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Comparison of muscle-to-nodule and parenchyma-to-nodule strain ratios in the differentiation of benign and malignant thyroid nodules: Which one should we use?

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ABSTRACT

Objective: The aim of this study is to investigate the diagnostic accuracy of muscle-to-nodule strain ratio (MNSR) in the differentiation of benign and malignant thyroid nodules and to see if there was a difference between MNSR and parenchyma-to-nodule strain ratios (PNSR) in diagnosis.
Methods: A total of 106 consecutive patients (88 women and 18 men; age range 19–79 years) with thyroid nodules were prospectively examined using ultrasound and sonoelastography before the fine-needle aspiration biopsy. The mean MNSR and PNSR were calculated for each nodule and the elasticity score was determined according to four-point scoring system.
Results: According to the four-point scoring system, 44 of the 83 benign nodules had a score of one or two while 22 of the 23 malignant nodules had a score of three or four ($p < 0.001$). Using ROC analysis, the best cutoff point for MNSR 1.85 and for PNSR 3.14 was calculated. The sensitivity and specificity for the MNSR were 95.6%, 92.8%, respectively; for the PNSR were 95.6%, 93.4%, respectively, when the best cutoff points were used ($p < 0.001$). The κ value for the PNSR and MNSR methods was 0.87, which indicated an almost perfect agreement ($p < 0.001$).
Conclusions: Sonoelastography has a high diagnostic accuracy in the differentiation of benign and malignant thyroid nodules. There was no significant difference between MNSR and PNSR in the differentiation of benign and malignant thyroid nodules. Therefore, we think that MNSR could safely be used in situations where PNSR could not be used.

1. Introduction

Thyroid nodules are very common, especially in the inadequate iodine regions. Less than 5% of palpable thyroid nodules are malignant, but the incidence of thyroid cancer is increasing [1]. Therefore, the primary purpose of clinical diagnosis is to identify whether thyroid nodules are benign or malignant, develop optimal treatment plans accordingly in order to reduce unnecessary surgeries and surgical complications and, eventually, to improve the health of patients.

Ultrasonography (US) is a cheap, noninvasive, easily applicable and the first preferred imaging method for the evaluation of thyroid nodules. Many studies have been performed to determine the role of US in differentiating between benign and malignant nodules [2–5]. Several sonographic parameters are useful for predicting thyroid malignancy; however, the sensitivity, specificity, negative, and positive predictive values for these parameters are highly variable across patients and across different devices and no single sonographic parameter has both high sensitivity and high specificity alone [2–5].

Tissue stiffness can be measured by ultrasound through different techniques. The acoustic radiation force impulse (ARFI) elastography approach provides information about the stiffness of target tissues using high-intensity, short-duration acoustic pulses (push pulses) to propagate shear waves through the sampled tissues. ARFI quantification estimates tissue stiffness by measuring shear-wave velocity in a region of interest [6]. The shear-wave ultrasound elastography technique is a noninvasive method used to measure tissue elasticity. The imaging method is based on acoustic radiation force impulses passing through tissue to obtain an elastic

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modulus. The result is a local measurement, in kilopascals, of the tissue elasticity at each point of interest of an organ [7].

Sonoelastography is a newly developed dynamic imaging technique that displays tissue elasticity by measuring the degree of distortion under the application of an external force. The principle of sonoelastography states that when tissues of the body are compressed, the softer parts deform more easily than the harder parts. Tissue stiffness is determined quantitatively and an index known as "strain ratio" is defined. An index called parenchyma-to-nodule strain ratio (PNSR), which is calculated by the mean strain of the normal thyroid parenchyma by dividing the mean strain within the thyroid nodule, is defined [8]. However, it can be deceiving to use this index in patients with nodules covering all of the thyroid gland without leaving any normal parenchyma or absence of abnormal thyroid parenchyma (*i.e.*, thyroiditis). It can be beneficial to use an adjacent muscle to the thyroid as a reference instead of normal thyroid parenchyma in such patients. In this method, the muscle-to-nodule strain ratio (MNSR) is calculated by the mean strain of the adjacent muscle (strap muscle) to the thyroid by dividing the mean strain of the thyroid nodule [9]. To our knowledge, these two methods were not used together and compared in any study in the differentiation of benign and malignant thyroid nodules.

The aim of this study is to explore the diagnostic value of sonoelastography and MNSR in the differential diagnosis of benign and malignant thyroid nodules and to see whether there is any difference between MNSR and PNSR in the diagnosis.

2. Materials and methods

2.1. Patients

This prospective study was approved by the institutional ethics committee and informed consent was obtained from all patients. Between November 2011 and April 2012, 152 consecutive patients with thyroid nodules referred for ultrasound-guided fine-needle aspiration (FNAB) were examined through US, color Doppler ultrasound (CDU), and sonoelastography before FNAB. A FNAB on suspicious thyroid nodule was performed according to the Society of Radiologists in Ultrasound criteria for selecting thyroid nodules for aspiration [10]. Patients with nodules larger than 40 mm, purely cystic nodules, less than 50% solid component containing nodules, shell-calcified nodules, patients with abnormal thyroid parenchyma (*i.e.*, thyroiditis) were excluded from the study.

Table 1
Elasticity scores.

Score	Characteristics
1	Elasticity in the whole examined nodule
2	Elasticity in a large portion of the examined nodule
3	No elasticity in a large portion of the examined nodule
4	No elasticity in the whole examined nodule

2.2. Conventional thyroid ultrasound imaging and sonoelastography (imaging and analysis)

Both conventional US imaging and sonoelastography were performed before FNAB with 12-MHz linear probe on an Aplio XG ultrasound machine (Toshiba Medical Systems, Otawara, Japan) by the same radiologist with 4 years of thyroid US and 2 years of thyroid sonoelastography experience. Subsequently, all the enrolled patients underwent FNAB.

The presence or absence of hypoechogenicity, microcalcification, poorly defined margins, an anteroposterior/transverse (A/T) diameter ratio of one or greater, and type three Doppler color flow pattern of the thyroid nodules was determined in the conventional US examination [11].

Sonoelastographic measurements were performed immediately after conventional US imaging. All patients were required to hold their breath and to avoid swallowing during the course of the examination to keep the image stable. The US probe was placed on the thyroid with the patient in supine position in a transverse orientation. After placing a sonoelastographic image box in a manner that covered the thyroid nodule completely, five or six compressive and decompressive forces were applied in antero-posterior direction. Compression and relaxation waveforms were shown on the elastographic screen above and below the baseline of the waveform scale, respectively and data were recorded if the dynamics met the requirements. The elastogram was displayed over the B-mode image in a color scale that ranged from red—which indicated components with the greatest elastic strain (*i.e.*, softest components)—to blue, which indicated components with no strain (*i.e.*, hardest components). According to the classification proposed by Asteria et al., the visualization patterns were classified into four types (Table 1) [11]. Strain ratio measurements (PNSR and MNSR) were obtained from appropriate relaxation waves, which had a sinusoidal shape in the waveform scale.

The mean strain of the thyroid nodule and that of the surrounding normal thyroid tissue at the same depth selected as a reference were measured. The mean strain of the nodule was determined by

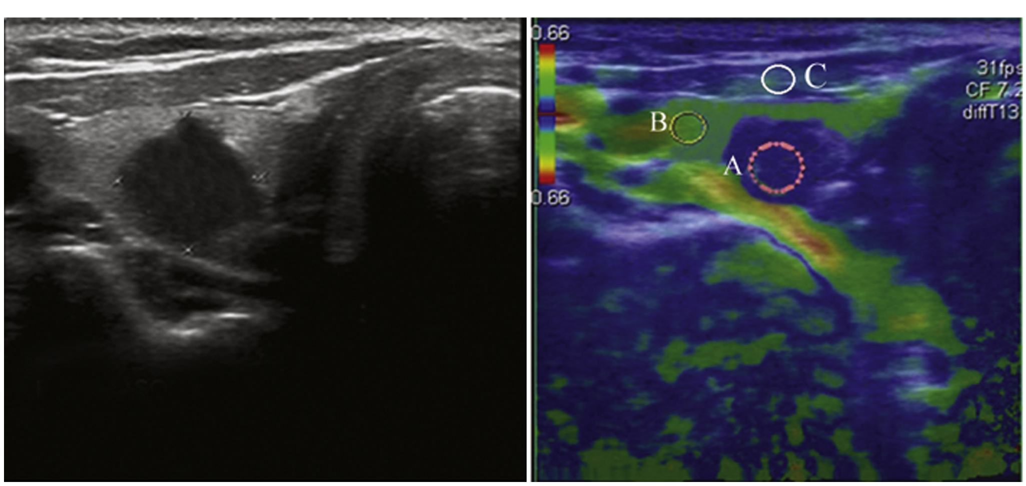

Fig. 1. Measurement of parenchyma-to-nodule strain ratio (PNSR) = mean strain of thyroid tissue (B)/mean strain of the nodule (A). Measurement of muscle-to-nodule strain ratio (MNSR) = mean strain of the strap muscle (C)/mean strain of the nodule (A).