Acoustic Radiation Force Impulse Elastography: Tissue Stiffness Measurement in Limb Lymphedema

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Conflicts of interest are listed at the end of this article.

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Purpose: To evaluate the feasibility of cutaneous and subcutaneous limb tissue elasticity measurement in participants with limb lymphedema by using acoustic radiation force impulse (ARFI) elastography.

Materials and Methods: From July 2015 to June 2017, ARFI elastography was performed in 64 participants with lymphedema (seven men and 57 women; age range, 23–85 years) by using a US system. Tissue stiffness quantification with shear-wave velocity (SWV) was obtained in the cutaneous and subcutaneous limb tissues. Lymphoscintigraphy was the reference standard.

Results: SWV was significantly higher in limbs with lymphatic obstruction than in unaffected limbs (cutaneous tissue: 2.75 m/sec vs 1.74 m/sec, respectively; subcutaneous tissue: 1.90 m/sec vs 1.35 m/sec, respectively; $P < .001$). SWV was significantly different among limbs without lymphatic drainage obstruction, with partial obstruction, and with total obstruction (cutaneous tissue: 1.74 m/sec vs 2.75 m/sec vs 2.77 m/sec; subcutaneous tissue: 1.35 m/sec vs 1.90 m/sec vs 1.90 m/sec, respectively; $P < .001$). By using a cut-off value of 2.10 m/sec and 1.43 m/sec for cutaneous and subcutaneous tissue, respectively, sensitivity was 83.1% (59 of 71) and 80.3% (57 of 71), and specificity was 86.0% (49 of 57) and 70.2% (40 of 57) for manifestation of lymphatic obstruction. The corresponding areas under the receiver operating characteristic curve were 0.91 and 0.83, respectively.

Conclusion: Acoustic radiation force impulse elastography showed that cutaneous and subcutaneous tissues are stiffer in lymphedematous limbs than in unaffected limbs. Acoustic radiation force impulse elastography is a feasible imaging modality for noninvasive tissue stiffness quantification in limb lymphedema.

Online supplemental material is available for this article.

Lymphedema is a condition in which protein-rich fluid accumulates in the cutaneous and subcutaneous tissue because of lymphatic drainage dysfunction (1). Chronic lymphedema leads to inflammation, adipose tissue hypertrophy, and fibrosis (2). Lymphedema may affect as many as 140 000 000–250 000 000 people worldwide (3). It is estimated to affect 2 000 000–3 000 000 people in the United States, and secondary lymphedema accounts for the majority of the cases (4). Lymphedema causes impaired limb function from swelling and stiffness, recurrent episodes of soft tissue infection, poor cosmesis, and various psychologic and social issues (5). The diagnosis of lymphedema relies on imaging of lymphatic truncal structures, flow dynamics, and lymph nodes. Lymphatic imaging modalities include conventional oil contrast agent–enhanced lymphography, radionuclide lymphoscintigraphy, indocyanine green lymphography, and MR lymphangiography (1,2). Currently, radionuclide lymphoscintigraphy is considered the standard test for the diagnosis of lymphedema (6).

Stiffness of lymphedematous limb is a major cause of patient discomfort and impaired limb function. Understanding the mechanical properties of soft tissue in lymphedematous limbs is critical in clinical diagnosis and treatment planning. In addition, objective and quantitative evaluation of soft tissue stiffness would enable health practitioners to monitor disease severity, determine treatment effect, and allow for early detection of treatment failure and the need for surgical intervention. Several methods have been proposed to measure the stiffness of the soft tissue, including tonometer, noncontact type stiffness imager, and recently, SkinFibroMeter (Delfin Technologies, Kuopio, Finland) (7–9). However, some of these methods require compression in the skin, which may cause pain and discomfort, and they only measure skin stiffness without quantification of the subcutaneous tissue, which is also largely affected by lymphedema.

US-based elastography techniques are noninvasive imaging tools to evaluate tissue stiffness. Strain US elastography has been used to evaluate limb lymphedema and has a moderately positive correlation with indocyanine green lymphography (10,11). However, strain US elastography provides only semiquantitative measurements in which a color-coded map of the tissue strain is shown for visual evaluation and scoring. At acoustic radiation force impulse (ARFI) elastography, focused and short-duration acoustic push pulses induce within-tissue shear stress, which generates shear waves that propagate through the tissue. By