The Effects of Testing Environment on Soft Tissue Properties

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Accurate characterization of the mechanical behavior of soft tissues is needed for medical simulation, diagnostic, and tissue engineering purposes. Determining the complex behavior of soft tissues requires mechanical testing in their natural state. Such in vivo tests are wrought with ethical, accessibility, physiological noise, and uncontrolled boundary condition issues. Several groups have developed means for in vivo mechanical testing, but the interpretation of their results remains to be understood. Conversely, testing biological tissues under ex vivo conditions is desirable because it allows for precise control of the boundary conditions, ease of accessibility, and use of fewer animals. However, the behavior and properties of the tissues are drastically altered once removed from their natural state. This study seeks to quantify the differences in the viscoelastic response of soft tissues between four different test conditions. We introduce a new ex vivo set-up that allows for near in vivo testing.

A system was developed to mimic the natural environmental condition of the liver for *ex vivo* mechanical testing. The system maintains the structural integrity of the liver post mortem by perfusing the organ with physiologic solutions at appropriate pressures and temperature (39 C). Adjusting the heights of the perfusate reservoirs kept the pressures to the hepatic artery and the portal vein at 100-120 mmHg and 15-20 mmHg respectively.

Mechanical testing was performed using the VESPI (Visco-Elastic Soft-Tissue Property Indentation) device. Large strain (>30%) indentations typical of surgical manipulations and diagnostic palpations were applied to the organ using a known load and displacements were recorded over time. These creep tests were performed on whole porcine livers *in vivo, ex vivo* perfused, and *ex vivo* unperfused on the same locations. *In vitro* tests on a sectioned lobe under warm ischemic conditions were also done. Biopsies were taken for histology on the *ex vivo* states over time and compared against an *in vivo* control.

Initial results indicate over a 50% difference in the steady state strain response of the liver between the *in vivo* and *ex vivo* unperfused states. A 17% difference is noted between the *in vivo* and the *ex vivo* perfused states. The *in vitro* condition did not achieve a steady state response within 5 minutes of load application. Both the *in vivo* and the *ex vivo* perfused conditions show good repeatability over time within the same location, whereas the *ex vivo* unperfused state drastically changes with time. Histological evaluations of the samples over time suggest that structural integrity was maintained in the perfused state but that cellular dissociation was more severe in the unperfused condition.

Since human's can detect differences in force as small as 10%, it is clear that *ex vivo* testing alone is not sufficient to accurately characterize the mechanical behavior of soft tissues. After minor modifications (changes in perfusate and pressure as suggested by histology) are applied, the *ex vivo* perfusion system is one method for obtaining the desired results in an accessible, ethical, and controlled manner.

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