Application of thyroid imaging reporting and data system (TI-RADS) in thyroid ultrasonography interpretation by less experienced physicians

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Aims and objectives

The number of diagnosed nonpalpable thyroid nodules is increasing as a consequence of the widespread use of ultrasonography (US) in health surveillance and an increase in the number of US-guided fine needle aspiration (US-FNA) being performed [1]. Thyroid nodules are found in up to 67% of adults by US [2]. However, fewer than 5.0-6.5% of incidentally discovered thyroid nodules are malignant [3]. Thus, it is important to establish criteria to select thyroid nodules for FNA according to malignancy risk.

US is an important diagnostic tool in predicting thyroid malignancy and selecting thyroid nodules which should be assessed by FNA [4-6]. Known suspicious US features include marked hypoechogenicity, microlobulated or irregular margins, microcalcifications and taller-than wide shape, and a combination of these features are known to provide better diagnostic accuracy than using only one feature [4, 7, 8]. Many organizations have recommended guidelines for the selection of thyroid nodules for biopsy using size criteria or suspicious US features [9-12]. However, various terms such as probably benign, indeterminate, low suspicious, and suspicious and different criteria hinder effective communication between reporting radiologists and clinicians. In breast imaging, the Breast Imaging Reporting and Data System (BI-RADS) is widely used to assess the probability of malignancy and need for biopsy [13]. Based on this system, breast nodules can be established with a certain malignancy rate for each category. Similar to BI-RADS, the Thyroid Imaging Reporting and Data System (TI-RADS) was developed for risk stratification of thyroid nodules using US features [14-16].

Although several studies have suggested that TI-RADS helps avoid confusion among physicians and patients and reduces unnecessary benign cytologic results, applying this approach is difficult in the daily practice because of its complexity. In a study looking for novel approaches to overcome the complexity of TI-RADS, Kwak et al recently reported that as the number of suspicious US features increased, the fitted probability and risk of malignancy also increased. And they demonstrated that the following US features showed a significant association with malignancy: solid component, hypoechogenicity, marked hypoechogenicity, microlobulated or irregular margins, microcalcifications, and taller than wide shape [17]. However, this study was limited in that each suspicious US feature was regarded with the same weight of malignancy probability. Thereafter, a diagnostic prediction model derived from the total risk score was proposed that reflected the different probabilities of malignancy from each suspicious US feature, and the resulting model showed that US risk scores could predict thyroid malignancy well [18]. However, radiologists involved in these previous studies were experienced in thyroid imaging who had more than 5 years of experience. Therefore, the purpose of this study was to verify the usefulness of TI-RADS in the less experienced physicians with less than 1 yr experience in thyroid imaging.
Methods and materials

Study population

This retrospective study was approved by the institutional review board and required neither patient approval nor informed consent for review of patients' images and medical records. However, written informed consent was obtained from all patients for US-FNA prior to each procedure as part of our hospital's daily practice. From March 2012 to May 2012, 259 consecutive thyroid nodules of 248 patients were imaged with gray-scale US and US-FNA was performed by 4 less experienced radiologists. Of these, fifty-five thyroid nodules including indeterminate (n = 15) or nondiagnostic results (n = 40) at cytologic evaluation were excluded because they did not undergo surgery or repeat US-FNA. Inclusion criteria were as follows; (a) thyroid nodules in which thyroid surgery was performed (n = 63), (b) benign or malignant results at cytologic evaluation (n = 139), and (c) benign or malignant results at US-FNA or thyroid surgery after nondiagnostic cytologic results (n = 2). Finally, 204 thyroid nodules in 195 patients (26 men and 169 women; mean age, 51 years; age range, 16-88 years) were enrolled in this study. Among 204 thyroid nodules, 65 nodules (32%) were malignant and 139 (68%) were benign.

Real-time Gray-scale US

Real-time gray-scale US was independently performed by one of four board-certificated less experienced radiologists (<1 yr experience in thyroid imaging) and were assigned arbitrarily according to the hospital's daily schedule, using a 6-to 14-MHz linear array transducer (EUB-7500, Hitachi Medical, Tokyo, Japan) or a 5-to 12-MHz linear array transducer (iU 22, Philips Medical Systems, Bothell, WA, USA). Before this study, each radiologists had experience of thyroid US for 8, 9, 7 and 7 months during resident practices in different hospitals, respectively. During this study period, all four radiologists have underwent fellowship training in thyroid imaging for 1 month in same hospital. Of 204 thyroid nodules, 15, 39, 55, and 95 thyroid nodules were imaged by physician 1, 2, 3, and 4, respectively, in this study.

US features of all thyroid nodules were prospectively recorded for clinical use according to internal component, echogenicity, margins, calcifications, shape, and final assessment by the radiologists who had performed US. The internal component was classified as complete solid, cystic portion greater than 50%, or cystic portion less than or equal to 50%. Echogenicity was classified as hyperechogenicity, isoechochogenicity, hypoechochogenicity (with respect to normal thyroid parenchyma), or marked hypoechochogenicity (defined as decreased echogenicity when compared to the strap muscle). Margins were classified as well defined, microlobulated or irregular. Calcifications were classified as microcalcification (less than or equal to 1mm in diameter; tiny, punctuate, hyperechoic foci, either with or without acoustic shadows), macrocalcification, or no calcification. Shape was defined as taller than wide (ratio of the
anteroposterior diameter to the transverse diameter \# 1) or wider than tall. Suspicious features of thyroid nodules on US included marked hypoechoogenicity, not well defined margins, microcalcifications and taller than wide shape. All radiologists classified the thyroid nodules into two categories, as either positive for malignancy or negative for malignancy \[4, 7\]. When thyroid nodules showed any of the suspicious features, they were classified as positive for malignancy. When thyroid nodules showed none of the suspicious features, they were classified as negative for malignancy.

US-FNA was performed on thyroid nodules with suspicious US features or the largest of thyroid nodules in patients with multiple thyroid nodules that did not have suspicious US features \[4, 7\]. US-FNA was performed with a 23-gauge needle attached to a 2-mL disposable plastic syringe and each lesion was aspirated at least twice with the freehand technique. Samples obtained were expelled on glass slides, smeared, and placed immediately in 95% alcohol for Papanicolaou staining. The remaining material in the syringe was rinsed in saline for cell block processing \[19\]. Cytopathologists were not on site during the aspiration procedure and cytology slides were interpreted by an experienced pathologist to confirm the cytologic diagnosis. Based on the Bethesda System for Reporting Thyroid cytology, FNA cytology results were classified as nondiagnostic, benign, atypia of undetermined significance/ follicular lesion of undetermined significance (AUS/FLUS), suspicious for follicular neoplasm or suspicious for a Hurthle cell neoplasm, suspicious for malignancy and malignancy \[20\].

The number of suspicious US features for each thyroid nodule was counted using our prospectively recorded US data. According to the results of a previous study, solid component, hypoechoogenicity, marked hypoechoogenicity, microlobulated or irregular margins, microcalcifications, and taller than wide shape were counted as suspicious US features \[17\]. We applied the TI-RADS category 3 (Probably benign) to nodules with no suspicious US feature (Fig. 1), category 4a (Low suspicion for malignancy) to nodules with one suspicious US feature, category 4b (Intermediate concern for malignancy) to nodules with two suspicious US features, category 4c (Moderate concern but not classic for malignancy) to nodules with three or four suspicious US features (Fig. 2), and category 5 (Highly suggestive of malignancy) to nodules with five suspicious US features (Fig. 3), respectively, according to the results of the previous study \[17\].

Another study proposed a new prediction model derived from the total risk score that took into consideration the different risk scores of each suspicious US feature \[18\]. They estimated the risk score for each suspicious US feature by calculating the odds ratios of thyroid malignancy. According to this Kwak et al's recent study, we applied a score of 2 to hypoechoogenicity, a score of 6 to marked hypoechoogenicity, a score of 1 to taller than wide shape, a score of 5 to microlobulated or irregular margins, and a score of 2 to microcalcifications \[18\]. Then, the total risk score of each thyroid nodule was calculated by summing the scores of each suspicious US feature and the percentage of malignancy was obtained according to the total risk score.
Statistical analysis

To determine the association between malignancy and patient age and nodule size, an independent two-sample $t$ test was used. Patient gender was compared between benign and malignant nodules using the Chi-square test. The rate of malignancy in thyroid nodules according to the TI-RADS category were also calculated. The receiver-operating characteristic curve (ROC) analysis was performed to assess the accuracy of two models predicting thyroid malignancy derived from the number of suspicious US features and a total risk score. The Delong method was used to compare the area under curves (AUCs) between the two prediction models. Associations between two models and the risk of malignancy were analyzed using penalized B-splines and Cochran-Armitage trend test. Analysis was performed with SAS software (version 9.2; SAS Institute, Cary, NC, USA). Statistical significance was assumed when the $P$ value was less than 0.05. All reported $P$ values are 2-sided.
Images for this section:

Fig. 1

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Fig. 2

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Fig. 3

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Results

The mean size of the thyroid nodules was 16.2 ± 11.6 mm (range, 2-65mm). The malignant nodules were significantly smaller than the benign nodules (mean size, 12.6 mm ± 11.2 vs 17.9 mm ± 11.6, respectively; \( P = 0.003 \)). Gender did not differ significantly between malignant and benign nodules (\( P = 0.514 \)), nor did age (\( P = 0.350 \)).

Of 204 thyroid nodules, TI-RADS category 3, 4a, 4b, 4c, and 5 represented 4% (1/23), 0% (0/43), 13.5% (5/37), 56.1% (46/82), and 68.4% (13/19) of the carcinomas, respectively. Of 65 thyroid cancers, 1 (2%), 5 (7%), 46 (71%), 13 (20%) nodules were subgrouped to the TI-RADS category 3, 4b, 4c, and 5, respectively. The percentage of malignancy according to the sum of risk scores for each thyroid nodule is shown in Table 4. The malignancy rate was 2.2 % (1/46) in thyroid nodules with the sum of risk scores presenting as zero. The predictive power (\( A_z = 0.827 \)) of the model using the number of suspicious US features of each thyroid nodule was not significantly superior to that (\( A_z = 0.833 \)) of the model using the total risk score of each thyroid nodule (\( P = 0.673 \)). Penalized B-splines demonstrated that the risk of malignancy tended to increase as the number of suspicious US features and the total risk score increased in each thyroid nodule (Fig. 4 and 5). According to the Cochran-Armitage trend test, as the number of suspicious US features and the total risk score of each thyroid nodule increased, the risk of malignancy increased (\( P < 0.001 \)).
Conclusion

Both the number of suspicious US features and the total risk score are applicable and show comparable results in the risk stratification of thyroid nodules by less experienced radiologists in thyroid imaging.
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