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● *Original Contribution*

COMPARISON BETWEEN THIN-SLICE 3-D VOLUMETRIC ULTRASOUND AND CONVENTIONAL ULTRASOUND IN THE DIFFERENTIATION OF BENIGN AND MALIGNANT THYROID LESIONS

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Abstract—We explored the efficacy of thin-slice volumetric 3-D ultrasound (3-DUS) in distinguishing between benign and malignant thyroid nodules. A total of 103 thyroid nodules were evaluated prospectively using 3-D gray-scale ultrasonography. The shape, margin, halo and potential capsular invasion of the nodules were compared with the findings of conventional 2-D ultrasound (2-DUS). Of the 103 thyroid nodules, there were 50 pathologically confirmed benign lesions and 53 malignant lesions (51.5%). Shape irregularity, ill-defined margins and capsular invasion provided sensitivities of 90.0%, 47.2% and 39.6% and specificities of 88.0%, 84.0% and 100%, respectively, for the malignant lesions. The diagnosis of thyroid cancer was improved in 3-DUS compared with 2-DUS, with a sensitivity of 88.7%, specificity of 90.0%, positive predictive value of 90.4%, negative predictive value of 88.2% and accuracy of 89.3%. The sensitivity of detection for lesions with capsular invasion increased to 39.6% with 3-DUS, more than twice that of 2-DUS. Three-dimensional US is highly accurate in diagnosing thyroid nodules, particularly those with capsular invasion. (E-mail: Yuxinjiangxh@163.com) **© 2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Thyroid nodule, 3-D ultrasound, Diagnosis.**

INTRODUCTION

Ultrasound has an accuracy of 67%–92% in the diagnosis of thyroid nodules (Moon et al. 2007; Stacul et al. 2007; Tae et al. 2007) and remains one of the most frequently used approaches for imaging these lesions. However, ultrasound suffers certain limitations: (i) conventional static images sometimes do not completely reflect the structures of the thyroid nodules; (ii) the procedure is highly dependent on the operator(s); and (iii) systematic reviews and analyses are often not available. By contrast, 3-D ultrasound (3-DUS) can be used to automatically acquire a series of 2-D images containing spatial data. Three-dimensional US avoids the limitations of gray-scale ultrasound by displaying the lesion features *via* reconstruction. However, few studies to date have explored the application of 3-DUS for thyroid diseases; most studies have focused on applications for thyroid/nodule volume measurement (Andermann et al. 2007; Lyshchik et al. 2004; Ying et al. 2008). We analyzed the 3-D volumetric characteristics of thyroid nodules by performing multiplanar reconstruction of the 3-D volumetric data of the thyroid nodules and explored the diagnostic value of 3-DUS in the differential diagnosis of these lesions by comparing the lesion features determined in this manner with those from 2-D ultrasound (2-DUS).

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METHODS

Patients

The experimental protocol was approved by a local institutional review board, and informed consent for the study was obtained from all human patients. Ninety-six consecutive patients with complete pre-operative 3-DUS data who underwent surgical operations for thyroid nodules from March 2008 to April 2009 were prospectively enrolled in this study. Two patients withdrew

from the study before surgery; therefore, 103 thyroid nodules in 94 patients were included in the final analysis. Clinical physicians make surgical decisions based on (i) suspicion of malignancy or malignancy diagnosed on fine-needle aspiration (FNA) (n = 12, 12.8%); (ii) high suspicion of malignancy on US without FNA (n = 42, 44.7%); (iii) suspected recurrence after resection of thyroid papillary carcinoma (n = 2, 2.1%); (iv) multiple endocrine neoplasms (n = 2, 2.1%); (v) metastatic cancer from the thyroid confirmed by pathology (n = 2, 2.1%); (vi) hyperthyroidism with thyroid nodules (n = 3, 3.2%); and (vii) retrosternal goiter or compression of the trachea (n = 31, 33.0%). Of the 103 investigated nodules, 18 (17.5%) were from male patients and 85 (82.5%) were from female patients. The mean age of these patients was 43.6 ± 12.2 y (range: 19–71 y).

Machine and examinations

Sonographic examinations were performed with a Voluson E8 (GE Healthcare, Milwaukee, WI, USA) with an 11 L-D high frequency probe with a frequency range of 6–15 MHz for 2-DUS and a RSP6-16-D 3-D volumetric probe for 3-DUS. The default conditions for thyroid examinations were applied. During examination, the patient was in the supine position, and the anterior area of the neck was fully exposed. Two-dimensional US was performed first, and during this procedure, sagittal, coronal and oblique gray-scale images of the thyroid and its surrounding tissues and lymph nodes were obtained. The dynamic range, depth, gain and focus were adjusted to obtain the optimal image. The shape, border, margin, halo and potential capsular invasion of the thyroid nodules were recorded. Three-dimensional US was then initiated. The patient was asked to hold his or her breath and to avoid swallowing. Three-dimensional volumetric US was performed using the built-in 3-D gray-scale mode with the RSP6-16-D 3-D volumetric probe. The 3-D sample frame was set to include the index lesion and the maximum amount of adjacent tissues, approximately 3–4 cm in depth and 4 cm in width. The sweep angle was 15–29° based on the nodule size. Then the probe was stabilized and initial automatic volume data were acquired. The digital images acquired with conventional 2-DUS and 3-DUS were transferred to a personal computer and analyzed using 4-D VIEW PC software (Version 6.2), which provides the same interface as the scanner.

Image analysis

Volumetric data were analyzed using the VOCAL (virtual organ computer-aided analysis) imaging program (GE Healthcare, Kretz Ultrasound, Zipf, Austria), which enables the automatic calculation of volumetric data. The "manual mode" was applied in our study. The image was rotated 30° for each analysis, and the profile of each nodule was drawn in six planes to obtain the shape of the nodule. Then, the size of each nodule was obtained by drawing the nodule twice and calculating the average value. Two radiologists with at least 5 y of experience in thyroid sonography, who were blinded to the clinical conditions and pathologic findings of the patients, independently evaluated the 2-DUS and 3-DUS features of the lesions and then summarized the diagnostic results. If the two radiologists did not agree on the diagnosis, the result was discussed until agreement was reached.

Multiplanar imaging analysis was applied to the 3-D images, during which three perpendicular sections were used—a horizontal section (plate A), a longitudinal section (plate B) and a coronal section (plate C)—along with a spatial 3-D image of coronal section obtained after these three sections were combined. The various planes could display 3-D images from different sections and in different directions. To evaluate nodule features, a 100% surface smooth algorithm was chosen for volume rendering of 3-D data. The thickness of the slice was adjusted according to lesion size empirically, approximately 15%–25% of the maximal diameter of the nodule.

The features of the lesions observed *via* 2-DUS and 3-DUS included shape (regular or irregular) (Fig. 1), margin (clear or unclear), halo (complete and regular, irregular/incomplete or none) (Fig. 2) and capsular invasion (distant, adjacent or invaded) (Fig. 3).

The halo features were defined as follows: a regular slim hypoechoic rim around the thyroid nodule (complete and regular halo); a hypoechoic rim around the thyroid nodule, with varied width or with interruptions (irregular/incomplete halo); or no obvious hypoechoic rim visible around the thyroid nodule (absence of halo). The relationship between the nodule and the capsule was defined as follows: distant = thyroid gland tissue visible between the nodule and the capsule; adjacent = an unbroken capsule despite the absence of thyroid gland tissue between the nodule and the capsule; capsular invasion = continuously interrupted capsule.

Pathologic diagnosis

Two pathologists with at least 5 y of experience in thyroid pathology independently issued their diagnoses after observing the sections of the surgically removed thyroid lesions. These pathologists were also blinded to the ultrasound results at diagnosis. If the two pathologists did not agree on the diagnosis, the result was further discussed until agreement was reached.

Statistical analysis

The statistical analysis was performed using SPSS 11.0 software (SPSS, Chicago, IL, USA). Normally distributed data are expressed as the mean ± standard