computation of the strain ratio (SR) **[28].**

Fig (3). Hitachi apparatus. Left image: low strain ratio, soft nodule, and strain elastography with an average of 3.57. Grayscale image on the right Transversal section of a solid thyroid nodule in the US **[29].**

Strain (color map), strain ratio geometric measures, and elastography to B-mode size ratio (EI/B) ratio are the parameters used in strain elastography. In addition to external compression, strain elastography can also be carried out by internal force using the tissue's transversal displacement. This method is secondary to Siemens devices' use of acoustic radiation force impulse imaging, which analyzes individual images or a predetermined time loop but does not provide a real-time evaluation **[30].**

The amount of external pressure that is applied must be medium and quantified for each device. For Hitachi machines, the compression scale is always displayed, and the pressure should be between 3 and 4; for Siemens machines, the pressure should be approximately 50 quality factors; and for Philips devices, the pressure level should remain constant and be displayed on the screen **[31].**

Elastography techniques: Strain elastography

The Rago group, which used the Ueno scale for breast lesions, modified for thyroid lesions, provided the first information about elastography in thyroid nodular pathology. They described qualitative strain elastography evaluation as follows: Score 1 is for elasticity throughout the lesion; Score 2 is for mostly soft tissue; Score 3 is for soft peripheries; Score 4 is for the entire hard nodule; and Score 5 is for elasticity that extends past the 2B margins of the nodule, which is originally described and utilized by Hitachi Machines **[32].**

Other popular color schemes for thyroid RTE include the 4-point Asteria scale, which is derived from the Itoh scale for the breast: Scores of 1 and 4 represent the original, fully elastic, mostly soft, mostly hard, and entirely hard nodules that Hitachi Machines used. Nodules with Asteria scores of 3 or 4 or Rago scores of 4 and 5 are typically regarded as highly suspicious for malignancy in RTE elastography. According to the first findings of the second assessment, Rago's criteria had a sensitivity of 97% and a specificity of 100%, while Asteria's criteria had a sensitivity of 94.1 and an 81% **[33].**

Shear wave elastography methods

Shear waves are transverse components of particle displacements that travel through tissues at a speed that depends on the stiffness of the tissue. Shear wave elastography measures the attenuation of these waves to determine the elasticity of the tissues. The acoustic radiation force impulse (ARFI) and the supersonic shear wave are the two applicable techniques **[34].**

Supersonic shear waves, which are focused ultrasound-induced waves, are used in thyroid imaging. The elasticity of ROI (measured in kilopascals) or the wave velocity (measured in m/s) as the wave attenuates along a perpendicular direction to the transducer can be directly measured. The color map shows that the hard tissues are red, and the soft tissues are blue. ARFI does not use color-coded images; instead, it uses short-duration acoustic pulses to excite the tissue within the ROI and measures the lesions' speed (m/sec) **[35].**

Elastography comes in two main varieties, each with unique diagnostic features. They employ various techniques to create transversally propagating waves, which move through thyroid tissue at varying speeds depending on how stiff the tissue is: Techniques for quantifying force impulses in acoustic radiation and real-time shear wave elastography **[34].**

ARFI quantification measures the velocity of ultrasonic waves to approximate the tissue stiffness. The device's ARFI option is activated during a breathing pause, the standard ROI (5 mm diameter or 2 cm diameter) is placed on the solid part nodule, and the device measures the speed. For each nodule, five to ten consecutive measurements are advised in order to obtain a reliable assessment. The normal speed range is 0 to 9 m/sec; the tissue stiffness increases with increasing speed **[2].**

Since the procedure's initial application in 2010, several publications have assessed SSE's diagnostic efficacy. The assessment produces qualitative data independently of the operator, including color maps with the subsequent color codes: Elasticity index (EI) expressed in kilopascals is used to evaluate quantitative information; blue indicates soft tissue and red indicates hard tissue. SSE is shown as strain elastography by placing ROI on the nodular lesion and displaying it in parallel with greyscale US. At least three loops without any transducer movement should be recorded for quantitative evaluation **[36].**

Advantages of elastography

Elastography is a non-invasive imaging modality that measures tissue stiffness and has many benefits in a range of clinical settings. Elastography allows physicians to evaluate tissue elasticity right away by giving them real-time images of the stiffness of the tissue during the examination. Making decisions can be aided by this dynamic feedback, which may also lessen the need for extra steps. Elastography gives more details about the properties of the tissue than conventional ultrasonography does. It offers a more thorough description of the target tissue, including its echogenicity, margins, and vascularization, when combined with grayscale and Doppler ultrasound **[30].**

Limitations of elastography: The accuracy of the evaluation and the quality of the elastography images may vary depending on the operator. The operator's or sonographer's expertise and experience may have an impact on the outcome. To cut down on variability, training and standardized procedures are crucial. When nodules are situated in difficult anatomical places, like deep within the body or close to bony structures, elastography might be less accurate. In these situations, the elastography image quality might be jeopardized **[30].**

Scintigraphy in Thyroid Nodule Evaluation

The usefulness of scintigraphy resides in its capacity to produce functional images that illustrate the body's radiopharmaceutical distribution and activity. Critical information regarding the physiological processes occurring in the tissues and organs under examination is provided by these images **[37].**

In addition to structural imaging modalities like X-rays, CT scans, and MRIs, scintigraphy offers priceless information about the physiological processes taking place within tissues and organs. Scintigraphy is a patient-friendly imaging modality that involves the intravenous administration of radiopharmaceuticals and is generally well-tolerated by patients **[38].**

- With the use of diverse forms and techniques, each specifically designed for a particular clinical application, scintigraphy enables functional imaging of a variety of tissues and organs. Technetium-99m scans and radioactive iodine are two popular scintigraphy techniques **[21].**

- **Procedure:** we use Technetium-99m scans involve the intravenous injection or inhalation of a radiopharmaceutical containing ^99mTc. The choice of radiopharmaceutical compound depends on the clinical application. The gamma camera captures the emitted gamma radiation from the radiopharmaceutical, creating scintigraphic images that reveal the distribution and behavior of ^99mTc within the body **[21].**

- Another radiotracer substance is radioactive iodine: A small amount of radioactive iodine, typically iodine-131 (^131I), is administered orally as a liquid or capsule. The thyroid gland actively accumulates radioactive iodine, allowing its functional assessment with a gamma camera. The gamma camera captures the emitted gamma radiation, generating images that depict the distribution and activity of the radiopharmaceutical within the thyroid **[21].**

Limitations of Scintigraphy

Because scintigraphy exposes patients to ionizing radiation, its use must be carefully considered and justified, especially in certain patient populations. Compared to other imaging modalities, scintigraphy usually has a lower spatial resolution, which limits its capacity to provide precise anatomical information. Standardized protocols and training are necessary because the quality of equipment and operator skill can affect the quality of scintigraphy images **[39].**

The role of scintigraphy in assessing thyroid nodule functionality and differentiating hot, warm, and cold nodules.

To differentiate between hot, warm, and cold thyroid nodules and to evaluate the functionality of thyroid nodules, scintigraphy—more especially, radioactive iodine scintigraphy—is an indispensable tool. This method helps with the diagnosis and treatment of thyroid disorders by providing unique insights into the metabolic activity of the thyroid gland and its nodules **[18].**

Fig (4): thyroid scintigraphy showed a cold nodule at the isthmus **[17].**

Thyroid Nodule Characterization: Scintigraphy can assist in distinguishing between hot, warm, and cold thyroid nodules when an ultrasound or physical examination detects them, offering crucial information for risk assessment and management choices **[4].**

In summary, radioactive iodine When evaluating thyroid nodule functionality and differentiating between hot, warm, and cold nodules, scintigraphy is a vital tool. This practical knowledge helps identify nodules with the potential to become cancerous, diagnose hyperthyroidism, and identify the main cause of excessive hormone production. Clinical decision-making is guided by the data gathered from scintigraphy, which eventually results in more accurate and patient-centered treatment of thyroid disorders **[40].**

During a routine ultrasound examination, elastography can be done in real-time and yields immediate results, enabling on-the-spot evaluation. Conversely, scintigraphy is a functional imaging modality that evaluates thyroid gland function and metabolic activity using radioactive tracers. Instead of focusing on a single nodule, scintigraphy describes the thyroid gland's overall function. It is especially helpful in situations where thyroid function is an issue, like hyperthyroidism **[2].**

To assess diseases such as Graves' disease or thyroiditis, scintigraphy can measure the thyroid's uptake of radioactive iodine **[6].**

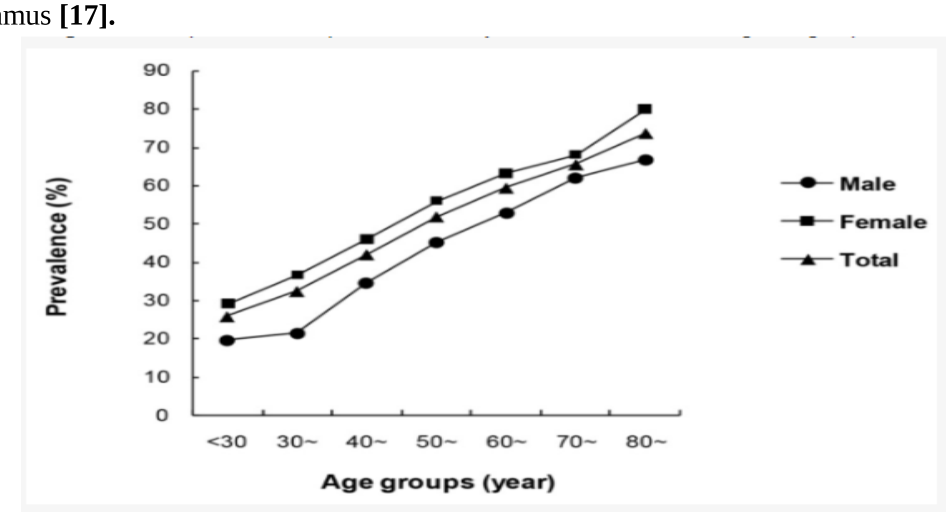
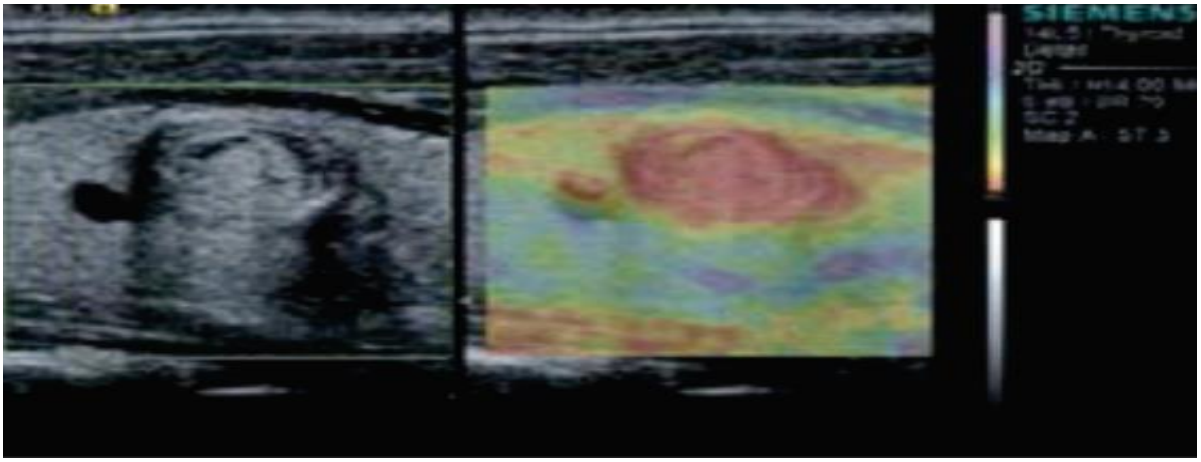


Fig (1). Comparison of thyroid nodule prevalence across various age groups. [11]



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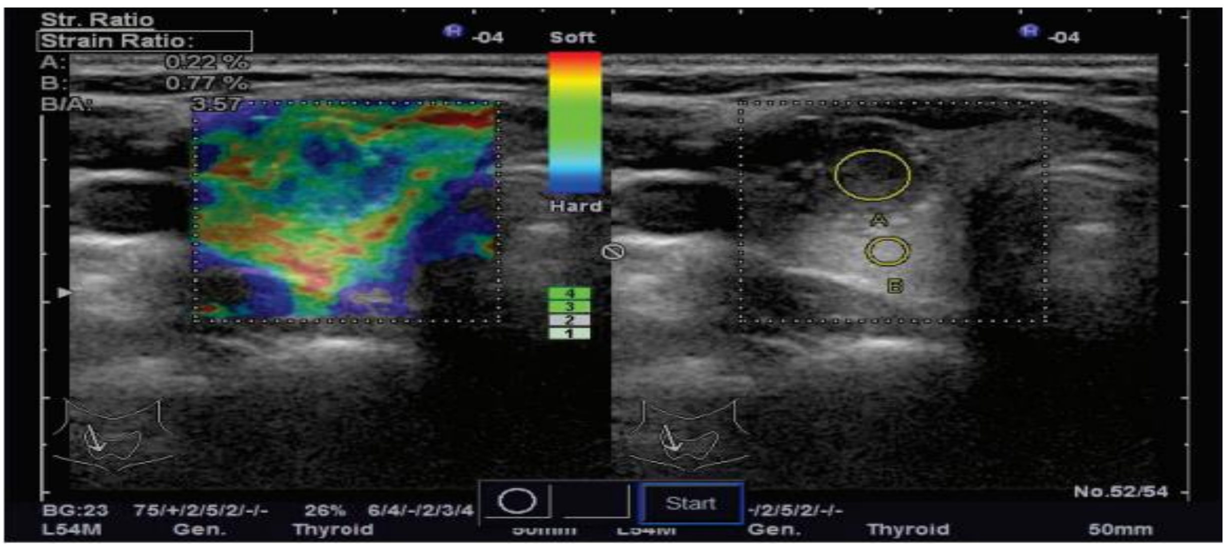

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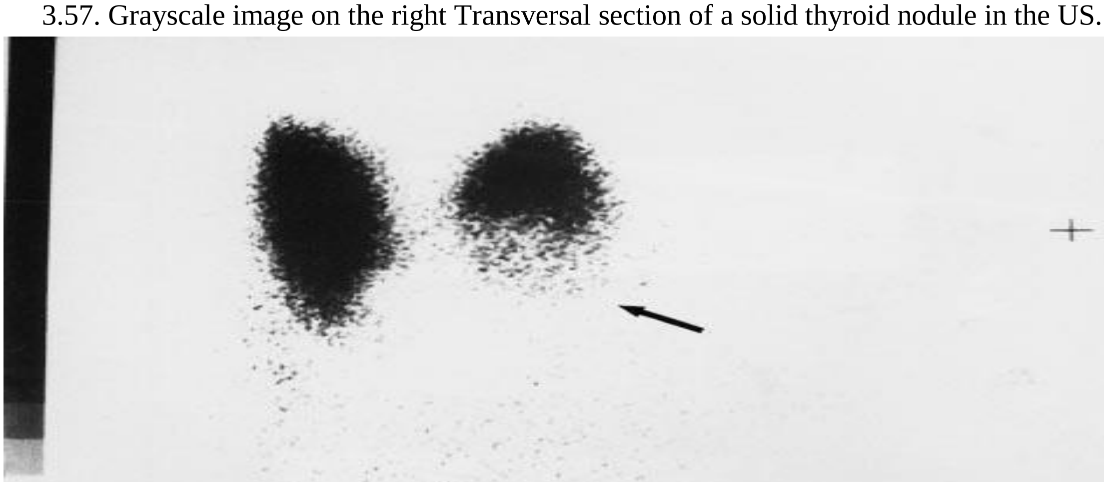

Fig (4): thyroid scintigraphy showed a cold nodule at the isthmus. [17]

CONCLUSION

In summary, depending on the clinical objectives, elastography or scintigraphy should be used to evaluate thyroid nodules. Elastography is a better option if the main goal is to characterize a thyroid nodule's stiffness to distinguish between benign and malignant nodules. Scintigraphy is the recommended method if evaluating the thyroid gland's general function or looking into thyroid function issues is necessary.

Your healthcare provider will select the most appropriate diagnostic method based on your symptoms, medical history, and diagnostic objectives. Elastography and scintigraphy may be combined in certain circumstances to offer a thorough assessment of thyroid nodules and thyroid function.

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