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Elastography & Interventional US

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EFSUMB Guidelines on Elastography:
Part I: Basic Principles & Technology

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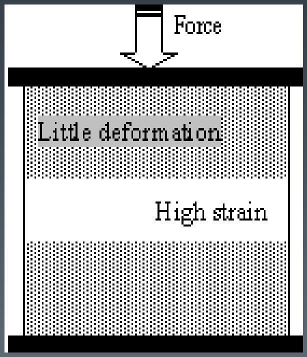

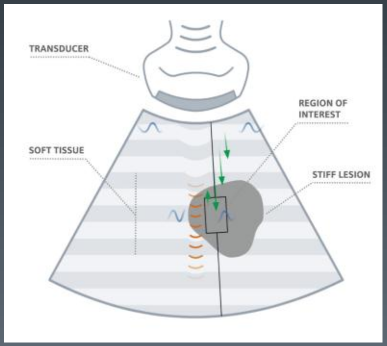

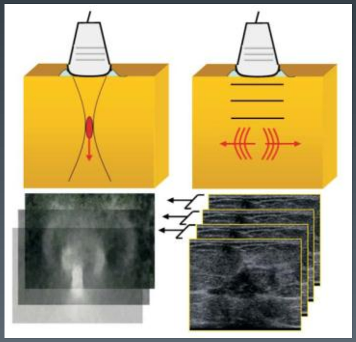

US Elastography

Rapidly evolving in recent years
Growing general interest, a lot of available techniques, level of scientific evidence

EFSUMB

2011: steering committee selected European experts
Sept 2012: consensus meeting in Bologna

Supported by the industry
(BK medical, Echosens, Esaote, GE, Hitachi Aloka, Philips, Siemens, Supersonic, Toshiba)
No influence on the content

EFSUMB Guidelines on Elastography: Part I

EFSUMB Guidelines and Recommendations on the Clinical Use of Ultrasound Elastography. Part 1: Basic Principles and Technology

Authors: J. Bamber[1], D. Cosgrove[2], C. F. Dietrich[3], J. Fromageau[1], J. Bojunga[4], F. Calliada[5], V. Cantisani[6], J.-M. Correas[7], M. D'Onofrio[8], E. E. Drakonaki[9], M. Fink[10], M. Friedrich-Rust[11], O. H. Gilja[12], R. F. Havre[13], C. Jenssen[14], A. S. Klauser[15], R. Ohlinger[16], A. Saftoiu[17], F. Schaefer[18], I. Sporea[19], F. Piscaglia[20]

Ultraschall Med. *2013 Apr;34(2):169-84*

EFSUMB Guidelines and Recommendations on the Clinical Use of Ultrasound Elastography. Part 2: Clinical Applications

Authors: D. Cosgrove[1], F. Piscaglia[2], J. Bamber[3], J. Bojunga[4], J.-M. Correas[5], O. H. Gilja[6], A. S. Klauser[7], I. Sporea[8], F. Calliada[9], V. Cantisani[10], M. D'Onofrio[11], E. E. Drakonaki[12], M. Fink[13], M. Friedrich-Rust[14], J. Fromageau[3], R. F. Havre[15], C. Jenssen[16], R. Ohlinger[17], A. Săftoiu[18], F. Schaefer[19], C. F. Dietrich[20]

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Outline

- ❑ Basic principles
- ❑ Quasi-static methods
- ❑ Dynamic methods
- ❑ Recommendations
- ❑ Safety issues
- ❑ Appendix-definitions & explanations *(online only)*

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Tissue Displacement

Directly (as distance): ARFI

Converted to strain*: Strain imaging

Calculate the speed of shear waves: Shear wave

*Strain: has no units
= the amount of deformation of an element of the medium compared to its original size and shape

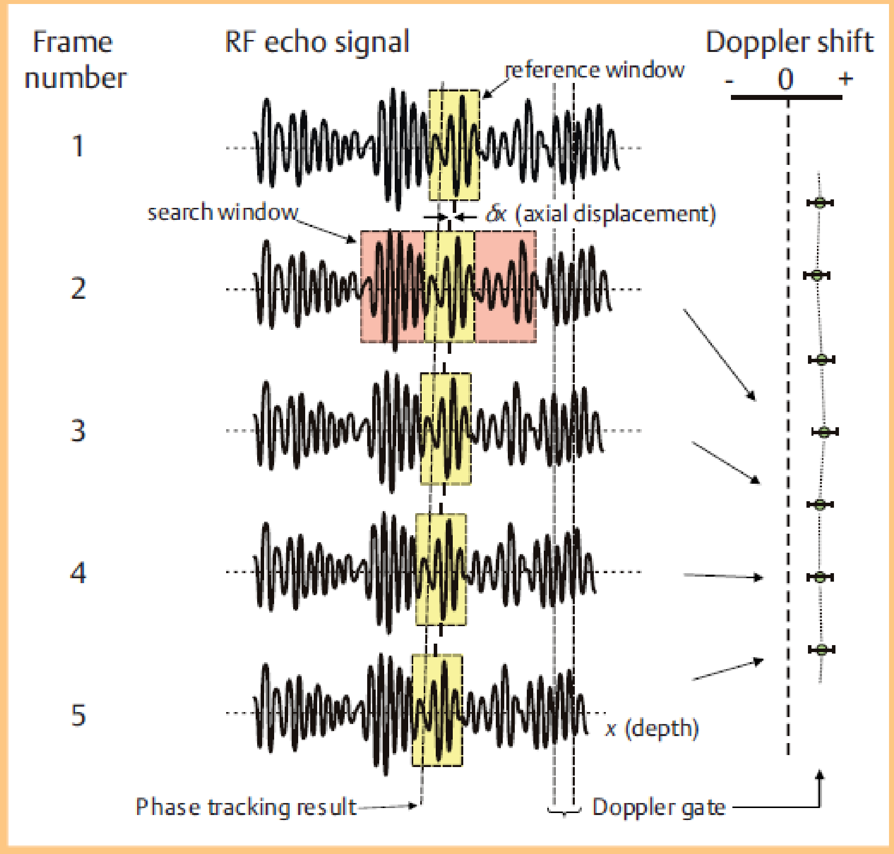
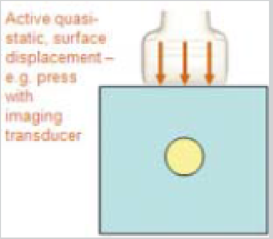
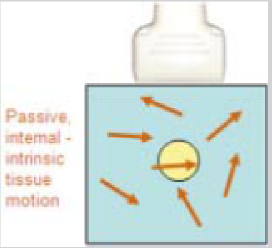
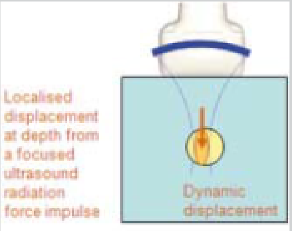
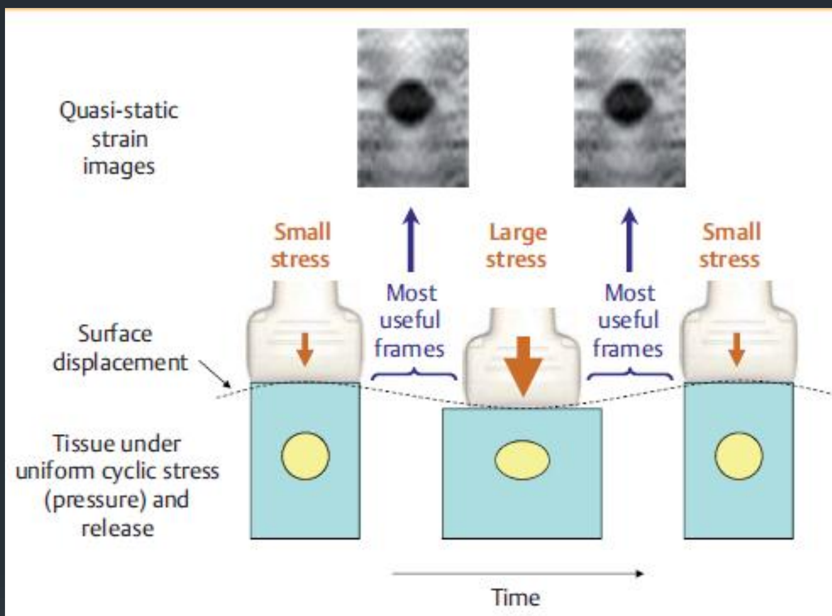


Fig. 4 The two main methods for estimating displacement used in elastography are RF-echo correlation tracking and Doppler processing. In this

Strain imaging:
Strain Elastography & ARFI (qualitative)

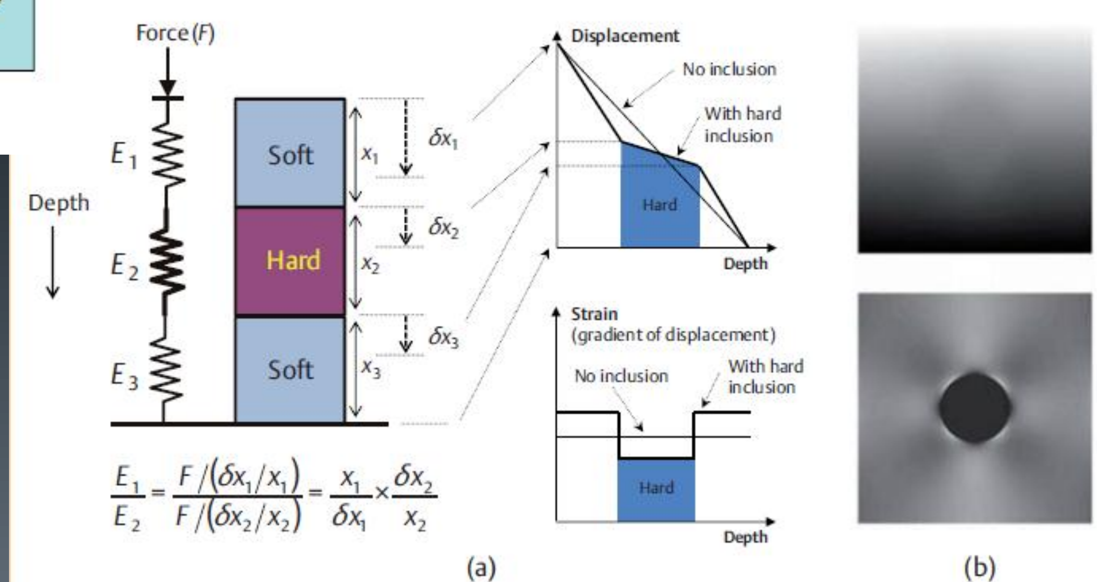
	method	type of force	applied force	property displayed	qualitative/ quantitative	imaging/ measure-ment	commercial implementation	illustration
displacement or strain imaging	strain elasto-graphy (SE) *and* strain-rate imaging (SRI)	quasi static	mechanically induced – *either* active external displacement of tissue surface[1] *or* passive internal physiologically induced[2]	strain or strain rate	qualitative, although tools often provided to analyse image characteristics	full area image, refreshed at up to the ultrasound frame rate[3]	Esaote GE Hitachi Aloka Philips Samsung Medison Siemens Toshiba Ultrasonix Zonare	 
	acoustic radiation force impulse (ARFI) imaging		ultrasound induced – focused radiation force impulse at depth	displace-ment	qualitative	single image within a box	Siemens	

Strain Elastography



Stress is:
- **Transducer induced**
- **Physiologically induced**

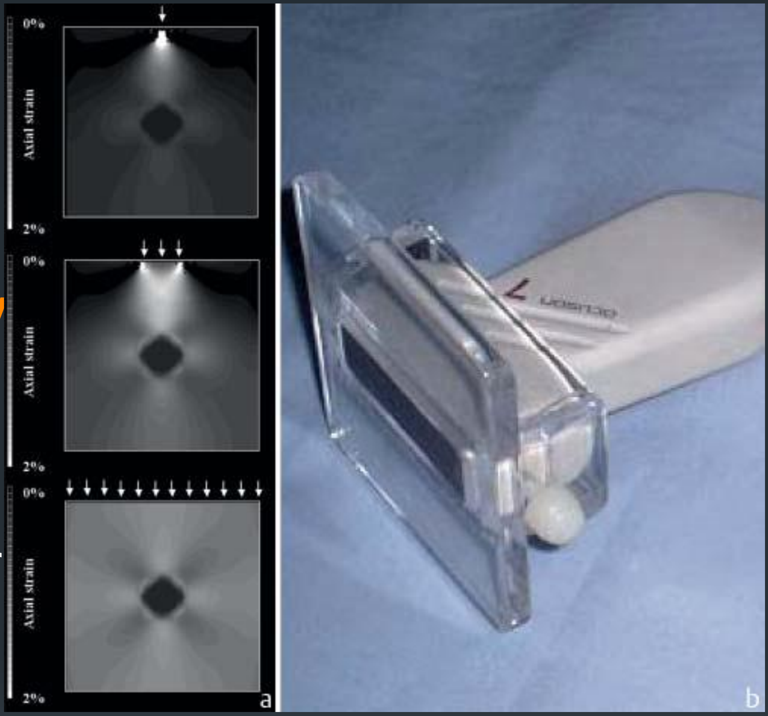
*Strain: the spatial gradient of displacement, has no units
= the amount of deformation of an element of the medium compared to its original size and shape



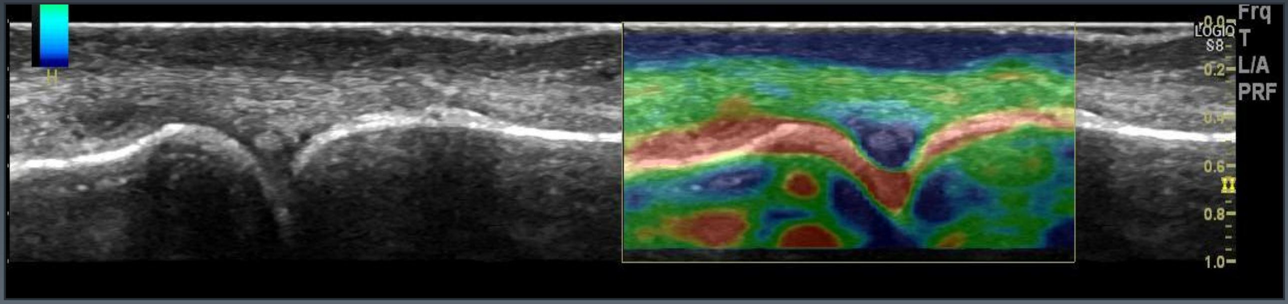
Strain Elastography Artefacts

Small compressor generates strain of poor penetration and homogeneity

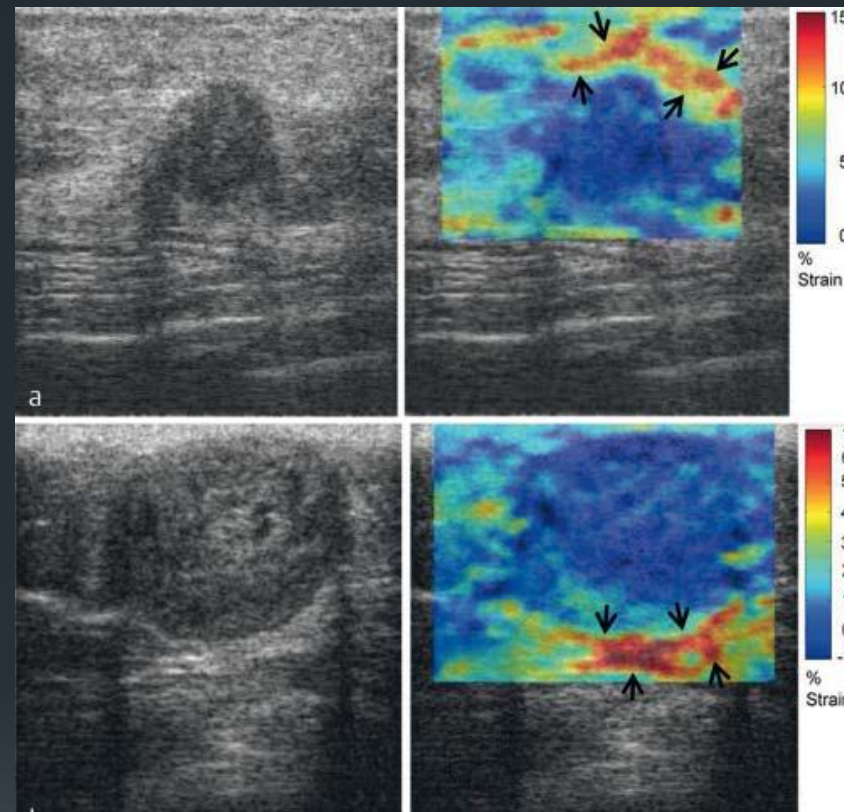
-footprint extender
-place a finger on either sides of the transducer and move them with the transducer



Friction between transducer and skin causes less strain (stiff) –more gel needed

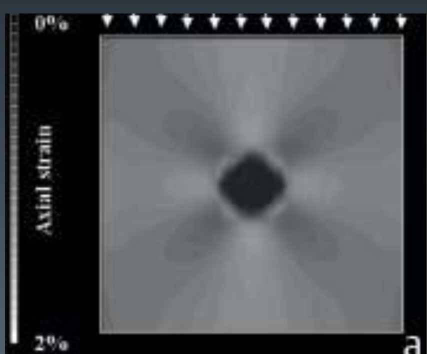


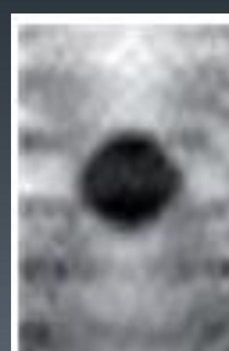
Strain Elastography Artefacts



Soft tissue strains more when it is <u>next to hard tissue</u>

Stress concentration
"Maltese cross" artefacts
(inhomogenous background around a stiff lesion)

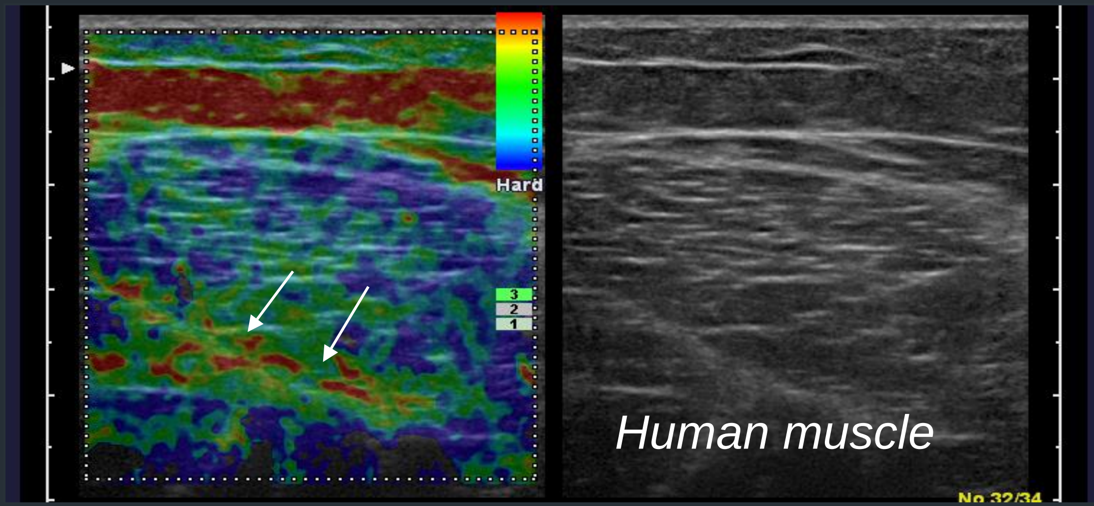


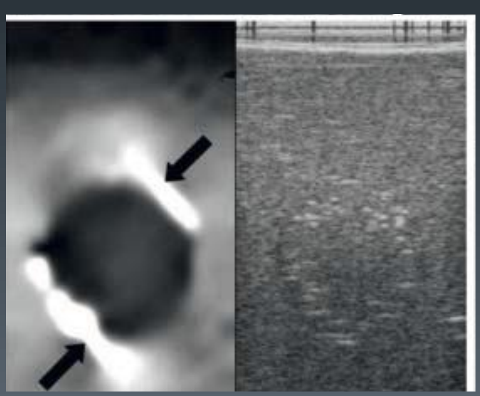


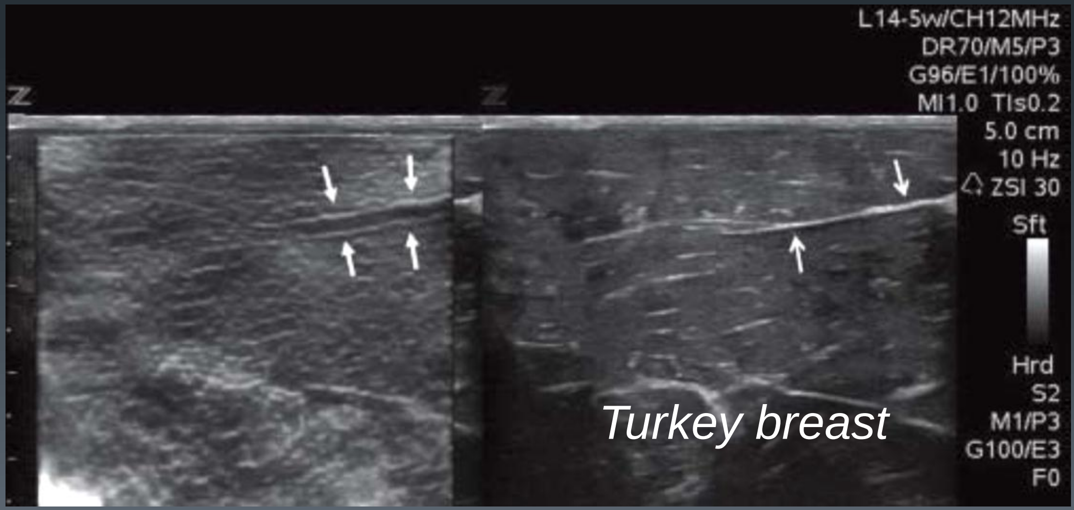
Strain Elastography Artefacts

Soft tissue strains more when it is next to a slippery boundary

Edge enhancement artefacts
(soft lines around boundaries)







Strain Elastography Artefacts

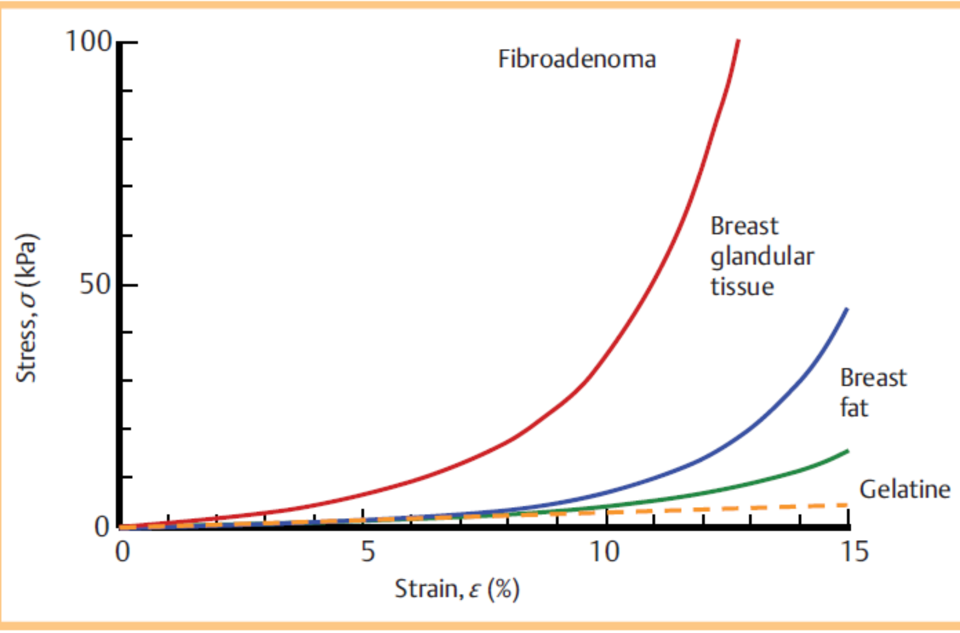
Strain increases with increasing force
because tissues are mechanically non linear

Tissue gets harder the more we press and the faster we press

Near constant rate of pressure
But not constant pressure

because poroelastic effects will cause the strain image to change with time

Young's modulus=slope of the curve
Higher strain –steeper slope

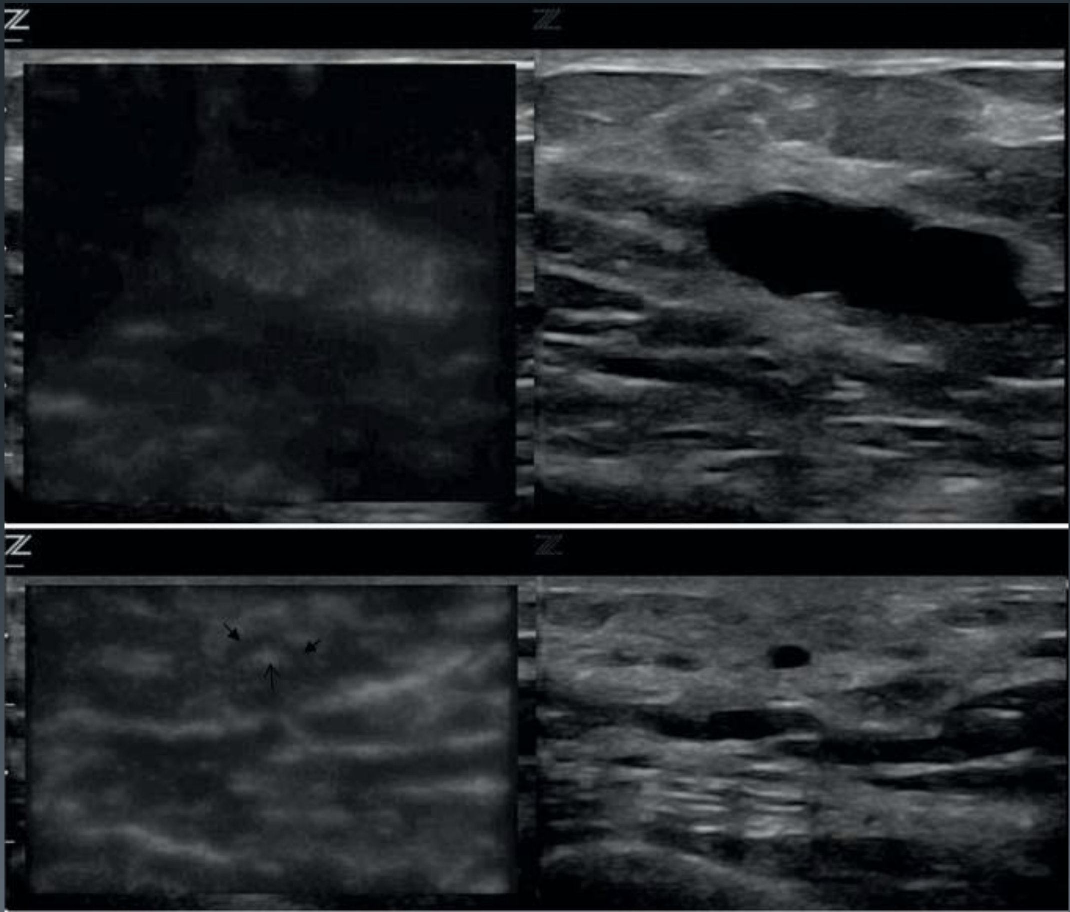


Strain Elastography Artefacts

Appearance of cysts varies depending on system settings and the size of the cyst

Small cyst: bulls eye

Big cyst: stop palpating, then switch to high rejection (gain), zero persistence
=
the cyst filled with strain noise, tissue has zero strain

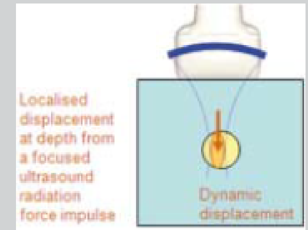


Strain Elastography

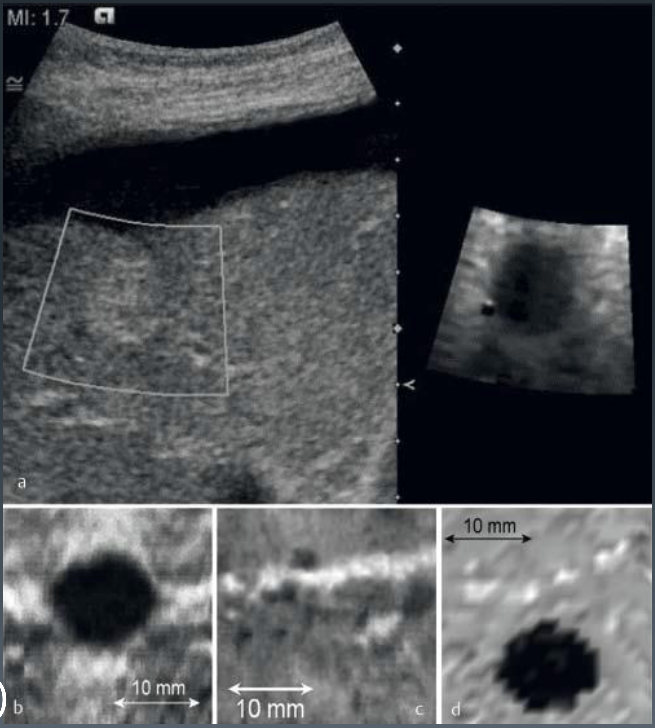
How to get good quality strain images:

- Close proximity to the transducer (< 3 –4cm)
- Near homogeneous tissue (e. g. liver)
- No anatomical planes that allow slipping
- Some distance to tissue boundaries
- No structures (e. g. large veins) that would damp the shear stress
- A broad stress source relative to the width of the imaged region
- A limited number of diagnostic targets

ARFI (qualitative image)

displa	acoustic radiation force impulse (ARFI) imaging		ultrasound induced – focused radiation force impulse at depth	displace-ment	qualitative	single image within a box	Siemens	

Axial displacement caused by a focused US pulse
Displacement is displayed directly as a qualitative map

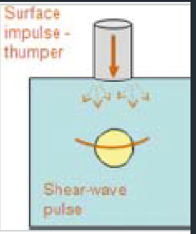


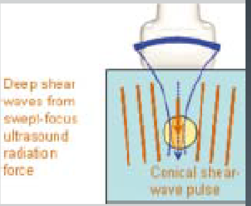
strain ARFI

Advantages
Less operator dependent, Better resolution,
Less concentration artefacts, Better SNR at depth,
Less influenced by slipping
Drawbacks
Contrast is easily influenced by the amount of reflection (calcium)
Transducer heating (high power to produce pushing beam)

Shear wave speed imaging & measurement

shear-wave speed MEASUREMENT	transient elasto-graphy (TE)[4]	dynamic	mechanically induced – impulse ("thump") at tissue surface	shear-wave speed[5]	quantitative	single meas-urement, beam-line average	Echosens
	point shear-wave elastography (pSWE), also known as ARFI quantification[4]		ultrasound induced – focused radiation force impulse at depth	shear-wave speed[5]	quantitative	single meas-urement, ROI average	Siemens Philips
shear-wave speed IMAGING	shear-wave elas-tography (SWE)[4]		ultrasound induced – radiation force impulses focused at various depths	shear-wave speed[5]	quantitative	single image within a colour box	Siemens
			ultrasound induced – radiation force focus swept over depth faster than shear-wave speed to create a Mach cone	shear-wave speed[5]	quantitative	image within a colour box, refreshed at up to several per second[3]	SuperSonic Imagine





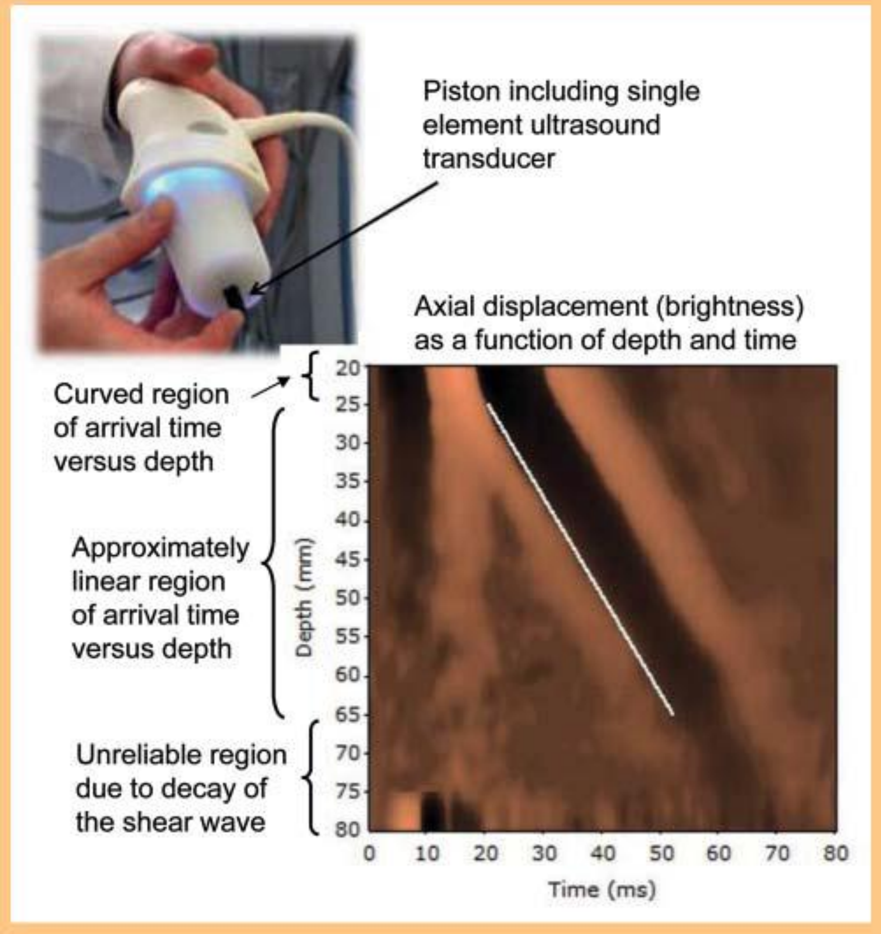
Shear wave speed imaging & measurement
Transient Elastography

Short automatic pulse
(created by transducer-a piston)

Shear wave speed is measured
as the slope and then converted to
a Young modulus (kPa)

Echosens system: liver elasticity

- No conventional US scanner
- Limited by ascites and obesity



Shear wave speed measurement at a location using ARFI *(point SWE)*

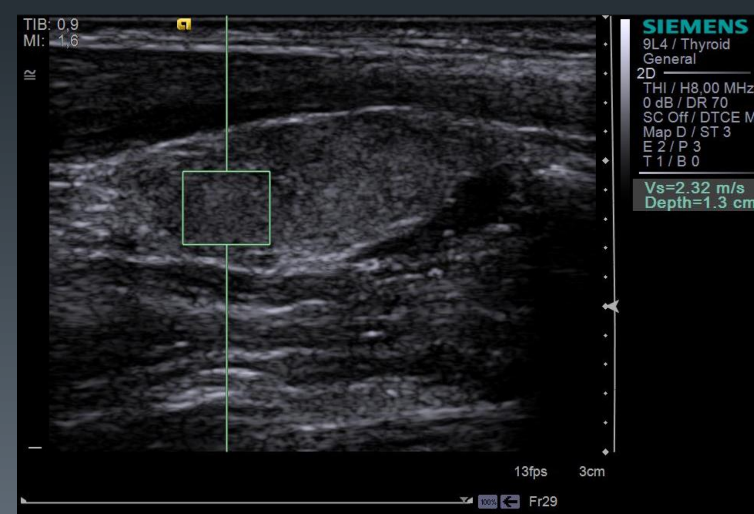
The displacement generated by ARFI creates a transient shear wave

Time of arrival of the shear wave at lateral positions of the ROI

Average SW speed in the ROI is calculated (m/sec) or converted to Young's modulus (kPa)

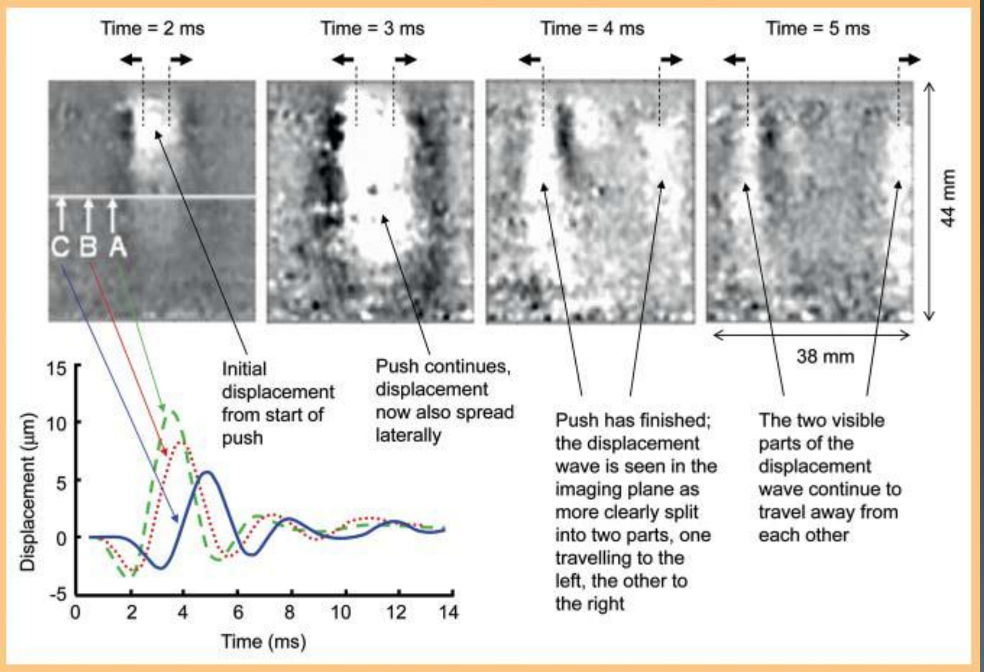
- No elasticity images are produced
- Depth up to 8 cm
- Possible in ascites, obesity
- Conventional US guidance

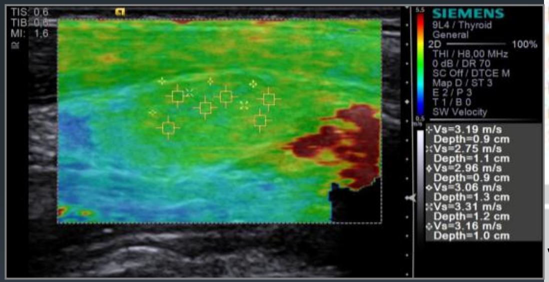
ARFI quantification (Siemens), Philips



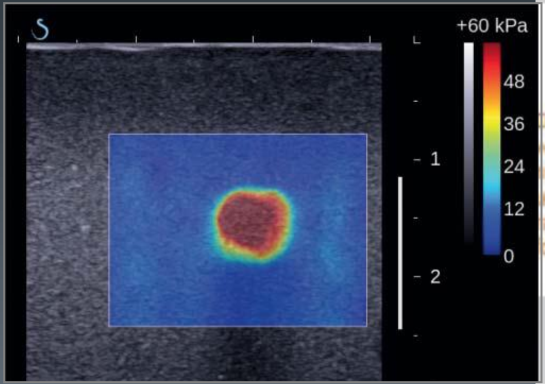
Shear wave speed imaging & measurement
Shear wave Elastography

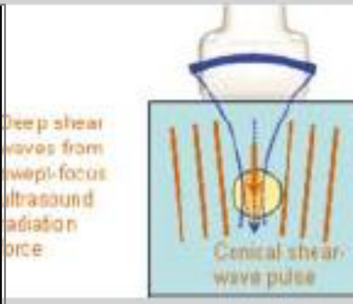
Acoustic radiation force focus is swept down the acoustic axis
Generates displacement at all positions along the axis
Shear wave in a shape of a cone that travels away





Siemens S3000





Supersonic

Shear wave speed imaging & measurement
Shear wave Elastography

- Quantitative: speed (m/sec) or Young modulus (kPa)
- No stress concentration artifacts
- Good penetration *(breast 3,5cm, liver 8cm)*
- Potentially measure the viscous component

limitations

- Minimize probe pressure (intercostal imaging of liver, no pressure at skin)
- At interfaces or tissue layers there are other types of waves *(Rayleigh, Lamb, Love waves),* artefacts but correction methods are under development
- Spatial resolution a little worse than strain and ARFI displacement imaging

Elastography types

- **Strain imaging** *(qualitative maps only)*
  Strain Elastography, ARFI imaging

- **Shear wave speed measurement** *(measurement only, no image)*
  Transient elastography, point ARFI

- **Shear wave speed imaging** *(measurements and image together)*
  Siemens S3000 (single image),
  Supersonic Imagine (images refreshed up to several per second)

Elastography safety issues

Strain and shear wave:
identical safety issues as conventional US

ARFI:
higher TI but within AIUM limits,
safety issues similar to Doppler (eye, fetus etc)

Conclusion

- Knowledge of physics and technology
- Technology is expected to further develop
- Improvements are expected in:

  image quality
  ease of use
  quantification methods
  tissue characteristics measurable *(viscous component)*

EFSUMB Guidelines on Elastography: Part I

EUROSON SCHOOL 2014, Athens
www.drakonaki.gr

Fabio Piscaglia, EFSUMB President, Christoph F Dietrich, EFSUMB President Elect and David Cosgrove First Author of Elastography Guidelines.

Authors and industry at the Elastography meeting in Bologna September 2012.

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