



# Maximal, minimal, and mean pulsed Doppler parameters: Which should be utilized in the diagnosis of thyroid nodules?



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**AIM:** To compare the diagnostic efficacy of the maximal, minimal, and mean pulsatility index (PI) and resistance index (RI) and determine which should be utilized in the evaluation of thyroid nodules.

**MATERIALS AND METHODS:** A total of 224 consecutive patients with thyroid nodules were included in this prospective study. Doppler signals from three different nodular arteries were obtained and six Doppler parameters were used for final analysis: maximal PI (PI<sub>max</sub>), minimal PI (PI<sub>min</sub>), mean PI (PI<sub>mean</sub>), maximal RI (RI<sub>max</sub>), minimal RI (RI<sub>min</sub>), and mean RI (RI<sub>mean</sub>).

**RESULTS:** Eighty-five patients had malignant and 139 cases had benign thyroid nodules. All three sets of PI and RI parameters were significantly higher in malignant than in benign thyroid nodules ( $p = 0.000$  for all). The area under the receiver operating characteristic (ROC) curve (Az) of PI<sub>max</sub> was significantly higher than that of PI<sub>min</sub> ( $p = 0.046$ ) and higher than that of PI<sub>mean</sub> ( $p = 0.161$ ). The Az value of RI<sub>max</sub> was higher than that of RI<sub>mean</sub> and RI<sub>min</sub>; however, the differences were not significant ( $p = 0.403$ , and  $p = 0.058$ , respectively). The Az values of the three sets of PI parameters (PI<sub>max</sub>, PI<sub>min</sub>, and PI<sub>mean</sub>) were significantly higher than those of the corresponding sets of RI parameters ( $p = 0.005$ ,  $p = 0.003$ , and  $p = 0.003$ , respectively).

**CONCLUSION:** Maximal pulsed Doppler parameters should be utilized in the evaluation of thyroid nodules. PI parameters were superior to the RI parameters in determining malignant nodules.

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## Introduction

Ultrasound has been shown to improve the characterization of thyroid nodules as malignant or benign.<sup>1–4</sup> It has been strongly recommended by the American Thyroid

Association (ATA) that diagnostic thyroid ultrasound should be performed in all patients with known or suspected thyroid nodules.<sup>5</sup> Grey-scale and colour Doppler ultrasound have been widely employed in the evaluation of thyroid diseases, and features such as shape, margin, echogenicity, composition, calcifications, halo, and internal blood flow have been used to differentiate benign from malignant thyroid nodules.<sup>1,2,6</sup>

The consensus conference statement of the Society of Radiologists in Ultrasound (SRU) suggested that both

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grey-scale and colour Doppler ultrasound are not adequate to distinguish benign from malignant nodules with a high degree of confidence.<sup>1</sup> It was reported that the Kim and the American Association of Clinical Endocrinologists (AACE) criteria are more accurate than the SRU criteria<sup>1,6–8</sup>; however, the Kim and AACE guidelines do not achieve both high specificity and high sensitivity in the diagnosis of thyroid cancer using grey-scale ultrasound.<sup>8</sup> In particular, there is overlap in the ultrasound features of follicular carcinoma (FC) and follicular adenoma (FA)<sup>9</sup>; in addition, the follicular variant of papillary thyroid carcinoma (FVPTC) tends to show more benign ultrasound features.<sup>10,11</sup>

In several studies pulsed Doppler ultrasound has been used to measure Doppler parameters such as the pulsatility index (PI) and resistance index (RI) of blood flow within the thyroid nodules<sup>12–19</sup>; however, there is controversy regarding the value of Doppler parameters in the differential diagnosis of malignant and benign nodules. On comparison, there is inconsistency in the measurement of the Doppler parameters in these studies. In the studies conducted by Cerbone et al.,<sup>12</sup> De Nicola et al.,<sup>15</sup> Chammas et al.,<sup>16</sup> Tamsel et al.,<sup>17</sup> Bakhshaei et al.,<sup>19</sup> and Li et al.,<sup>20</sup> the PI or RI values were recorded as the mean of the indices obtained, whereas in other studies the methods used to calculate the Doppler parameters were not standardized.<sup>13,14,18</sup>

Obviously, multiple PI and RI values would be produced if samples were taken at multiple sites within a nodule. Thus, the maximal, minimal, and mean values of the PI and RI for each nodule could be obtained, but can the maximal or minimal PI and RI values be used to distinguish the nature of thyroid nodules? If their diagnostic value is confirmed, then which parameters have the best value in determining whether a nodule is malignant or benign? To the authors' knowledge, there have been no previous studies that have focused on this issue. Therefore, the present study was undertaken to compare the diagnostic efficacy of the maximal, minimal, and mean PI and RI and to determine which parameters should be utilized in the evaluation of thyroid nodules. Moreover, the Doppler parameters of FA, FC, and FVPTC with benign grey-scale ultrasound features.

## Materials and methods

### Patients

A total of 252 consecutive patients with both palpable and non-palpable thyroid nodules were examined between January 2005 and March 2008. Twenty-eight patients were excluded: nine patients whose target thyroid nodules were avascular on Doppler ultrasound and 19 patients without histopathological diagnosis. Thus 224 nodules in 224 patients (178 women and 46 men, from 18–92 years, mean  $47.9 \pm 12.7$  years) were included in the study. Informed consent was obtained from all patients, and the study was approved by the Ethics Committee of Ruijin Hospital.

### Imaging

Imaging was performed with two commercially available systems (Esaote Technos MPX and MyLab 90, Esaote, Genoa, Italy) equipped with a high-frequency small parts probe (LA523, 4–13 MHz). Doppler gain was increased, then reduced until clutter noise disappeared, thus yielding optimal sensitivity to visualize as many vessels as possible. All examinations were performed by two radiologists with 10 and 20 years of experience in thyroid ultrasound, respectively.

Initially, the thyroid was scanned with grey-scale ultrasound to localize and evaluate the nodule. If a patient had more than one nodule, then the nodule with suspicious ultrasound features was selected for Doppler evaluation. The nodular vessels were visualized using the colour Doppler in different planes. The vascular pattern was categorized as two types<sup>15,21</sup>: peripheral vascularity, defined as blood vessels predominantly in the peripheral part of the nodule with or without a small amount of central vessels (Fig 1); and central vascularity, defined as blood vessels predominantly in the centre part of the nodule regardless of blood vessels in the peripheral part (Fig 2). Finally, pulsed Doppler ultrasound examination of the vessels within the nodule was performed. The insonation angle is technically difficult to set in small nodule vessels,<sup>15,16</sup> and moreover, both the PI and RI are angle-independent parameters; therefore, angle correction was not applied. Doppler signals from three different nodular arteries, either the centre or the periphery, were obtained, and the PI and RI for each peripheral and central artery was measured and recorded as peripheral PI, peripheral RI, central PI, and central RI. Minimal transducer pressure was used in order to avoid nodular arterial flow velocity waveform alterations during the examination.

As the parameters of each target nodule were measured in three vessels at different areas, three readings were obtained. The maximal and minimal values of PI and RI were recorded and the mean values were calculated from the three measurements. Therefore, six Doppler parameters were used for final analysis in the present study: maximal PI (PI<sub>max</sub>), minimal PI (PI<sub>min</sub>), mean PI (PI<sub>mean</sub>), maximal RI (RI<sub>max</sub>), minimal RI (RI<sub>min</sub>), and mean RI (RI<sub>mean</sub>). It is well known that Hashimoto's thyroiditis (HT) can cause increased intrathyroidal blood flow<sup>22</sup>; thus, both malignant and benign groups were divided into two subgroups, i.e., HT subgroup and no-HT subgroup, to explore whether HT influences the Doppler parameters of the nodules. The final diagnosis of benign or malignant was determined at histopathology after surgery.

### Statistical analyses

All quantitative data were expressed as the mean  $\pm$  standard deviation (SD). Associations between vascular pattern and malignancy were calculated with the Chi-squared test. The non-parametric Mann–Whitney *U*-test was used to assess whether there were differences between the Doppler parameters in the benign and

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