Repeatabilty of mechanical property maps in breast tumors

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Breast cancer statistics

- Excluding skin cancer, breast cancer is the most common cancer in women.
- Breast accounts for 1/3 of cancers found in women.
- Breast Cancer is the 2nd leading cause of cancer death among women (after lung cancer).
- Breast masses present as stiff lumps, and hence are known to have pathological mechanical properties.

TABLE 2. Age-Specific Probabilities of Developing Invasive Female Breast Cancer[a]

IF CURRENT AGE IS:	THE PROBABILITY OF DEVELOPING BREAST CANCER IN THE NEXT 10 YEARS IS:	OR 1 IN:
20	0.06%	1,732
30	0.44%	228
40	1.45%	69
50	2.31%	43
60	3.49%	29
70	3.84%	26
Lifetime risk	**12.29%**	**8**

[a]Among those free of cancer at the beginning of the age interval. Based on cases diagnosed between 2008 and 2010. Percentages and "1 in" numbers may not be numerically equivalent due to rounding. Probabilities derived using the National Cancer Institute DevCan Software (version 6.7.0).

Statistics from [2]

Desmoplastic effect

- The stiffness of tumors is likely due to the desmoplastic effect, in which excessive connective tissue (stroma) forms around an invasive tumor [1].

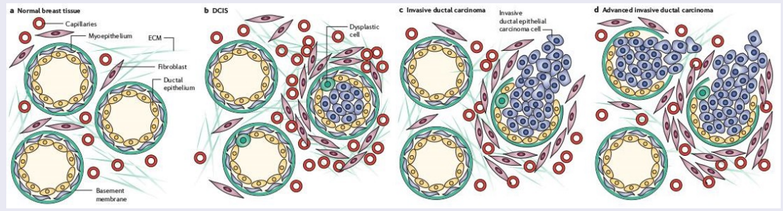


Illustration of desmoplasia from : [5]

- The morphology of the connective tissue (collagen fibers) around the tumor depends on the tumor nature.
- SHG images of collagen fibers from breast tissue.

Source: [3]

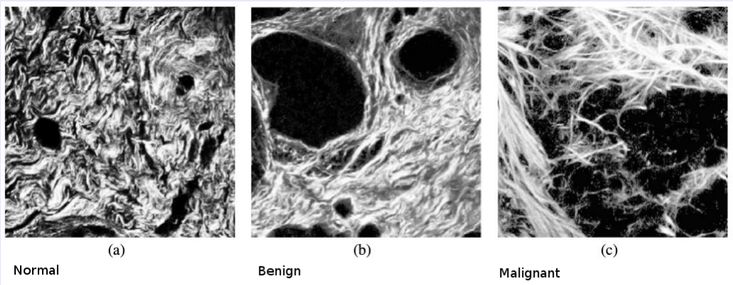


Figure 1. SHG images of (a) normal, (b) benign and (c) malignant breast tissue. Differences in the collagen fibre shape are evident between tissue groups.

Source: [4]

- The changes in tissue structure and morphology on the micro-scale changes the behavior and properties of tissue on the mm scale.

Imaging material properties

- Bayesian inversion from ultrasound image sequences coupled with a mathematical model of tissue deformation allows us to make images of breast tissue mechanical properties.

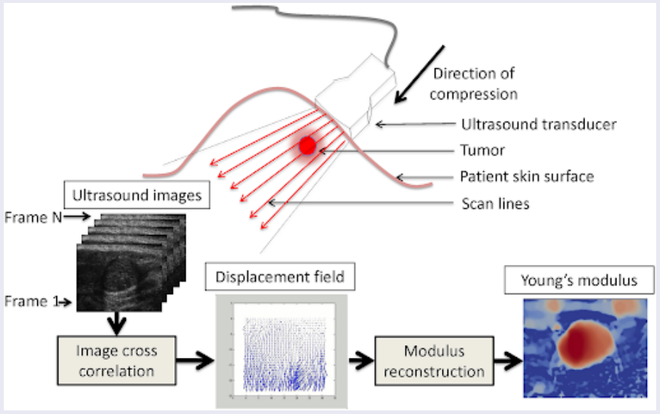


Image courtesy of Dawei Song

Mechanical Model

- Veronda-Westmann [6] strain energy function(incompressible,plane stress):

$$W = \mu\left(\frac{e^{\gamma(I_1-3)}-1}{\gamma} - \frac{I_2-3}{2}\right) \quad (1)$$

$$\mathbf{S} = \mu\left(2e^{\gamma(I_1+1/I_2-3)}(\mathbf{I}-\frac{1}{I_2}\mathbf{C}^{-1}) - \frac{1}{I_2}\mathbf{I} - (I_2-\frac{I_1}{I_2})\mathbf{C}^{-1}\right) \quad (2)$$

- Objective function

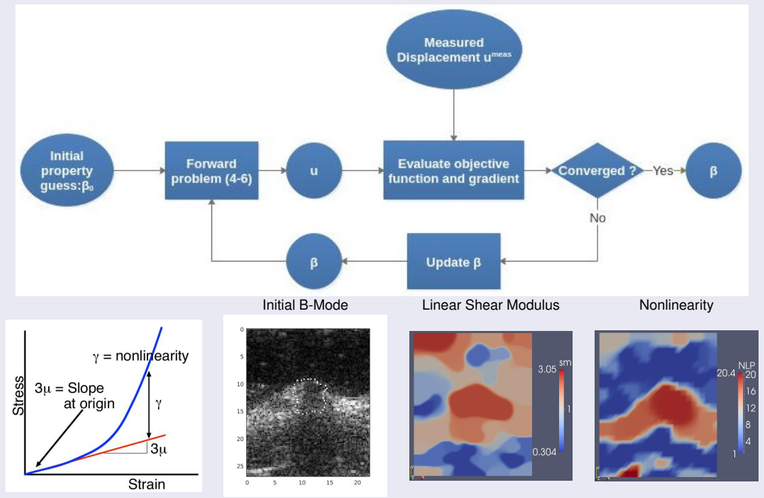
$$C[\beta] = \int_A (u_y(\beta) - u_y^{meas})^2 dA + \alpha \int_A \sqrt{|\nabla\beta|^2 + c^2}\, dA \quad (3)$$

Here β is a material parameter (either the linear shear modulus μ or the non-linearity parameter γ).

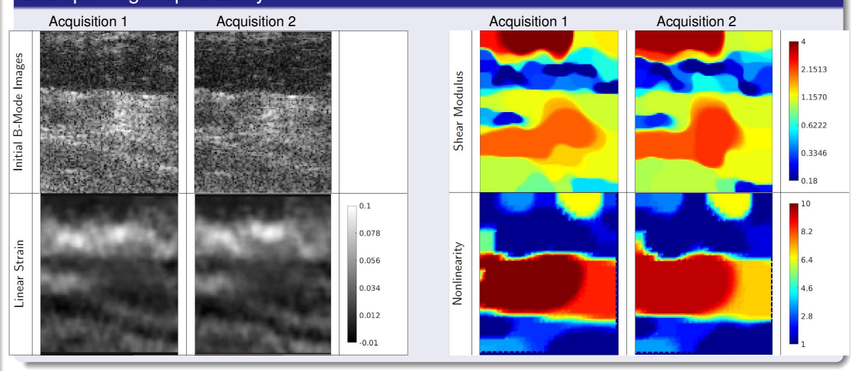
- Governing equations and boundary conditions

$$\nabla\cdot(\mathbf{FS}) = 0 \text{ on } \Omega_0 \quad (4) \qquad u_y = u_y^{meas} \text{ on } \partial\Omega_0 \quad (5) \qquad t_x = 0 \text{ on } \partial\Omega_0. \quad (6)$$

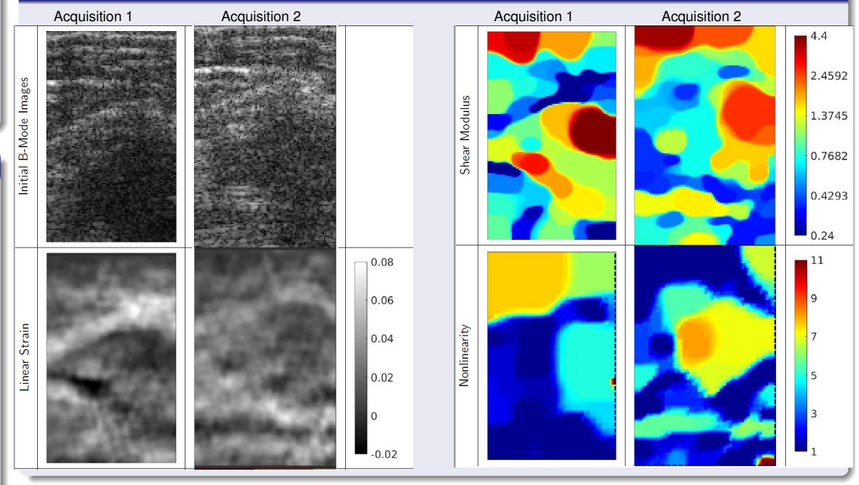
Linear and nonlinear modulus reconstruction



Example: high repeatability



Example: low repeatability



Discussion and conclusions

- Changes in tissue at the micro level, result in alterations to behavior and properties at the macro level.
- Mechanical property images can serve as adjunct images to potentially improve diagnosis at screening time.
- We studied the repeatability of our reconstructions using data from patients who were imaged multiple times.
- When acquisitions represent similar regions of tissue (as measured by correlation between initial ultrasound images) the resulting mechanical property reconstructions are highly repeatable.
- When acquisitions represent different regions (or imaging planes) of tissue the resulting reconstructions are less repeatable.
- When insufficient strain is applied to adequately observe nonlinear behavior, the resulting nonlinearity reconstructions could exhibit very low repeatability.
- Repeatability of nonlinearity can vary noticeably with processing parameters.

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