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● *Original Contribution*

TWO-DIMENSIONAL ULTRASOUND MEASUREMENT OF THYROID GLAND VOLUME: A NEW EQUATION WITH HIGHER CORRELATION WITH 3-D ULTRASOUND MEASUREMENT

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Abstract—This study aimed to develop a new two-dimensional (2-D) ultrasound thyroid volume estimation equation using three-dimensional (3-D) ultrasound as the standard of reference, and to compare the thyroid volume estimation accuracy of the new equation with three previously reported equations. 2-D and 3-D ultrasound examinations of the thyroid gland were performed in 150 subjects with normal serum thyrotropin (TSH, thyroid-stimulating hormone) and free thyroxine (fT4) levels (63 men and 87 women, age range: 17 to 71 y). In each subject, the volume of both thyroid lobes was measured by 3-D ultrasound. On 2-D ultrasound, the craniocaudal (CC), lateromedial (LM) and anteroposterior (AP) dimensions of the thyroid lobes were measured. The equation was derived by correlating the volume of the thyroid lobes measured with 3-D ultrasound and the product of the three dimensions measured with 2-D ultrasound using linear regression analysis, in 75 subjects without thyroid nodule. The accuracy of thyroid volume estimation of the new equation and the three previously reported equations was evaluated and compared in another 75 subjects (without thyroid nodule, $n = 30$; with thyroid nodule, $n = 45$). It is suggested that volume of thyroid lobe may be estimated as: volume of thyroid lobe = $0.38 \cdot (CC \cdot LM \cdot AP) + 1.76$. Result showed that the new equation (16.9% to 36.1%) had a significantly smaller thyroid volume estimation error than the previously reported equations (20.8% to 54.9%) ($p < 0.05$). There was a significantly larger thyroid volume estimation error when thyroid glands with nodules were examined ($p < 0.05$). With the use of the appropriate thyroid volume equation, 2-D ultrasound can be a useful alternative in thyroid volume measurement when 3-D ultrasound is not available. (E-mail: htmying@polyu.edu.hk) **© 2007 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Thyroid gland, Volume, Equation, Ultrasound.**

INTRODUCTION

Assessment of the thyroid gland size is important in the diagnosis and management of different thyroid diseases. Enlargement of the thyroid gland may indicate thyroid disorders such as Graves' disease and thyroiditis and may be associated with iodine deficiency goiter (Miyakawa et al. 1992; Gritzmann et al. 2000). Measurement of thyroid size also helps in planning the dosage in radioiodine therapy for patients with Graves' disease (Reinartz et al. 2002; van Isselt et al. 2003). Ultrasound is a common imaging tool in the assessment and measurement of thyroid glands. It is noninvasive, relatively inexpensive and readily accessible. Although measurement of the size of thyroid gland is not a routine clinical practice in some centres, ultrasound is a common imaging method to use when it is necessary to evaluate the thyroid size. In the assessment of the size of thyroid gland, measurement of the thyroid gland volume is a common practice for at least 20 y because it is more accurate in the evaluation of the thyroid size. Thyroid gland volume is usually estimated with the use of ellipsoid formula by measuring the length, width and thickness of thyroid lobe with two-dimensional (2-D) ultrasound. With the advancement of technology, three-dimensional (3-D) ultrasound is now available for volumetric measurement of thyroid gland (Lyshchik et al. 2004a; Ng et al. 2004; Ying et al. 2005a; Rago et al. 2006). It has been reported that 3-D ultrasound measurement of the thyroid gland volume is highly correlated

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with the surgical reference volume of the thyroid gland (Lyshchik et al. 2004a). Although it has been proven that 3-D ultrasound is more accurate and reliable (intra- and inter-operator variability) than 2-D ultrasound in volumetric measurements of human organs including thyroid gland (Riccabona et al. 1996; Chang et al. 1997; Chou et al. 1997; Lyshchik et al. 2004a, 2004b; Ying et al. 2005a), 3-D ultrasound is not available in all centres, especially in developing countries. Therefore, 2-D ultrasound with the use of ellipsoid formula is still widely used in the evaluation of thyroid gland volume.

With the ellipsoid model in 2-D ultrasound, the length, width and thickness of each thyroid lobe are measured, and multiplied together and by a constant. Previous studies proposed different ellipsoid equations with the use of different constant values, $\pi/6$ or 0.524 (Brown and Spencer 1978), 0.479 (Brunn et al. 1981) and 0.529 (Shabana et al. 2006), for thyroid gland volume estimation. However, there is scant information in the literature about comparison of the accuracy in thyroid volume estimation among different ellipsoid equations. The present study aimed to develop a more accurate equation for 2-D ultrasound thyroid volume estimation using 3-D ultrasound measurement as the standard of reference and to compare the measurement accuracy of the newly developed equation with other previously reported equations.

MATERIALS AND METHODS

Subjects and data collection

A total of 150 subjects with no history of thyroid diseases or thyroid surgery were recruited in the study. There were 63 men and 87 women, and the age range was 17 to 71 y (mean age = 37.7 y). All subjects completed a questionnaire about their demographic information, such as age, gender and medical history. Subjects with a family history of thyroid diseases, or with a history of thyroid diseases or thyroid surgery were excluded. Blood sample was drawn in each subject by venipuncture to evaluate the thyroid hormone levels. Serum thyrotropin (TSH, thyroid-stimulating hormone) was assayed by analytical reagent kits for TSH (VIDAS® TSH, bioMerieux China Ltd., Jiangmen, Guangdong, China) and serum free thyroxine (fT4) level was evaluated by analytical reagent kits for fT4 (VIDAS® fT4, bioMerieux China Ltd., Jiangmen, Guangdong, China). Subjects with a TSH level between 0.27 and 4.7 μIU/mL, and a fT4 level between 9 and 20 pmol/L were considered to be normal. (Col et al. 2004; Surks et al. 2004). This study was approved by the Human Subject Ethics Subcommittee of the Department of Health Technology and Informatics of the Hong Kong Polytechnic University. All subjects signed a consent form before the commencement of the study.

2-D and 3-D ultrasound examination of the thyroid glands were performed in the subjects. All ultrasound examinations were conducted using a Philips HDI 5000 ultrasound unit with a 12 to 5 MHz linear transducer (Bothell, WA, USA). On 3-D ultrasound, the ultrasound unit was used in conjunction with a 3-D add-on system (TomTec 3D Sono-Scan Pro, Munich, Germany). All ultrasound examinations were performed using the SonoCT® real-time compound imaging and XRES™ adaptive image-processing functions for higher image resolution (Philips Medical System, Bothell, WA, USA). Our previous studies on the evaluation of the accuracy and reliability of the 3-D ultrasound in volumetric measurements using tissue specimen phantoms have shown that the 3-D ultrasound system used in the present study has a high accuracy (92.2% to 99.8%), inter-observer reproducibility (90% to 98.6%) and intra-observer repeatability (95.5% to 99.5%) in volumetric measurements (Ng et al. 2004; Pang et al. 2005, 2006; Ying et al. 2005a). Therefore, in this study the thyroid volume measured with 3-D ultrasound was used as the standard of reference.

In the ultrasound examination, subjects lay supine on the examination table with the neck hyperextended and the shoulders were supported with a pillow. The thyroid lobes were scanned separately with the subject's head turned away from the side under examination. Transverse and longitudinal scans of each thyroid lobe were performed to examine for any thyroid nodules. Subjects with incidental detection of thyroid nodule(s) in the ultrasound examination and their thyroid lobes with nodule(s) were identified and recorded.

On 2-D ultrasound, the craniocaudal (CC), lateromedial (LM) and anteroposterior (AP) dimensions of the thyroid lobe were measured. The LM and AP dimensions were measured in the transverse scan plane with a maximum cross-sectional area of the thyroid lobe (Fig. 1). The CC dimension was measured in the longitudinal scan of the thyroid lobe. The CC, LM and AP dimensions of the thyroid lobe were measured using the built-in electronic calipers. As the CC dimension of the thyroid lobe tended to be larger than the field of view of the ultrasound beam, extended field-of-view (EFOV) ultrasound was used to obtain the longitudinal scan (Fig. 2).

On 3-D ultrasound, the volume of the thyroid lobes was measured. With the 3-D system activated, a transverse scan of the entire thyroid lobe was performed through a single sweep from the superior border to the inferior border. The acquired images were then automatically stored in the system. Same 2-D and 3-D ultrasound