

MEASURING THE MECHANICAL PROPERTIES OF SOFT BIOLOGICAL TISSUES IN-VIVO

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Introduction

Determination of the mechanical properties of soft biological tissue is a key issue for a number of medical applications, such as surgery planning, surgical training deploying virtual reality based simulators and for diagnosis. Quantitative data on the mechanical behavior of human organs in-vivo are very limited due to the obvious experimental difficulties, in particular when testing internal organs.

Experimental technique

An experimental procedure suitable for in-vivo testing in open surgery under sterile conditions has been developed and applied. The technique, called aspiration experiment, is based upon the pipette aspiration procedure. The device consists of a tube in which the internal pressure can be controlled according to a desired pressure law. The experiment is performed by (i) gently pushing the tube against the tissue to ensure a good initial contact, (ii) creating a (time variable) vacuum inside the tube so that the tissue is sucked in through the aspiration hole (diameter of 10 mm). A digital camera records the tissue deformation and a pressure sensor measures the applied pressure. A control system guarantees the repeatability of the same loading conditions for all the experiments performed and therefore allows a direct comparison of the results obtained in different tests.

Mechanical behavior of soft tissues

From the analysis of the experimental data a proper constitutive model is determined through iterative finite element calculations. The mechanical behavior is directly related to the tissue's microstructure and depends on the health condition of the tissue. With the aspiration experiment relatively small changes (20-30%) in the parameters characterizing tissue's mechanical response can be identified, even under the non-ideal testing conditions of the operation room during surgical intervention. Alterations of the mechanical behavior due to pathologies (for example a tumor or, in the case of a uterus, pre-natal diseases) are therefore easily detectable so that the device can be applied for diagnostic purposes.

Experimental results

Cyclic experiments were performed in order to investigate the phenomenon called "pre-conditioning" which is related to the capability of the tissue to recover its initial properties after mechanical loading. Comparison of in-vivo and ex-vivo experiments demonstrated that pre-conditioning is more pronounced in a dead tissue.

Clinical studies have been recently performed on 9 uterine cervixes. The tissues have been tested in-vivo during vaginal/abdominal hysterectomy and 5 of them were subsequently tested in ex-vivo, approximately one hour after extraction. The next step in this study is to monitor the variation of the mechanical properties of the human cervix during pregnancy.

Currently, in-vivo testing of human livers is on-going at the hospital of Chur. First experiments were performed on a healthy liver during open surgery: these tests represent the first high quality mechanical data ever collected on a healthy living human liver.