INTRODUCTION

It is widely accepted that malignant thyroid nodules are harder than benign nodules. This concept serves as the basis for a number of diagnostic examinations, including palpation. The principle underlying elastography is that tissue compression produces strain within the tissue that is less in hard tissue, as compared with soft tissue (1). Sonographic elastography is an imaging technique for visualizing tissue stiffness in color or grayscale. The application of sonographic elastography for thyroid nodule scoring reportedly has good diagnostic performance to predict the malignant thyroid nodule (2-4). According to previous studies, sonographic elastography is approved as a promising adjunctive tool for evaluation of thyroid nodules (5-7). Most initial studies used elasticity scoring systems (on 5-point or 6-point scales) to assign different scores according to the proportion of colored...
tissue on the map. However, elastographic evaluations with these
elasticity scoring systems are qualitative in nature, highly opera-
tor-dependent, and have poor interobserver agreement and low
reproducibility (5, 8).

Acoustic radiation force impulse (ARFI) imaging is a new
elastography method for quantifying tissue elasticity (9). With-
out any need for external compression, this elastometric tech-
nique evaluates tissue stiffness while performing real time B-
mode examination. The tissue within a region of interest (ROI)
is mechanically excited by short-duration acoustic pulses, which
are generated by a probe. These pulses induce localized tissue
displacement within the ROI and its velocity can be calculated (10-13).
Shear wave propagation velocity is proportional to the square
root of the tissue elasticity; thus, faster shear wave propagation
is observed in stiffer tissue (9, 14, 15). ARFI imaging can pro-
vide qualitative (grayscale map) or quantitative (wave velocity
values, measured in m/s) information by Virtual Touch tissue
imaging (VTI) and Virtual Touch tissue quantification (VTQ),
respectively (9, 15). Of these 2 methods, only VTQ can quanti-
tatively describe thyroid nodule stiffness in terms of measured
shear wave velocity (10-12).

A few previous studies on ARFI for thyroid nodules reported
consistently good performance of ARFI for differentiating ma-
lignant thyroid nodule from the benign (10-13, 16, 17). How-
ever, the reported results varied from excellent value to just ac-
ceptable performance as an adjuvant tool.

The goal of this study was to evaluate the overall diagnostic
performance of VTQ value for predicting malignant thyroid
nodule, as compared with B-mode sonographic evaluation.

MATERIALS AND METHODS

Patients

From November 2011 to April 2012, the ultrasonography
(U) and clinical data of 146 thyroid nodules from 140 patients
who were referred for US and fine needle aspiration biopsy
(FNAB) were retrospectively reviewed. Seven nodules from 5 pa-
tients with unsatisfactory cytology results were excluded. Five
additional nodules from 5 patients with cytologic results showing
atypical cells of undetermined significance were also excluded;
these patients were also lost to follow-up. Seven more patients
with benign cytologic results and follow-up loss were also ex-
cluded. In total, 127 thyroid nodules (mean size: 16.4 mm,
range: 5 mm to 49.6 mm) from 123 consecutive patients (105
females, 18 males) were included in the study. The exclusion
criteria for this study were purely cystic or predominantly cystic
thyroid nodules that did not require FNAB. This study was ap-
proved by the local Human Research Ethics Committee.

Final Thyroid Nodule Diagnosis

Thyroid nodules were considered as benign based on 2 con-
secutive cytologic FNAB biopsy results; moreover, nodules were
required to show no interval change in size for at least 12 months
after the US exam. Patients were diagnosed with malignant thy-
roid nodules based on pathologic diagnosis after surgery, follow-
ing a suspicious malignant cytologic result in the fine-needle bi-
opsty.

Equipment, Scanning, and FNAB Procedure

One radiologist who had 12 years of experience with conven-
tional sonography and 3 years of experience in elastography, per-
formed the US and the FNAB. Patients underwent both B-mode
and ARFI imaging in the supine position with a sonography
scanner (Acuson S2000, Siemens Medical Solutions, Mountain
View, CA, USA). A linear array transducer (9L4, Siemens Medi-
cal Solutions) with a center frequency of 7.5 MHz (range, 5.0–
14.0 MHz) was used for US examination. Patients were posi-
tioned on their backs with their necks slightly extended.

Conventional B-mode images of each thyroid nodule were ini-
tially obtained. Next, the ARFI imaging mode was turned on and
the ROI was placed within the thyroid nodule to measure its VTQ
value. While the VTQ value was being measured, patients were
asked to hold their breath for a few seconds to minimize any po-
tential artifacts from patient motion.

Next, a FNAB was performed on each nodule that had been
evaluated by B-mode scanning and ARFI imaging. The FNAB
was performed using a 23-gauge needle attached to a 10 mL dis-
posable plastic syringe, and the aspirated material was expelled
onto glass slides and smeared. For Papanicolaou staining, all
smeared glass slides were fixed with 95% alcohol.
B-Mode Evaluation
The B-mode nodule images were retrospectively reviewed for shape, margin, echogenicity, and calcification. Nodule vascularity was not evaluated, because increased vascularity did not have good diagnostic performance for predicting malignancy in previous studies (18, 19). Additionally, the sonographic features of all thyroid nodules that underwent US-guided FNAB were recorded at the same time that FNAB was performed. In our study, only solid and predominantly solid nodules were included. Nodule shapes were classified as ovoid or round, irregular, and taller-than-wide (defined as a ratio of the transverse diameter to the anteroposterior diameter > 1). Nodule echogenicities were classified as hyperechoic (defined as more echogenic than the normal thyroid parenchyma), isoechoic (isoechoic compared to the normal thyroid gland), hypoechoic (hypoechoic compared with thyroid parenchyma), or marked hypoechoic (hypoechoic compared with the surrounding strap muscle). Nodule margins were classified as smooth, spiculated/microlobulated or ill-defined, whereas calcifications were classified as microcalcification (< 1 mm in size), macrocalcification (> 1 mm), or rim calcification. Among these findings, a taller-than-wide shape, marked hypoechoogenicity, a spiculated margin, and micro/macrocalcification were considered as suspicious malignant findings, based on the Korean Society of Thyroid Radiology guidelines (20). Each nodule was assigned a B-mode score, according to its sonographic findings, as follows: shape (ovoid or round, 1; taller-than-wide, 2), echogenicity (hyperechoic or isoechoic, 1; hypoechoic or marked hypoechoic, 2), margin (smooth or ill-defined, 1; speculated/microlobulated, 2), and calcification (absent or rim calcification, 1; macro/microcalcification, 2). The total score for each thyroid nodule was determined by calculating the sum of all the criteria (range, 4 to 8).

ARFI Evaluation and VTQ Value
After B-mode evaluation, the ARFI imaging mode was activated and the ROI (fixed size, 5 × 6 mm) was defined in the nodule, taking care to avoid the cystic area and calcification of the nodule. Also, ROI was placed at the central portion of nodule at a depth of 1.0 to 2.0 cm. The VTQ value of each thyroid nodule was measured 5 times continuously and the average value of these 5 measurements was calculated. An additional 1 to 2 minutes were needed to measure the VTQ value. The VTQ value expresses the shear wave speed in solid materials as numeric values in meters per second (m/s). Previous studies have shown that the VTQ value can be expressed as X.XX m/s in ARFI systems in some cases. This can be explained by a variety of possibilities including operator movement, patient respiration, erroneous ROI positioning (i.e., at the cystic portion of the nodule), or calcification (10, 12). If the VTQ value exceeds the upper detection limit (8.4 m/s) of the ARFI system, it is also shown as X.XX m/s (10). Among the cases in this study, only 1 solid and hypoechoic nodule without calcification in a patient with medullary carcinoma yielded a VTQ value of X.XX m/s. In this case, the X.XX value was considered as the upper limit (8.4 m/s).

Calculation of Combined Score
The combined score for each thyroid nodule was defined as the sum of the B-mode evaluation score and the VTQ value. For example, a thyroid nodule with a round shape, isoechoogenicity, and a smooth margin without calcification was given a B-mode score of 4. If the ARFI VTQ value of this nodule was 2 m/s, the combined score of this nodule was 6.

Statistical Analysis
All statistical analyses were carried out with MedCalc, version 13 (MedCalc Software, Mariakerke, Belgium). p values < 0.05 were considered as statistical significance. Qualitative data were compared with the chi-squared test. Receiver-operating characteristic (ROC) curve analyses were performed to evaluate the diagnostic performances of the B-mode score, the VTQ value, and the combined score in differentiating malignant from benign thyroid nodules. Cut-off values for each method of analysis were determined using Youden’s index. The areas under the ROC curves (Az) were calculated and compared using the z test.

RESULTS
Final Cytopathologic Diagnosis
Thirty-two of the 127 total thyroid nodules were malignant. Among the malignant thyroid nodules, 30 nodules were diagnosed as papillary carcinoma, 1 was follicular carcinoma, and the other was medullary carcinoma. The 2 consecutive cytologic results of the other 95 thyroid nodules were benign, nodular hyperplasia.
B-Mode Evaluation and Scoring

The mean size of the examined nodules was 17.9 mm (longest diameter of nodule) for benign and 11.8 mm for malignant nodules. The mean depth of both benign and malignant nodules was 13 mm without difference in the 2 groups. All nodules were evaluated according to the presence of suspicious malignant findings. The B-mode scores exhibited the following accuracies: 87%, shape; 76%, margin; 59%, echogenicity; and 65%, calcification. The Az for B-mode scoring was 0.895 [95% confidence interval (CI): 0.829–0.943] \( (p < 0.0001) \) with a cut-off value of 6.

ARFI Evaluation and VTQ Value

The VTQ values of the nodules were distributed from 0.97 m/s to 8.4 m/s and the mean value of 2.78 m/s. The Az for ARFI evaluation and VTQ value was 0.837 (95% CI: 0.761–0.897) \( (p < 0.0001) \) with a cut-off value of 3.28 m/s. Twenty-three of the 32 malignant nodules showed a high VTQ value (> 3.28 m/s) (Fig. 1), whereas 83 of the 95 benign nodules exhibited a low VTQ value (≤ 3.28 m/s) (Fig. 2).

Combined Score Evaluation

The mean combined score for the nodules was 8.53 (range, 4.97 to 16.4). The Az for the combined score was 0.912 (95% CI: 0.849–0.955) \( (p < 0.0001) \) with a cut-off value of 9.37. Twenty-seven nodules (84%) of all the malignant nodules showed a high combined score (> 9.37) and 85 (89%) of the benign nodules exhibited a low (< 9.37) combination score.

Diagnostic Performance

The diagnostic performances of the B-mode scoring, VTQ, and combination scoring approaches were shown in Table 1. B-mode scoring showed a sensitivity of 84%, a specificity of 85%, a positive predictive value (PPV) of 66%, a negative predictive value (NPV) of 94%, and an accuracy of 85%. Among the assessed categories, shape, echogenicity, and margin were significantly able to differentiate benign from malignant thyroid nodules. However, calcification did not show statistically meaningful results \( (p = 0.1911) \). ARFI evaluation/VTQ assessment showed a sensitivity of 75%, a specificity of 91%, a PPV of 73%, an NPV of 92%, and an accuracy of 86% \( (p < 0.0001) \). The combination scoring approach showed a sensitivity of 88%, a specificity of 87%, a PPV of 70%, an NPV of 95%, and an accuracy of 88% \( (p < 0.0001) \). The ROC curves for the B-mode scoring, VTQ assessment, and combined scoring approaches for the differentiation of benign from malignant thyroid nodules were shown in Fig. 3.
The areas under the curves for B-mode scoring, VTQ scoring, and combined scoring were 0.895, 0.837, and 0.912, respectively. ROC curve pairwise comparison analyses did not reveal any significant differences between the B-mode scoring and VTQ assessment approaches. However, the combined scoring method showed significantly improved performance, as compared with VTQ evaluation alone (p value = 0.0023). These results, including the areas under the curves, the 95% CIs, and the cut-off values were shown in Table 2.

DISCUSSION

US is the first choice imaging modality for evaluating thyroid nodules. According to B-mode findings, thyroid nodules are typically classified as probably benign, indeterminate, or suspicious. B-mode US findings and nodule classification are extremely important, because they are often used to determine whether a FNAB is necessary. Thyroid nodules that show findings typical of suspicious malignant and indeterminate nodules usually undergo further cytological evaluation according to nodule size (21). Recently, elastography was introduced as a new US diagnostic method that is useful for differentiating between malignant and benign thyroid nodules. Early studies on sonographic elastography used an elasticity scoring system to evaluate the thyroid nodules. US elastography coupled with an elasticity scoring system is reported to have good diagnostic value for the differential diagnosis of thyroid cancer (3, 4, 22, 23). Moreover, a real-time elasticity scoring system based on US elastography was reported to have exceptionally high diagnostic performance, with a sensitivity of 97%, a specificity of 100%, a PPV of 100%, and a NPV of 98% (4). However, recent studies of real-time elastography have shown somewhat lower diagnostic performance, as compared with previous studies. For instance, one study of the diagnostic performance of real-time elastography reported a sensitivity of 65%, a specificity of 72%, and an accuracy of 61% (5). Moreover, no statistically reliable interobserver agreement is reported in the application of a real-time elasticity scoring system to the diagnosis of malignant thyroid nodules (24). These contradictory results

Table 1. Results of Sonography Criteria for Benign and Malignant Thyroid Nodules

| Sonography Criteria | Benign (n = 95) | Malignant (n = 32) | Sens (%) | Spec (%) | PPV (%) | NPV (%) | Accu (%) | p-Value |
|--------------------|----------------|-------------------|----------|----------|---------|---------|-----------|---------|
| The shape          |                |                   | 75       | 91       | 73      | 91      | 87        | < 0.0001 |
| Ovoid or round, irregular | 86 (91) | 8 (25)            |          |          |         |         |           |         |
| Taller-than-wide   | 9 (9)          | 24 (75)           |          |          |         |         |           |         |
| The margin         |                |                   | 94       | 69       | 51      | 97      | 76        | < 0.0001 |
| Smooth, ill-defined| 66 (69)        | 2 (6)             |          |          |         |         |           |         |
| Spiculated/microlobulated | 29 (31) | 30 (94)          |          |          |         |         |           |         |
| Echogenecity       |                |                   | 97       | 46       | 38      | 98      | 59        | < 0.0001 |
| Isoechoic or hyperechoic | 44 (46) | 1 (3)            |          |          |         |         |           |         |
| Hypoechoic or marked hypoechoic | 51 (54) | 31 (97)        |          |          |         |         |           |         |
| Calcification      |                |                   | 41       | 74       | 34      | 79      | 65        | 0.1917   |
| Absent             | 70 (74)        | 19 (59)           |          |          |         |         |           |         |
| Present            | 25 (26)        | 13 (41)           |          |          |         |         |           |         |
| B-mode scoring     |                |                   | 84       | 85       | 66      | 94      | 85        | < 0.0001 |
| Lower (≤ 6)        | 81 (85)        | 5 (16)            |          |          |         |         |           |         |
| Higher (> 6)       | 14 (15)        | 27 (84)           |          |          |         |         |           |         |
| ARFI               |                |                   | 75       | 91       | 73      | 92      | 86        | < 0.0001 |
| VTQ value          |                |                   | 86 (91)  | 9 (28)   |         |         |           |         |
| Lower (≤ 3.28)     | 9 (9)          | 23 (72)           |          |          |         |         |           |         |
| Higher (> 3.28)    |                |                   | 88       | 87       | 70      | 95      | 88        | < 0.0001 |
| Combined score (9.72) | 85 (89) | 5 (16)          |          |          |         |         |           |         |
| Lower (≤ 9.72)     | 10 (11)        | 27 (84)           |          |          |         |         |           |         |
| Higher (> 9.72)    |                |                   | 88       | 87       | 70      | 95      | 88        | < 0.0001 |

Numbers in parentheses are percentages.

Accu = accuracy, ARFI = acoustic radiation force impulse, NPV = negative predictive value, PPV = positive predictive value, Sens = sensitivity, Spec = specificity, VTQ = Virtual Touch tissue quantification
ARFI is a recently developed US-based elastography modality that can provide quantitative information regarding tissue stiffness (9, 25). Compared with conventional elastography, ARFI imaging is expected to produce operator-independent, highly reproducible, and quantitative results (13, 17). Various studies have investigated the diagnostic potential of ARFI imaging to differentiate malignant thyroid nodules (10, 12, 13, 16, 17, 26). Some studies showed that ARFI imaging exhibits excellent diagnostic performance in the differentiation of thyroid nodules. In one study, ARFI imaging was reported to have a robust diagnostic performance in predicting malignancy, with a sensitivity of 96.8%, a specificity of 95.7%, a PPV of 93.75%, an NPV 97.8%, and an Az of 0.989 (17). Another study used a 2.85 m/s cutoff value and found that the Az of the ROC curve was 0.9453 in the prediction of malignancy (sensitivity: 94.4%, specificity: 85.3%, PPV: 77.2%, NPV: 96.6%) (16). A following study that used ARFI imaging to evaluate 98 thyroid nodules also found good diagnostic values; the sensitivity, specificity, PPV, and NPV in this study were 86.36%, 93.42%, 79.17%, and 95.95%, respectively (12). Recently, some studies showed somewhat lower diagnostic performances of ARFI imaging for thyroid nodules. One study of ARFI imaging reported a sensitivity, specificity, NPV, and PPV of 57%, 85%, 93%, and 38%, respectively, with a 2.57 m/s cut-off value (10). Another study on the diagnostic value of ARFI imaging reported a sensitivity, specificity, PPV, and NPV of 75%, 82.2%, 58.9%, and 90.5%, respectively; the Az in this study was 0.861 (95% CI: 0.804–0.918; \( p < 0.001 \)) (13).

The results of our study (sensitivity, 75%; specificity, 91%; PPV, 73%; and NPV, 92%) were similar to the diagnostic values in more recent studies that reported lower diagnostic performances for ARFI imaging of thyroid nodules. We compared ARFI imaging with B-mode evaluation and a combined method because this comparison most accurately reflects the clinical situation. The B-mode scoring approach showed a higher sensitivity (84%), specificity (85%), and NPV (94%), as compared with the ARFI evaluation. The ARFI evaluation of VTQ values showed a lower sensitivity (75%) and NPV (91.5%), as compared with the B-mode evaluation; however, the ARFI approach showed a higher specificity (90.5%) and PPV (72.7%). The B-mode scoring approach showed a higher Az value (0.895, \( p < 0.0001 \)), as compared with ARFI evaluation (0.837, \( p < 0.0001 \)); however, pairwise ROC curve comparison of both methods did not reveal any significant differences between them. These results indicated that both B-mode and ARFI evaluations have good diagnostic performance, and that the current ARFI evaluation technique is not a superior substitute for conventional B-mode imaging of thyroid nodules.

ARFI = acoustic radiation force impulse, AUC = area under the curve, CI = confidence interval, VTQ = Virtual Touch tissue quantification

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### Table 2. Comparison of Receiver-Operating Characteristic (ROC) Curves

|                      | AUC     | 95% CI      | Cut-Off Value | \( p \)-Value | Comparisons          |
|----------------------|---------|-------------|---------------|--------------|----------------------|
| B-mode scoring       | 0.895   | 0.829–0.943 | > 6           | < 0.0001     | √                    |
| ARFI VTQ value       | 0.837   | 0.761–0.897 | > 3.28        | < 0.0001     | \( p = 0.1470 \)  √    |
| Combined score       | 0.912   | 0.849–0.955 | > 9.37        | < 0.0001     | \( p = 0.3659 \)  √    |

Comparisons show pairwise comparison of checked (√) ROC curves with \( p \)-value.

ARFI = acoustic radiation force impulse, AUC = area under the curve, CI = confidence interval, VTQ = Virtual Touch tissue quantification
nodules. Interestingly, the combined evaluation approach showed the highest sensitivity (88%), specificity (87%), PPV (70%), and NPV (95%). Moreover, the combined scoring approach showed the highest Az value (0.912), which was significantly greater than that of ARFI evaluation alone ($p = 0.0023$). These results indicated that a combined evaluation that incorporates both B-mode findings and ARFI evaluation could be useful.

Our study had a few limitations. First, nodules identified as benign by FNAB that had not been surgically removed were included in the study. This could have increased the false negative results of benign nodules. We only included cases that were confirmed as benign with > 2 consecutive FNAB results, to minimize this effect; moreover, the nodules were required to have no interval change in size or sonographic configuration. Second, the fixed size and shape of the ROI of ARFI measurement could not represent the entire area of the nodule. Therefore, we performed multiple ARFI measurements by changing the location of ROI within possible range. Another limitation of our study was that only a few types of malignant nodules were included. Among the 32 malignant nodules, 30 were papillary carcinoma nodules, with only 1 follicular carcinoma and 1 medullary carcinoma nodule included. Additional studies of thyroid nodules with more variable malignant pathologies are needed to fully validate our findings. The sample size of this study was small and further prospective studies with large case series are required.

In a few cases, we found that the VTQ results conflicted with the pathologic results. For example, one case of follicular carcinoma showed a low VTQ value (average VTQ value, 1.91) in the ARFI evaluation indicative of a false negative (Fig. 4). Thus, this follicular carcinoma case could not be discriminated from a benign nodule in our study. The differentiation of follicular neoplasms from nodular hyperplasia remains a diagnostic challenge. In contrast, another benign nodule showed a high VTQ value (average VTQ value, 3.86) indicative of a false positive (Fig. 5). This benign nodule showed calcific degeneration, which may have led to a high VTQ value similar to that of a malignant nodule. From these results, we concluded that the ARFI VTQ value alone is not a reliable alternative diagnostic method to B-mode US findings. However, a high VTQ value could be considered as a suspicious malignant finding that further requires FNAB.

In conclusion, ARFI evaluation of the VTQ value is a good diagnostic modality for differentiating malignant thyroid nodules from benign nodules. However, ARFI evaluation is not superior to B-mode sonographic evaluation, but has a better diag-

**Fig. 4.** Solid, heterogeneous isoechoic nodule shows relatively low VTQ value (2.03 m/s). This nodule was confirmed as follicular carcinoma. VTQ = Virtual Touch tissue quantification

**Fig. 5.** Hypoechoic solid nodule with macrocalcification shows high VTQ value (4.71 m/s) in ARFI evaluation. This nodule was confirmed as benign nodule with calcific degeneration. ARFI = acoustic radiation force impulse, VTQ = Virtual Touch tissue quantification
nostic performance when combined with B-mode sonographic finding scores.

REFERENCES

1. Itoh A, Ueno E, Tohno E, Kamma H, Takahashi H, Shiina T, et al. Breast disease: clinical application of US elastography for diagnosis. *Radiology* 2006;239:341–350
2. Dighe M, Bae U, Richardson ML, Dubinsky TJ, Minoshima S, Kim Y. Differential diagnosis of thyroid nodules with US elastography using carotid artery pulsation. *Radiology* 2008;248:662–669
3. 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
4. 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
5. Moon HJ, Sung JM, Kim EK, Yoon JH, Youk JH, Kwak JY. Diagnostic performance of gray-scale US and elastography in solid thyroid nodules. *Radiology* 2012;262:1002–1013
6. Kwak JY, Kim EK. Ultrasound elastography for thyroid nodules: recent advances. *Ultrasonography* 2014;33:75–82
7. Sun J, Cai J, Wang X. Real-time ultrasound elastography for differentiation of benign and malignant thyroid nodules: a meta-analysis. *J Ultrasound Med* 2014;33:495–502
8. Bojunga J, Herrmann E, Meyer G, Weber S, Zeuzem S, Friedrich-Rust M. Real-time elastography for the differentiation of benign and malignant thyroid nodules: a meta-analysis. *Thyroid* 2010;20:1145–1150
9. Zhai L, Palmeri ML, Bouchard RR, Nightingale RW, Nightingale KR. An integrated indenter–ARFI imaging system for tissue stiffness quantification. *Ultrasound Imaging* 2008;30:95–111
10. Bojunga J, Dauth N, Berner C, Meyer G, Holzer K, Voelkl L, et al. Acoustic radiation force impulse imaging for differentiation of thyroid nodules. *PLoS One* 2012;7:e42735
11. Friedrich-Rust M, Romenski O, Meyer G, Dauth N, Holzer K, Grünwald F, et al. Acoustic Radiation Force Impulse-Imaging for the evaluation of the thyroid gland: a limited patient feasibility study. *Ultrasonics* 2012;52:69–74
12. Gu J, Du L, Bai M, Chen H, Jia X, Zhao J, et al. Preliminary study on the diagnostic value of acoustic radiation force impulse technology for differentiating between benign and malignant thyroid nodules. *J Ultrasound Med* 2012;31:763–771
13. Zhang YF, Xu HX, He Y, Liu C, Guo LH, Liu LN, et al. Virtual touch tissue quantification of acoustic radiation force impulse: a new ultrasound elastic imaging in the diagnosis of thyroid nodules. *PLoS One* 2012;7:e49094
14. Nightingale K, Soo MS, Nightingale R, Trahey G. Acoustic radiation force impulse imaging: in vivo demonstration of clinical feasibility. *Ultrason Med Biol* 2002;28:227–235
15. Palmeri ML, Wang MH, Dahl JJ, Frinkley KD, Nightingale KR. Quantifying hepatic shear modulus in vivo using acoustic radiation force. *Ultrason Med Biol* 2008;34:546–558
16. Zhan J, Diao XH, Chai QL, Chen Y. Comparative study of acoustic radiation force impulse imaging with real-time elastography in differential diagnosis of thyroid nodules. *Ultrason Med Biol* 2013;39:2217–2225
17. Zhang FJ, Han RL. The value of acoustic radiation force impulse (ARFI) in the differential diagnosis of thyroid nodules. *Eur J Radiol* 2013;82:e686–e690
18. Kim HG, Moon HJ, Kwak JY, Kim EK. Diagnostic accuracy of the ultrasonographic features for subcentimeter thyroid nodules suggested by the revised American Thyroid Association guidelines. *Thyroid* 2013;23:1583–1589
19. Moon HJ, Kwak JY, Kim MJ, Son EJ, Kim EK. Can vascularity at power Doppler US help predict thyroid malignancy? *Radiology* 2010;255:260–269
20. Moon WJ, Baek JH, Jung SL, Kim DW, Kim EK, Kim JY, et al. Ultrasonography and the ultrasound-based management of thyroid nodules: consensus statement and recommendations. *Korean J Radiol* 2011;12:1–14
21. American Thyroid Association (ATA) Guidelines Taskforce on Thyroid Nodules and Differentiated Thyroid Cancer, Cooper DS, Doherty GM, Haugen BR, Kloos RT, Lee SL, et al. Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer. *Thyroid* 2009;19:1167–1214
22. Asteria C, Giovanardi A, Pizzocaro A, Cozzaglio L, Morabito
갑상선결절의 양성과 악성의 감별진단을 위한 초음파 음향복사임펄스 탄성영상의 진단적 가치: B-모드 초음파소견과 비교

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목적: 갑상선결절에서 양성과 악성결절을 감별하는 데 초음파 음향복사임펄스 탄성영상(acoustic radiation force impulse elasticity imaging; 이하 ARFI)의 진단적 가치를 분석하고자 한다.

대상과 방법: 123명의 환자에서 약 127개의 갑상선결절을 초음파영상과 ARFI 기법으로 검사하였다. 각각의 결절에서 B-mode 초음파 악성소견을 점수화(B-mode score)하였고, ARFI 탄성을 수치화한 Virtual Touch tissue quantification (이하 VTQ score)을 구하였다. 그리고, 두 값을 합산한 값을 정리하였다. 양성과 악성결절을 감별하는 데 B-mode score, VTQ score 및 합산값의 유용성을 비교 분석하였다.

결과: 민감도, 특이도, 양성예측도, 음성예측도 및 정확도는 B-mode score가 84%, 85%, 66%, 94%, 85%; VTQ score가 75%, 91%, 73%, 92%, 86%; 합산값이 88%, 87%, 70%, 95% 및 88%였다. 수신기작동특성곡선(receiver-operating characteristic curve; 이하 ROC curve) 분석에서 B-mode score, VTQ score, 합산값의 ROC curve 아래 면적 값은 각각 0.895, 0.837 및 0.912였다. ROC curve 간 쌍대비교(pairwise comparison)에서 B-mode와 VTQ score, B-mode와 합산값 사이에 유의한 차이가 없었다. 합산값은 VTQ score에 비해 진단적 우위(\(p = 0.0023\))를 보였다.

결론: ARFI VTQ값은 갑상선의 양성과 악성결절을 구별하는 데에 좋은 검사법이다. 하지만, ARFI VTQ값은 B-mode 검사에 비해 진단적 우위는 없으며, B-mode 소견과 같이 시행하였을 때 더 유용하다.

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