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Review Article

Thyroid and Parathyroid Office Based Ultrasonography- Review Article

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Abstract

Because of superficial location and not being covered by boney structure, thyroid is the ideal organ for 2-dimensional gray scale ultrasonography. Availability of relatively low cost equipment and ever increasing number of endocrinologists with expertise in thyroid ultrasound has made it an integral part of thyroid practice in the office of endocrinologists. In particular, the current recommendation for fine needle biopsy of thyroid nodules is ultrasound guided biopsy. Follow up of thyroid nodules for change in size can also be better documented by ultrasound than palpation. Although cytology obtained by fine needle biopsy is the gold standard for detection of malignancy, yet ultrasound features of the nodules direct the clinician to select for biopsy the higher risk nodules in a multinodular gland. For detection of parathyroid adenoma isotopic parathyroid scan is preferable but ultrasound is occasionally is needed for confirmation, in particular for cases when parathyroid isotopic scan is ambiguous. The present article is an overview of ultrasonography of thyroid and parathyroid intended for endocrinologists.

Keywords: Thyroid, Gray scale ultrasonography, Fine needle biopsy

Introduction

Ultrasound is defined as a frequency not audible to human ear. Human ear cannot recognize frequencies above 20,000 Hertz (20 kHz). Diagnostic ultrasound has a frequency at the range of millions of Hertz (Mega Htz). Medical ultrasound technology was developed on the basis of sonar that was in use during the First World War. In the last several decades ultrasonography because of its safety and absence of radiation has been extensively used in obstetrics and cardiology by non-radiologists (1). Radiologists have also used ultrasound for imaging of internal organs. With advances in technology and production or more compact ultrasound machines, non-radiologists including endocrinologists have begun to use ultrasound imaging in bedside as an extension of their physical examination (2). Other examples of contribution of ultrasonography in endocrinology are endoscopic ultrasound done by endoscopists and intraoperatively by surgeons for localization of pancreatic islet cell tumors.

Transducers in ultrasonography use quartz or pisoelectric composite materials. Electrical current going through this crystal produces sound wave that goes through the tissue and returns. Sound is the propagation of mechanical energy through matter (1). The sound waves carry energy not matter. The qualities of the transmitting medium influence the sound transmission. Sound waves propagate by compression and rarefaction of molecules in transmitting media. Molecules of the medium vibrate around their resting position and transfer their energy to neighboring molecules.

The A- mode ultrasound uses only one crystal but B- mode or Gray scale 2- dimensional ultrasonography uses multiple crystals as high as over 128 crystals giving a 2 dimensional image that could be either longitudinal or transverse depending on the position of the transducer. Usually the transducer has a marker that in case of thyroid ultrasound should be directed at the right side of the patient (1).

Thyroid ultrasound

Thyroid because of superficial location and because of not being covered by boney structure is the ideal organ for 2 dimensional gray scale ultrasonography (3). Higher frequency ultrasound has better resolution but lower penetration. Lower frequency ultrasound has better penetration but lower resolution. Thus higher frequency is well suited for a superficial organ like thyroid. Frequencies between 5 to 15 MHz can be used with better images in thyroid ultrasonography as opposed to 2-5 MHz used for abdominal ultrasound. The sound wave does not transmit through air and, so gel is applied over the skin. Fluids and cysts and arteries and veins show as black echo free areas. Bone, cartilages and calcium deposits block passage of sound wave. Calcific spots show as bright spots and if large enough, produce echo free shadows. Cysts and fluid collections have enhancement distal to the cyst. Enhancement can occasionally be seen behind homogenous solid nodules. Shadowing is seen behind objects that do not transmit sound, such as calcification. Trachea and cartilages prevent the passage of the sound but have reverberation artifacts underneath.

Anatomy of the neck as seen by gray scale ultrasound

Thyroid overlies the thyroid cartilage and upper part of trachea (Fig. 1). It is a butterfly shaped gland. It weighs approximately 15 to 20 gram. The volume performed by means of ultrasonography (4-6) obtained from the 3 axes by an ellipsoid formula (7), or a mathematical model (8) is normally 15-20 ml (9). According one study ultrasound to some degree underestimates the actual volume as compared values obtained after surgical excision (6). The size has inverse relationship to iodine content of diet. It is usually larger in iodine deficient areas and is smaller in iodine sufficient countries like United Stated.

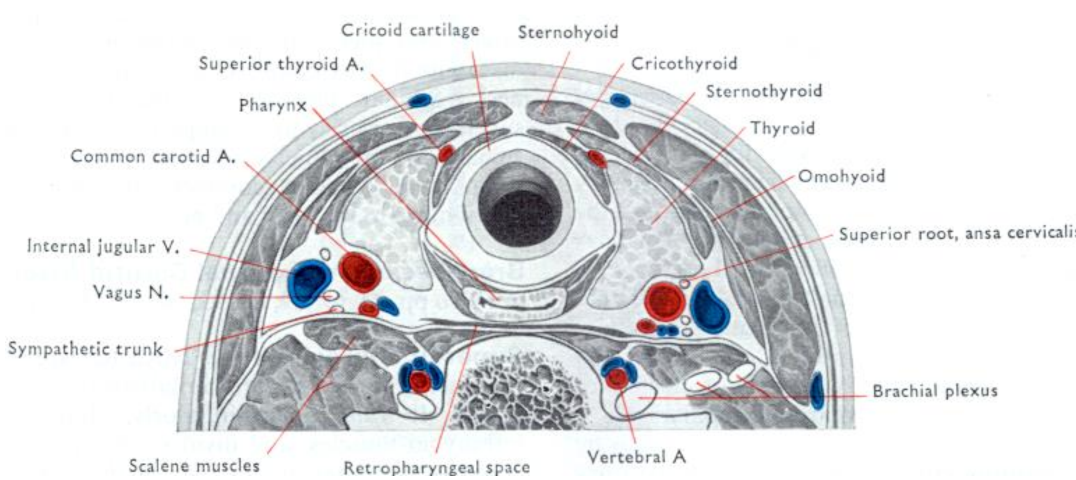

Fig. 1: Cartoon of transverse view of mid neck showing thyroid and anatomical surrounding

There is inverse relationship between urinary iodine and thyroid volume. There is also a relationship between age and body mass index (BMI) and also puberty stage in children and adolescents (4) the size may slightly increase during pregnancy (5). The dimensions of each normal thyroid lobe as measured by ultrasound are 35 by 15-20 by 10-15 millimeter for each lobe. Isthmus overlying trachea is not usually thicker than 3 millimeter, but can be thicker in iodine deficiency and in Hashimoto thyroiditis. The right lobe is usually slightly larger than the left lobe. Thyroid is covered by strap muscles anteriorly and by the longus coli muscles posteriorly. Anterolaterally it borders sternocleido-mastoid muscle. Laterally it borders common carotid artery and more laterally jugular vein (Fig. 2).

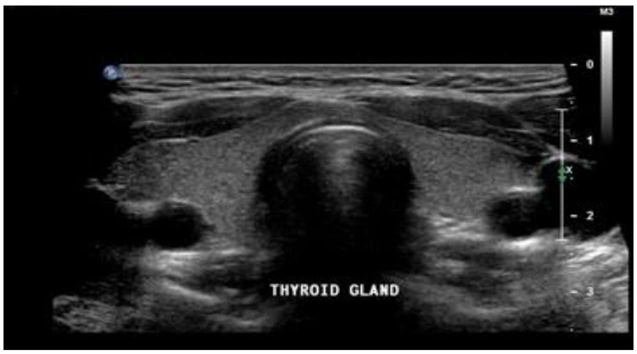

Fig. 2: Ultrasound of thyroid (transverse mid neck). T, trachea: R, right thyroid lobe; L, left thyroid lobe; I, isthmus; C, carotid artery; J, jugular vein. Arrow points to strap muscles

In the upper pole and lower pole superior and inferior thyroidal arteries and veins can be seen by color Doppler flow. Lateral to major blood vessels level III and II and IV lymph nodes can be seen (Fig. 3). Normal lymph nodes have an ellipsoid shape on longitudinal ultrasound view with a distinct hilum. Round, hyper vascular or partially cystic lymph nodes and nodes containing micro calcification are suspicious for malignancy. In Hashimoto thyroiditis lymph nodes may be larger but have normal shape. Esophagus is usually seem on the left side of trachea posterior and median to thyroid, it has a double lumen and should not be mistaken for a nodule. When the patient swallows a bright motion signal is seen in the image of esophagus. Occasionally esophageal diverticulum presents as air containing intra thyroidal image and may create diagnostic challenge in ultrasound interpretation (10). Rarely esophagus can be seen on the right side inferior and median to right lobe of thyroid. Trachea in ultrasound image is echo free and cartilage causes reverberation artifacts (Fig. 2). Parathyroid glands if normal cannot be visualized by thyroid sonography unless there is adenomatous enlargement, in hyperparathyroidism (11). In thyroid sonography other extra thyroidal structures can be identified by sonography (12).

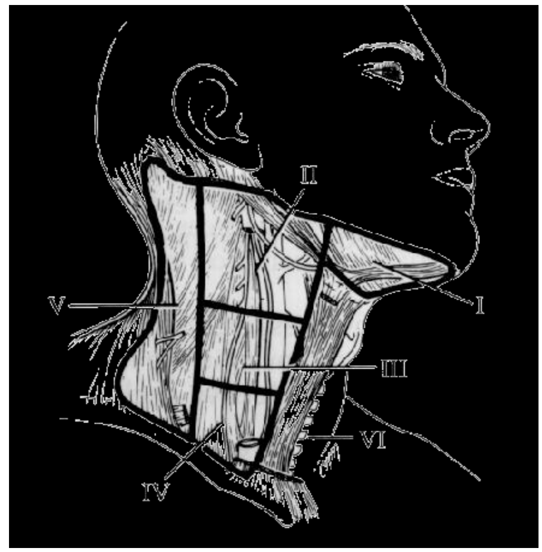

Fig. 3: Schematic view of the neck demonstrating seven anatomic levels for distribution of lymph nodes

Color and power Doppler flow

Doppler studies show movement thus are used to identify vascular structures such as carotid arteries and jugular veins. Assessment of parenchymal vascularity of the thyroid is also important. In a diffuse enlarged thyroid hypervascularity is in favor of Graves hyperthyroidism and Hashimoto thyroiditis (13, 14). On the contrary lack of vascularity may indicate amiodarone induced hyperthyroidism and be helpful in diagnosis of type I from type 2 amiodarone induced thyrotoxicosis (15). Type I hyperthyroidism is iodine induced and usually is associated with nodularity and may have normal vascularity. Type 2 amiodarone induced hyperthyroidism is related to destructive thyroid process. In destructive thyroiditis there is decreased blood flow to thyroid as opposed to Graves' disease (13). In evaluation of a nodule study of vascular pattern in the nodule is also of importance, peripheral vascularity (grade 1or 2) is suggestive of a benign nodule whereas chaotic central vascularity (grade 3 and 4) may suggest a malignant lesion or follicular neoplasm (16, 17). Occasionally Doppler flow signals can be seen within a cyst when debris move and it should not be mistaken with vascularity.

Thyroid nodules
Benign Nodules

Thyroid nodules are very common. In the United States 5% (18) of population have palpable nodules. 30-40% (18) of population has incidentally discovered thyroid nodules by imaging studies done for other purposes such as carotid ultrasound, chest CT or neck CT and MRI or PET scan. When nodules are found on other imaging studies, since US is a more accurate and sensitive for evaluation of thyroid abnormalities, an US is done both for confirmation and evaluation (18). Considering that only 38000 cases of thyroid cancer is diagnosed annually in the United States, it is logical to conclude that likelihood of any individual nodule being malignant would be very low (19, 20). Thus American Thyroid Association guidelines (21) recommend that for selection of lesions for biopsy ultrasonographic features should be considered. For solid nodules less than 1 cm risk factors including family history of thyroid cancer or history of neck and head radiation or ultrasonographic features should be considered for selection of nodules for biopsy. Solid nodules more than 1-1.5 centimeter usually require fine needle aspiration (FNA).

Malignant nodules

Features suggestive of papillary thyroid cancer include, hypo echoic image, irregular borders, sharp angles, micro-calcification and taller than wider size. Cystic nodules with solid components still could be cystic papillary cancers. The most specific feature for papillary cancer is micro-calcification but it still has a specificity of only 70% (22). In my practice and experience of others (23) any calcification especially in a node less than 1.5 centimeter should be considered suspicious and be selected for FNA (24). Ring like eggshell calcification in a nodule is more likely indicative of a benign lesion, particularly if it forms a closed ring (22, 25). Increased intra-nodular vascularity in particular if there is chaotic pattern should also be considered suspicious.

Follicular variants of papillary thyroid carcinomas show a relatively larger size, a lower incidence of a sonographically malignant feature, and a lower diagnostic rate of papillary cancer on cytology compared to conventional papillary cancer (26).

Follicular neoplasms are usually isoechoic or slightly hypoechoic but commonly have increased intra-nodular vascularity (17). However benign neoplasm in these cases cannot be distinguished from malignant ones, thus even after FNA and cytology they are considered suspicious with 15-29% rate of malignancy. Medullary cancer has no specific characteristics; it can be isoichoic or hypoechoic and be vascular and can even have calcifications (27). Hurtle cell cancer may have a halo indicating a capsule and intra nodular and perinodular vascularity but the findings are similar to follicular neoplasm or follicular carcinoma are non-specific (28).

Hurtle-cell variant of follicular carcinoma is more often seen in older patients with nodules having a heterogeneous appearance and may lack internal calcifications (29) But usually the features are non-specific (28). A cytological diagnosis or Hurthle cell neoplasm should also be considered suspicious and carries a post-surgical diagnosis of Hurthle cell neoplasm of 15%.

Diffuse enlargement of thyroid

In the absence of nodularity or malignancy, various autoimmune or non-autoimmune conditions may show increased thyroid size and volume and manifest ultrasonographic abnormalities. Hashimoto thyroiditis may present as enlarged goitrous thyroiditis or as atrophic thyroiditis. Echo pattern displays evidence of structural disruption such as heterogeneous echo texture, Swiss cheese appearance, or pseudo-nodularity. The earliest sign of Hashimoto thyroiditis could be hypoechogenicity. Pseudo-nodules may be hypoechoic and occasionally hyperechoic. In particular enlargement of the isthmus is noted. Earlier phases are associated with hypervascularity of thyroid on Doppler images, however long standing fibrotic hypothyroid

Hashimoto may be hypervascular or hypovascular depending on the degree of fibrosis (30). Longstanding hypothyroid Hashimoto is usually associated with smaller size of thyroid. Hashimoto thyroiditis usually is symmetrical. If there is significant asymmetry or a distinct nodule is present ultrasound is needed for further evaluation and possible FNA.

Graves' disease in the hyperthyroid stage may have similar heterogeneous echotexture but usually is not hypoechoic and is highly vascular and degree of vascularity is proportional to severity of hyperthyroidism. Italian ultrsonographers have coined the term "inferno" for hypervascular thyroid gland in Graves' disease.

Thyroid lymphoma is rare and usually develops in the background of Hashimoto thyroiditis (31). Although it occasionally may be localized and present as hypoechoic mass, or may have enhanced posterior echo (32), it is usually diffuse and ultrasound features are nonspecific. Suspicious clinical picture and rapid growth of thyroid should result in core or open biopsy.

Invasive fibrous thyroiditis or Riedels thyroiditis presents with aggressive clinical picture and extension of fibrosis outside of thyroid. Ultrasound shows hypoechoic pattern with reduced vascularity. Occasionally extension outside of thyroid with engulfment or narrowing of major vessels is seen in ultrasound images (33). Iodine deficiency may present as enlargement of thyroid and increased thyroid volume (34) and in advanced cases as multinodular goiter (35, 36). Other goitrogens such as pharmacologic iodine and lithium may also result in diffuse thyromegaly.

Evaluation of neck lymph nodes

A part of examination of thyroid should be evaluation of lymph nodes of the neck, particularly at levels II, III, IV and VI (Fig. 3). Normal lymph nodes are ellipsoid, with a hilum. Reactive lymph nodes may be larger but keep the usual shape. In autoimmune thyroid disease lymph nodes are more prominent. Prominent para-tracheal lymph nodes are characteristic of autoimmune thyroiditis (37). Malignant lymph nodes particularly papillary cancer have round appearance, are hypo echoic and may have microcalcification and may also be cystic. However, unilateral enlarged lymph nodes may be considered suspicious in the presence of an ipsilateral thyroid nodule (38). Follicular cancer is usually not associated with neck node metastases but Hurtle call cancer may have nodal metastases.

Ultrasound guided fine needle aspiration biopsy

At the present time standard of care for evaluation of thyroid nodules is ultrasound guided fine needle aspiration biopsy (39). This is usually done by FNA, either free hand or with the use of a guide. In my practice I routine use a guide. A core biopsy also can be done in selected cases (40) but does not have superiority to fine needle (25 to 27 gauge) in our experience (41). Aspiration by a 10 ml syringe or a capillary method without aspiration can be used. If the specimen is mixed with excessive blood, capillary method is preferable. The needle should be directed at the solid part of the nodule. In predominantly cystic lesions cystic material can be aspirated and cell blocks be prepared by cytologist. In evaluation of lymph nodes in particular if they are cystic and cytology may be non-diagnostic evaluation of wash out of the aspirate with measurement of thyroglobulin can distinguish metastatic lymph nodes from normal or reactive lymph nodes (42). The details of cytological evaluation and interpretation are out of the scope of this chapter.

Ultrasound elastograpy in evaluation of thyroid nodules

Ultrasound elastography (USE) is a newly developed technique for the evaluation of tissue stiffness. It is known that malignancies often show a low-strain value. USE is a useful adjunctive tool in the workup of thyroid nodules. A low strain value nodule is worrisome for malignancy, whereas a high strain value predicts a benign histology (43). The difference between benign and malignant nodules is due to stiffness and less pliability of malignant nodule. In fact this method quantitates the firmness of malignant nodules felt in palpation as compared to soft feeling benign palpable nodules. For this method special equipment is needed and its routine use requires more studies.

Parathyroid imaging

At the present time (99 m) Technetium-sestamibi scintigraphy with single-photon emission computed tomography (SPECT) imaging of parathyroid is the most sensitive diagnostic image for preoperative localization of parathyroid adenoma (44). However ultrasonography can be used as an alternative or in association with isotopic parathyroid scan for confirmation (45). In questionable cases and in re-operative cases confirmation by FNA and measurement of parathyroid hormone in aspirate sets the stage for minimally invasive surgery (11). Some authors have suggested that even in the unequivocal localization of parathyroid adenoma by isotopic scan an ultrasound should be done to detect co-existent thyroid pathology to avoid difficult intra operative decisions (46). However this issue is controversial. Normal parathyroid glands are not seen in ultrasound imaging. Usual ultrasonographic image of parathyroid adenoma is a triangular hypoechoic image posterior to thyroid (11). Parathyroid adenomas are pliable and with pressure of transducer the image changes and usually flattens (11).

Conclusion

With availability of sensitive and affordable ultrasound equipment, thyroid ultrasonography has become a part of thyroid practice and endocrinologists are using office ultrasound as extension of their physical examination for diagnosis of thyroid disorders. In particular ultrasound guided biopsy of thyroid nodules and follow up of nodules by thyroid ultrasound has become routine and is recommended by scientific organizations.

For follow up of thyroid cancer ultrasound of the neck is the most sensitive imaging for detection of metastatic lymph nodes from thyroid cancer. Neck ultrasound is also helpful in detection of parathyroid adenomas in conjunction with isotopic parathyroid scan.

Newer techniques such as ultrasound elastography may add new dimensions to diagnostic use of ultrasound in detection of malignant thyroid nodules.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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The authors declare that there is no conflict of interest.

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