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Measuring physiological properties of lymphoedemous tissues by ultrasound: theoretical foundations

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Roughly one in four breast cancer survivors report some degree of arm oedema. Lymphoedema is a build-up of excess lymph fluids in the tissues. Persistent lymphoedema leads to pain, diminished limb function, increased risk of infection, soft tissue fibrosis, and severe cases can be grossly disfiguring. From a mechanics perspective, the lymphoedemous tissue may be thought of as a two phase composite, consisting of both fluid and solid phases. Here we discuss the use of composites mixture theory to model the mechanics of lymphoedemous tissues. By treating the tissue as a fluid-solid composite, rules-of-mixtures may be used to estimate the effective moduli in terms of the properties of the individual components and their respective volume fractions in these two states. The mechanical properties of the tissue may be measured in vivo using a generalization of the methods of ultrasound elasticity imaging. We discuss how the measured "effective stiffness" depends upon whether the tissue is drained or undrained, and how ultrasound may be used to measure these properties. Thus we explore the possibility of evaluating volume fractions and component properties of the individual tissue phases from ultrasound elasticity imaging.