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Original Research Article

Comparison between Ultrasound Elastography and Fine Needle Aspiration Biopsy for Evaluation of Thyroid Nodules

Ibrahim Abbas Awad

Diagnostic Radiology Department, Faculty of Applied Medical Science, King Abdulaziz University, KSA.

ABSTRACT

Our study aimed to compare between ultrasound elastography (UE) and fine needle aspiration cytology (FNAC) in prediction of malignancy in thyroid nodules based on histopathology results.
A total of 60 patients with thyroid nodules, who had an indication of thyroidectomy, were involved in this study after approval was obtained. They were selected for ultrasound elastography (UE) and fine needle aspiration before surgery. Then followed by FNA, and further with histopathology after surgery.
19 cases in elastography examination which diagnosed as benign nodules and confirmed histologically were classified as score 1and 2. The sensitivity of the elastography was 87.5% and specificity 85.7% whereas FNA showed 87.5 %, and % 96.4 for sensitivity, specificity respectively. ROC analysis showed the area under the elastography curve was 0.88 (95% confidence interval, 0.712 to 1.02) while 0.92 (95% confidence interval, 0.779 to 1.06) for FNA curve.
FNA is still more reliable than ultrasound elastography, but UE is an easy, non-invasive and fast imaging technique that can help in thyroid scans to identify cases for FNA, reducing the number of unnecessary biopsies, and thus reducing risks and costs. However, future developments are needed for this promising diagnostic technique.

Key Words: Thyroid nodule – Ultrasound Elastography – FNA cytology**.**

INTRODUCTION

Thyroid nodular disease is a common finding in the general population, in particular in areas with iodine deficiency. Thyroid nodules can be detected by palpation in 5% of subjects [1,2] but can be detectable by thyroid sonography (US) in up to 50% of the general population. [3–5]

Fine-needle aspiration biopsy (FNAB) is a routine and valuable diagnostic procedure in a case of thyroid nodules with worrying US appearance. [6–7] It is the most reliable test used for screening malignant from benign thyroid nodules, with sensitivity 65%-98% and specificity ranging from 72%- 100%. [8]

Elastography is a newly developed ultrasonography technique to evaluate the thyroid nodules. Tissue elasticity is measured by application of an external compression on the tissue. With the applied compression the softer parts of tissues deform easier than the harder parts under pressure. [9] Benign thyroid nodules are approximately 1.7 times harder than the surrounding thyroid tissue, and malignant thyroid nodules are 5 times harder. [10]

The US elastogram was displayed over the B-mode image in a color scale that ranged from red, for constituents with greatest elastic strain (i.e. softer components), to blue for those with no strain (i.e. harder constituents). [11]

The elstograms obtained for thyroid nodules, their elasticity scores were classified according to the scores by Rago et

al. on scale 1-5.scores 4 and 5 were classified as suspicious for malignancy fig]. [12] Rago et al. elasticity scores originated and modified for thyroid nodules from the elasticity scoring system initially proposed by Ueno and Itoh which used for breast elastography results. [13]

Elastography is a new method which assesses tissue stiffness because all thyroid nodules that are firm on the palpation are suspicious of malignant, which adds diagnostic value in respect of malignancy prediction. [14,15] However, elastography is not widely used in clinical practice and not included in the major endocrine guidelines, but brings important information regarding the inelasticity of thyroid nodular lesions. [16]

The aim and objectives

The aim of our study was to evaluate the sensitivity, specificity and accuracy of ultrasound elastography in the diagnosis malignancy of thyroid nodules during preoperative investigation and compare its results with fine aspiration biopsy. Their results correlated with histological results obtained after thyroidectomy

MATERIALS AND METHODS

Patients

Between March 2012 and November 2013, this prospective study included 36 patients; five patients (13.9%) were males and 31 (86.1%) were females with the male: female ratio of about 1: 6.2. The age range was 19 to 80 years and mean age of 43 years. Those patients with thyroid nodules were referred for thyroid ultrasound, at Radiology Department, at king Abdulaziz university hospital. They were presenting with one or dominant nodule in the setting of multinodular goiter who had an indication for surgery due to thyroid nodule. All The patients were examined for the preoperative conventional ultrasound, real-time elastography, and fine needle aspiration. The final diagnosis was based on histopathologic results performed by the authorized personnel responsible for all histopathologic examinations at king Abdulaziz university hospital. Ethical approval from the medical research of our university and informed consent was obtained from all patients.

B-mode ultrasound

Ultrasound examination was done by expert sonographers and then re-examined by a radiologist to confirm all findings for each patient. Both B-mode ultrasound and real-time elastography were performed using a Philips IU22 system equipped with a high-frequency linear array transducer of 5-12 MHz. The examination was done with the patients lying supine with the neck slightly extended over a pillow.

With the probe placed gently on the thyroid, the ultrasound examination started with B-mode imaging. Images of each lobe were obtained in transverse and longitudinal planes. For interpretation of the conventional ultrasound, all ultrasound features for predicting malignant nodules such as the presence of irregular margins, hypo- echogenicity, absent halo sign , microcalcifications, solid composition, increased central vascularity, and taller than, wide' shape had been considered for evaluation of the nodules.

Real-time Elastography

Ultrasound strain elastography, color observation scoring method was performed during the conventional ultrasound examination of the thyroid gland. The same transducer was placed on the neck and then applying light compression at the skin surface. The box highlighted by the operator and positioned around the region of interest including the surrounding sufficient thyroid tissue to be evaluated. The stiffness of the tissues was coded or displayed in different colors that ranged from red for components with the greatest elastic strain (ie, softest components) to blue for those with no strain (i.e., hardest components) figure 1. Tissue stiffness on ultrasound elastography was evaluated using the scoring system by Rago et al., [12] which modified from scoring system of Ei Ueno and Itoh (2006), [13] that used for comparing breast elastography results. The scoring was classified into five

scores based on a color pattern with elastography to differentiate benign and malignant lesions FIG 1. The elastography score 1 and 2, describing high elasticity which were evaluated as a soft nodule (benign) with no need for surgical intervention, score 3 as Intermediate hardness (usually benign) while score 4, and 5, describing nodules with low elasticity (hard), were strongly predictive of malignancy. Table 1 FIG.2and 3

Table 1: Elasticity scoring system

Benign	
Score 1	Whole area is evenly coded green, with similar surrounding tissue
Score 2	Area with non-homogeneous elasticity shows mixed color of green ,blue, and red
Intermediate	
Score 3	Area coded green (soft) at the periphery, blue (stiff) at the center.
Malignant	
Score 4	Entire area is blue (stiff)
Score 5	Entire area and its surrounding area are blue (high stiff)

Figure 1: Elasticity scoring Rago Criteria for thyroid nodules which modified from Ei Ueno and Itoh

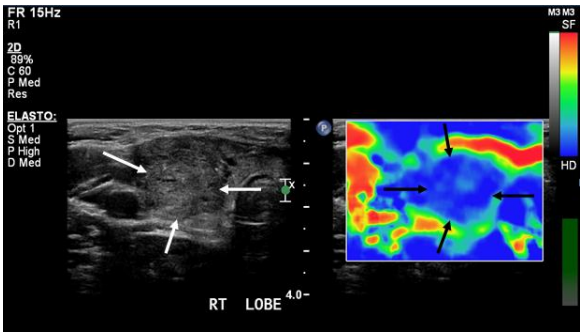

Figure 2: B mode ultrasound transverse image (A) showing a hypoechoic solid nodule in the right lobe (white arrows). Dual screen US Elastogram image (B), shows the entire nodule is completely blue, consistent with score 4(black arrows). Histopathology confirmed papillary carcinoma.

Ultrasound guided FNA biopsy:

The 36 patients were selected for the FNAC according to the results of their previous ultrasound, which recommended or suggested for FNA by the radiologists and requested by pathologist.

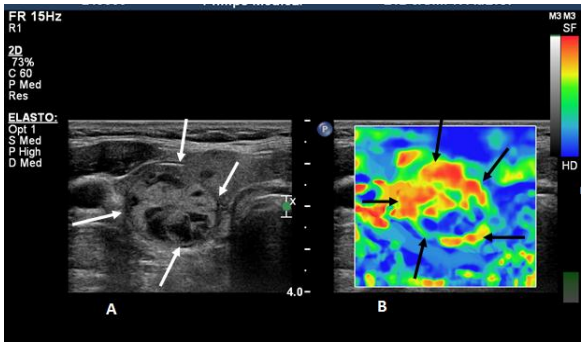

Figure 3: B mode US image (A) and split screen US Elastogram (B) showing a mixed echogenicity with a peripheral halo sign solitary thyroid nodule within the right lobe of the thyroid (white arrows). On elastogram, the nodule shows mixed color of blue, green and red and was assigned a score of 2 (black arrows) These results were suggestive of benign disease. Histopathology revealed nodular goiter.

All thyroid nodule biopsies (FNAC) were performed under ultrasound guidance. The neck was cleansed with antiseptic. Then the transducer also cleaned with an antiseptic and dressed in sterile glove.

By interventional radiologists, a “fine” or “thin” (21- to 25-gauge) needles; was then inserted through the skin under direct imaging guidance and advanced it to the site of the thyroid nodule and samples of tissue aspirated. Specimens were collected, smeared on slides which stored in a stand with 10% formalin solution. After the procedure completed, the specimens sent for cytological evaluation at the main laboratory of King Abdul-Aziz university hospital. Then the Results of FNAC were

compared with those of histopathological results.

Procedure for Histology Specimen Analysis

Tissue for routine pathological examination should be delivered to the histopathology fixed in a suitable-size container filled with 10% neutral buffered formalin unless otherwise indicated. All samples to be submitted through the histopathology laboratory.

The pathologists in king Abdulaziz university hospital performed the pathology evaluation on formalin fixed and paraffin embedded tissue followed by grossing according to international protocols [(17)] A pathologist made a report in all cases, which used as the reference standard for comparison between ultrasound elastography and fine needle aspiration results in the current study.

Statistical Analysis

Data analysis was performed using SPSS (statistical program for social science version 16) for description of quantitative and qualitative variables as mean, SD, number and percentage. The sensitivity, specificity, positive predictive values (PPV) and negative predictive values (NPV) accuracy were calculated for ultrasound elastograhy results and fine needle aspiration results using histopathology as the reference standard.

Receiver operating characteristic (ROC) curves analysis used to evaluate the diagnostic performance and ability of each test and correlated to each other.

RESULTS

Our study included thirty-six patients who were scheduled for total or lobectomy due to thyroid nodules, 31 (86.1%) females; and 5(13.9%) male mean age, 48years (range 19–80 years).All the patients had either solitary or dominant nodule in the preparation of multinodular goiter. Table 2.

Of the total 36 patients involved in study most of the patients affected by thyroid nodules were female compared with the male patients and increased with increasing of the age Table 3.

Table: 2 Sex distributions of 36 patients included in the study.

SEX	Frequency	Percent
M	5	13.9
F	31	86.1
Total	36	100.0

Histopathology Results

Among the 36 studied cases, 8 nodules (22.2 %) had a final diagnosis of malignancy on histopathology. Seven of them were papillary, and one medullary thyroid carcinomas. In patients with thyroid cancer, there were three men and five women Table 3. The remaining 28(77.8%) of the total nodules (36) had benign diagnosis on histopathology examination 13 were nodular goiters, 9 hashimoto's thyroiditis and 6 were follicular adenomas.

Table: 3 Distribution of the histopathology results according to the age group and sex.

Age group	Sex		Histopathology .Result			Total
	Female	Male	Medullary	Papillary	Benign	
<20	1	1	1	1	1	3
21-30	1	0		1	2	3
31-40	2	0		2	6	8
41-50	0	2		2	10	12
>50	1	0		1	9	10
Total	5	3	1	7	28	36

Fine needle Aspiration Result

The FNA results showed 27(75%) benign, 1(2.8%) likely benign and positive for malignancy in 7 cases (22.2%). When these cases were compared with their histopathological diagnosis, 27 cases (75%) were confirmed as the benign nodule, while the one case which likely benign was diagnosed histopathologically as malignant (false negative). The FNA showed a sensitivity of 87.5%, a specificity of 96.4%, with a positive predictive value of 87.5 %, a

negative predictive value of 96.4%, and the overall adequacy (accuracy) of 94.4% in the prediction of malignancy Table 4.

Table 4: Predictivity of Fine Needle Aspiration Biopsy in Patients with Thyroid Nodules those Resulted in Benign lesions (B) or Malignant (M) on Histopathology.

FNA Result	Histopathology Result		Sensitivity %	Specificity %	PPV%	NPV%	Accuracy %	P
	B	M						
B	27	1	87.5	96.4	87.5	96.4	94.4	0.000
M	1	7						
Total	28	8						

Ultrasound Elastography Result

From the total 36 cases examined by ultrasound elastography, their results revealed 69.4% benign lesions including all the benign lesions that were diagnosed as probably benign while 30.6% were reported as malignant. Table (6)

Regarding the elastography scores, 19 of the 36 nodules had scores of 1 and 2, and all of these nodules were diagnosed histopathologically as benign. Of 36 nodules, score 3 had one case confirmed histopathologically as malignant. Eight of the 36 nodules had a score of 4 and 5, and 7 of these nodules were proved histopathologically as malignant and one nodule as the benign Table 5. Based on Itoh scoring system, scores of 1 and 2 were significantly seen in benign nodules, and score 3 was seen in-between benign and malignant nodules in the criteria, while scores of 4 and 5 mostly observed malignant nodules, with sensitivity and specificity of 87.5% and 85.7 respectively. The positive predictive value (PPV) was 63.6%, negative predictive value (NPV 96%) and the accuracy of the technique was 81.1%, Table 6.

Table5: Shows distribution of ultrasound elastography scores results among benign and malignant nodules. in 36 thyroid lesions with histopathology.

Elasto. Score	Histopatho .Result		Total nodules,
	Benign nodule	Malignant nodule	
Score 1&2	19	0	19
Score 3	8	1	9
Score 4 & 5	1	7	8
Total	28	8	36

Table (6): Predictivity of ultrasound elastography in patients with thyroid nodules that resulted in benign lesions (B) or malignant (M) on histology

Elastography Result.	Histopathology		Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %	P
	B	M						
B	24	1	87.5	85.7	63.6	96	81.1	0.000
M	4	7						
Total	28	8						

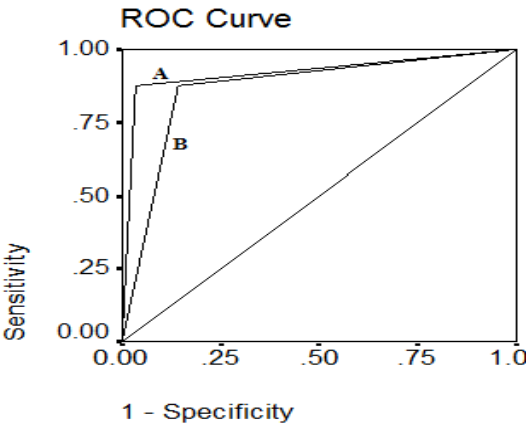

Figure 4: Illustration of two ROC curves (A) for FNA and (B) for Ultrasound Elastography The curve A test is best

A receiver operating characteristic curves for distinguishing malignant from benign nodules according to the fine aspiration and elasticity score are shown in Figure 2. These ROC curves allow us to quantitatively compare different between FNA (A) and the real time ultrasound elastography (B) and show if there is a statistically significant difference between the two tests. With ROC analysis, the closer a curve lies to the top left corner, the greater the area underneath it. Thus, a larger area under the ROC curve means a better test. The area under the ROC curve of FNA was

0.92 (confidence interval, 0.779–1.06), while for the elastography the area under the curve was 0.886 (confidence interval, 0.712–1.02), with no significant difference between the two tests (P= 0.000, P=0.002 respectively). This represents that the FNA is still showed slightly better performance than the elastography.

DISCUSSION

Thyroid nodules are growths or lumps in the thyroid gland in the front of the neck. Most thyroid nodules are not cancer and do not cause problems. Many don't even need treatment.

The thyroid cancer nearly 1% of all cancers, and 90% of malignant tumors of endocrine, and is responsible for 0.4% of cancer deaths. [18] Female / male ratio is 4: 1. Large parts of these tumors are well-identified tumors arising from follicular cells, and have a good prognosis. [19, 20]

Although FNA is the best method in helping to decide between nodules that require surgery and those can be followed. It gives a high rate in the diagnosis of thyroid tumors, differentiating between benign and malignant lesions can sometimes be very difficult. FNA is particularly inadequate in the recognition of follicular cancers from follicular adenomas, which are more common. [21]

This method is an ultrasonography technique that detects the stiffness of lesions and accordingly, uses to distinguish benign lesions from malignant lesions using the ultrasound machine.

Elastography is a newly developed diagnostic technique and is a non-invasive which evaluates the degree of tissue distortion that occurs when the nodule is selected for an external pressure. It is based on the principle of easier deformation of soft tissue under compression. [22-24] thus allowing a semi-quantitative determination of tissue elasticity. [24]

If a nodule is identified in the thyroid gland, the distinction between benign / malignant nodules should be aimed to minimize unnecessary surgical interventions. Particularly, before the decision has been taken for total thyroidectomy it is important the diagnosis of malignant tumors prior to thyroid operations, if necessary. At this stage, the diagnosis of malignancies should be confirmed by preoperative diagnostic imaging tool and FNA. Elastography is one of the latest advances in ultrasound technology and is a non-invasive imaging method that quantitatively and qualitatively assesses tissue stiffness. It is additional to gray scale and color Doppler results and ensures avoiding unnecessary FNA at this stage.

The elastography results and fine needle aspiration cytology were statistically compared with histopathology results which were taken as the reference standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPP), and accuracy for both elastography and fine aspiration cytology were calculated.

When comparing the elastography results versus FNA based on histological reports, we found that the FNA overall accuracy (94.4%) was slightly higher than the ultrasound elastography (86.1%), and that both of them with the same sensitivity (87.5%) and both were better higher in negatives predictive values than positives, whereas the FNA showed higher Specificity, and positives predictive values than ultrasound elastography.

The scoring of the elastography was highly effective and rewarding in distinguishing benign from malignant nodules in an undefined cytological result. Therefore, in our study group the 28 cases with benign on histopathology (true negative), 19 nodules had score 1 and 2 and no false negative cases. While score 3,4,5, describing malignancy, were scored in the remaining 17 nodules, eight of whom resulted in having malignant thyroid nodules, seven of those eight cases having a final diagnosis of malignancy on histology and 1case was diagnosed as benign (false positive).

Elastography is performed by comparing the stiffness level of the lesion to the rest of the thyroid tissue. Therefore, in cases of thyroiditis, and multinodular thyroid without normal thyroid tissue surrounded by them to make a comparison with, elastography may give mistaken results. [25,26] Likewise, calcified nodules and nodules with a more than 20% cystic component can also be misleading. [27]

In the current study result compared to the reports of [25,26] was no different between them. On elastography 4nodules had being found as malignant (false positive), whereas reported histological as benign nodules. This incorrect diagnosis due to that those 4 cases, 2were hashimoto's thyroiditis, and the other 2 diagnosed as multinodular goiter, that affected the predictivity of US elastography in this group of patients.

Follicular carcinomas can be misleading on ultrasound elastography and fine needle aspiration. Other limitation of this study was the effect of Hashimoto thyroiditis or patients containing multiple nodules that were not adequately assessed due to the absence of healthy surrounding tissues for comparison with elastography. The increasing of the number of patients containing autoimmune thyroid disease and multiple nodules reduces the performance of USE test.

Bojunga et al [28] reported that US elastography and even FNAB were not suitable for the diagnosis of follicular carcinoma; in their study they missed 4 of 9 follicular cancers on US elastography. In agreement with the report of, [28] in our study, we had 2 cases follicular carcinomas missed, one case on US elastography and the other one on the FNA which were diagnosed as benign follicular tumors by them.

The current study summarized, that all the benign nodules had scores of 1and 2 with no malignant nodules in these scores. Most malignant thyroid nodules had elastic scores of 4 and 5. Elastography showed a sensitivity of 87.5%, specificity of 85.7% and an accuracy of 81.1%.

The final predictive power of the real time elastography technique with recently published studies as shown in the table below there is a variety in their results that decreases with increasing number of the participants. For example, the predictive result in the studies of Rago et al, [26] Hong et al [25] and Rubaltelli et al [29] including our result who used small sample size were higher than those of Çakır et al [30] and Moon et al [31] who used a large group of participants. The result of our study was consistent with Rubaltelli et al. [29]

Table 7: Summary of some studies published on thyroid nodule elastography

Authors No. of Patients Sensitivity. Specificity PPV NPV
Rago et al [26] 2007 92 100 97 100 98
Hong et al [25] 2009 90 88 90 81 93
Çakır et al [30] 2011 292 58 71 49 78
Rubaltelli et al [29] 2008 40 82 88 64 95
Moon et al[31] 2012 676 65,4 95,3 59,6 71,7
Current study 36 87.5 85.7 63.4 96

PPV: positive predictive value NPV: negative predictive value

From the ROC curve, we proved that the cutoff elastography score for malignant nodule is score 4, as the AUC was (0.888).while the area under the ROC curve of FNA was 0.92. According to the results of the curves of the two tests, the FNA still had better performance than USE. So, we suggest FNA to be performed all nodules with elastography score 3, 4 and 5 whereas scores 1 and 2 do not need FNA.

CONCLUSION

FNA test is still more reliable than ultrasound elastography, but UE is an easy, non-invasive and fast imaging technique that can help in thyroid scans to identify cases for FNA, and be reducing the number of unnecessary biopsies, and thus reducing risks and costs. Larger prospective studies are needed to confirm our results and to define the diagnostic accuracy of this technique and to determine its ability for replacing FNAC in the future. However, future developments are needed for this promising diagnostic technique. The use of new elastography techniques, such as share

wave-based USE,that is user independent and quantitative, which may overcome these challenges.

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REFERENCES

1. Cooper DS, Doherty GM, Haugen BR, Kloos RT, Lee SL, Mandel SJ, Mazzaferri EL, McIver B, Pacini F, Schlumberger M, Sherman SI, Steward DL, TuttleRM2009 American Thyroid Association (ATA) Guidelines Taskforce on Thyroid Nodules and Differentiated Thyroid Cancer. Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer. Thyroid 19:1167–1214
2. Gharib H, Papini E, Paschke R, Duick DS, Valcavi R, Hegedus L, Vitti P; AACE/AME/ETA Task Force on Thyroid Nodules 2010 American Association of Clinical Endocrinologists, Associazione Medici Endocrinologi, and European Thyroid Association Medical Guidelines for Clinical Practice for the Diagnosis and Management of Thyroid Nodules. Endocr Pract 16(Suppl 3):468–475
3. Gharib H, Papini E, Paschke R 2008 Thyroid nodules: a review of current guidelines, practices, and prospects. Eur J Endocrinol 159: 493–505
4. Rago T, Chiovato L, Aghini-Lombardi F, Grasso L, Pinchera A, Vitti P 2001 Non-palpable thyroid nodules in a borderline iodine-sufficient area: detection by ultrasonography and follow-up. J Endocrinol Invest 24:770–776
5. Aghini-Lombardi F, Antonangeli L, Martino E, Vitti P, Maccherini D, Leoli F, Rago T, Grasso L, Valeriano R, Balestrieri A, Pinchera A 1999 The spectrum of thyroid disorders in an iodine-deficient community: the Pescopagano survey. J Clin Endocrinol Metab 84: 561–566
6. Stangierski A, Ruchała M, Warmuz-Stangierska I et al. Pain associated with fine-needle aspiration biopsy of thyroid nodules. Przegl Menopauz 2012; 3: 233–238.
7. İnci MF, Özkan F, Yüksel M et al. The effects of sonographic and demographic features and needle size on obtaining adequate cytological material in sonography-guided fine-needle aspiration biopsy of thyroid nodules. Endocrine 2013; 43: 424–429.
8. Bukhari M.H., Khan A.A., Niazi S., et al.: Better thyroid cytopathology reporting system may increase the clinical management and patients' outcome. J. Cytol. Histol., 3: 6, 2012.
9. Lyshchik A, Higashi T, Asato R, et al. Thyroid gland tumor diagnosis at US elastography. Radiology 2005; 237: 202–211.
10. Luo S, Kim EH, Dighe M, Kim Y. Thyroid nodule classification using ultrasound elastography via linear discriminant analysis. Ultrasonics 2011; 51: 425-431.
11. Rago T, Vitti P, Chiovato L, et al. Role of conventional ultrasonography and color flow-doppler sonography in predicting malignancy in ''cold'' thyroid nodules. Eur J Endocrinol 1998;138:41–6.
12. Rago T, Fiore E, Scutari M, et al. Male sex, single nodularity, and young age are associated with the risk of finding a papillary thyroid cancer on fine needle aspiration cytology in a large series of patients with nodular thyroid disease. Eur J Endocrinol 2010;162:763–70.
13. Ueno E, Ito A. Diagnosis of breast cancer by elasticity imaging. Eizo Joho Med 2004;36:2–6.
14. Nell S, Kist J, Debray TP, de Keiser B, van Oostenbrugge TJ, et al. Qualitative elastography can replace thyroid fine needle aspiration in patients with soft thyroid nodules. A systematic review and meta analysis. Eur J Radiol. 2015; 84(4):652–661.
15. Kim MH, Luo S, KO SH, Lim DJ, Lim Y. Elastography can effective decrease the number of fine-needle aspiration biopsies in patients with calcified

thyroid nodules. Ultrasound Med Biol. 2014; 40(10):2329–2335.
16. Dudea SM, Botar-Jid C. Ultrasound elastography in thyroid disease. Med Ultrason. 2015; 17(1):74–96.
17. Sneed DC. Protocol for the examination of specimens from patients with malignant tumors of the thyroid gland, exclusive of lymphomas: a basis for checklists. Cancer Committee, College of American Pathologists. Arch Pathol Lab Med. 1999; 123: 45-49
18. Sethi K, Sarkar S, Das S, Mohantly B, Mandal M. Biomarkers for the diagnosis of thyroid cancer. J Exp Ther Oncol 2010; 8: 341-352.
19. Maitra A, Abbas AK: The Endocrine System. In Kumar V, Abbas AK, Fausto N (eds). Pathologic Basis of Disease. 7th ed. Philadelphia, Elsevier Saunders; 2005.p.1164-1189.
20. Thompson L DR, Adair C: Non-neoplastic lesions of the thyroid gland, benign neoplasms of the thyroid gland, malignant neoplasms of the thyroid gland. In Goldblum JR (eds). Endocrine Pathology. C L Elsevier;2006.p.1-142.
21. Klonoff DC, Greenspan FC. The thyroid nodule. Adv Intern Med 1982; 27: 101-106.
22. Lerner RM, Huang SR, Parker KJ. Sonoelasticity images derived from ultrasound signals in mechanically vibrated tissues. Ultrasound Med Biol 1990; 16: 231-239.
23. Ophir J, Alam SK, Garra B, Kallel F, Konofagou E, Krouskop T, et al. Elastography: ultrasonic estimation and imaging of the elastic properties of tissues. Proc Inst Mech Eng H 1999; 213: 203-233.
24. Lyshchik A, Higashi T, Asato R, Tanaka S, Ito J, Mai JJ, Pellot- Barakat C, Insana MF, Brill AB, Saga T, Hiraoka M, Togashi K 2005 Thyroid gland tumor diagnosis at US elastosonography. Radiology 237:202–211
25. Hong Y, Liu X, Li Z, Zhang X, Chen M, Luo Z. Real-time ultrasound elastography in the differential diagnosis of benign and malignant thyroid nodules, J. Ultrasound Med 2009; 28: 861-867.
26. Rago T, Santini F, Scutari M, Pinchera A, Vitti P. Elastography: new developments in ultrasound for predicting malignancy in thyroid nodules. J Clin Endocrinol Metab 2007; 92: 2917-2922.
27. Rago T, Vitti P. Potential value of elastosonography in the diagnosis of malignancy in thyroid nodules. Q J Nucl Med Mol Imaging 2009; 53: 455-464.
28. Bojunga J, Herrmann E, Meyer G, et al. Real-time elastography for the differentiation of benign and malignant thyroid nodules: a meta-analysis. Thyroid 2010;20:1145–50
29. Rubaltelli L, Corradin S, Dorigo A, Stabilito M, Tregnaghi A, Borsato S, Stramare R Differential diagnosis of benign and malignant thyroid nodules at elastosonography. Ultraschall Med, 2009; 30:175-179.
30. Cakir B, Aydin C, Korukluoglu B, Ozdemir D, Sisman IC, Tuzun D, Oguz A, Guler G, Guney G, Kusdemir A, Sanisoglu SY, Ersoy R 2011 Diagnostic value of elastosonographically determined strain index in the differential diagnosis of benign and malignant thyroid nodules. Endocrine 39:89-98.
31. Moon HJ, sung MJ, Kim EK et al. Diagnostic performance of Gray Scale US and elastography in solid thyroid nodules. Radiology, 2012;262:3; 1002-1013.

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