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Original Article

Acoustic radiation force imaging of the thyroid—generation of reference values by Virtual Touch Imaging and Quantification☆

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ABSTRACT

Objectives: To investigate potential subject-related confounding factors for thyroid acoustic radiation force impulse (ARFI) elastography.
Methods and materials: A total of 194 subjects participated in the study.
Results: The standard values in the right lobe were 2.52±0.35 m/s (ventral half) and 2.43±0.40 m/s (dorsal half). In the left lobe, velocities of 2.56±0.37 m/s (ventral) and 2.48±0.42 m/s (dorsal) were noted. A clear difference was observed between measurement values in the ventral and dorsal half ($P<.0001$). By contrast, none of the other factors exerted any effect on the measurements.
Conclusions: ARFI–Virtual Touch Imaging and Quantification appears to be a suitable and relatively robust method for examining the thyroid gland.

1. Introduction

Because of the lack of naturally occurring iodine in the local soils and waters of the Federal Republic of Germany, there is a high prevalence of thyroid disorders (33%) [1,2]. The main diagnostic procedures are conventional ultrasound, scintigraphy, and, as the previous gold standard, fine-needle aspiration cytology. Palpation as a means of physical examination represents a simple option for identifying an enlargement or local hardening of thyroid tissue. This is based on the assumption that neoformations, particularly malignant ones, exhibit a harder consistency than healthy organ parenchyma. It is on this simple principle that elastography works—a technique that was described for the first time in 1991 by Ophir et al. [3,4]. One of the most recent procedures, the quantitative method of acoustic radiation force imaging, uses an acoustic signal that induces the propagation of shear waves in tissue through absorption of energy. These waves propagate perpendicularly to the emitted ultrasound beam and are detected by the ultrasound probe. By measuring the time to maximum deformation of the tissue and the time to reach the baseline state, the shear wave velocities can be reconstructed by means of special algorithms. As the velocity of the shear wave is proportional to the square of the modulus of elasticity, a high shear wave velocity is an indication of a stiffer tissue with a high modulus of elasticity, whereas low shear wave velocities indicate soft tissue [5]. An advantage of this noninvasive, quantitative method is the reproducibility of the results through the generation of investigator-independent, absolute measurement values. Several studies have shown that acoustic radiation force impulse (ARFI) elastography in particular is able to reliably detect suspect malignant lesions [6–11]. The new technique can serve in the future as a decision tool with regard to which nodules and, in particular, which areas of the nodule should be investigated by means of puncture, thus reducing the rate of unnecessary investigations and inconclusive aspirates. Improved diagnostic precision in follicular carcinoma would also be conceivable. Even in diffuse thyroid disorders, such as Hashimoto's thyroiditis, elastography can be helpful, as recent studies have suggested [12,13].

There are few data to date for ARFI–Virtual Touch Imaging and Quantification (VTIQ) in a large population with healthy thyroid parenchyma. The aim of this study was therefore to generate reference values for ARFI elastography and to investigate possible subject-related factors affecting shear wave velocity, such as sex or age.

☆ Conflict of interest: Neither the authors nor the authors' institutions have conflicts of interest. This includes financial or personal relationships that inappropriately influence (bias) their actions within 3 years of the work being submitted. All authors have participated sufficiently, and approved the manuscript and its submission.

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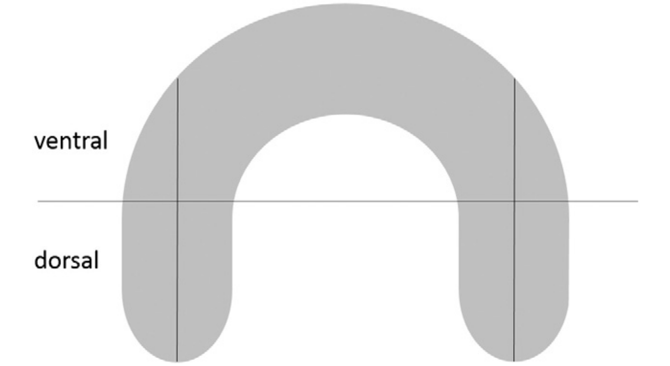

Fig. 1. Definition of ventral and dorsal measuring position for shear wave velocity (idealized representation).

2. Materials and methods

2.1. Patients

The study was conducted with the approval of the local Ethics Committee and complies with the Declaration of Helsinki in its latest revised version, Seoul 2008. The study was conducted from March 2013 to August 2013 at the University Hospital Ulm in Germany. Subjects were recruited through advertising at the University Hospital and in the newspaper. Therefore, the population consisted partly of voluntary students and partly of people from the general population. The inclusion criteria were defined as the subject's written informed consent and age of ≥18 years. In order to obtain as representative a set of results as possible, only healthy subjects could be included. To this end, subjects with known chronic thyroid disorders or those regularly taking medication were excluded. In addition, a prior B-mode ultrasound was performed, after which participants with abnormal findings were also excluded.

2.2. B-mode ultrasound

At the beginning of the study, each subject underwent an ultrasound scan of the thyroid (linear array, 7–12 MHz). Size, shape, and echo texture were determined, with both lobes being assessed individually and in two planes. The length, width, and depth were measured and the volume was calculated from the following formula:

$$\frac{\text{Length(in mm)} \times \text{width(in mm)} \times \text{depth(in mm)}}{2}$$

2.3. Acoustic radiation force imaging—VTIQ

All measurements were made with an Acuson S3000 (Siemens, Erlangen, Germany). Subjects were asked to incline the head backward and hold the breath. The transducer was placed longitudinally, immediately medial to the sternocleidomastoid muscle (Fig. 1). To obtain optimum results, an area of the organ with exclusively homogeneous thyroid parenchyma was identified for each measurement. The resultant elastogram is displayed in B-mode, in which the color blue represents soft tissue with a low shear wave velocity and red represents hard tissue and a high shear wave velocity. In the elastogram, also known as a Q box, as many regions of interest (ROIs) as required may be inserted manually. Within the ROIs, the shear wave velocity is determined and displayed on the monitor in m/s. The generated elastogram was divided in four squares with the help of two lines. In each quadrant, two elastography measurements were determined. This therefore produced eight measurement values per side (Figs. 1 and 2).

The following factors impacting on shear wave velocity were studied: sex, age, thyroid volume, measurement depth, difference between thyroid lobes, consumption of oral contraceptives, body mass index, and smoking.

2.4. Statistical analysis

Statistical analysis was performed by means of SAS 9.2 (SAS Institute Inc., Cary, NC, USA). For the descriptive presentation of the results, relative and absolute frequencies were initially calculated as qualitative characteristics. For quantitative values, means, standard deviations, medians, minima, maxima, first and third quartiles, interquartile ranges (IQR), and 95% confidence intervals were used for the characterisation. The quartile dispersion coefficient (IQR/median) was used as a relative measure of dispersion. The distribution of the ARFI measurements was tested for normality by means of a Shapiro–Wilk test, and any correlations that were present were expressed by means of the *t* test or the Wilcoxon rank sum test for continuous parameters. For categorical parameters, the chi-squared test was used. In the case of a normal

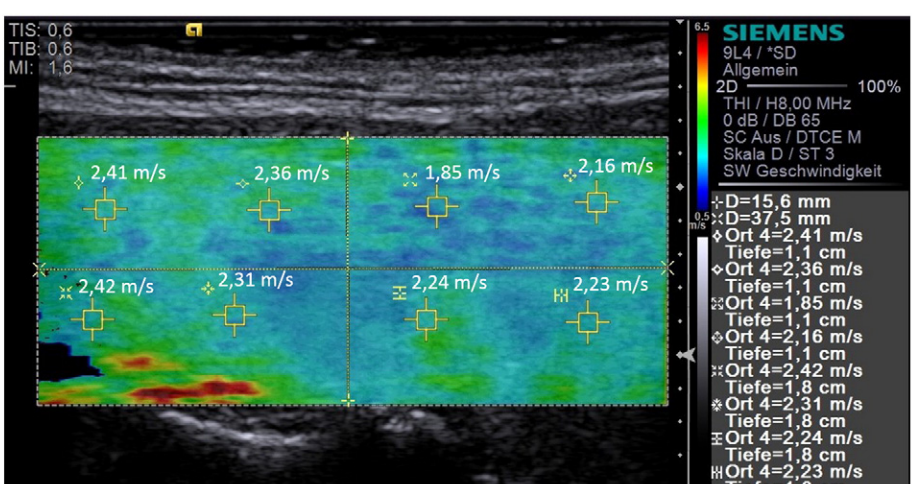

Fig. 2. Shear wave velocity measurements by means of eight ROIs (small boxes) in the color elastogram. The respective shear wave velocity is given in m/s on the right of the image under "Site 4" and the associated measurement depth is given in cm under "Depth."