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Stiffness of salivary gland and tumor measured by new ultrasonic techniques: Virtual touch quantification and IQ

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ABSTRACT

Objective: To evaluate normal salivary gland stiffness and compare the diagnostic performance of virtual touch quantification (VTQ) and virtual touch imaging quantification (VTIQ) for head and neck tumor.
Methods: A total of 92 measurements were examined, comprising 77 normal salivary glands, 11 benign tumors and four malignant tumors. Examinations were made to evaluate normal salivary gland stiffness and compare the diagnostic performances of new ultrasonic techniques regarding head and neck tumor.
Results: The mean values of VTQ and VTIQ for the normal salivary group (NSG) were 1.92 and 2.06 m/s, respectively. The VTQ and VTIQ values were correlative, and there were no statistical differences in each mean value between the normal parotid glands and submandibular glands. For the benign tumor group (BTG), four of the 11 values were non-numeric and were considered above the measurable range. The mean VTIQ value for the BTG was 4.24 m/s. For the malignant tumor group (MTG), all four VTQ values were non-numeric. The mean VTIQ value for the MTG was 6.52 m/s. For the mean VTIQ values, significant differences were observed among the three groups. The optimum VTQ cutoff value to detect malignant tumors was above the measurable range, and that of VTIQ was 4.83 m/s.
Conclusion: The VTQ and VTIQ values were correlative for the salivary glands, and the stiffnesses of normal parotid glands were almost same as those of submandibular glands. VTQ and VTIQ values could be applied for the preoperative diagnosis in salivary gland lesions.

1. Introduction

In salivary gland tumor, although most head and neck cancer is diagnosed pathologically with squamous cell carcinoma, there are various histopathological types, of which squamous cell carcinoma is rare. One of the most serious problems regarding salivary gland tumor is that many are difficult to identify as either benign or malignant before treatment. Due to the density of the cancer cells and blood vessels, the stiffness of the cancer tissue increases, which begins at an early stage.

Elastography is a new ultrasonic technique that characterizes the conditions of lesions in greater detail than B-mode ultrasonography. Elastography is based on two major imaging techniques. The first method is strain elasticity imaging, also called static elastography. Its implementation requires continuous transducer compression or external mechanical compression. This compression cannot be quantified, and the site of compression cannot be restricted to the specific areas under investigation. The second method is acoustic stress elasticity imaging, or dynamic elastography, including acoustic radiation force impulse (ARFI) imaging, which applies a short-duration acoustic radiation force to the region of interest (ROI) without producing movement of the whole target [1]. This technique requires no external compression and exploits short-duration acoustic radiation forces to generate localized tissue displacements. ARFI imaging can enable qualitative visual and quantitative value measurements [2]. The more elastic a tissue is, the more displacement it undergoes. The displacements result in shear-wave propagation away from the region of excitation and are tracked by using ultrasonic correlation-based methods.

By measuring the time to peak displacement at each lateral location, a quantitative implementation named virtual touch

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quantification (VTQ) can calculate the shear wave velocity (SWV) within the tissue. VTQ gives an objective numerical evaluation of the tissue stiffness from 0.8 to 8.4 m/s [3]. Virtual touch imaging quantification (VTIQ) is a new form of two-dimensional shear wave imaging and displays a color-coded image using up to 256 spatially distributed ARFI push pulses and detection pulse sequences that can measure localized SWV from 0.5 to 10 m/s in multiple locations.

At present, few clinical results using VTQ and VTIQ have been reported, especially with regard to head and neck lesions. In this study, the VTQ and VTIQ values of normal salivary glands as well as head and neck tumors were measured to evaluate normal salivary gland stiffness and compare the diagnostic performance of VTQ and VTIQ for head and neck tumor.

2. Materials

The study was approved by the Institutional Review Board and Ethics Committee of Fukushima Medical University. From March 2013 to November 2013, a total of 38 patients (men: 24, women: 14, age range, 27–85 years; mean age, 65 years) participated in the study. Patients' clinical records were anonymized and de-identified prior to analysis.

Among all 38 of the patients, 15 were follow-up patients after tumor resection and eight were patients with thyroid disease. Seventy-seven salivary glands (parotid gland: 42, submandibular gland: 35), which contained neither mass lesion nor sialoadenitis, were examined and categorized as the normal salivary group (NSG). Fifteen patients had solitary masses (parotid gland: 14, submandiblar gland: 1) in the salivary gland lesions. Four of 15 masses were diagnosed as malignant tumor (acinic cell carcinoma: 2, squamous cell carcinoma: 1, low grade adenoid cystic carcinoma: 1), and were categorized as the malignant tumor group (MTG). The remaining 11 regions were categorized as the benign tumor group (BTG). In total, 92 regions were divided into three groups (NSG, BTG and MTG) and measured with VTQ and VTIQ.

3. Methods

3.1. Virtual touch quantification (VTQ)

VTQ measurements were performed with an Acuson S3000 ultrasound system (Siemens Medical Solutions) using a linear array transducer with bandwidth of 4–9 MHz. For VTQ measurement, the patient is required to lie in a position identical to that used for conventional ultrasonography examination. The transducer is gently applied together with a sufficient amount of contact gel. Anatomical location for measurement is defined by region of interest (ROI) placement. Acoustic push pulse is applied adjacent to the ROI with fixed dimensions of 5 mm × 5 mm. Tracking beams are then applied adjacent to the acoustic push pulse. Time between generation of the shear wave and the passing of shear wave peak at an adjacent location is utilized to compute the VTQ value in meters per second (m/s, Fig. 1a). Sometimes the VTQ produces non-numeric results, which are all expressed as X.XX (Fig. 1b). There could be two main reasons to account for such a result: First, the method does not conform to the biomechanical testing standard, and shear waves cannot be generated and propagated in the target. Second, the target is so hard that the results are above the maximum value used by this system [4]. In our study, non-numeric results were considered to be above the measuring range. Each ROI was measured three times in the same region, and the VTQ value was defined as the average of three-time measurements. A non-numeric VTQ value rate was calculated in each group.

3.2. Virtual touch imaging quantification (VTIQ)

For VTIQ measurement, the measuring system, patient position and transducer condition are the same as those for VTQ. A user-defined ROI (maximum size: 25 mm × 38 mm) is placed and acoustic push pulses are applied across the ROI. Then stiffness shown by a color-coded two-dimensional shear wave is

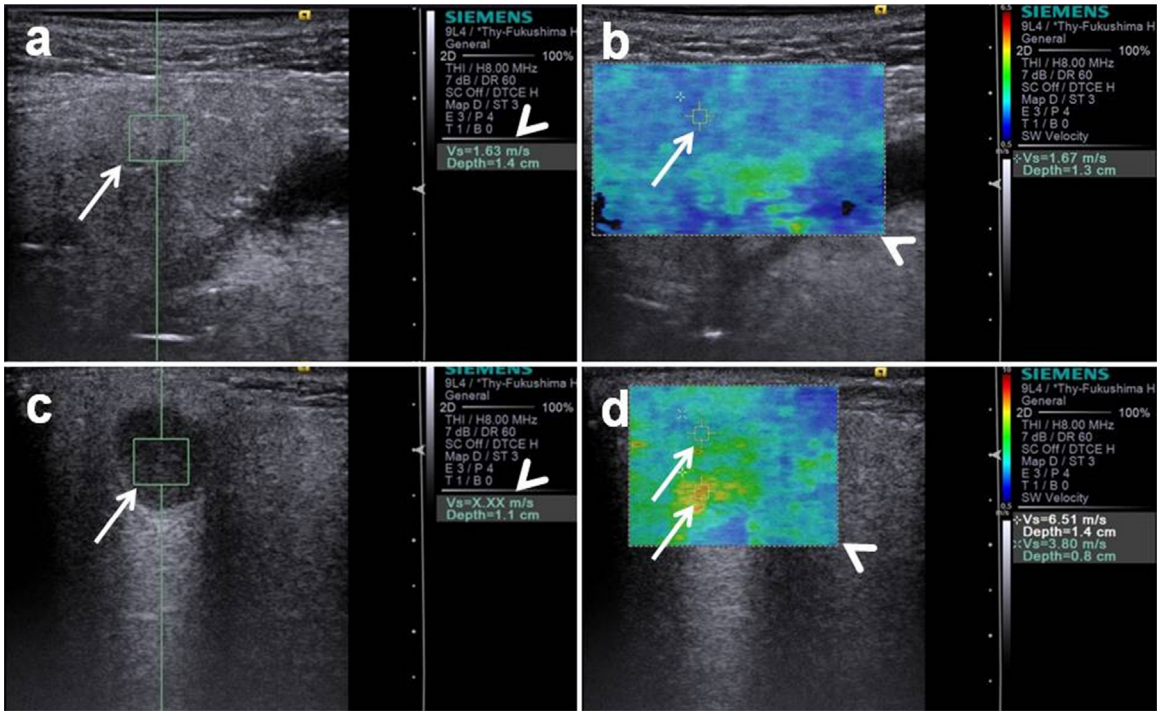

Fig. 1. VTQ and VTIQ measurements for 47-year-old female with acinic cell carcinoma of right parotid gland. (a) VTQ value of normal left parotid gland (1.63 m/s, arrowhead) was measured applying adjacent to the ROI with fixed dimensions of 5 mm × 5 mm (arrow). (b) VTIQ value of normal left parotid gland (1.67 m/s, arrow) was measured within the user-defined ROI (arrowhead). (c) VTQ value of right parotid tumor, applying adjacent to the ROI (arrow), was expressed as X.XX m/s (arrowhead). This means non-numeric results were produced. (d) VTIQ values of right parotid tumor (6.51 and 3.80 m/s, arrows).

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