Contrast-Enhanced Ultrasound Improves the Accuracy of the ACR TI-RADS in the Diagnosis of Thyroid Nodules Located in the Isthmus

Kontrastverstärkter Ultraschall verbessert die Genauigkeit des ACR-TIRADS bei der Diagnose von Schilddrüsenknoten im Isthmus

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ABSTRACT

Objectives To evaluate the diagnostic performance of the American College of Radiology (ACR) Thyroid Image Reporting and Data System (TI-RADS), contrast-enhanced ultrasound (CEUS), and a modified TI-RADS in differentiating benign and malignant nodules located in the isthmus.

Methods This retrospective study was approved by the institutional review board. Informed consent was obtained. Grayscale ultrasound (US) and CEUS images were obtained for 203 isthmic thyroid nodules (46 benign and 157 malignant) in 198 consecutive patients (156 women, mean age: 44.7 years ± 11.3 [standard deviation]; 47 men, mean age: 40.9 years ± 11.0). The area under the receiver operating characteristic curve (AUC) of the diagnostic performance of the ACR TI-RADS, CEUS, and the modified TI-RADS were evaluated.

Results Lobulated or irregular margins (P = 0.001; odds ratio [OR] = 9.250) and punctate echogenic foci (P = 0.007; OR = 4.718) on US and hypoenhancement (P < 0.001; OR = 20.888) on CEUS displayed a significant association with malignancy located in the isthmus. The most valuable method to distinguish benign nodules from malignant nodules was the modified TI-RADS (AUC: 0.863 with modified TR5), which was significantly better than the ACR TI-RADS (AUC: 0.738 with ACR TR5) (P < 0.001) but showed no significant difference with respect to CEUS (AUC: 0.835 with hypoenhancement) (P = 0.205). The diagnostic value was significantly different between CEUS and the ACR TI-RADS (P = 0.028).

Conclusion The modified TI-RADS could significantly improve the accuracy of the diagnosis of thyroid nodules located in the isthmus.

ZUSAMMENFASSUNG

Ziel Bewertung der diagnostischen Leistung des Thyroid Image Reporting and Data Systems (TIRADS) des American College of Radiology (ACR), des kontrastverstärkten Ultraschalls (CEUS) und eines modifizierten TIRADS zur Differenzierung von benignen und malignen Knoten im Isthmus.


Ergebnisse Lobulierte oder unregelmäßige Ränder (p = 0,001; Odds Ratio [OR] = 9,250) und punktförmige echogene Herde (p = 0,007; OR = 4,718) im US und Hypoenhancement (p < 0,001; OR = 20,888) im CEUS zeigten eine signifikante As-
soziation mit Malignität im Isthmus. Die wertvollste Methode zur Unterscheidung von benignen und malignen Knoten war das modifizierte TIRADS (AUC: 0.863 mit modifiziertem TR5), welches signifikant besser war als ACR-TIRADS (AUC: 0.738 mit ACR TR5; p < 0.001), aber keinen signifikanten Unterschied zu CEUS (AUC: 0.835 mit Hypoenhancement) zeigte (p = 0.205). Der diagnostische Wert unterschied sich signifikant zwischen CEUS und ACR-TIRADS (p = 0.028).

**Schlussfolgerung** Das modifizierte TIRADS konnte die Genauigkeit der Diagnose von Schilddrüsenknoten im Isthmus signifikant verbessern.

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**Introduction**

The thyroid isthmus is a relatively small but central part of the thyroid that links the left and right lobes of the thyroid. Thyroid nodule location has reportedly been an independent risk factor in predicting the risk of malignant nodule [1]. According to previous reports [2–5], malignant nodules located in the thyroid isthmus are more aggressive than those located in the thyroid lobes, including multifocal malignancies, thyroid gland envelope invasion, extrathyroidal extension, and even lymph node metastases. The findings suggest that total thyroidectomy is an appropriate method for malignant nodules located in the isthmus [2, 6]. Among the medical imaging technologies for the examination of the thyroid, grayscale ultrasound (US) is the most commonly used tool, mainly because it provides real-time scanning and simple operation, is cost-effective, and does not use radiation [7]. The American College of Radiology (ACR) Thyroid Imaging Reporting and Data System (TI-RADS) [8] aims to improve the diagnostic accuracy of thyroid nodules by US. Nodules are assigned points based on features in five classifications (composition, echogenicity, shape, margin, and echogenic foci) and are then categorized into one of five TI-RADS risk categories [8]. However, the role of the TI-RADS in the diagnosis of thyroid nodules within the isthmus is still controversial. Hahn et al. [9] reported that malignant thyroid nodules located in the isthmus more frequently presented with a well-defined margin (31.3 %) and a wider-than-tall shape (91.7 %). Though several studies [10–12] have reported that the total accuracy of the ACR TI-RADS in diagnosing thyroid nodules ranged from 52.0 ~ 92.1 %, the accuracies of the ACR TI-RADS in isthmic thyroid nodules were not reported in their studies.

Contrast-enhanced ultrasound (CEUS) is a relatively new technique to display the hemodynamics of thyroid nodules and is considered to be an effective method to distinguish benign from malignant thyroid nodules [13–15]. However, there is no evidence that CEUS can accurately diagnose thyroid nodules located in the isthmus.

The aim of this study was to evaluate the diagnostic performance of the ACR TI-RADS, CEUS, and a modified TI-RADS in distinguishing benign from malignant thyroid nodules located in the isthmus.

**Methods**

**Patients**

The local institutional review board approved this retrospective study, and the requirement to obtain informed consent of patients was waived. This study was performed at our institution from January 2015 to December 2018. During this time, the initial population included 227 thyroid nodules located in the isthmus in 222 consecutive patients (age > 18 years). Nodules that were solid, hypoechoic, lobulated or with irregular margins, taller-than-wide, or contained microcalcifications on grayscale US were selected for US-guided fine needle aspiration (FNA) [16, 17]. CEUS examination was performed on all thyroid nodules prior to FNA. Pathological diagnosis was based on FNA [18, 19] or surgical results when available. Only benign or malignant nodules were included unless a nodule underwent repeat FNA or surgery that certified benignity or malignancy. Twenty-four nodules were excluded for indeterminate or nondiagnostic pathological results. The final study population comprised 203 nodules from 198 patients (156 women, mean age: 44.7 years ± 11.3 [standard deviation]; range: 22 ~ 69 years; 47 men, mean age: 40.9 years ± 11.0, range: 23 ~ 63 years). Of the 198 patients, 5 had two nodules. FNA and surgery were performed on 116 nodules, and 87 had undergone only FNA (active surveillance instead of resection was implemented if nodules were slow-growing, and there was no appearance of lymph node metastases or distant metastases). The median size of the nodules was 0.8 cm (interquartile ranges [IQRs]: 0.6 ~ 1.2).

**US and ACR TI-RADS diagnostic criteria**

All ultrasonography examinations were performed with two commercially available scanners (Mylab90 [Esaote, Genoa, Italy], equipped with an L523 linear-array transducer for grayscale US and an LS522 for CEUS; Resona7 [Mindray, Shenzhen, China], equipped with an L11–3U linear-array transducer for both grayscale US and CEUS). If all or most of the thyroid nodule was located in front of the trachea in a transverse US image, it was defined to be located in the isthmus.

US features were recorded for each thyroid nodule including size (the maximal diameter on US); composition (solid or almost completely solid, mixed cystic and solid, spongiform, and cystic or almost completely cystic); echogenicity (compared to the surrounding normal parenchyma, classified as anechoic, hyperechoic, isoechoic, hypoechoic, or very hypoechoic if the echogenicity was lower than the cervical strap muscle); shape (wider-than-tall or taller-than-wide shape was assessed by measurements, taller-than-wide was defined as the anteroposterior diameter exceeding the transverse diameter in the transverse plane [20]); margin (smooth, ill-defined, lobulated or irregular, and extra-thyroidal extension, extra-thyroidal extension was characterized by loss of the echogenic thyroid capsule or/and frank invasion of perithyroid soft tissue [21]); and echogenic foci (punctate echogenic foci,
rim or peripheral calcifications, macrocalcifications, and no or large comet-tail artifacts). The nodules were then reclassified following the ACR TI-RADS guideline [8].

**CEUS and diagnostic criteria**

CEUS was performed with the same instrument used for grayscale US. The contrast medium was SonoVue (BR1; Bracco, Milan, Italy), which is a sulfur-hexafluoride-filled microbubble contrast agent encapsulated by a flexible phospholipid shell. SonoVue was injected intravenously as a bolus at a 1.2 mL dose, followed by 5 mL of normal saline flush. The timer on the ultrasound machine was started, and the imaging plane was kept as stable as possible. Each contrast imaging acquisition lasted at least 2 minutes after the bolus injection and was digitally stored as raw data. If multiple nodules in one patient required CEUS, an interval of 10 minutes was needed to avoid the effects of the last injection.

The CEUS diagnostic criteria are separated into nonenhancement (no enhancing signal visible at the whole nodule), hypoenhancement, isoenhancement, or hyperenhancement compared with the parenchyma of the thyroid gland.

**Image interpretation and the modified TI-RADS**

Ultrasonography images and videos stored in a computer workstation were reviewed in a random order by two radiologists (with 22 and 17 years of experience in thyroid US) blinded to the patient data. First, each radiologist reviewed the US and CEUS images independently. Subsequently, two radiologists discussed the images in which there was a divergence of their views and reached a consensus on the US features and CEUS enhancement patterns in those cases.

Modified TI-RADS categories were classified on the basis of the following criteria (Fig. 1): if the CEUS indicated nonenhancement, one level was subtracted from the ACR TI-RADS category except TR1; if the CEUS indicated hypoenhancement, one level was added to the ACR TI-RADS category except TR5; if CEUS indicated hyper- or isoenhancement, the modified TI-RADS category remained the same as the ACR TI-RADS category.

**Statistical analysis**

Quantitative data are expressed as the means with standard deviations or medians and IQRs. Groups were compared using the variance, Kruskal-Wallis, chi-squared and Fisher’s exact tests depending on distribution. The rankings of valuable features on US and CEUS were evaluated according to the odds ratios (ORs). The weighted kappa statistic (κ) [22] was performed to assess the consistency between the ACR TI-RADS and modified TI-RADS classifications; and interobserver agreement among the two radiologists regarding the ACR TI-RADS classifications, and CEUS enhancement patterns of the nodules. The diagnostic values of the ACR TI-RADS, CEUS and modified TI-RADS were estimated using accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under receiver operating characteristic (ROC) curve analysis, with 95% confidence intervals (CIs). All statistical analyses were performed with the SPSS, version 16.0 (SPSS, Chicago, IL) and MedCalc Software, version 9.3.8.0 (Mariakerke, Belgium).

**Results**

**Characteristics of patients and isthmic thyroid nodules**

Among 203 nodules, 157 were malignant and 46 were benign. Seventeen benign and 99 malignant nodules were certified by histopathological results, while 29 benign and 58 malignant nodules were certified by cytological reports. The detailed pathological types are as follows: the malignant thyroid nodules were all papillary thyroid carcinomas; the benign nodules included 6 inflammatory nodules, 14 adenomatous nodular goiters, 9 hemorrhagic necrotic colloid nodules, 10 nodular goiters, and...
there were 7 nodules coexisting with Hashimoto’s thyroiditis in 10 nodular goiters.

The basic features of patients and nodules are outlined in Table 1. Sex (P = 0.065) and nodule size (P = 0.204) were not associated with malignancy. There were significant differences in

<table>
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<th>malignant nodules</th>
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<tr>
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<td>116 (73.4 %)</td>
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IQR = interquartile range.
* A P-value < 0.05 was regarded as statistically significant.
† Statistically significant.
* Nodules could have more than one type of echogenic foci.
the median age at the time of diagnosis in all patients with malignant (42 years, IQR: 34 ~ 52) and benign (51 years, IQR: 37 ~ 56) nodules (P = 0.014).

Valuable features of US
Malignancy located in the thyroid isthmus more frequently had a solid composition (99.0%), hypoechoogenicity (89.2%), a wider-than-tall shape (73.2%), punctate echogenic foci (47.8%), and lobulated or irregular margins (44.6%) (Table 1). Solid or almost completely solid component (P = 0.002), lobulated or irregular margins (P < 0.001) and punctate echogenic foci (P < 0.001) were found more frequently in malignancies, whereas other US features had no value (P > 0.05).

Valuable features of CEUS
Among the 157 malignant nodules, 134 indicated hypoenhancement (Fig. 2, 3), 22 indicated isoenhancement, 1 indicated hyperenhancement. Among the 46 benign nodules, 10 indicated hypoenhancement, 24 indicated isoenhancement, 2 indicated hyperenhancement, and 10 indicated nonenhancement (Fig. 4). The CEUS diagnostic criteria were associated with malignant nodules (P < 0.001) (Table 1).

Rankings of the valuable features of US and CEUS
Three features on US and CEUS displayed a significant association with malignancy located in the isthmus (Table 2): lobulated or irregular margins (P = 0.001) and punctuate echogenic foci (P = 0.007) on US and hypoenhancement (P < 0.001) on CEUS. The OR of hypoenhancement was 20.888, higher than that of lobulated or irregular margin (OR = 9.250) and punctate echogenic foci (OR = 4.718).
Diagnostic accuracies of isthmic thyroid nodules by the ACR TI-RADS, CEUS and the modified TI-RADS

The incidence of malignancy of ACR TI-RADS TR4 and TR5 was 61.3 % and 90.8 %, respectively. The incidence of malignancy of modified TI-RADS TR4 and TR5 was 21.2 % and 93.2 %, respectively, and the incidence of malignancy of isthmic thyroid nodules classified as modified TR4 was dropped from 61.3 % to 21.2 % compared with that of the initial ACR TI-RADS classification (▶ Table 3).

In the comparison between ACR TI-RADS and modified TI-RADS classifications (▶ Table 4), among the 119 thyroid nodules classified as TR5 by the ACR TI-RADS, 4 were downgraded to TR4 by the modified TI-RADS. Among the 80 thyroid nodules classified as TR4 by the ACR TI-RADS, 46 were upgraded to TR5 and 6 was downgraded to TR3 by the modified TI-RADS. Among the 4 thyroid nodules classified as TR3 by the ACR TI-RADS, 1 was upgraded to TR4 and 1 was downgraded to TR2 by the modified TI-RADS. Among 203 nodules, 145 were categorized in the same risk categories by the ACR TI-RADS and modified TI-RADS classification systems. The consistency between the two classifications was 0.536 (95 % CI 0.419 ~ 0.652).

The AUC of the ACR TI-RADS was 0.738 (95 % CI 0.672 ~ 0.797, P < 0.001) and the best cut-off value for predicting malignancies was > TR4. Application of this cut-off value resulted in a sensitivity of 68.8 % (95 % CI 60.9 ~ 75.9), a specificity of 76.1 % (95 % CI 61.2 ~ 87.4), and an accuracy of 70.4 %. The AUC of modified TI-RADS was 0.863 (95 % CI 0.807 ~ 0.907, P < 0.001) and the best cut-off value for predicting malignancies was > TR4. Application of this cut-off value resulted in a sensitivity of 95.5 % (95 % CI 91.0 ~ 98.2), a specificity of 76.1 % (95 % CI 61.2 ~ 87.4), and an accuracy of 91.1 %. The AUC of CEUS was 0.835 (95 % CI 0.777 ~ 0.884, P < 0.001) with hypoenhancement. Application of this cut-off value resulted in a sensitivity of 85.4 % (95 % CI 78.8 ~ 90.5), a specificity of 78.3 % (95 % CI 63.6 ~ 89.1), and an accuracy of 83.7 % (▶ Fig. 5). The most valuable method for distinguishing benign nodules from malignant nodules located in the isthmus was the modified TI-RADS, which was higher than the ACR TI-RADS alone (P < 0.001) but showed no significant difference with respect to CEUS (P = 0.205). The diagnostic value was significantly different between CEUS and the ACR TI-RADS (P = 0.028).

Interobserver agreement

The two radiologists showed excellent agreement, with a κ of 0.862 ± 0.036 for the ACR TI-RADS classification and a κ of 0.836 ± 0.039 for CEUS enhancement pattern assessment.
Discussion

Malignant isthmic thyroid nodules are more likely to invade surrounding tissues compared to malignancies located in thyroid lobes [2–5]. Early and correct diagnosis of malignant thyroid nodules located in the isthmus has great significance for clinical treatment selection and outcome prediction.

For 5- to 10-mm suspicious thyroid nodules, when patients have clinical symptoms, suspicious clinical signs, suspicious cervical lymph node metastasis, medical radiation, or contact history of radiotherapy, family history of thyroid cancer, and other high suspicion of thyroid cancer, the standard of FNA should be relaxed appropriately [8]. Thyroid US is gradually included in the routine physical examination in our country, resulting in an increased incidence rate of thyroid nodules suspicious for PTC. Patients are likely to experience fear or anxiety at the thought of leaving their cancer untreated. Therefore, some papillary thyroid microcarcinomas were included in this study.

In the present study, malignancies located in the thyroid isthmus more frequently had a solid composition (99.0 %), hypoechogenicity (89.2 %), a wider-than-tall shape (73.2 %), punctate echogenic foci (47.8 %), and lobulated or irregular margins (44.6 %). The cut-off value for the prediction of malignancies was ACR TI-RADS TR5, and the AUC of the ACR TI-RADS for predicting a malignant nodule was 0.738 in our study, which was lower than previous studies based on malignant thyroid nodules located in the lobe [23, 24]. These variable US features seem to be due to thyroid nodules growing in the narrow isthmic space, which affects the diagnostic result. Improvements can be made in the application of the ACR TI-RADS for the differentiation of benign and malignant thyroid nodules located in the isthmus.

In recent years, CEUS has been introduced to improve the diagnostic performance of grayscale US in thyroid nodules, and the sensitivity and specificity were reported to be 85 % and 82 %, respectively [14]. There is no unified standard and feature of CEUS for the diagnosis of malignancy. Studies from numerous researchers suggest that most of the contrast indicating hypoen-
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There were several limitations in this study. Firstly, 87 nodules were certified by cytological reports. False-negative and false-positive cytological results may have existed. Secondly, all 157 malignancies located in the isthmus were papillary thyroid carcinomas. There were no cases of follicular neoplasms. Studies to analyze the TI-RADS and CEUS in follicular neoplasms located in the isthmus are anticipated. Thirdly, because it was hard to select two ROIs (a single ROI contained the whole nodule, and a similar ROI area was selected from adjacent normal thyroid tissue as a reference) within the narrow isthmic space in transverse sonogram, we did not perform a quantitative CEUS evaluation. Although a meta-analysis of seven eligible studies concluded that the qualitative CEUS evaluation showed better sensitivity and specificity in the diagnosis of thyroid nodules compared with the quantitative CEUS evaluation [15], the quantitative analysis of CEUS in the diagnosis of thyroid isthmic nodules in this study had not been performed, which needs to be evaluated in the future. Finally, this study represents the work of a single thyroid clinic, there is always the risk of potential bias with respect to data collection, and the number of cases was relatively small. These results should be confirmed by a large sample size in a multi-center study.

In conclusion, the present study suggested that the modified TI-RADS could significantly increase the diagnosis accuracy of thyroid nodules located in the isthmus.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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