

Magnetic Resonance Liver Elastography: The Bare Essentials for Radiologists

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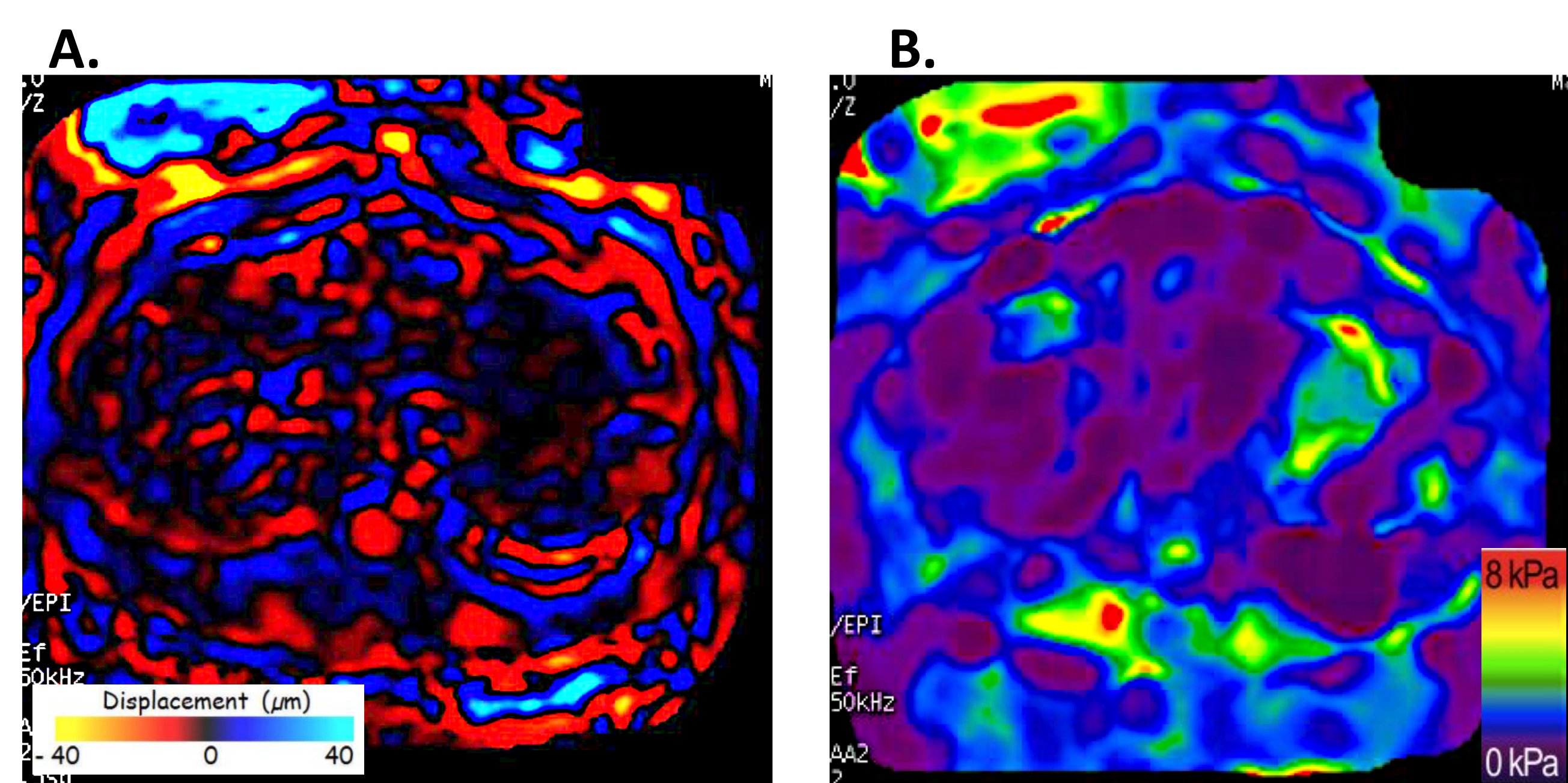
Concept

- Magnetic Resonance Liver Elastography (MRE) is a tool for quantitatively assessing the mechanical properties of tissue.
- It is a safe, noninvasive alternative to liver biopsy.
- It is currently being used for both detection and staging of liver fibrosis, to better analyze focal liver lesions (i.e. benign versus malignant), and to assess response to treatment

The basic principles of MRE are as follows:

- 1) While a normal liver is soft, a diseased liver (i.e. fibrosis) becomes stiff.
- 2) Shear waves propagate faster in stiff tissues than in soft tissues.
- 3) By generating external vibrations, and thus creating shear waves in the liver, an MRI can be used to process images of these shear waves.
- 4) The processed images provide invaluable information about different regions of interest and their stiffness.

Example Images:



A. Wave Image of a healthy liver, the color reflects displacement in micrometer. **B. Corresponding elastogram** of same patient's liver, the color reflects the degree of stiffness in kPa.

Basic Definitions

- **Elasticity** is the property of solid materials to return to their original shape and size after deforming forces have been removed.
- **Stress** is the applied force or system of forces that tends to deform a body.

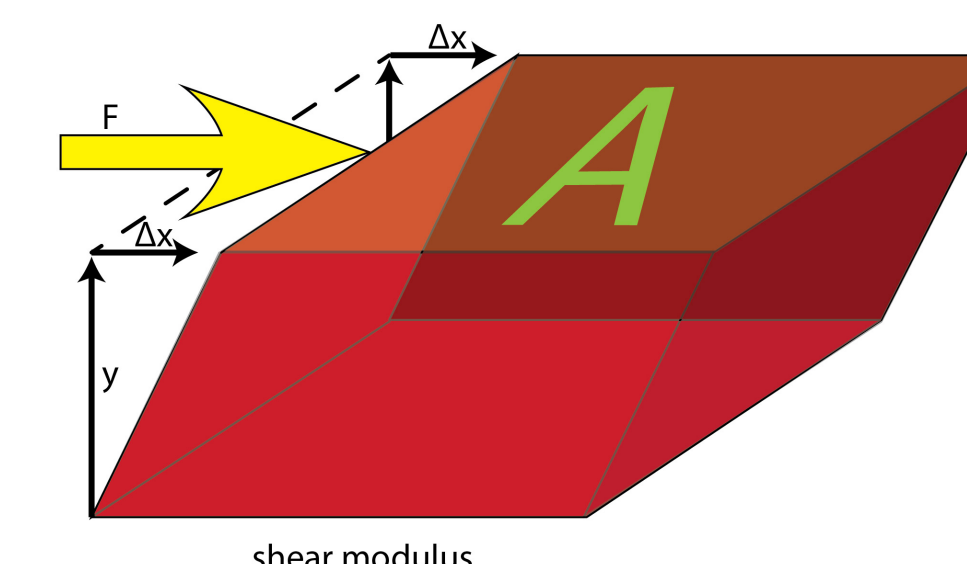
Basic Definitions (Continued)

- **Strain** is the response of material to an applied stress, which causes the material to deform (change in dimension/original dimension)
- **STRESS = MODULUS * STRAIN**

There are three basic types of stress with three associated moduli:

- **Young's modulus** – Force applied perpendicular to the face of an object to create longitudinal strain.
- **Shear modulus** – Force applied tangentially to the face of an object to create shear strain.
- **Bulk modulus** – Force applied uniformly over the face of the object to create volumetric strain.

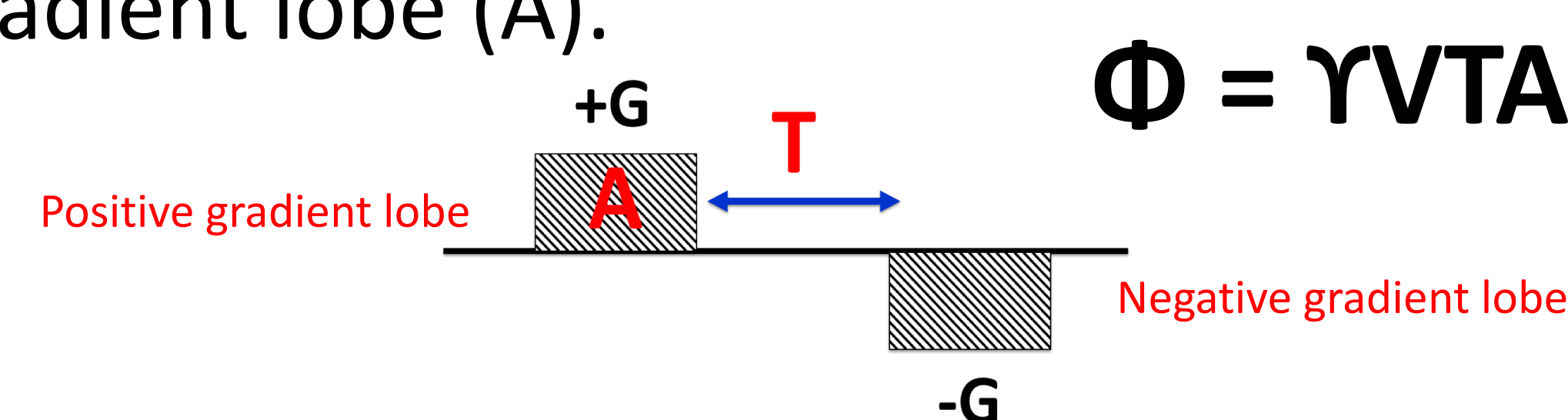
- Shear stress $\rightarrow \tau = \text{Force (F)}/\text{Area(A)}$
- Shear strain $\rightarrow \gamma = \Delta x/y$ (change in dimension/Original dimension)
- $G = \text{Shear Modulus}$
- $\tau = G * \gamma$



MR Phase Contrast Technique

Basis of phase-contrast angiography:

- Spins that are moving in the same direction as a magnetic field gradient develop a *phase shift* that is proportional to the velocity of the spins.
- Moving spins will acquire a net phase shift (non-zero) relative to the stationary spins.
- Net phase shift (Φ) is proportional to gyromagnetic ratio γ , the velocity of the moving spins (V), the time interval between the lobes of the bipolar gradient (T), and the area of each gradient lobe (A).

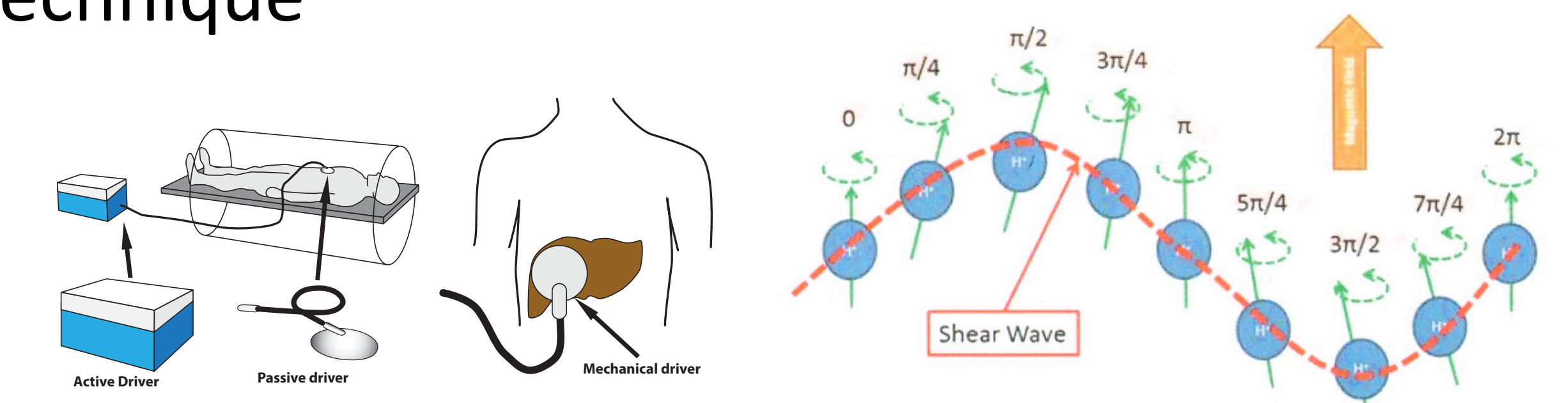


Simplest phase-contrast pulse sequence:

- Bipolar gradients.
- Two gradients with equal magnitude (but opposite direction) are used to encode the velocity of the spins.
- Positive and negative lobes cancel out for stationary spins.

Putting it All Together

- By use of an external mechanical driver (i.e. *by creating vibrations*), shear wave motion in the liver is induced.
- These shear waves cause cyclic spin displacement of protons, which, in the presence of synchronized motion sensitive gradients (MSGs) and motion-encoding gradients (MEGs), are encoded within the MR signal utilizing MR Phase Contrast technique



- Cyclic spin displacement is manifested as phase shift of the spins, which in turn reflects velocity of the spins
- Velocity directly reflects the propagation of shear waves through the tissues, which in turn is affected by tissue **STIFFNESS**
- Shear wave images are created next and are based on the spin displacement/spin velocity. The intensity at every pixel in a wave image represents the local value of displacement undergone by the tissue.
- Finally, an inversion algorithm is then applied to the shear wave images to create the final elastogram.
- Regions of interest may then be drawn to assess the tissue stiffness.

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