

Update on Ultrasound Diagnosis for Thyroid Cancer

FN Baig¹, SYW Liu², SP Yip¹, HKW Law¹, MTC Ying¹

¹Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Hunghom, Hong Kong

²Department of Surgery, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong

ABSTRACT

Thyroid nodules are prevalent in the general population. Distinguishing benign and malignant thyroid nodules is a clinical challenge. Although ultrasonography is commonly used for the assessment of thyroid nodules, previous studies have found that its usefulness is controversial. Therefore, there is a need to assess the clinical value of ultrasonography reported in the literature. This article reviews the literature on the clinical value of greyscale ultrasonography, colour and power Doppler ultrasonography, and ultrasound elastography in differentiating benign and malignant thyroid nodules.

Key Words: Neoplasms; Thyroid gland; Ultrasonography

中文摘要

甲狀腺癌超波診斷的最新進展

FN Baig、廖玉華、葉社平、羅嘉慧、應天祥

甲狀腺結節在一般人口中是很普遍的。區分良性和惡性甲狀腺結節是一個臨床挑戰。雖然超聲波檢查常用於評估甲狀腺結節，但以往的研究結果存在爭議。因此，有必要評估以往文獻報導超聲波檢查的臨床價值。本文回顧灰度超聲波、彩色和能量多普勒超聲波，以及超聲波彈性成像在鑑別良性和惡性甲狀腺結節中的臨床價值。

INTRODUCTION

Thyroid nodules are discrete lesions found in 20% to 76% of the general population. There has been a 2- to 3-fold increase in the incidence of thyroid cancer over the past 30 years.¹ Thyroid ultrasonography is the first-line imaging investigation for identifying and

characterising thyroid nodules. Thyroid ultrasonography has various advantages, such as high availability, non-invasiveness, relative low cost, and excellent temporal and spatial resolution. Doppler ultrasonography and ultrasound elastography can evaluate the vascularity and stiffness of thyroid nodules, respectively.² How-

Correspondence: Dr MTC Ying, Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong.
Email: michael.ying@polyu.edu.hk

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ever, operator dependency is a major limitation of ultrasonography. Ultrasonography is important in the assessment of the malignancy risk of thyroid nodules, and in the selection of nodules for fine-needle aspiration, cytology, and treatment.³ Ultrasonography also helps in guiding fine-needle aspiration because of its real-time capability. Most thyroid nodules are incidental findings, but their risk of malignancy correlates well with the findings of subsequent ultrasonography.⁴

In clinical settings, thyroid ultrasonography is indicated in the following conditions: palpable mass in the anterior neck, dysphagia, dyspnoea, dysphonia, persistent cough (not related to cold), palpitation, cardiac arrhythmia, monitoring of treatment of thyroid disease, and postoperative follow-up.³ In this article, we review the clinical value of greyscale ultrasonography (GSU), Doppler ultrasonography, and ultrasound elastography in the differentiation of benign and malignant thyroid nodules. We also discuss the application of microvascular imaging techniques in the Doppler ultrasound assessment of thyroid nodules.

GREYSCALE ULTRASONOGRAPHY

GSU is a useful imaging technique for assessing the morphology of the thyroid gland and the pathology of thyroid nodules. In general, the normal thyroid gland has a homogeneous echotexture. It is hyperechoic compared to the adjacent sternocleidomastoid muscle. In adult humans, the thyroid volume ranges from 5 cm³

to 20 cm³; the volume varies with sex, age, body weight, and other physiological and environmental factors.⁵

Each thyroid lobe has a globular appearance (height 3-4 cm, width 1-1.5 cm, depth 1 cm) and is interconnected by the isthmus, which is identified as a homogeneous structure (height 0.5 cm, depth 2-3 cm) anterior to the trachea. The pyramidal lobe is usually not visible on ultrasonograms of adults but can be observed on those of young children. The oesophagus is located slightly to the left; the oesophageal lumen is air and fluid-filled, with the sonographic appearance of a hyperechoic centre surrounded by a hypoechoic rim due to the presence of oesophageal musculature. Together, these features give the oesophagus a characteristic 'bull's eye' shape on greyscale ultrasonogram. Sternocleidomastoid and strap muscles are located on the anterior aspects of the thyroid gland. The common carotid artery is situated lateral to the thyroid lobe on both sides. Further lateral to the common carotid artery is the internal jugular vein. A patent internal jugular vein is compressible by the transducer and can be distended by a Valsalva manoeuvre for better visualisation. Other manoeuvres, such as swallowing, can be used for identification of the oesophagus (Figures 1 and 2). For scanning of large goitres, panoramic ultrasound can be used to obtain images with a large field of view (Figure 3).

Malignant features of thyroid nodules such as microcalcification, absent halo sign, heterogeneity, irregular

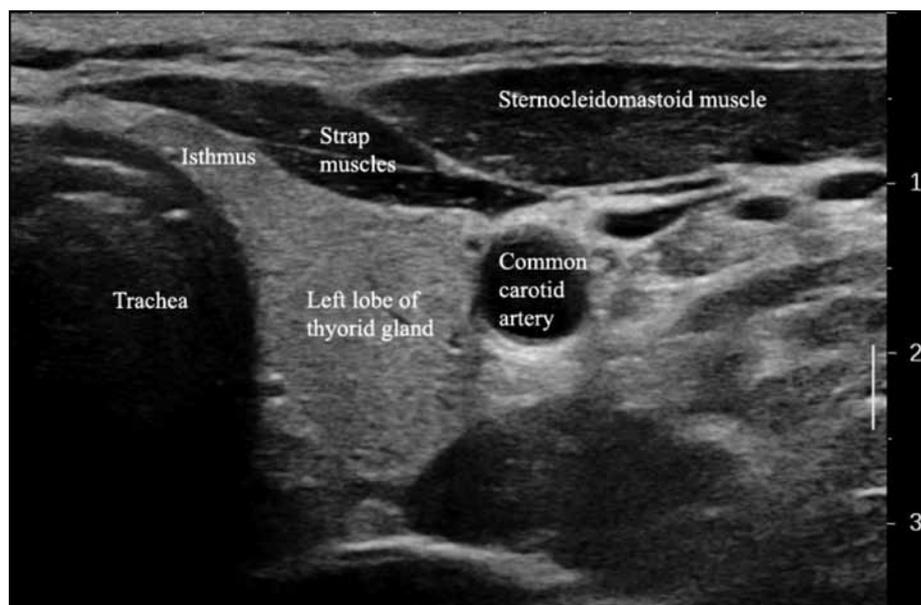


Figure 1. Transverse greyscale ultrasonogram showing a normal left thyroid lobe and adjacent anatomical structures.

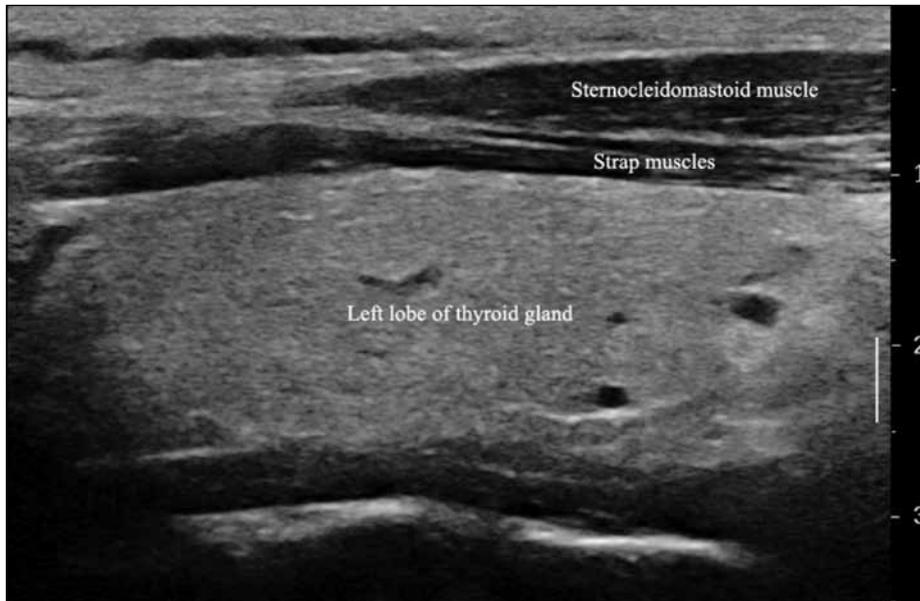


Figure 2. Longitudinal greyscale ultrasonogram showing the left lobe of a normal thyroid gland.

border, and height-to-width ratio of >1 can be identified using GSU; GSU can also be used to differentiate cystic from solid nodules.^{6,7} However, the sensitivity and specificity of GSU vary considerably, from 52% to 97% and from 26% to 83%, respectively.⁸ Therefore, a clear understanding of the common ultrasound features of benign and malignant nodules is essential in the ultrasonography of thyroid nodules.

Features of Benign Thyroid Nodules on Greyscale Ultrasonography

Cystic Component

Thyroid nodules with a greater cystic proportion are usually benign, as are spongiform (multiple cystic components in Figure 4) nodules; however, not every cystic nodule is benign. Papillary thyroid cancer tends to appear cystic when it is large.⁹

Comet Tail Sign

The comet tail sign is highly specific for benign thyroid nodules and represents colloid lesions. The overall sensitivity, specificity, and accuracy of this sign are 74%, 83%, and 81%, respectively.¹⁰ There is a high similarity between the appearance on ultrasonography of colloid and that of small punctate calcifications (a highly specific feature of papillary thyroid cancer) because both are hyperechoic. However, a distinction can be made by noticing the presence of the comet tail sign behind the colloid. Punctate calcifications do not exhibit the comet tail sign (Figure 5).¹¹

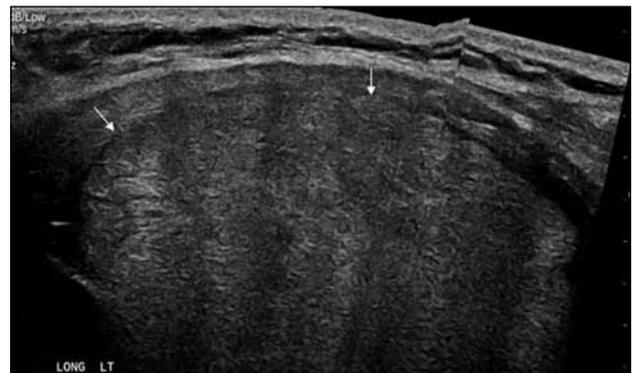


Figure 3. Panoramic greyscale ultrasonogram demonstrating an extended field of view in a longitudinal scan of a benign nodule (arrows) in the left lobe of a thyroid gland.



Figure 4. Transverse greyscale ultrasonogram showing a benign thyroid nodule with spongiform appearance (arrows).

Regular Margins

In comparison with malignant thyroid nodules which usually have irregular margins (55.6%) due to tumour infiltration and stromal changes, benign thyroid nodules tend to have well-defined borders (83.3%), possibly because they are localised and do not proliferate in an uneven manner (Figure 6).¹²

Peripheral Halo Sign

The peripheral halo sign is common in benign thyroid nodules. The peripheral halo sign appears thin and complete, with hypoechoic rims surrounding the nodule (Figure 7). The peripheral halo sign is possibly associated with the rapid but controlled growth of thyroid neoplastic cells, which causes compression of

the adjacent thyroid parenchyma.¹³ A halo may also appear in malignant nodules; however, these halos are usually incomplete, possibly owing to the uneven and uncontrolled cell growth of thyroid cancer cells. In most cases, a halo sign is absent in malignant thyroid lesions.¹⁴

Multinodularity

Multinodularity is commonly observed in benign thyroid lesions (Figure 8). Malignant thyroid nodules are usually solitary.¹³ However, the risk of thyroid cancer with multinodularity should not be underestimated.¹⁵ Benign and malignant thyroid nodules may be found in the same gland. It has previously been reported that 10% to 20% of papillary thyroid cancer are multicentric.¹⁶



Figure 5. Transverse greyscale ultrasonogram showing a benign thyroid nodule with colloid depositions which are shown as hyperechoic foci with comet tail signs (arrowhead).

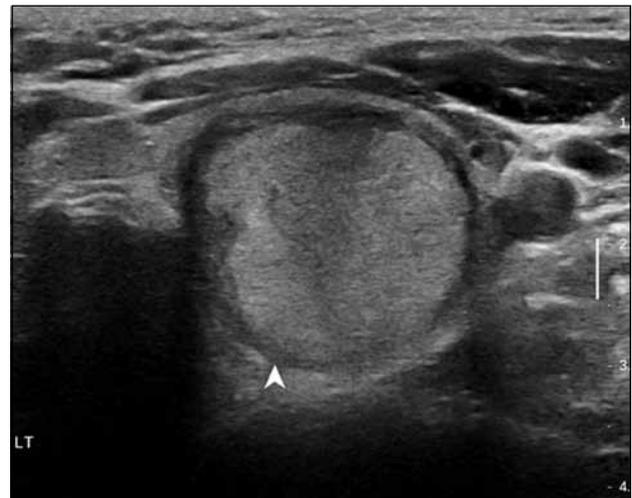


Figure 7. Transverse greyscale ultrasonogram showing a benign thyroid nodule with hypoechoic peripheral halo sign in the left thyroid lobe (arrowhead).



Figure 6. Longitudinal greyscale ultrasonogram showing a benign thyroid nodule which is isoechoic when compared with adjacent normal thyroid parenchyma and has well-defined, regular margins (arrows).

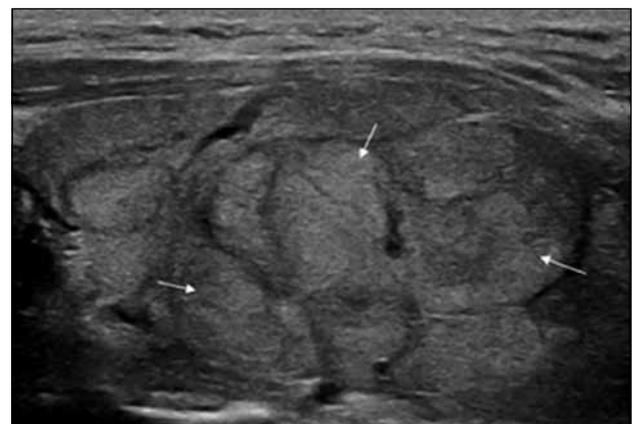


Figure 8. Longitudinal greyscale ultrasonogram showing a multinodular goitre in a thyroid lobe. Multiple nodules within the thyroid gland are indicated by arrows.

Features of Malignant Thyroid Nodules on Greyscale Ultrasonography

Echogenicity

Solid malignant tumours, such as papillary thyroid cancer, are packed with denser material, such as collagen, and have higher interstitial fluid pressure when compared with normal thyroid follicles. This higher interstitial pressure may weaken the acoustic impedance at the interface and decrease ultrasound reflection that results in the hypoechoic appearance of malignant thyroid nodules (Figure 9).¹⁷

Irregular Margins

Malignant thyroid nodules tend to have irregular margins.¹⁸ This could be because thyroid tumour cells proliferate in an uneven manner, leading to the irregular nodular margins seen on ultrasonography (Figure 9).¹³

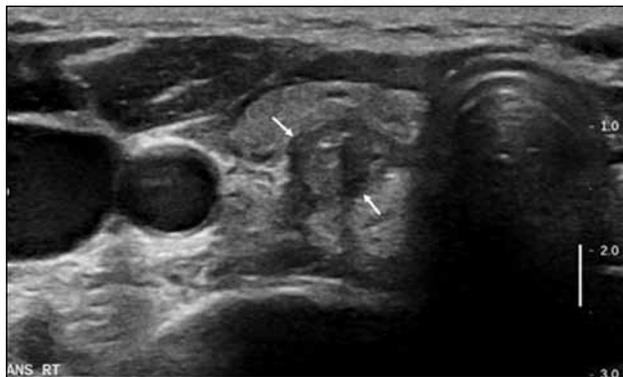


Figure 9. Transverse greyscale ultrasonogram showing a hypoechoic malignant thyroid nodule in the right thyroid lobe (arrows). The nodule appears hypoechoic when compared with the adjacent thyroid parenchyma and has ill-defined, irregular borders.



Figure 10. Longitudinal greyscale ultrasonogram showing a hypoechoic malignant thyroid nodule with microcalcification (arrow) at the peripheral region of the nodule.

Microcalcification

Microcalcifications appear as hyperechoic foci without acoustic shadows on GSU. The presence of microcalcifications within thyroid nodules is highly associated with thyroid malignancy. Ultrastructural investigation of thyroid nodules with microcalcifications shows thickening of the base lamina of neoplastic papillae followed by calcification, collagen production by necrotic tumour cells, and formation of ‘psammoma bodies’ (Figure 10).¹⁹

Aspect Ratio Greater than 1 or Taller-than-wide Appearance

An aspect ratio (i.e. anteroposterior diameter relative to transverse diameter) of >1 is associated with malignant thyroid nodules.²⁰ The presence of an aspect ratio >1 raises the suspicion of thyroid malignancy, and papillary thyroid cancer tends to demonstrate taller-than-wide appearance.²¹ It has been suggested that the tall cell variants of papillary thyroid cancer might be associated with the taller-than-wide appearance of this kind of tumour on ultrasonography (Figure 11).²²

Although GSU can be used to accurately identify suspicious features for malignancy (i.e. microcalcification, irregular margins, hypoechoicity, and taller-than-wide appearance), the sensitivity and specificity of GSU vary considerably.⁸ Moreover, these findings are based on subjective and qualitative assessments and vulnerable to intra- and inter-observer variability. The American Thyroid Association suggests that no single or combination of GSU features are sensitive or specific enough to detect all malignant thyroid nodules.^{13,23} The diagnostic performance of various GSU features conferring malignancy among available studies in the literature are compared in Table 1.^{7,12,20,22-30}

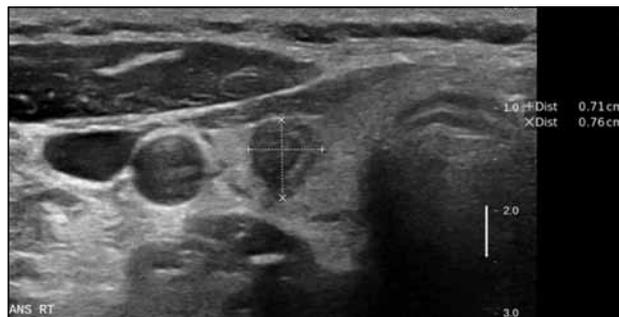
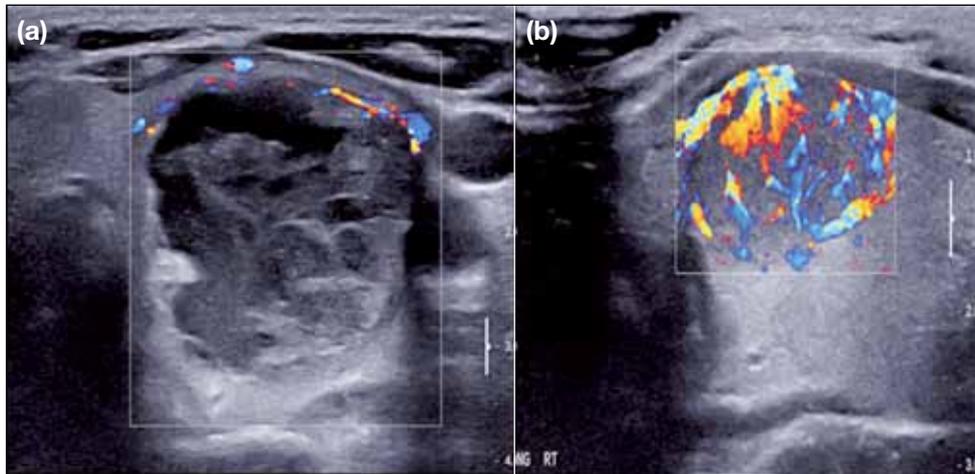


Figure 11. Transverse greyscale ultrasonogram showing a malignant nodule in the right thyroid lobe with an aspect ratio (anteroposterior diameter relative to transverse diameter) of >1 .

Table 1. Diagnostic performance of various greyscale ultrasound features in differentiating benign and malignant thyroid nodules.

Features suspicious of malignancy	Median sensitivity (%) \pm 1 standard deviation	Median specificity (%) \pm 1 standard deviation
Hypoechoogenicity ^{7,12,22-30}	67.4 \pm 22.4	74.0 \pm 19.9
Irregular margins ^{7,12,23-28,30}	55.3 \pm 14.8	83.1 \pm 8.4
Microcalcification ^{7,12,20,23-30}	56.0 \pm 17.7	88.8 \pm 9.6
Taller than wide ratio >1 ^{7,12,22,23,26,29,30}	56.0 \pm 20.7	91.4 \pm 6.1

**Figure 12.** Colour Doppler ultrasonograms showing (a) a benign thyroid nodule in the left thyroid lobe demonstrating peripheral vascularity; and (b) a malignant nodule in the right thyroid lobe showing vascularity in both peripheral and central regions of the nodule.

DOPPLER ULTRASOUND

Colour and power Doppler ultrasonography have been used in the detection and assessment of the vasculature in normal structures and pathologies.¹⁴ The usefulness of Doppler ultrasonography to predict thyroid malignancy by assessing thyroid nodular vascularity remains controversial.^{24,31,32} Some studies have claimed that hypervascularity is an independent predictor of thyroid cancer.^{14,33} Khadra et al³⁴ reported that hypervascularity may indicate a high risk of thyroid malignancy when combined with suspicious GSU features in thyroid nodules with indeterminate cytology. However, they also claimed that hypervascularity itself was not an independent predictor of thyroid malignancy.³⁴ Some studies have suggested that central vascularity is a feature for thyroid malignancy, whereas benign thyroid nodules tend to have peripheral vascularity (Figure 12).^{23,35-38} However, other studies have noticed a higher association of central vascularity with benignity rather than malignant status of thyroid nodules.^{31,39,40} Shah et al⁴¹ suggested that, when making a decision for thyroidectomy, intranodular vascularity on ultrasonography should not be used as an independent

parameter to determine the risk of malignancy in patients with an atypical cytology result.⁴¹ Some studies have found that the vascular pattern of the thyroid nodule (avascularity, peripheral and central vascularity) was useful in predicting thyroid malignancy,^{35,36,42} whereas others have found that vascular pattern was not useful in predicting malignancy.^{39,43-45} The conflicting findings in these studies likely arose because the nodular vascularity was qualitatively assessed by visual perception and thus would be prone to intra- or inter-observer variation.⁴⁶

It has been reported that using objective and quantitative measurement of nodular vascularity would allow a more accurate prediction of thyroid malignancy.⁴⁷ In a recent study, Baig et al³⁷ proposed a novel method that used an automated computer-aided approach for regional segmentation of thyroid nodules. The vascularity indexes of the peripheral and central sections of the thyroid nodule were evaluated to differentiate benign and malignant lesions. This proposed approach is objective, highly reproducible, and has the advantage of eliminating the risk of intra- or inter-observer

variation inherent with manually outlining regions of interest between the peripheral and central sections of a thyroid nodule. The authors further elaborated that central vascularity, when combined with suspicious GSU features for malignancy, enhanced the diagnostic accuracy of the proposed approach in identifying thyroid malignancy.³⁷

Previous studies have assessed the pulsatility index and resistance index of thyroid nodules to differentiate benign and malignant nodules. However, the results of these studies were controversial and inconsistent.^{23,44,48-51} Some studies suggested that the resistance index was higher in malignant nodules than that in benign nodules.^{50,52,53} However, Tamsel et al⁴⁴ reported that resistance index was not a useful predictor of thyroid malignancy. Moreover, the reported cut-off for resistance index between benign and malignant nodules varied from 0.665 to 1.53.^{44,48-51,54} Pulsatility index was found to be a useful predictor for thyroid malignancy.⁴⁸⁻⁵⁰ However, more studies are needed to standardise the optimum cut-off between benign and malignant nodules.⁴⁸⁻⁵⁰ Although the pulsatility index and resistance index of thyroid nodular vascularity can be evaluated, their measurement using spectral Doppler ultrasound is time-consuming. Therefore, the roles of pulsatility index and resistance index in routine clinical practice are limited.

With the advancement of technology, ultrasound techniques for the assessment of microvasculature have been developed, such as superb microvascular imaging (developed by Toshiba Medical Systems Corporation, Tochigi, Japan) and AngioPLUS (PLanewave UltraSensitive™ imaging; Supersonic Imagine, Aix-en-Provence, France).

Superb microvascular imaging uses a unique algorithm and allows visualisation of smaller blood vessels without clutter. Conventional Doppler ultrasound uses a wall filter to remove clutter and motion artefacts at the cost of losing low-flow frames. In contrast, superb microvascular imaging uses an advanced algorithm to identify and eliminate tissue motion artefacts and determine blood flow with a higher accuracy.⁵⁵ Kong et al⁵⁶ evaluated 113 thyroid nodules and performed a comparative study between power Doppler ultrasonography and superb microvascular imaging to identify thyroid malignancy. They found that intranodular vascularity was 75.9% sensitive and 91.2% specific for superb microvascular imaging,

compared with 41.8% sensitive and 82.3% specific with power Doppler ultrasonography. The authors suggested that superb microvascular imaging for evaluating intranodular vascularity was useful for predicting thyroid cancer and that it enhanced the diagnostic accuracy when combined with suspicious GSU features. However, the absence of intranodular vascularity does not exclude the risk of malignancy.⁵⁶

AngioPLUS is a recently launched technique for the detection and evaluation of small blood vessels with high sensitivity. AngioPLUS provides a high image resolution and three-dimensional wall filtering that allows efficient discrimination between blood vessels and soft tissues.⁵⁷ To date, no clinical study has evaluated the value of AngioPLUS in the assessment of thyroid vasculature. AngioPLUS is commonly used in combination with colour or power Doppler ultrasonography. In our experience, AngioPLUS in combination with colour or power Doppler ultrasonography has higher sensitivity than solely colour or power Doppler ultrasonography in the assessment of thyroid vasculature (unpublished data). More studies are warranted to determine the clinical role of AngioPLUS in differentiating benign and malignant thyroid nodules.

ULTRASOUND ELASTOGRAPHY

Ultrasound elastography is a novel technique that quantifies the elastic properties of soft tissues. This technique provides information on tissue stiffness and evaluates the degree of distortion of soft tissue under stress. The basic principle of ultrasound elastography is that the force applied to the soft tissue is proportional to the tissue deformation (strain). It can be expressed as Young's modulus (E), i.e. applied force/strain.³⁶ Because Young's modulus is dependent on the applied stress, tissue strain is only comparable in elasticity maps with a homogeneous stress field. Ultrasound elastography allows tissue to undergo reversible deformation and provides data on the acoustic and mechanical properties of the area under study. Softer parts of a tissue are less resistant to stress compared with stiffer regions within the same tissue.⁹ There are two main variants of elastography techniques: strain elastography (SE) and shear-wave elastography (SWE), which provide qualitative and quantitative assessments of tissue stiffness, respectively. SE is also known as freehand quasistatic elastography or real-time elastography, which is an add-on module incorporated with standard ultrasound units. It is widely available in commercial units and can be used with a conventional

ultrasound transducer.⁵⁸ The technology employs mechanical force (either an external force applied by a transducer, or an internal source of compression, such as carotid pulsation) to induce tissue strain that results in axial displacement. Ultrasound waves are sent before and after tissue displacement. A high degree of tissue displacement (i.e. higher strain) is associated with the softer regions of tissue whereas stiffer regions exhibit minimal or no displacement (i.e. lower or no strain). The time difference between regions of interest of two consecutive images is recorded while dedicated software evaluates tissue strain. This software generates a colour-coded elastography image, i.e. an elastogram.^{58,59}

Currently, there is no standardised method available for the qualitative interpretation of an elastogram.⁶⁰ However, two assessment methods are commonly used in clinical practice: the elastography scoring system and the strain ratio (SR). The elastography scoring system, which is based upon four to six scales, assesses relative tissue stiffness within the lesion. According to this assessment system, softer lesions are assigned lower elastography scores and stiffer lesions are given higher elastography scores. For SR measurements, regions of interest are selected on the target lesion and the adjacent reference tissue. The SR is computed as the ratio between the strain of the target lesion and the strain of the reference tissue within the same image. In general, an SR of >1 suggests the target lesion has a higher stiffness than the reference tissue. The risk of malignancy of a lesion can be interpreted as higher with increasing SR and lower with decreasing SR.

The elastography scoring system and SR are used as diagnostic parameters for SE. Therefore, SE is more subjective and yields qualitative and semi-quantitative information.⁶¹⁻⁶³ All SE methods require a trained and experienced operator to perform freehand cyclic compression to achieve reproducible results. Freehand compression is difficult to standardise and may introduce non-uniform compression among different operators, creating potential intra- or inter-observer variation.⁶⁴ In a recent study, SE was found to be useful in predicting thyroid malignancy. However, the authors found that the addition of SR to colour mapping was not as useful as colour mapping alone.⁶³ In contrast, a recent meta-analysis suggested that SR was a better predictor of thyroid malignancy than any other qualitative ultrasound feature.⁶⁵ Another study found that SR was useful in identifying papillary thyroid cancer.⁶⁶ Various studies have claimed that SE provides promising results in

differentiating benign and malignant thyroid nodules.⁶⁷⁻⁷⁰ Another study that included 102 thyroid nodules claimed that results recorded using carotid artery pulsation were more reliable than those recorded with an external source of compression.⁷¹ Two previous studies showed that a reduction of 53% and 60.8% in the rate of fine-needle aspiration of thyroid nodules can be achieved by using a standard deviation of strain within the thyroid nodule with systolic or diastolic stiffness index, respectively.^{67,72} Despite the usefulness of an intrinsic compression method (i.e. carotid artery pulsation), there are some inherent drawbacks caused by carotid artery pulsation, such as non-uniform tissue deformation and SR index (ratio of strain distributed in two regions of interest). The SR between adjacent normal thyroid parenchyma and thyroid lesions can easily be affected by hypertension, carotid atherosclerosis, or arrhythmia. Medullary thyroid carcinoma and follicular thyroid carcinoma should not be evaluated by SE alone because they may appear soft and introduce false-negative results leading to a missed diagnosis.⁷³

SWE quantifies local tissue stiffness without being affected by any hard regions in the vicinity of the region of interest.⁷⁴ SWE does not require manual compression but uses highly focused ultrasound impulses at various depths of the tissue to induce tissue displacement. Tissue displacement of a few microns results in the generation of shear waves which propagate transversely and perpendicular to the direction of ultrasound waves. Shear waves travel at a much faster rate in stiffer regions than in softer regions. Shear-wave velocity is directly proportional to the square root of the Young's modulus, assuming the homogeneous density of the medium of propagation. To measure the soft-tissue stiffness, the propagation speed of shear waves is tracked by an ultrafast sonographic tracking technique, and the tissue stiffness is quantified and expressed in units of m/s or kPa.^{75,76} Compared with SE, SWE is more objective, less operator-dependent, and highly reproducible. The tissue stiffness calculated by SWE is expressed as an elasticity index ($E_{\text{maximum}}, E_{\text{mean}}, E_{\text{minimum}}$) [Figures 13 and 14].

One recent meta-analysis, which comprised of 131 studies, including 1867 thyroid nodules from 1525 patients, found that the pooled sensitivity and specificity of SWE in differentiating benign and malignant thyroid nodules were 84.3% and 88.4%, respectively.⁷⁷ The authors concluded that SWE was more promising in differentiating benign and malignant thyroid nodules than any other ultrasound elastography technique.⁷⁷

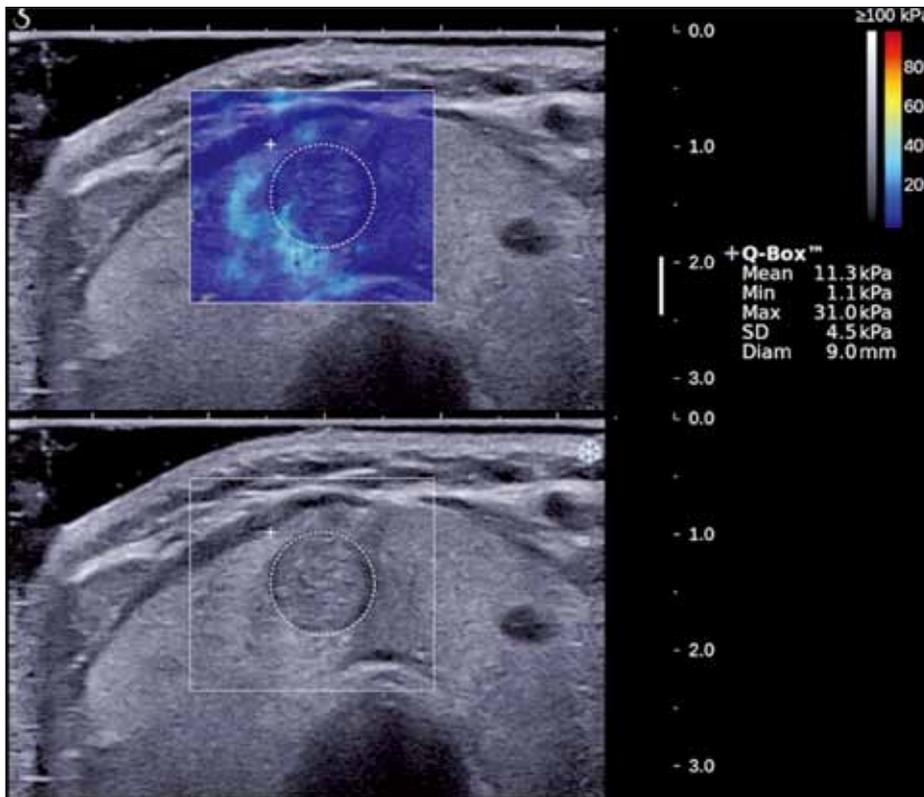


Figure 13. Shear-wave elastogram showing a transverse scan of a benign thyroid nodule. The benign nodule has lower stiffness values (mean 11.3 kPa, minimum 1.1 kPa, maximum 31 kPa) than does the malignant nodule shown in Figure 14.

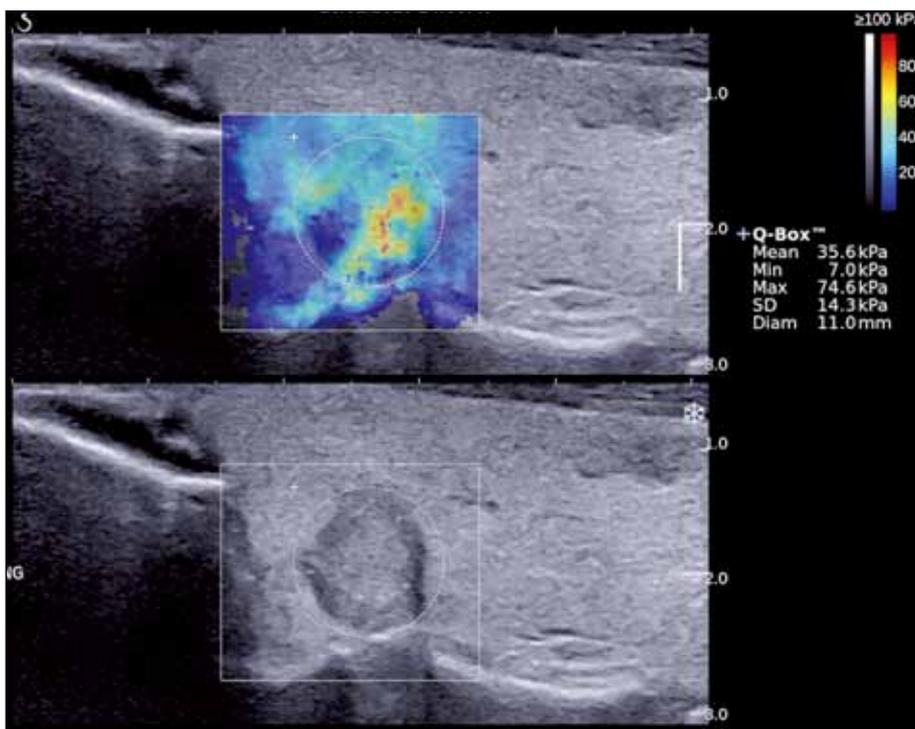


Figure 14. Shear-wave elastogram showing a longitudinal scan of a malignant thyroid nodule. The malignant nodule has higher stiffness values (mean 35.6 kPa, minimum 7 kPa, maximum 74.6 kPa) than does the benign nodule shown in Figure 13.

Table 2. Diagnostic performance of GSU alone and GSU + ultrasound SWE combination in differentiating benign and malignant thyroid nodules.

Method of ultrasound shear-wave technique	Sensitivity		Specificity	
	GSU (%)	GSU+SWE (%)	GSU (%)	GSU+SWE (%)
$E_{\text{maximum}} \geq 67.3 \text{ kPa}^{12}$	96.3	70.4	46.4	83.3
$E_{\text{mean}} \geq 23.1 \text{ kPa}^{12}$		74.1		79.8
$E_{\text{maximum}} \geq 65 \text{ kPa}^{59}$	77.1	97.1	58	55.3
$E_{\text{minimum}} \geq 85.2 \text{ kPa}^{78}$	92.9	95	60.8	56.7
$E_{\text{minimum}} \geq 39.3 \text{ kPa}^{79}$	76.2	87.1	83	92.9
$E_{\text{maximum}} \geq 53 \text{ kPa}^{60}$	90.5	50	59.7	72.5
$E_{\text{mean}} \geq 62 \text{ kPa}^{60}$		50		80.0
$E_{\text{minimum}} \geq 65 \text{ kPa}^{60}$		50		82.5
$E_{\text{mean}} \geq 34.5 \text{ kPa}^{80}$	89.1	95.7	90.1	94.5

Abbreviations: E = Young's modulus; GSU = greyscale ultrasound; SWE = shear-wave elastography.

Few studies have evaluated the efficacy of combining SWE with GSU in identifying thyroid malignancy. The results of studies that have combined GSU with SWE are summarised in Table 2.^{12,59,60,78-80} The value of combining SWE with GSU in distinguishing benign and malignant thyroid nodules remains controversial. Some studies found an increase in sensitivity but a decrease in specificity when combining the two ultrasound modalities.^{59,78,79} In contrast, other studies have shown the opposite result, in which combining GSU and SWE demonstrated an increase in specificity but a decrease in sensitivity.^{12,60} Furthermore, another study has demonstrated an increase in both sensitivity and specificity when combining SWE with GSU.⁸⁰ Further studies are warranted to verify the clinical significance of combining SWE with GSU in assessing thyroid malignancy.

The performance of SWE has also been evaluated in predicting thyroid malignancy in thyroid lesions with indeterminate cytology. A recent study found that SWE was 93.3% sensitive and 100% specific with an overall diagnostic accuracy of 97.8% for thyroid nodules with indeterminate cytology.⁸¹ Therefore, SWE may be useful in the diagnosis of thyroid nodules with indeterminate cytology.

CONCLUSIONS

Ultrasonography is a useful and reliable imaging method for assessing thyroid nodules and for distinguishing benign and malignant thyroid nodules. In ultrasound examination of thyroid nodules, GSU is the most commonly used imaging technique. Other techniques such as Doppler ultrasound and ultrasound

elastography can be used as an adjunct to enhance diagnostic accuracy. The efficacy of new ultrasound techniques in thyroid nodule assessment, such as superb microvascular imaging, AngioPLUS and SWE, should be further explored and verified in large-scale studies.

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