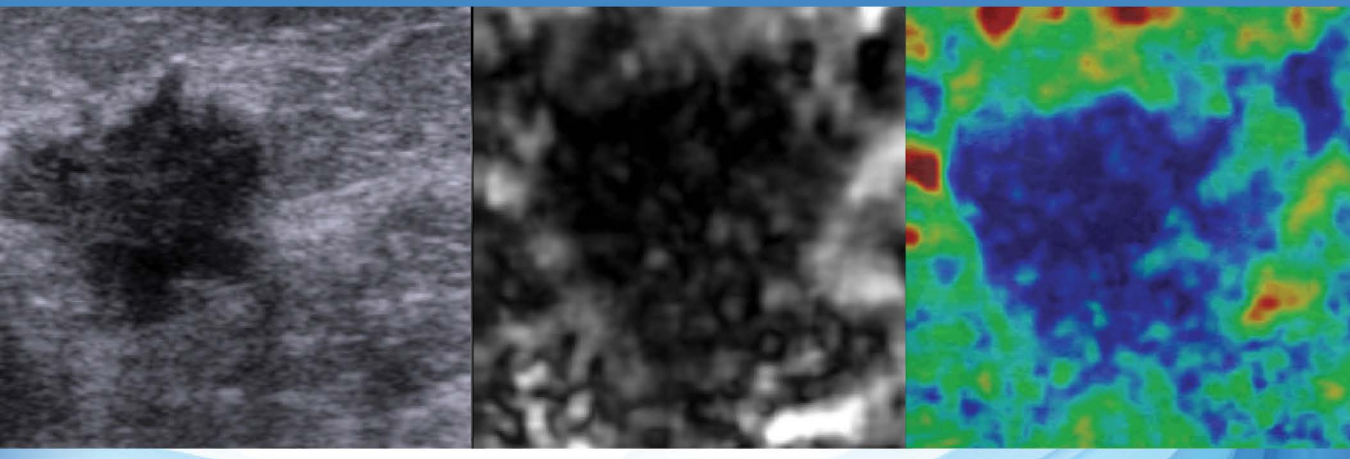
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Breast Elastography

Basic Principles and Interpretation of Clinical Cases



Christina An. Gkali
Constantine Dimitrakakis
Maria Sotiropoulou

JAYPEE

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SECTION 2

BASIC PRINCIPLES OF ELASTOGRAPHY

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CHAPTER 3 Elastography and Tissue Strain: What Clinicians Need to Know

Christina An. Gkali

Ultrasound imaging is a first-line imaging modality for a wide range of indications, playing a major role in screening, diagnosis, and therapeutic interventions for various diseases and pathologies. However, even with enormous improvements in recent years, conventional ultrasound is limited in its ability to differentiate between the mechanical properties of tissue, which can be important in assessing the morphology and physiology of focal or diffuse disease.

Ultrasound elastography was initially introduced as a new imaging method adjunct to ultrasound in order to overcome ultrasonography limitations, such as increased number of unnecessary biopsies.

The system which was used for all the cases described in this book was a Siemens Acuson S2000. The techniques that we are going to describe are strain imaging and acoustic radiation force impulse (ARFI) based on our equipment.

Compression elastography offered the promise of a new dimension of ultrasound. In addition to the anatomic detail visible in B-mode and the flow imaging offered by color Doppler, elastography was intended to enable visualization of tissue stiffness, long known as a harbinger of disease and malignancy (palpation searches for stiffness, after all). Early compression elastography could provide relative, qualitative visualization of tissue stiffness differences for assessing focal lesions, but lacked the ability to quantify stiffness differences of these lesions.

Acoustic radiation force impulse technology allows to enable both qualitative and quantitative assessment of the mechanical stiffness (elasticity) differences in tissue. Ultrasound systems can be configured with a wide range of elastography technologies and applications, helping physicians evaluate conditions of the liver, breast, thyroid and other organs.

ELASTOGRAPHY AND TISSUE STRAIN

The perfect diagnostic tool would have 100% sensitivity (a positive result when disease is present) and 100% specificity (a negative result in the absence of disease) in all cases. Such a technology does not exist, of course. However, the use of more than one imaging tool can provide overall higher diagnostic accuracy than one imaging modality alone. This is true when adding elastography to conventional ultrasound and when using multiple elastography technologies in cooperation.

Modern elastography can refer to multiple technologies. Some depend upon heavy user-generated manual pressure. More advanced elasticity imaging, enabled by sophisticated architecture, can detect extremely small changes in tissue displacements (on the order of 1–10 μm). These advanced elastography tools rely less on manual pressure and can detect tissue stiffness based on native tissue motion, induced by the patient's cardiac pulsations and respiration.

Using ARFI technology, rather than manual compression techniques, tissue is compressed by an acoustic beam. One advantage of this approach is that the acoustic beam is focused at

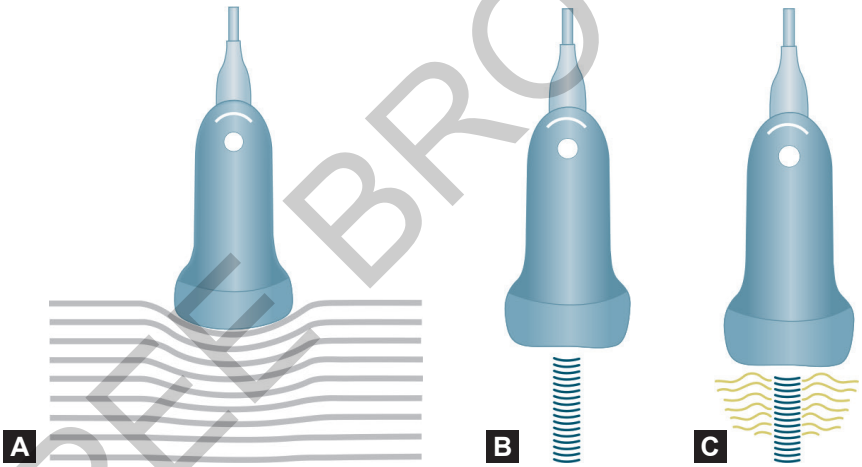
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the region of interest (ROI) to maximize the local displacement of tissue, rather than just at the skin surface with uncontrollable stress being applied in deeper tissues. This more controllable application of stress improves the uniformity of the resulting elastogram.

Acoustic radiation force impulse technology also induces and tracks the propagation of shear waves (transverse waves) for quantification of tissue stiffness. An increase in shear wave velocity correlates closely with increasing tissue stiffness, providing a more precise indication of true tissue elasticity at a point location.

This ability to quantify tissue stiffness, rather than qualitatively evaluating stiffness compared to surrounding tissue with focal lesions, expands the clinical utility of elastography to homogeneous tissue, such as liver and spleen.

In addition, compared to manual compression, ARFI offers a reduction in user technique dependence. The user simply initiates the acquisition of the elastogram or quantitative measurement with the push of a button, further improving interoperator reproducibility, which is an important aspect of clinical utility (Figs. 3.1A to C).



Figs. 3.1A to C: Elastography technologies attributed schematically. (A) Compression elastography; (B) Acoustic radiation force impulse (ARFI) elastography; (C) Shear wave detection for quantification at a single point.

HOW ELASTOGRAPHY WORKS

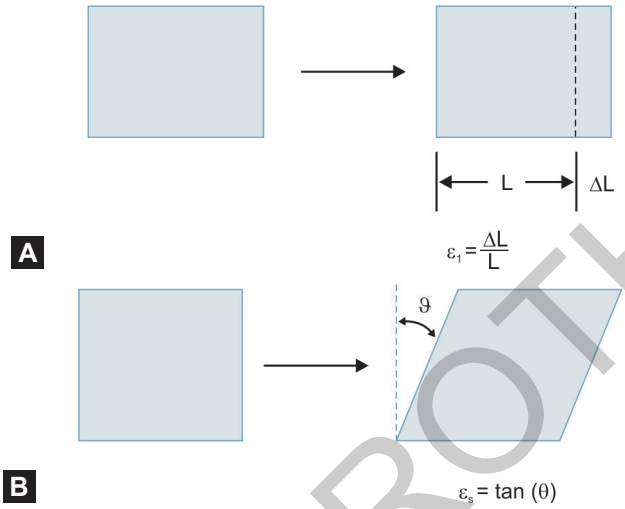
Physics of Tissue Strain

Many studies have characterized the normal range of elasticity values of various tissue types and that certain disease processes can change the viscoelastic properties of tissue. Elastography tools work by measuring how much strain tissues exhibit in response to stress. The relationship between stress and strain provides information about the mechanical stiffness of the tissue in question.

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Stress and strain are not the same. Stress is the force exerted and strain is what happens to the tissue in response to the pressure.

Two kinds of strain exist, longitudinal and shear, as shown in Figures 3.2A and B.



Figs. 3.2A and B: (A) Longitudinal strain; (B) Shear strain.

Longitudinal, or normal strain, occurs when tissue is either stretched or compressed. Shear strain occurs as a result of angular forces, such as twisting or bending.

In tissue, both longitudinal and shear strains are usually present when manual compression force or radiation force is used. In fluid, pressure is the same in all directions; therefore, shear strain and shear waves do not exist in fluids.

Hooke's law describes the relationship between stress and strain for most materials, including viscoelastic tissue:

$\sigma = Y\varepsilon$

where

σ is a deformation proportional to the force of ε.

Young's modulus or modulus of elasticity can be computed by examining the slope of the stress/strain diagram in the elastic portion of the curve, as shown in Figure 3.3.

The shear modulus G, also known as the modulus of rigidity, can also be calculated through examination of a shear stress versus shear strain curve.

In elastic materials, the relationship between the velocity of a shear wave and shear modulus is:

$$v_s = \sqrt{\frac{G}{\rho}}$$

where G is the tissue shear modulus and ρ is the solid tissue density.

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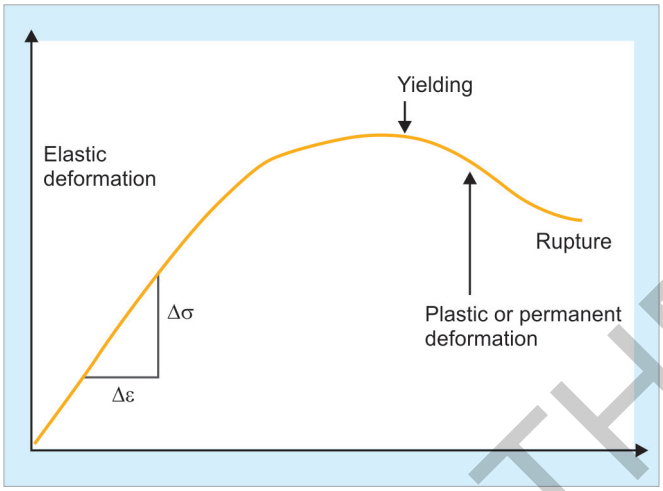


Fig. 3.3: Relationship between strain and stress in any material.

Tissues with a higher shear modulus, or modulus of rigidity (less compliant to shear forces), will have a higher shear wave velocity than tissues with a lower modulus of rigidity (more compliant to shear forces).

SUGGESTED READING

Rosen J, Brown J, De S, Sinanan M, Hannford B. Biomechanical Properties of Abdominal Organs In Vivo and Postmortem Under Compression Loads. Journal of Biomechanical Engineering. 2008; Vol. 130, 021020-1.

Wellman, et. al. Breast Tissue Stiffness in Compression is Correlated to Histological Diagnosis. Harvard BioRobotics Laboratory Technical Report, 1999. https://biorobotics. harvard.edu/pubs/1999/mechprops.pdf.

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Breast Elastography

Basic Principles and Interpretation of Clinical Cases

Salient Features

- Provides the specialist with a detailed practical guide to the techniques of breast elastography (provided by our equipment-Acuson Siemens, S2000)
- Interpret images obtained with both types of elastography (Strain Imaging and Acoustic Radiation Force Impulse Imaging)
- Presents some pitfalls of elastography



Christina An. Gkali MD candidate PhD is currently working as Resident at the Department of Radiology in "Alexandra" General Hospital of Athens, Athens, Greece. She has a special interest in breast imaging, including breast ultrasound, digital mammography and contrast enhanced digital mammography. She has published in PubMed Journals mainly on imaging of the breast pathology. She is also a peer reviewer in journals alike (Ultrasound Quarterly). She is an avid researcher, with International Awards (Certificate of Merit, RSNA 2014).

Dr Christina Gkali has lectured at regional and international meetings. She is a member of RSNA, ECR, and EUSOBI. She is graduate of Greek School of Mastology.



Constantine Dimitrakakis MD PhD is currently working as Associate Professor at the Department of Obstetrics and Gynecology in Medical School of Athens University, Athens, Greece, as Head of Breast Unit in Alexandra General Hospital and Adjunct Scientist, NICHD, NIH, USA. He has a special interest in the role of androgens on breast cancer risk. He was fellow at NICHD, NIH, USA. Prior to that, he did his Obstetrics and Gynecology residency in Athens University.

He has published extensively in PubMed Journals (over 70 articles) mainly on the breast, laboratory and clinical studies on hormone therapy and breast cancer. He has also clinically based research on the role of androgens on breast cancer risk and contributed several chapters to books and peer reviewed journals alike (The Breast, Journal of Clinical Endocrinology and Metabolism, BioMed Central journals etc.)

He is an avid educator and academician researcher, with over 10 International Awards and numerous International Collaborations, he has been responsible for both clinical and laboratory breast research at the NIH, USA, with focus on the effects of Hormone Therapy on breast cancer risk and possible modifications of it.

Dr. Dimitrakakis has lectured at, and chaired various sessions in regional and international meetings. He is an active member of the American Association of Cancer Research (AACR), member of NIH FARE (fellow's awards of research excellence), member of the Bioethics Committee of the Greek Ministry of Health and member of EUSOMA, EMAS, ESC and Greek Societies.



Maria Sotiropoulou MD PhD is currently working as a Senior Consultant/Director at the Department of Histopathology in "Alexandra" General Hospital of Athens, Athens, Greece. She has a special interest in Breast and Gynecologic Pathology. Prior to that, she did her Pathology training in Evangelismos Hospital, Athens, Greece. She was in New York University, Bellevue Hospital in Gynecologic Department for six months. She has PhD in Pathology from Medical School, Athens University.

She has published extensively in Breast, Gynecologic and Gastrointestinal Pathology. She collaborates in clinical trials for Breast Pathology in HeLLENIC COOPERATIVE ONCOLOGY GROUP (HeCOG) with a lot of publications. Dr Sotiropoulou has lectured at, and chaired various sessions in regional and international meetings. She is a member of the working group for Breast and Gynecologic systems of Greek Society of Pathology and the European Society of Pathology and has extensive educational work for residents in Pathology and in sub-specialization in Breast and Gynecologic Pathology for Pathologists.

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