High-resolution ultrasonography is a valuable diagnostic tool in the evaluation of thyroid disorders. It is non-invasive, inexpensive and most widely used radiological method for diagnosing thyroid diseases. Since it does not use ionizing radiation, it is the imaging modality of choice for evaluating thyroid lesions in children and pregnant females. Modern US scanners permit real-time imaging of organs and help to guide diagnostic and therapeutic interventional procedures. Two major limitations of thyroid ultrasound are (i) it cannot determine the thyroid gland function, and (ii) it cannot evaluate the retrosternal area for ectopic thyroid tissue or retrosternal extension of an enlarged thyroid gland.[1]

**CLINICAL INDICATIONS**

Thyroid ultrasound is recommended by the American Association of Clinical Endocrinologists (AACE) and Associazione Medici Endocrinologi (AME) [2] in the following conditions:

1. Patients with a palpable thyroid nodule or with multinodular goiter (MNG).
2. Patients with high risk for thyroid malignancy; i.e. patients with history of familial thyroid cancer, multiple endocrine neoplasia (MEN) type II and irradiated neck in childhood.
3. Patients with palpable cervical lymphadenopathy suspicious of malignancy.

Thyroid ultrasound is not recommended as a screening test in the general population nor in patients with a normal thyroid on palpation and low risk of thyroid cancer.

**ROLE OF THYROID ULTRASOUND**

1. To detect and characterize the thyroid masses, including metastases to neck lymph nodes and post-operative residual or recurrent tumor in the thyroid bed.
2. To differentiate between possible benign and probable malignant thyroid masses, based on their sonographic appearance.
3. To guide the diagnostic (FNAC/biopsy) and therapeutic interventional procedures [1,3,4].

**ULTRASOUND MODALITIES**

Real-time grayscale (B-mode) is a basic type of scanning that provides real-time 2D images of the thyroid gland in various shades of gray [1,5].

Tissue harmonic imaging (THI) is a recently introduced sonographic technique using the effect of generation of harmonics (integral multiples of the emitted frequency) in the insonated tissue. It is often available as an option on grayscale scanners with standard probes. THI improves grayscale contrast between the thyroid nodules and adjacent parenchyma, thereby enhancing lesion detectability and characterization, hence used as an adjunct to conventional thyroid sonography [1,5].

Adaptive coloring utilizes a color map to stain a grayscale image. This option is available on grayscale scanners with standard probes. Color inversion helps in detection of small (< 10 mm size) isoechoic thyroid lesions as it improves the definition of nodule contours and posterior acoustic changes [1,5].

Panoramic scan provides an extended field of view that helps in visualization and measurement of long structures. The precise dimensions and volume of the lobes and the whole gland can be obtained using this technique [1,5].

Color, power and pulse-wave Doppler help in the classification of thyroid nodule(s). Both color Doppler imaging (CDI) and power Doppler imaging (PDI) are used to evaluate the vascularity (blood flow pattern) of the thyroid gland and the nodule(s). However, PDI is more sensitive than CDI in detecting low velocity blood flow in the tissues. Pulse-wave Doppler (PWD) permits analysis of the velocity, spectral waveform pattern and various Doppler indices like peak systolic velocity (PSV), end-diastolic velocity (EDV), resistive index (RI), and pulsatility index (PI) of blood flow in the thyroid arteries. Combined power and pulse Doppler study (duplex Doppler sonography) is very useful for screening thyroid nodules with high risk of malignancy with high sensitivity (92.3%) and specificity (88%) [1,6].

Fast computer processing of ultrasound images permit 3D-image reconstruction of the thyroid gland, the lesion and the surrounding structures. It provides volume data of the affected and normal thyroid tissue and helps in assessment of the planes that are usually inaccessible. 3D reconstruction of the vascular structures (3D-PDI) allows accurate assessment of vascular pattern within the lesion, in terms of vessel distribution, density and irregularity. 4D (real time 3D) ultrasound defines thyroid lesions more precisely with relatively less noise artifact [5,7].

Contrast-enhanced ultrasound (CEUS) is a newly developed valuable tool in characterizing thyroid nodule(s). SonoVue and Levovist are the most commonly used ultrasound contrast agents.
for thyroid nodules. Intravenously administered ultrasound contrast agents improve the sensitivity of CDI and PDI and hence improve the visualization of small nodules < 10 mm in size. It also helps in differentiating benign from malignant lesions as both have different enhancement patterns. However, overlapping findings may limit the potential of this technique. High cost, long scan time are other major limitations of CEUS [2,5,7].

Elastography is a newly innovated dynamic technique that uses ultrasound to estimate tissue hardness/elasticity by measuring the degree of distortion under external force. The technique is very useful to differentiate malignant from benign lesion. Real-time elastography quantifies tissue stiffness better than conventional elastography. Elastography possibly can solve the dilemma in reaching an accurate diagnosis for the cytologically indeterminate nodules. Limitations of US elastography include (i) technical difficulties such as applying uniform pressure and determining the direction of applied pressure taking into consideration the convex shape of the gland and anatomical structures like the centrally located trachea that make the technique difficult to carry out (ii) longer training time to obtain image suitable for diagnosis, (ii) expensive and (iv) time consuming [3,5,7,8].

A study done by M Giusti et al. in 2012 found that properly performed color Doppler ultrasound scores better with high specificity and PPV as compared to elastography and CEUS. According to this group, elastography or CEUS alone are expensive, time consuming and of limited utility in selecting patients for thyroidectomy. However, elastography in conjunction with conventional ultrasound and Doppler examination may enable accurate image diagnosis while decreasing the number of unnecessary FNA examinations. Additional clinical research is expected in the near future to improve the efficacy of these techniques [8].

**DISEASES OF THYROID GLAND**

**Congenital and developmental anomalies**

*Thyroglossal duct cyst* is the most common congenital neck mass which clinically presents as painless midline neck mass. Persistence of the thyroglossal duct results in formation of thyroglossal cyst. US examinations [Figure 1] demonstrate a well-defined anechoic to hypoechoic cystic lesion with posterior acoustic enhancement. Internal echoes within the cyst may be due to infection or hemorrhage.

*Ectopic thyroid gland* occurs due to an arrest in usual descent of a part or all of the thyroid tissue along the normal pathway. Ectopic gland may be sublingual (midline at foramen cecum), suprathyroid or infrathyroid in position. Ectopic thyroid tissue may be detected on USG, CT and radionuclide scans. Normal thyroid gland may or may not be present in normal position.

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**FIGURE 1.** Thyroglossal cyst in a patient who presented with midline neck swelling. Ultrasound neck reveals a large, well-defined anechoic cystic lesion (asterisk) with multiple low level internal echoes (due to hemorrhage or infection) and posterior acoustic enhancement. X-ray neck lateral view of the same patient shows large, soft tissue/cystic midline swelling (white arrow). [Figure reproduced with permission from Indian Journal of Endocrinology and Metabolism]

**FIGURE 2a.** Adenomatous multinodular goiter in a 48-year-old patient with thyrotoxicosis. Transverse gray-scale ultrasound neck shows diffuse enlargement of the thyroid gland with multiple small echogenic nodules involving both lobes and the isthmus (arrows). Diffusely increased parenchymal vascularity is seen on color Doppler sonogram. FNA biopsy confirmed the diagnosis. [Figure reproduced with permission from Indian Journal of Endocrinology and Metabolism]

**FIGURE 2b.** Colloid multinodular goiter in a 50-year-old female patient. Transverse gray-scale ultrasound neck image reveals enlarged thyroid gland with multiple echogenic colloid nodules with internal cystic areas (arrow) showing 'ring down' artifact. Color Doppler image shows predominantly increased peripheral vascularity, with some intra-gioitrous vascularity. [Figure reproduced with permission from Indian Journal of Endocrinology and Metabolism]
Congenital agenesis or hypoplasia of the thyroid gland may occur due to developmental failure of all or part of thyroid gland. It may be unilobar type or may involve the isthmus only. On USG, agenesis of isthmus is characterized by absence of isthmus with the lateral lobes positioned independently on either side of the trachea [9].

DIFFUSE THYROID DISEASE

Diffuse enlargement of the thyroid gland may occur in iodine deficiency, familial hyperplasia, multinodular goiter, Hashimoto’s (chronic lymphocytic) thyroiditis, de-Quervain’s (subacute) thyroiditis and Graves’ disease. The sonographic features of these diseases may be so subtle that a confident radiological diagnosis may not possible most of the time. However, these conditions have entirely different clinical and biochemical profiles, and hence the US findings should always be viewed in connection with clinical and biochemical status of the patient [1,3].

US appearances of different causes of diffuse thymomega may be listed as follows:

**Familial hyperplasia**: Diffuse glandular enlargement with inhomogenous echotexture, normal reflectivity.

**Multinodular goiter**: Diffuse asymmetric glandular enlargement with inhomogenous echotexture, iso, hypo or hyper echoic nodules with normal intervening parenchyma [Figure 2a]. Associated features like cystic degeneration, moving internal echoes within the cyst due to infection/hemorrhage, colloidal degeneration (seen as comet-tail artifact) [Figure 2b] and dystrophic calcification may be present. Intrinsic nodular vascularity favors multifocal carcinoma rather than MNG [1,3].

**Hashimoto’s (chronic lymphocytic) thyroiditis**: Painless diffuse glandular enlargement with coarse, hypoechoic and heterogeneous echotexture. No normal intervening parenchyma seen; presence of fine echogenic fibrous septae may give pseudolobulated appearance to the gland. Increased parenchymal vascularity is evident on color Doppler examination [Figure 3]. Occasionally, nodular form of Hashimoto’s thyroiditis may occur. Discrete hypoechoic micronodules of 1-6 mm size strongly favor chronic thyroiditis. The nodules may be present within the normal thyroid gland or in the sonographic background of diffuse Hashimoto’s thyroiditis. Both benign and malignant nodules are known to exist and are best differentiated on a PET scan or FNAC. Perithyroidal satellite lymph node, especially the “Delphian” node just cephalad to the isthmus is a common association with Hashimoto’s thyroiditis. Small atrophic gland represents end stage Hashimoto’s thyroiditis. Characteristic US findings when correlated with clinical and laboratory findings (demonstration of serum thyroid antibodies and antithyroglobulin antibodies) is extremely useful in the diagnosis of Hashimoto’s thyroiditis [1,3].

**De-Quervain’s (subacute granulomatous) thyroiditis**: Painful enlargement of one or both thyroid lobes (typically following a viral illness) with characteristic focal hypoechoic (map like) areas that show decreased or no blood flow. Enlarged level VI chain lymph nodes are present in majority of patients.1,3

**Graves’ disease (thyrotoxicosis)**: Diffuse glandular enlargement with low reflectivity. No nodule is detected. Color Doppler reveals a spectacular “thyroid inferno” with marked hypervascularity both in systole and diastole.1,3

**SOLITARY THYROID NODULE**

Solitary thyroid nodule is an interesting clinical situation where US helps to group them into cystic or solid and benign or malignant.

**True (simple) thyroid cyst** appears anechoic, has thin and smooth wall. The lesion does not show internal echo, solid element or calcification. **Complex thyroid cyst** may occur due to colloid or hemorrhagic degeneration in nodular goiter or as a result of cystic degeneration in a malignant nodule [1,3].

Although there is some overlap between ultrasound appearance of benign [Figure 4] and malignant [Figure 5] solid nodules, certain **gray scale** US features are helpful in differentiating the two. Hyper- or iso-echoic nodule with spongiform appearance is the most reliable criterion for benignity on gray scale ultrasound. Hypoechoic halo around the nodule, coarse/curvilinear calcification are useful ancillary findings. “Ring down” or “comet-tail artifact” is typical of benign cystic colloid nodule. Whereas, micro-calcifications, local invasion and lymph node metastases are highly specific features of a malignant nodule. Marked hypoechoigenicity and ill-defined irregular margins are less specific findings of malignancy. The number, size and interval growth of nodules are nonspecific characteristics. A suspicious thyroid nodule should be investigated further by FNA biopsy. Vascular flow within a thyroid nodule can be detected with **color and power Doppler US**. Marked intrinsic hypervascularity favors thyroid malignancy while perinodular flow is characteristic of benign thyroid lesion. A complete avascular nodule is very unlikely to be malignant. Enhancement patterns on CE-US may differ for benign and malignant lesions. Ring enhancement is common in benign lesions while heterogeneous enhancement favors malignancy. On **ultrasound elastography** a soft benign nodule deforms more easily as compared to a hard malignant nodule when manually compressed.
by ultrasound probe. US elastography and vascularity assessment of the nodule helps to optimize sampling at FNA.[3,5,7,10]

DIAGNOSTIC PITFALLS

Potential diagnostic pitfalls of thyroid ultrasound includes: (i) multifocal carcinoma may be mistaken for benign multinodular goiter, (ii) cystic or calcified nodal metastases may be mistaken for nodules in multinodular goiter, (iii) cystic variant of papillary carcinoma may be mistaken for cystic hyperplastic nodule, and (iv) failure to recognize microcalcifications in papillary thyroid cancer. [10].

CONCLUSION

Ultrasound is a valuable tool for diagnosing various thyroid diseases. It also helps to guide various interventional procedures and in follow-up for recurrence of thyroid carcinoma after thyroidectomy. Recent developments in ultrasound are very helpful in differentiating benign and malignant thyroid nodule(s), and thus avoid over investigation of benign nodule and unnecessary FNA biopsies.

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REFERENCES