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● *Original Contribution*

QUANTITATIVE ASSESSMENT OF HEALTHY SKIN ELASTICITY: RELIABILITY AND FEASIBILITY OF SHEAR WAVE ELASTOGRAPHY

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Abstract—The goal of this study was to investigate the reliability and feasibility of shear wave elastography by assessing the elasticity of the healthy skin of 40 volunteers. Young's moduli for bilateral fingers, forearms, anterior chest (sternum), and anterior abdomen were determined with both transverse and longitudinal sectional measurements. Reliability of measurements was evaluated using intra- and inter-class correlation coefficients with two observers. Our results revealed that the elastic modulus values of the skin between symmetric parts of fingers and forearms did not statistically different. No differences were found between the transverse and longitudinal sections of forearms, anterior chest, and abdomen ($p > 0.05$), except for middle fingers ($p = 0.004$). Inter-observer and intra-observer repeatability (inter- and intra-class correlation coefficients) varied from moderate to excellent depending on the skin site (0.62–0.91). In conclusion, shear wave elastography reached a good consistency in measuring healthy skin elasticity. Further studies are needed to provide more information on the factors that influence the reliability of shear wave elastography measurements in both healthy and diseased skin. (E-mail: wsqiuli@126.com) Copyright © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Shear wave elastography, Healthy skin elasticity, Inter- and intra-class correlation coefficients.**

INTRODUCTION

Skin is commonly involved in systemic diseases, such as systemic sclerosis (SSc). The extent of skin and internal organ involvement predicts the general outcome of patients (Hesselstrand et al. 2008). The skin with scleroderma in the edematous and fibrotic phases is significantly thicker than that in the atrophic phase or in healthy skin (Kaloudi et al. 2010). Skin elasticity may provide adequate information about related disease diagnoses and stages of disease progression.

Clinicians observe the magnitude of the skin and subcutaneous tissue deformation by lifting and compressing the skin of patients with a force, which is subjective to a certain degree. The scoring systems most widely used to clinically assess the severity of diseases are the modified Rodnan skin score (mRSS) in SSc (Hou et al. 2015) and the Localized Scleroderma Cutaneous Assessment Tool (LoSCAT) in morphea (Czirják et al. 2008; Kelsey and Torok 2013). These metrics are either subject to operator-dependent judgment or only semiquantitative; further validation is required to determine their utility in monitoring disease progression in both clinical trials and actual practice (Arkachaisri et al. 2010).

To solve this problem, an efficient imaging method is needed to assess the skin's elastic properties. Elastography ultrasound (EUS) through several approaches, such as strain EUS, shear wave EUS (SWE), acoustic radiation force impulse EUS (ARFI), and transient EUS, can meet the requirement (Drakonaki et al. 2012). Strain EUS was first used in the assessment of skin involvement in SSc (Iagnocco et al. 2010). However, this technique relies on some form of tissue deformation with moderate exerted pressure (Cosgrove et al. 2012; Drakonaki et al. 2012), is qualitative rather than quantitative and might be operator dependent (Hou et al. 2015). ARFI provides quantitative information on tissue elasticity by measuring shear wave velocity (SWV) in a region of interest (Syversveen et al. 2012). Similarly, SWE is based on the estimation of velocity of shear waves from sonographic push pulses (Yoon et al. 2014), which are captured by ultrafast imaging techniques (Woo et al. 2015). The elasticity of tissue is assessed by measuring the speed of shear wave

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propagation as indicated in the formula $E = 3\rho c_s^2$, where E is the elasticity of tissue, ρ the volume density of tissue and c_s the speed of wave propagation (Balleyier et al. 2013). Tissue elasticity is then calculated and presented in terms of the Young's modulus (kPa) in a real-time color-coded map overlaid on gray-scale images. The elasticity values in a region of interest (ROI) are calculated in this map automatically. As shear waves travel more slowly in softer tissue and faster in stiffer tissue (Hou et al.2015), the tissue's stiffness is positively related to shear wave velocity (Cosgrove et al. 2012; Ferraioli et al. 2014). Lee et al. (2015) found that both ARFI and SWE can indicate that the diseased dermis is stiffer than healthy dermis, but SWE provides better differentiation between normal and sclerotic skin.

The purpose of this study was therefore to investigate the reliability and feasibility of SWE in healthy skin elasticity examination, including the difference in elastic modulus values for bilateral fingers and forearms, the difference between transverse and longitudinal section measurements and intra- and inter-observer reproducibility. Thus, the present research was carried out to provide a methodologic basis for the further study of skin in pathologic conditions. We hypothesized that good consistency would be obtained when SWE was used appropriately to assess skin stiffness.

METHODS

Participants

Between April 2015 and 2015 in the West China Hospital of Sichuan University, China, a total of 40 healthy volunteers were enrolled in this study. Volunteers with a history of systemic dermatologic disorder, rheumatic disease, metabolic disease, endocrine disease, carcinoma, or scars were excluded. Verbal informed consent was obtained from all volunteers, and the study was supported by the West China Hospital of Sichuan University ethics committee. characteristics of the volunteers are summarized in Table 1.

Equipment and study design

Shear wave elastography was performed using the ultrasound equipment Aixplorer (SuperSonic Imaging, Aixen-Provence, France) with a 4- to 15-MHz linear probe, which can precisely separate epidermal–dermal echoes and dermal–subcutaneous tissue echoes. First, coupling agents (Ambition T.C., Chongqing, China) were applied between the tip of the transducer and the surface of the skin, ensuring that the two layers of echogenic linear structure (epidermis and interface between dermis and subcutaneous) were distinct and parallel. When a B-mode image was obtained, the scanner was switched to the SWE mode, and the probe was maintained at the same position without compressing the tissue. Superficial musculoskeletal setting and "standard" or "penetration" mode were selected. The scale of elasticity modulus was adjusted to 100 kPa for best image quality. According to our experience, the modification of mode and scale will not change the Young's modulus if a completely filled square ROI and a stable image are ensured. It has also been proven that other stand-off devices, such as ultrasound gel, do not influence the appearance of the elastogram (De Zordo et al. 2010). Figure 1 is a standard SWE image. On the basis of mRSS, Moore et al. (2003) reported that 17 parts of the skin could be evaluated with good reliability. In our study, six locations were assessed by SWE: bilateral dorsal middle fingers, bilateral forearms (10 cm proximal to the ulnar styloid), anterior chest (sternum) and anterior abdomen (10 cm distal to the sternum) (Fig. 2). All of the aforementioned locations had to be kept relaxed during examination (Luo et al. 2015). Because of respiratory movements, the patients were asked to hold their breath after exhaling for chest and abdomen examinations.

Two sonographers (A, B), both with training in SWE, carried out the measurement and score rating. The following steps were applied in the study. (i) Sonographer A measured the skin elasticity (Young's modulus) of bilateral fingers and forearms in longitudinal section to

Table 1. Basic characteristics of the healthy volunteers enrolled in this study

Gender (female:male)	20:20
Age	30.75 ± 12.06*
Body mass index	21.00 ± 2.59

* Mean ± standard deviation.

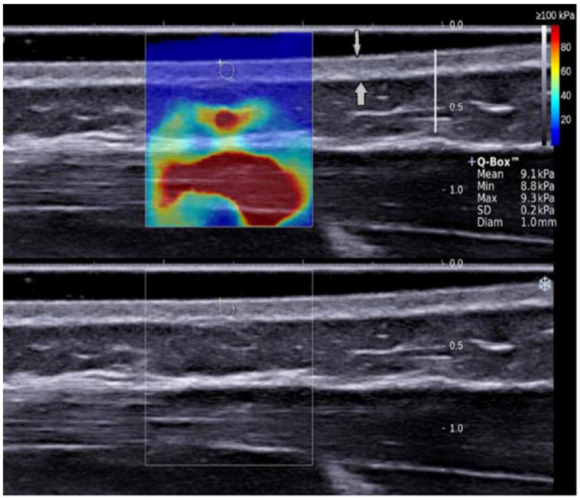

Fig. 1. Shear wave elastography image of a volunteer's forearm healthy skin and corresponding Young's modulus. The skin elasticity of the forearm skin was 9.1 kPa. The *thin arrow* points to epidermal–dermal echoes, and the *thick arrow*, to dermal–subcutaneous tissue echoes.