Influence of Section Orientation of Ultrasound Shear Wave Elastography on the Measurement of TI-RADS Category 4 Thyroid Nodules Stiffness

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Abstract: Thyroid shear wave elastography (SWE) is widely used as a noninvasive screening tool for thyroid nodules (TN) diagnosis. Herein, we assessed the effect of SWE section orientation on the stiffness measurement of TI-RADS category 4 TN. In this retrospective study, we followed up patients who had 2D ultrasound and elastography of the thyroid with pathological findings at our institution. The reliability and agreement between the aforementioned evaluations were further examined via calculation of the mean and maximum modulus values of the TN in both section orientations. As a result, there was good agreement in the measurement of the shear wave modulus of TN between the two different views, which provides relative flexibility for patients with anatomical or physiological defects.

Keywords: Ultrasound Shear Wave Elastography; Cross-Sectional Orientation; Thyroid Nodules; Modal Values

Introduction

With the widespread use of ultrasound technology, the diagnosis rate of thyroid cancer has increased year by year[1], and the 2022 China Cancer Ranking shows that thyroid cancer has risen to the third place among new malignancies in Chinese women. Recently, ultrasound elastography is widely employed as a noninvasive diagnostic tool to evaluate thyroid nodules (TN)[2]. At present, most clinics utilize two primary forms of ultrasound elastography: strain (SE) and shear wave elastographies[3]. SE, also called compressional elastography, was the initial elastographic procedure employed for TN assessment[4]. However, the main limitation of SE are the operator's dependence on the angle, intensity and duration of compression and the fact that quantitative elastography data cannot be obtained using this method[5-6]. More recently, shear wave elastography (SWE) received a lot of attention. This method measures tissue stiffness using shear wave velocity (SWV) and is used to reflect the nature of TN. SWE is a technique to quantitatively and objectively evaluate and image tissue elasticity in diagnostic imaging[1] , and various factors can affect the elastography assessment of TN, including carotid pulsation, patient body characteristics, tracheal motion, and peripheral muscle effects. Since the patient body characteristics, particularly a short neck and prominent carotid artery, may restrict the elastographic assessment of nodule stiffness, we focused on the transverse and longitudinal directional effects on the measurement of thyroid nodule stiffness.

1. Materials and Methods

1.1 Study subjects

Forty-two patients with TN, aged 22-68 years, with an average age of (47±10) years, with a maximum nodule diameter of 3-20 mm and a mean maximum diameter of (8.6±4.2) mm, attending the First Affiliated Hospital of Shandong First Medical University from February 2022 to June 2022 were selected. The inclusion criteria were: all patients received conventional preoperative ultrasonography, elastography, and nodules according to C -TIRADS classification criteria [7] for nodules conforming to C -TIRADS category 4, and all nodules were confirmed to be papillary thyroid carcinoma or micropapillary thyroid carcinoma by fine needle aspiration cytology and postoperative pathology. This investigation received ethical approval from our institution and obtained signed informed consents from all participants prior to the initiation of the study.

1.2 Instruments and methods

Instrument: Siemens ACUSON S2000 ultrasound diagnostic instrument was used for real-time elastography.

Conventional ultrasound: The patient is positioned supine with the head extended backward, fully exposing the thyroid gland in the neck. The instrument is adjusted appropriately to achieve optimal imaging quality and the target lesion is classified by C-TIRADS.

2D SWE elastography: The same suspicious nodule was found in the conventional ultrasound mode, and the SWE option in VT mode was selected. Patients were instructed to hold their breath and acquire both transverse and longitudinal elastograms of the nodule to reduce any breathing effects. After the acquisition is completed, the system automatically freezes and applies Velocity or Elasticity display mode. At least 3 measurements are taken, Emax is selected, and the average value is calculated after removing the highest and lowest values: Emean.

1.3 Statistical methods

SPASS version 25.0 was employed for all data analyses, and all data were provided as mean ± standard deviation, using fine needle aspiration cytology and postoperative pathological findings as diagnostic criteria. The intra-group correlation coefficient (ICC) was used to quantitatively summarize the reliability of the maximum and mean modulus values in transverse and longitudinal views. Bland-Altman plots were used to show the overall agreement between the stiffness measurements of transverse and longitudinal images.

Table 1

Maximum modulus value ICC intra-group correlation coefficient results

BI-directional mixing/random consistency	ICC intra-group correlation coefficient	95% CI
Single metric ICC(C,1)	0.720	0.535 ~ 0.839
Mean metric ICC(C,K)	0.837	0.697 ~ 0.912

Average modulus value ICC intra-group correlation coefficient results

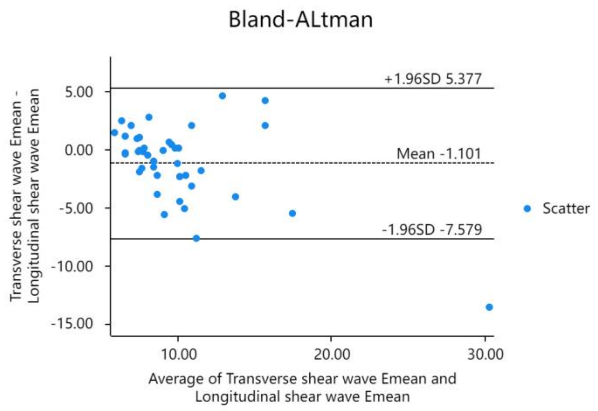
BI-directional mixing/random consistency	ICC intra-group correlation coefficient	95% CI
Single metric ICC(C,1)	0.726	0.543 ~ 0.842
Mean metric ICC(C,K)	0.841	0.704 ~ 0.914

Maximum modulus value ICC intra-group correlation coefficient results

BI-directional mixing/random consistency	ICC intra-group correlation coefficient	95% CI

C for consistency,1 for single measure, and K for mean measure

Figure 1 Bland-ALtman



2. Results

From February 2022 to June 2022, 42 nodes in 37 patients met the enrollment criteria.

As can be seen from Table1, the final ICC correlation coefficient values were 0.837 (95% CI: 0.697 - 0.912) and 0.841 (95% CI: 0.704 - 0.914), with correlation coefficient values higher than 0.75 within the ICC group, implying a high level of agreement in the effect, i.e., indicating a high level of agreement in the measurement of SWE modulus of TN for the two different views. In particular, the mean modulus values were measured. Thus, for the mean modulus values, the Bland-Altman plots(Fig 1) show that there is almost no deviation in the stiffness values between the transverse and longitudinal measurements over a wide range, indicating a good level of agreement. However, as can be seen from Table 2: The data has 42 samples, and the mean values of the measurements in both longitudinal and transverse directions are 10.488 and 9.387, respectively, and the use of paired t-test shows that a 0.05 level of significance (t=2.158, p=0.037) is presented between the longitudinal shear wave Emean and the transverse shear wave Emean, as well as the particular comparison differences were such that the average longitudinal shear wave Emean value (10.49) would be markedly elevated, compared to the average transverse shear wave Emean value (9.39).

Table 2：Bland-altman description statistics

project	quantitative value
Sample size	42
Mean value (longitudinal section)	10.488
Mean value (Transverse section)	9.387
Mean value (difference)	1.101
Standard deviation (difference)	3.305
95% CI(Mean value of difference)	0.071 ~ 2.131
95% CI(difference)	-5.377 ~ 7.579
T value (H0: average difference =0)	2.158
P value (H0: average difference =0)	0.037
CR value(Coefficient of Repeatability)	6.754

3. Discussion

Ultrasound elastography is highly sensitive to tissue stiffness. More recently, it has been developed and refined even further to provide the quantitative assessment of tissue stiffness. SWE uses a sequence of acoustic radiation force pulses to produce transverse waves, which move perpendicular to the ultrasound beam, resulting in transient displacements[9]. The generation process is as follows: shear waves are first produced via focused acoustic radiation force using a linear US array, which itself produces local stress and local displacement within the tissue; then, the newly formed shear waves move along the adjoining tissue in the transverse plane at a slower speed, perpendicular to the main wave thus producing the acoustic radiation force, resulting in shear tissue displacement; then, fast plane wave excitation is employed to detect the shear waves as they propagate through the tissue, then, the fast plane wave excitation is employed to detect tissue displacement and SWV as the shear wave propagates, and the tissue displacement is computed via the scatter tracking algorithm; finally, the tissue displacement map is utilized for SWV (cs) calculation, expressed in m/s, and its velocity increases with the increase of structural stiffness. The SWV distribution at each pixel is directly proportional to the Young's modulus E, which is computed using a simple formula and expressed in units of pressure (usually kPa) for tissue stiffness and elasticity. Young's modulus $E = 3\rho c^2$, where E is the Young's modulus, ρ is the tissue density, and c is the shear wave propagation velocity[3,8]. Herein, we compared the results of the two acquisition directions of the images to assess whether there are differences between them. In our study, there was an agreement between the maximum and average modulus values in the transverse and longitudinal sections, as presented in Figures 1.

The main benefits of SWE over other techniques are as follows: it is operator independent, reproducible, and quantitative. Nevertheless, multiple factors hinder SWE use in the evaluation of TN.Kim et al. revealed that elastography results were less reliable in 32% of the nodules. Thus, they concluded that elastography must be employed to TN that show reliable results only[11]. Similarly, most other elastography studies have examined diagnostic efficiency, diagnostic precision, inter and intraobserver agreements, and other factors. However, there is no specific statement on the usage of specific image orientations to compute the maximum and average modulus values of TN, so this study discusses the effect of transverse and longitudinal views on the elastography assessment of TN. There is good agreement between the maximum and mean modulus values of TN in transverse and longitudinal views, although a particular comparison of the differences reveals that the average longitudinal shear wave Emean value (10.49) would be markedly elevated, compared to the average transverse shear wave Emean value (9.39). This may be because of reduced frequency of influence by carotid pulsation on the longitudinal section and the absence of thyroid tracheal compression; the mechanical characteristics of the surrounding tissue may affect the tissue density and propagating shear wave speed, and the muscle tissue is highly anisotropic[9], which may disrupt the propagation of shear waves perpendicular to the muscle fiber orientation. In terms of thyroid, the shear wave propagates perpendicular to the direction of the anterior thyroid neck muscle fibers during the longitudinal sweep, and it will have a lower propagation velocity and modulus, so the mean value of the longitudinal thyroid will be higher than the transverse one, and therefore the SWE in the longitudinal view will be a little more accurate for malignant nodules. Our study shows that both directions of SWE can be used more flexibly for the analysis and evaluation of TN.

Limitations of our study: (1) Both transverse and longitudinal images do not show the exact same area within individual nodules. Thus, some of the measurement variation between orientations may be owing to the heterogeneity of the nodules themselves. This problem can be mitigated by obtaining several images in each direction of individual nodules. (2) The total sample size of 42 nodules is small and may be subject to bias. (3) The TN selected for this study were all papillary thyroid carcinoma or micropapillary thyroid carcinoma by cytopathological analysis, which is too homogeneous in pathological type and malignant only. Herein, the focus was on measurement consistency, and not diagnosis, thus restricting the influence of benign and malignant nodules on the relevant outcome.

Conclusion

In summary, this investigation reveals that SWE in both section directions (transverse and longitudinal) can provide good diagnostic performance. Transverse and longitudinal views showed good agreement and reliability for maximum and mean modal values of TN, with only small deviations. This good agreement provides flexibility in cases such as patients with limited neck mobility, patients with difficulty in fully extending the neck, and nodules that cannot be fully and clearly visualized in a single view in the transverse or longitudinal plane.

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Conflict of interest disclosure—All authors declare that they have no conflict of interest.

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