Breast Elastography

2016 Annual Symposium

Michigan Sonography Society

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What is Elastography?

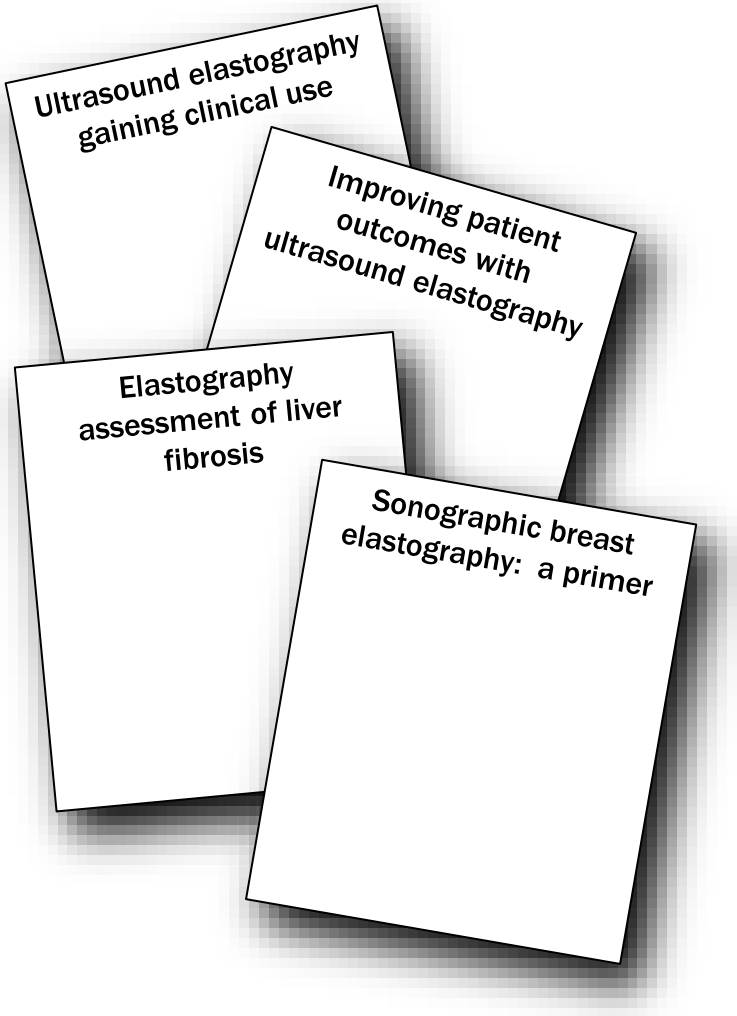
- Palpation has been used as a diagnostic tool for thousands of years
- Many pathologies result in increased tissue stiffness (e.g. cancer, fibrosis, cirrhosis, etc.)
- Elastography is a non-invasive form of tissue characterization with the goal of mapping tissue stiffness

Barr Study

- Breast lesions were measured for the largest length on both standard ultrasound imaging and elasticity imaging
- Biopsy showed that elasticity imaging correctly identified all 17 malignancies and 105 of 106 benign lesions
- Sensitivity of 100% and Specificity of 99%

"Elasticity Imaging Identifies Cancers and Reduces Breast Biopsies"
by Richard Barr, MD, PhD, Youngstown, Ohio, RSNA Press Release, November 2006.

Elastography Pioneer



Dr Richard Barr
Youngstown, OH

2 Main Types

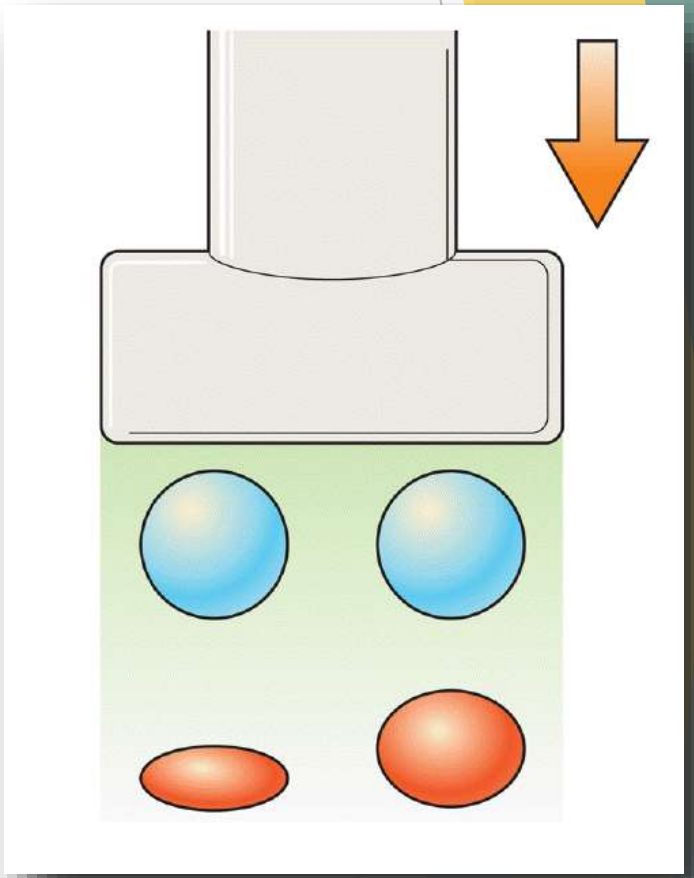
Strain Elastography

and

Shear Wave Elastography (SWE)

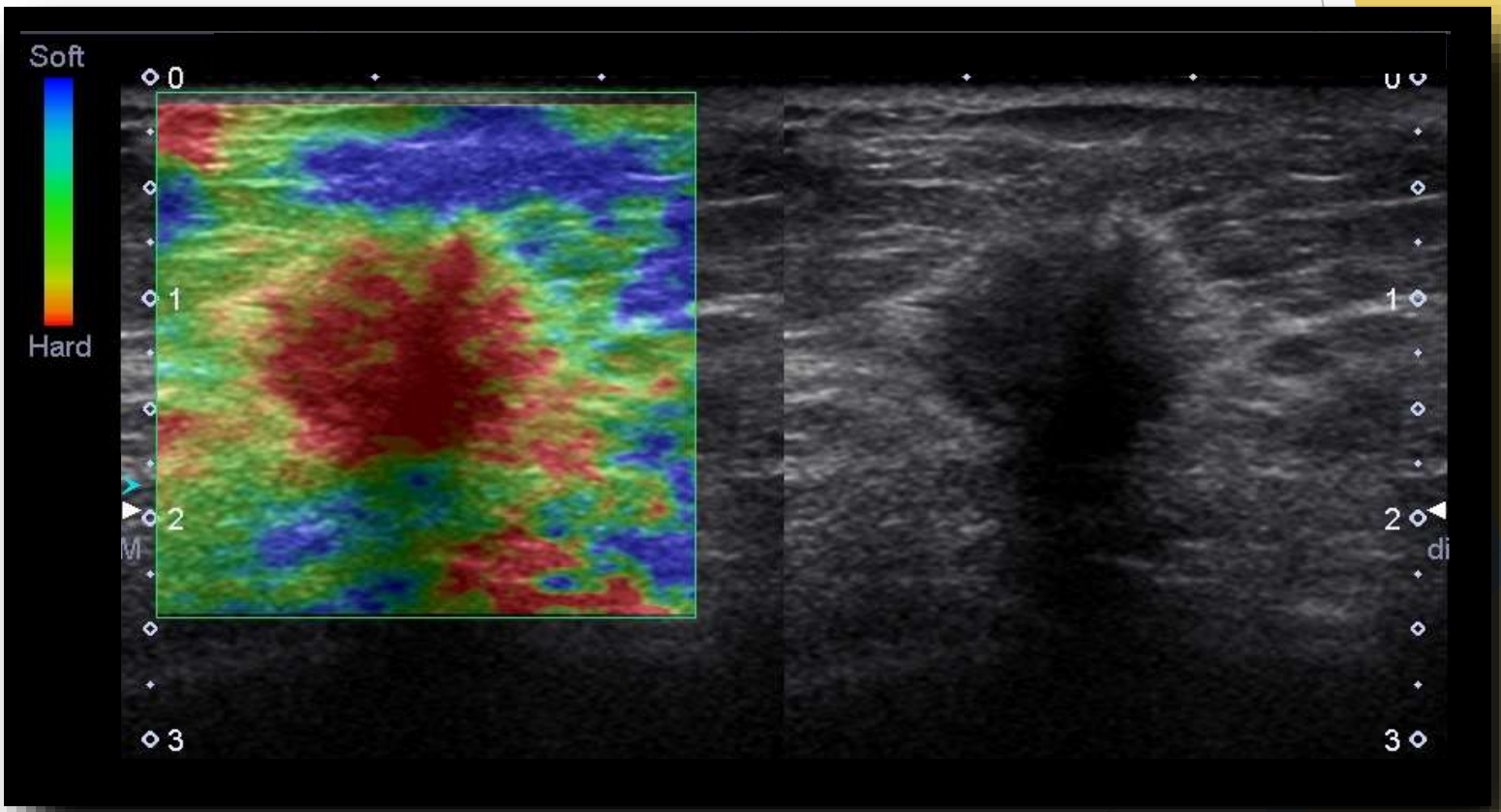
Strain Elastography

- Uses mechanical compression to cause deformation of tissues
- Uses a color map displaying a Qualitative comparison of tissue stiffness
- Highly useful in breast imaging

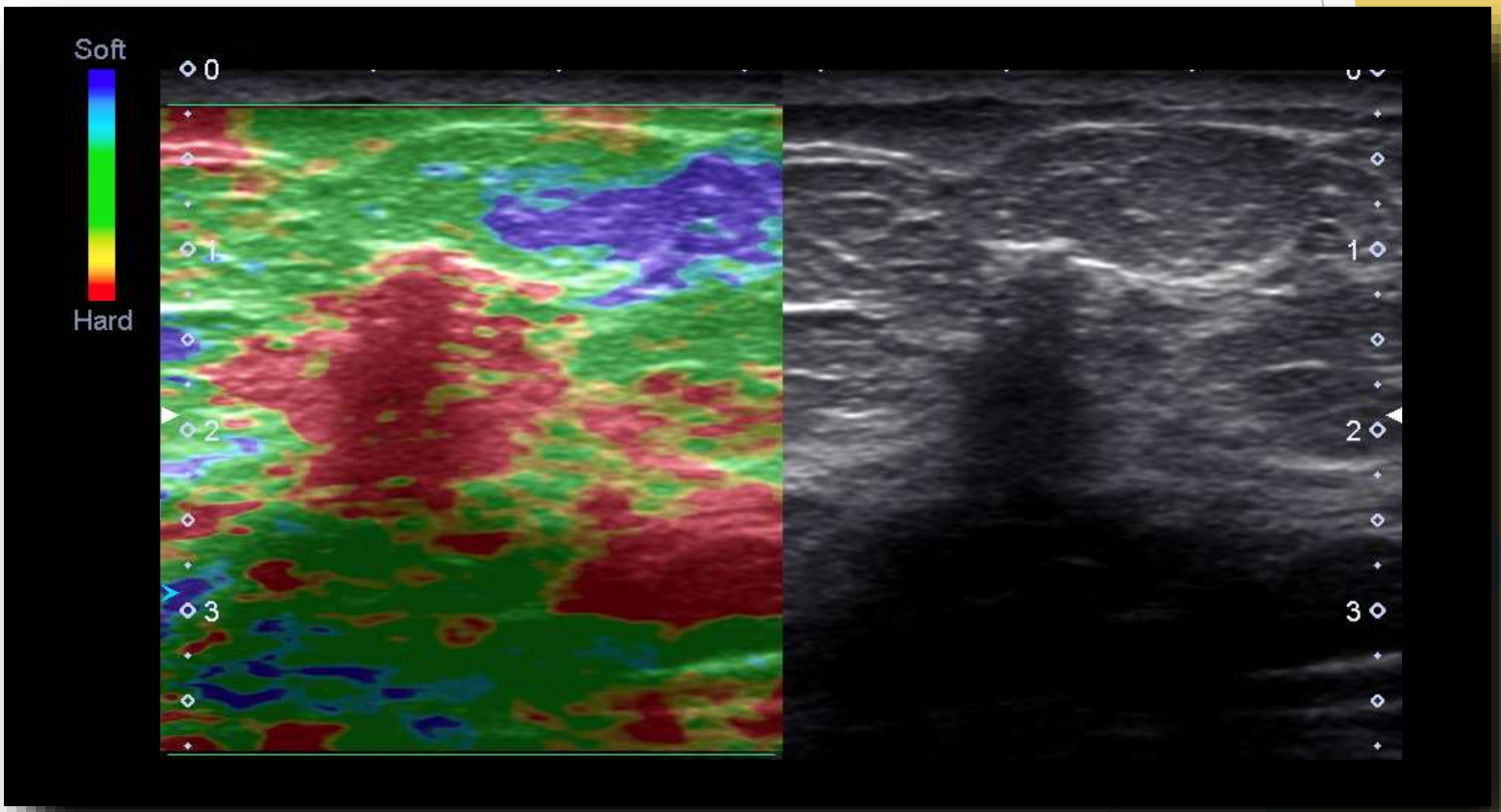


First Generation Strain Elastography

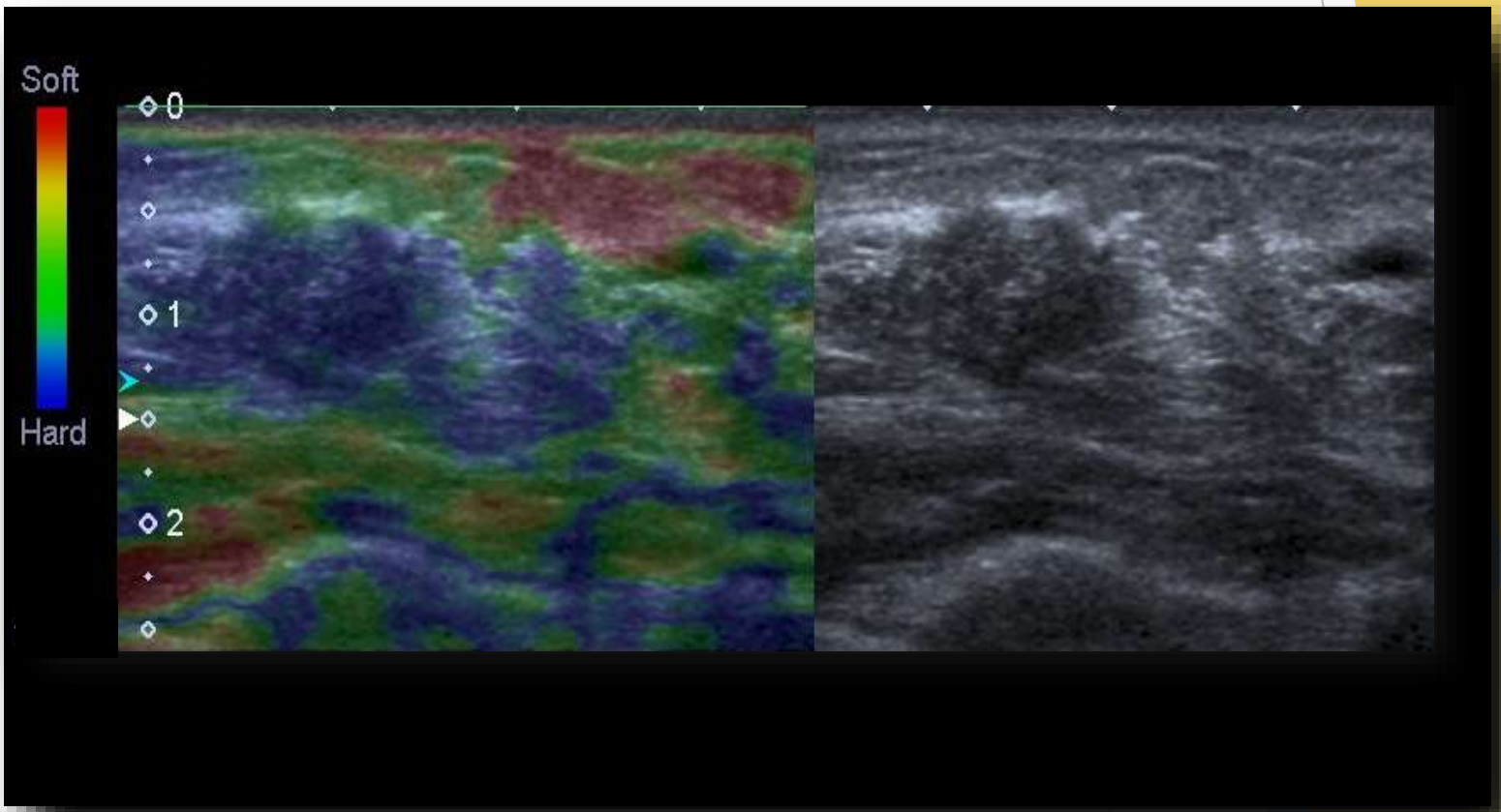
Strain Elastography – Breast Cancer



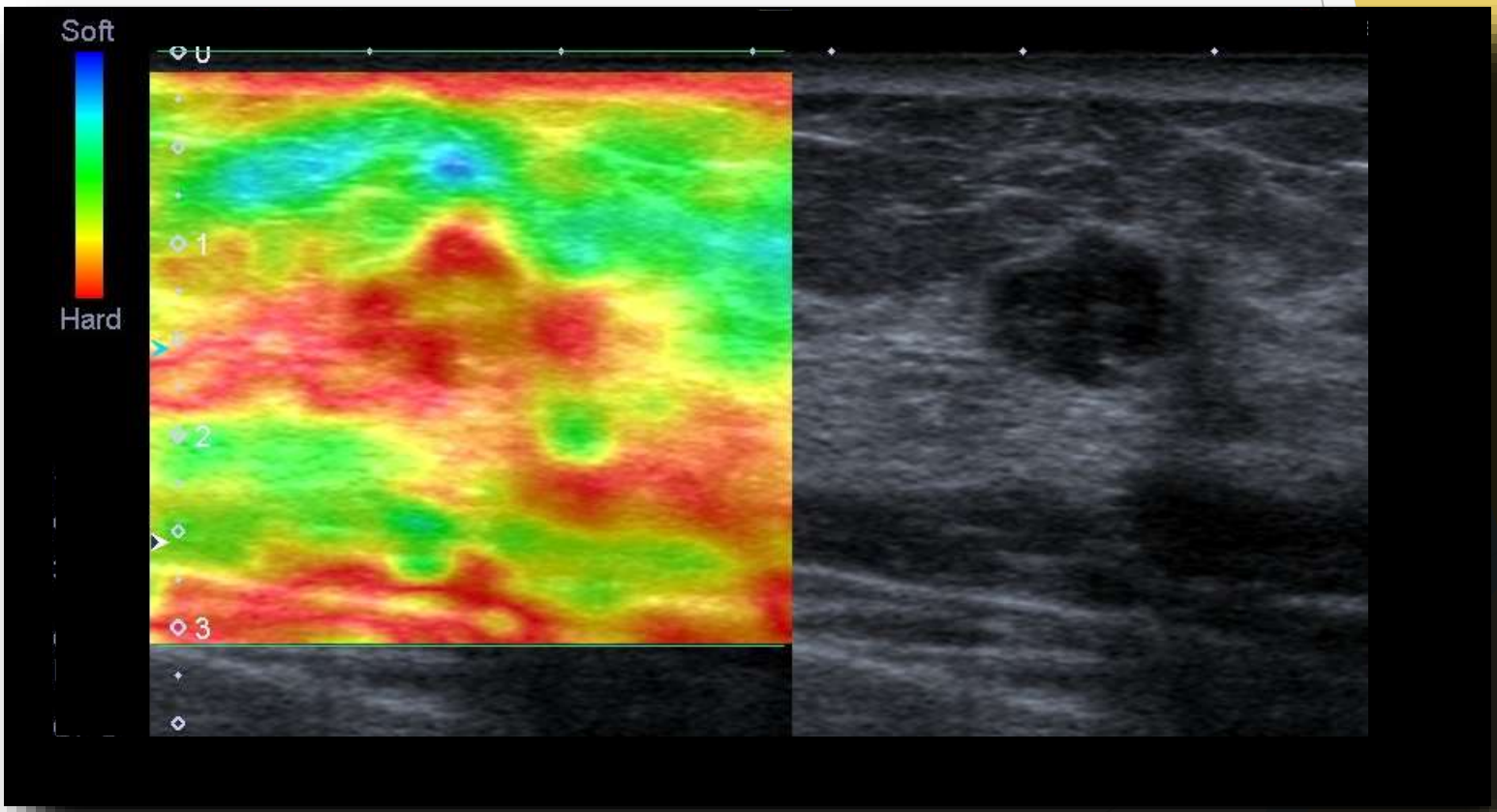
Strain Elastography – Breast Cancer



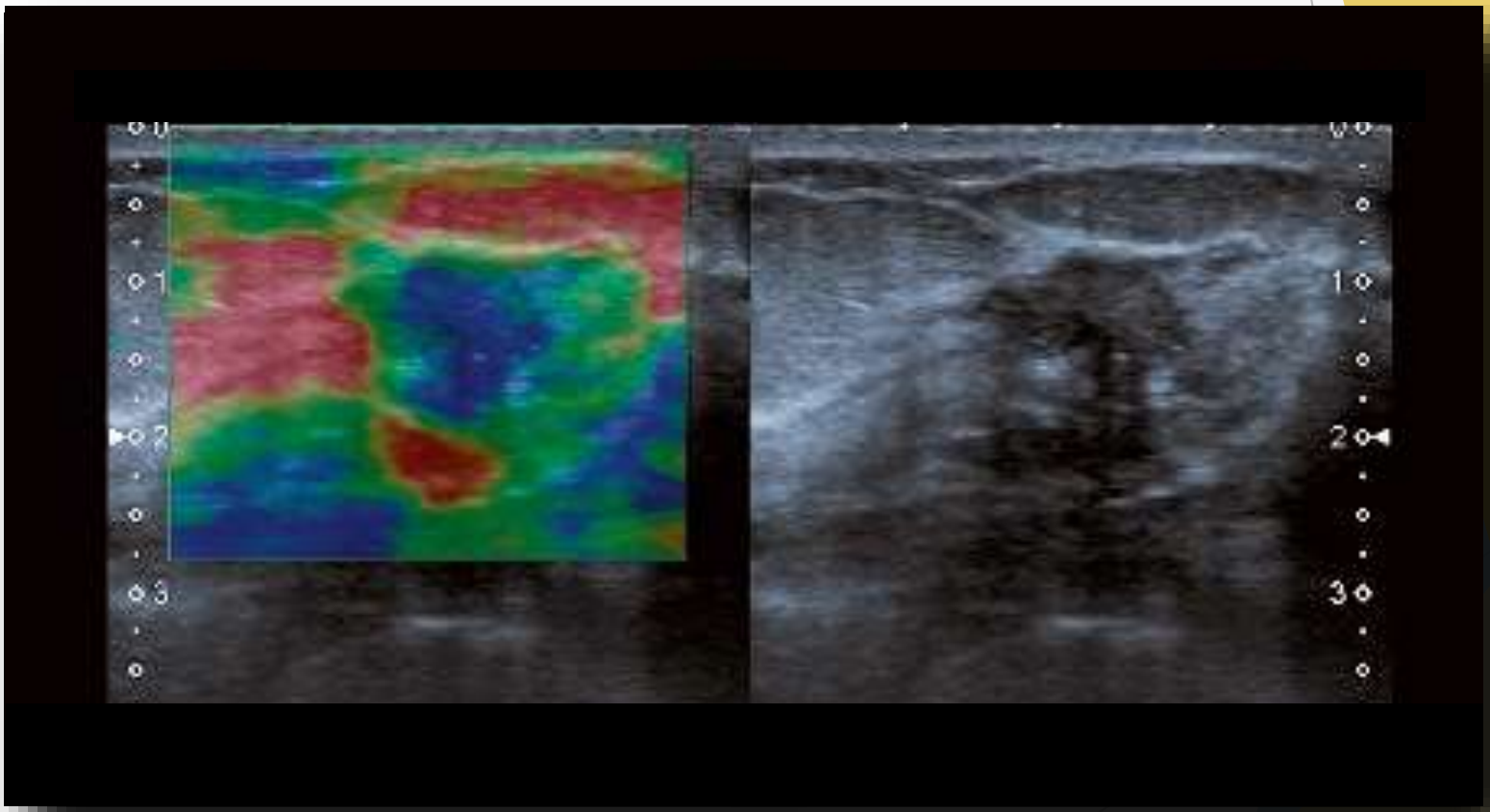
Strain Elastography – Breast Cancer



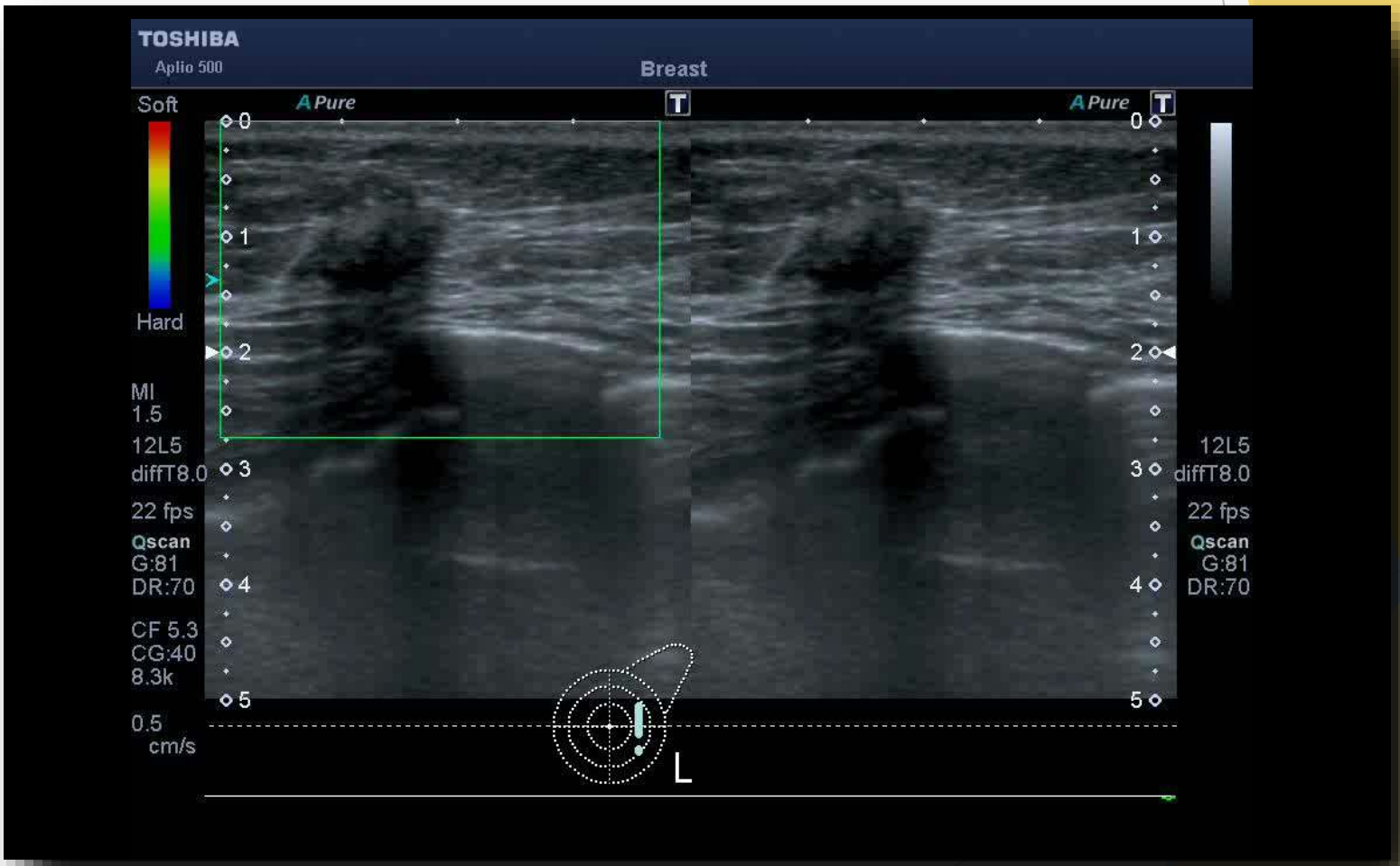
Strain Elastography – Breast Cancer



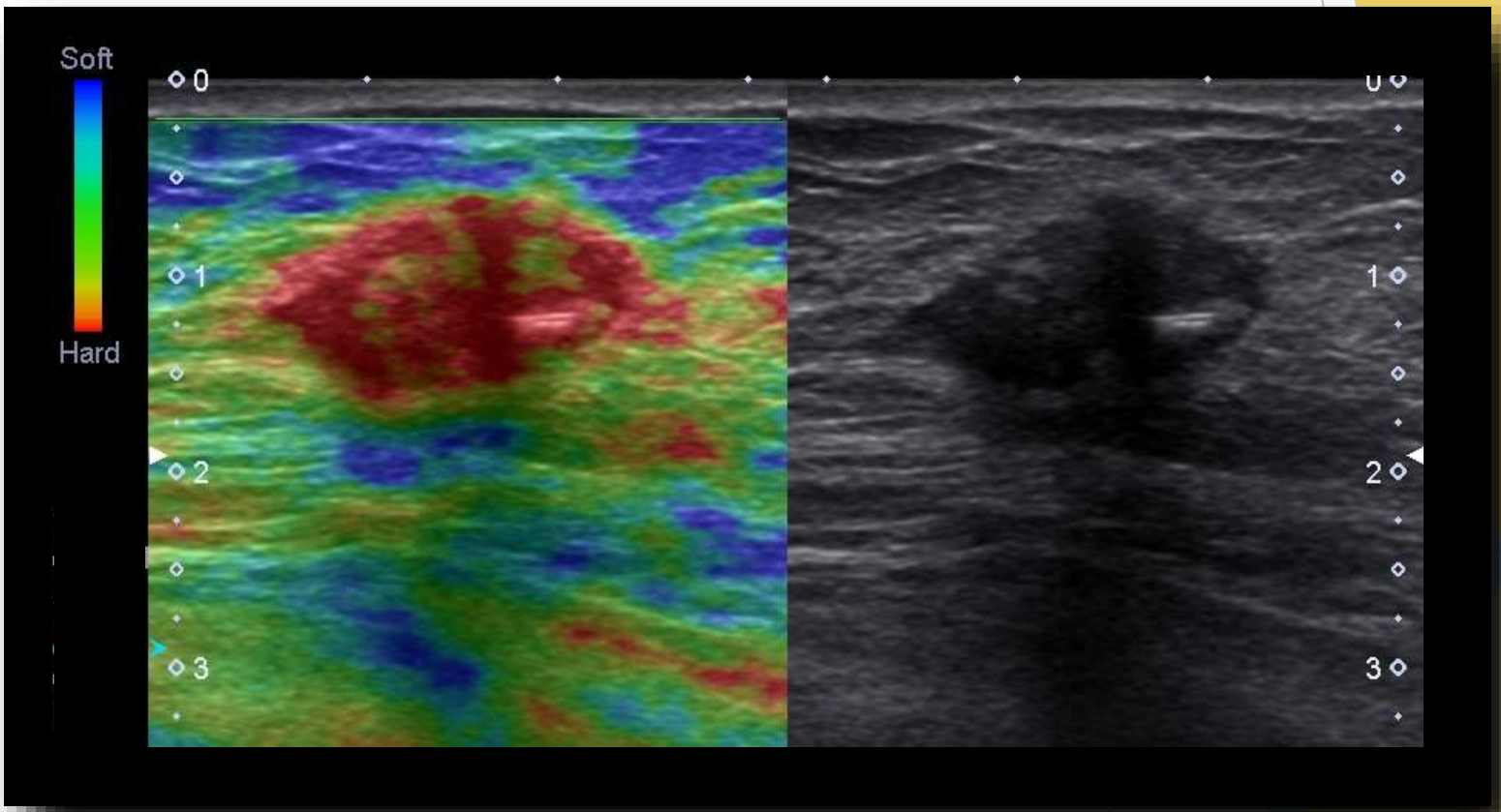
Strain Elastography – Breast Cancer



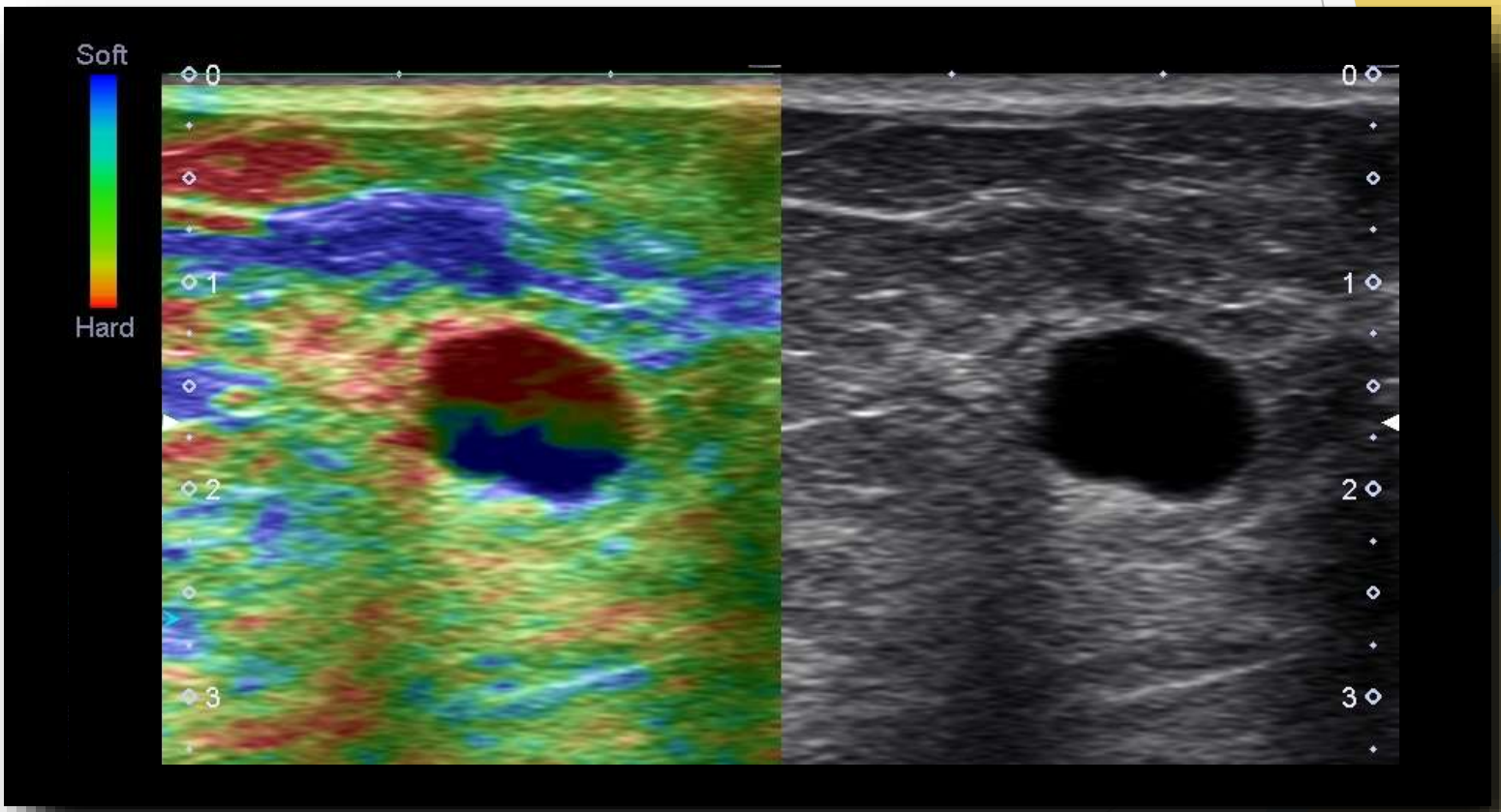
Strain Elastography – Breast Cancer



Strain Elastography – Breast Cancer



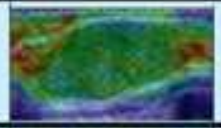
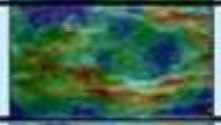
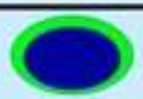
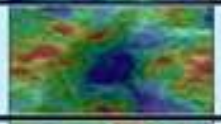
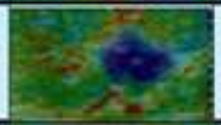
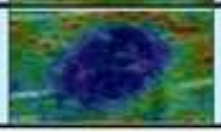
Strain Elastography – Breast Cyst



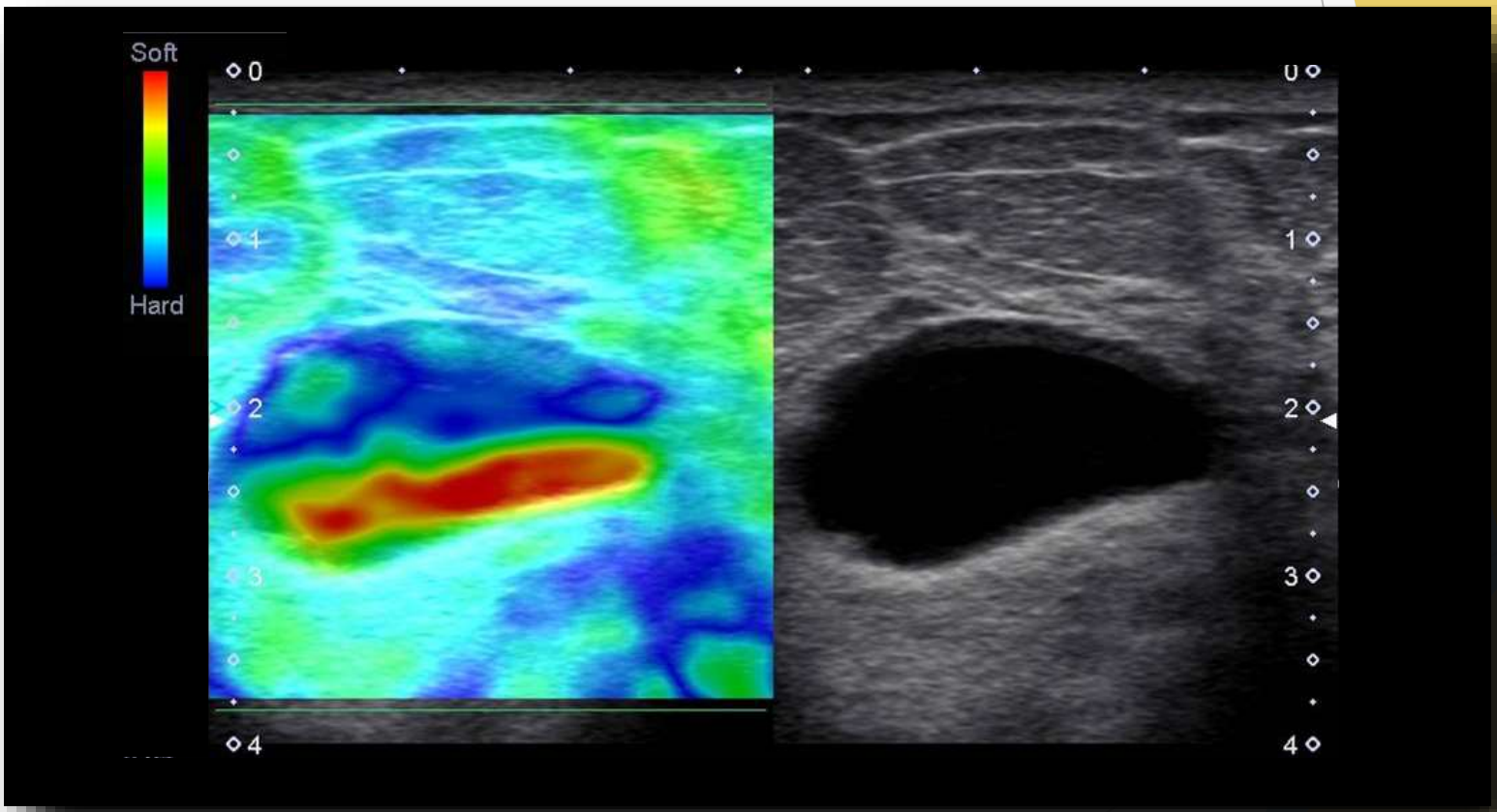
Strain Elastography – Breast

Tsukuba Elasticity Score Patterns

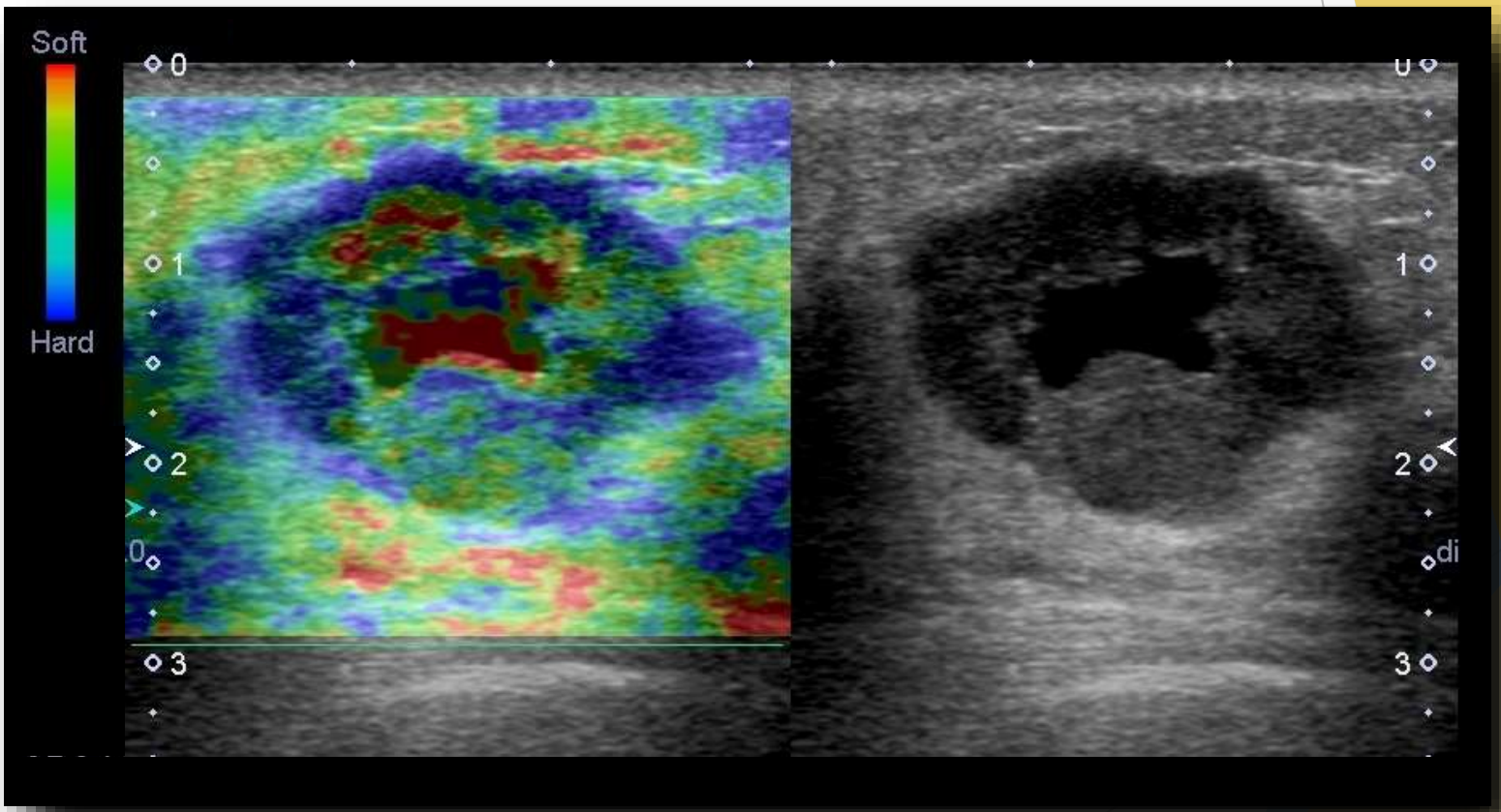
Itoh A, Ueno E, Tohno E etal. Breast Disease: Clinical Application of US Elastography for Diagnosis. *Radiology 2006; 239:341 - 350*

Score	Classification Standard		Typical Image
1	Strain is seen in the entire hypoechoic area (the entire lesion is shown in green similar to the surrounding tissue)		
1*	BGR (blue-green-red) 3 layer pattern – typical artefact seen in a cystic lesion		
2	Strain is seen within most of the hypoechoic area but some areas show no strain (the lesion is a mixture of green and blue)		
3	Strain appears only in the periphery with no strain in the centre of the lesion (the centre of the lesion is shown as blue with the periphery in green)		
4	No strain is measured within the lesion (the entire lesion is shown in blue)		
5	No strain is measured within the lesion nor in the surrounding tissues (the lesion and the surrounding tissues are blue)		

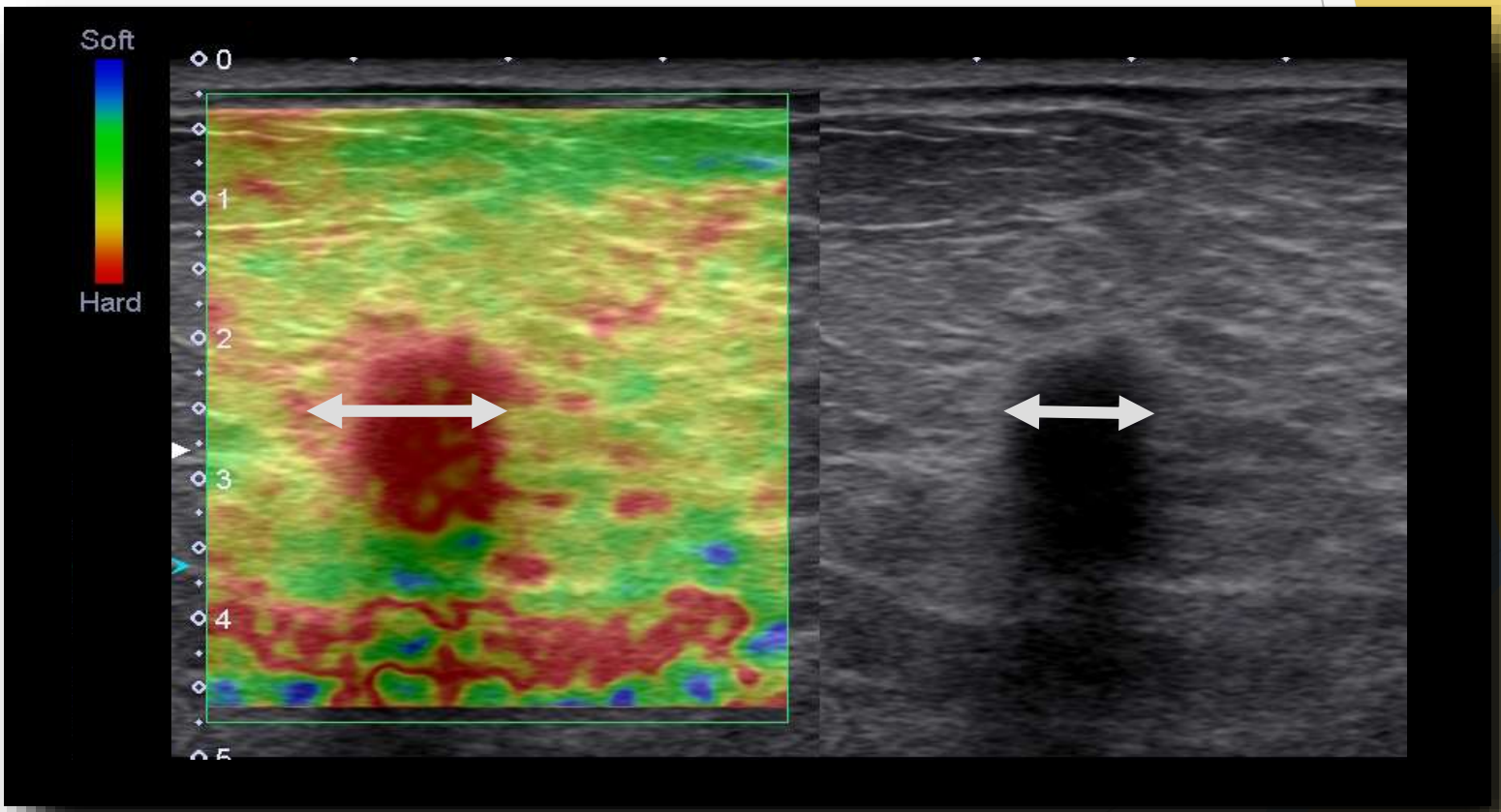
Strain Elastography – Breast Cyst



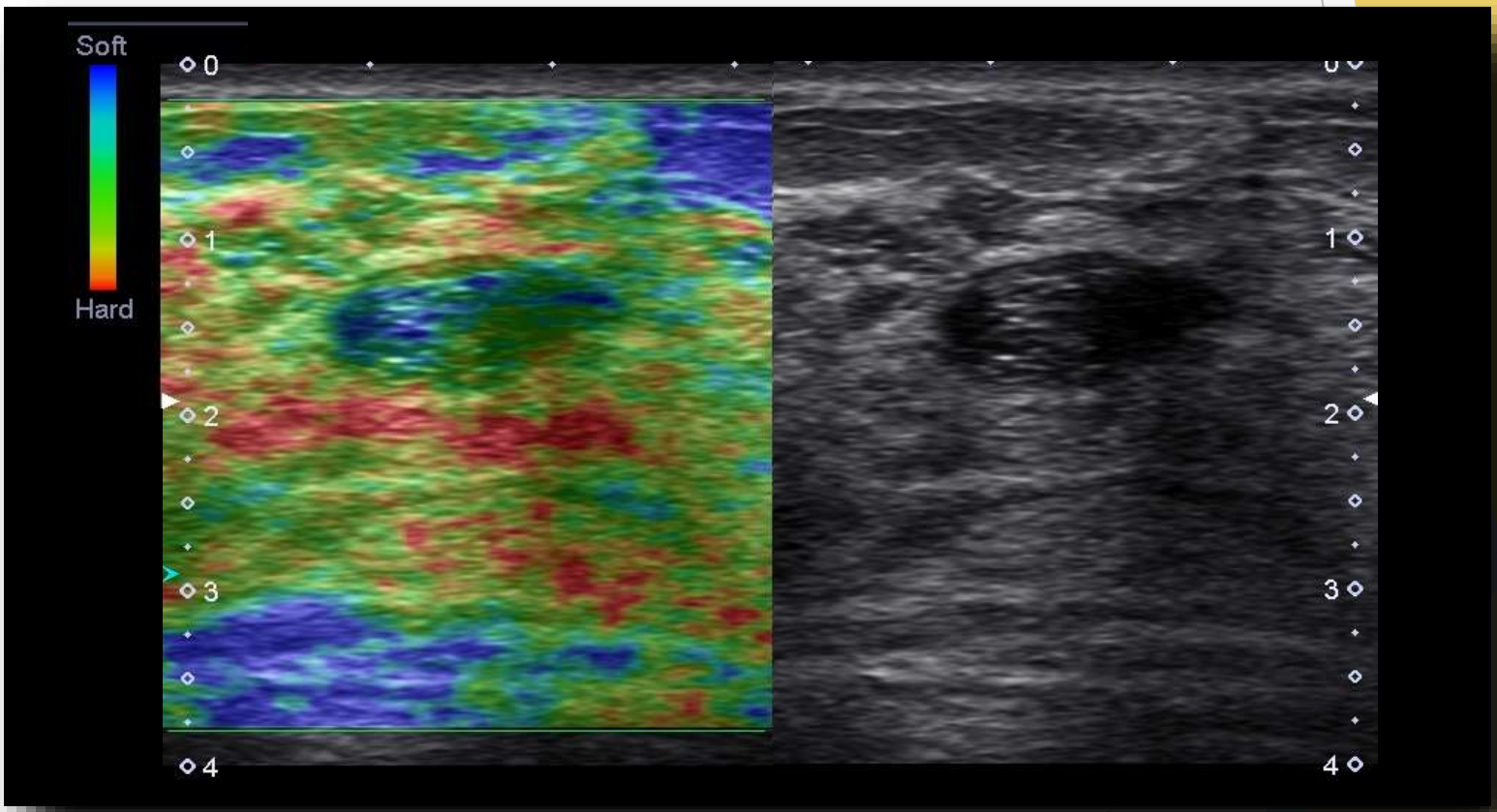
Strain Elastography – Breast Cancer



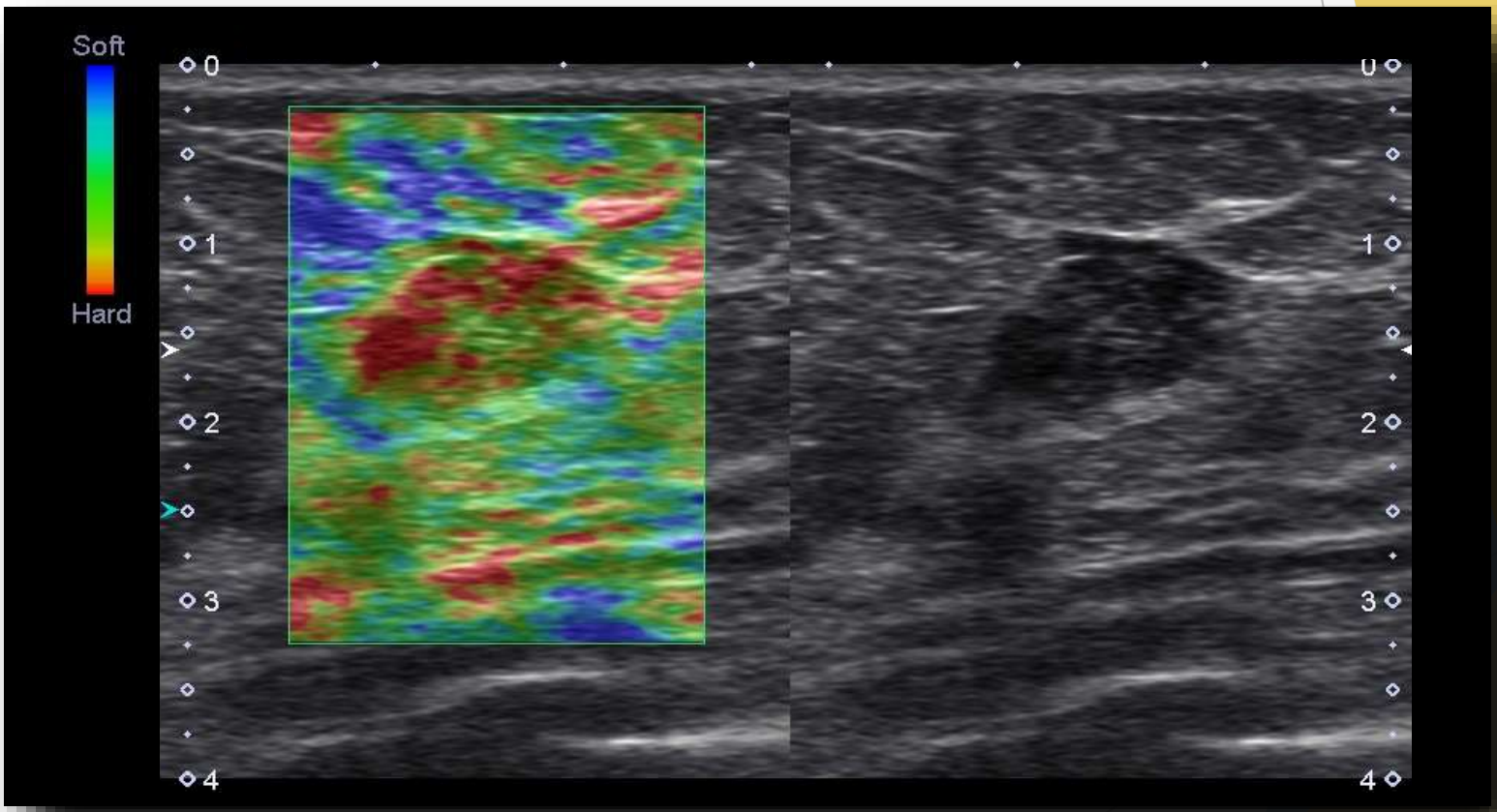
Strain Elastography – E/B Ratio > 1



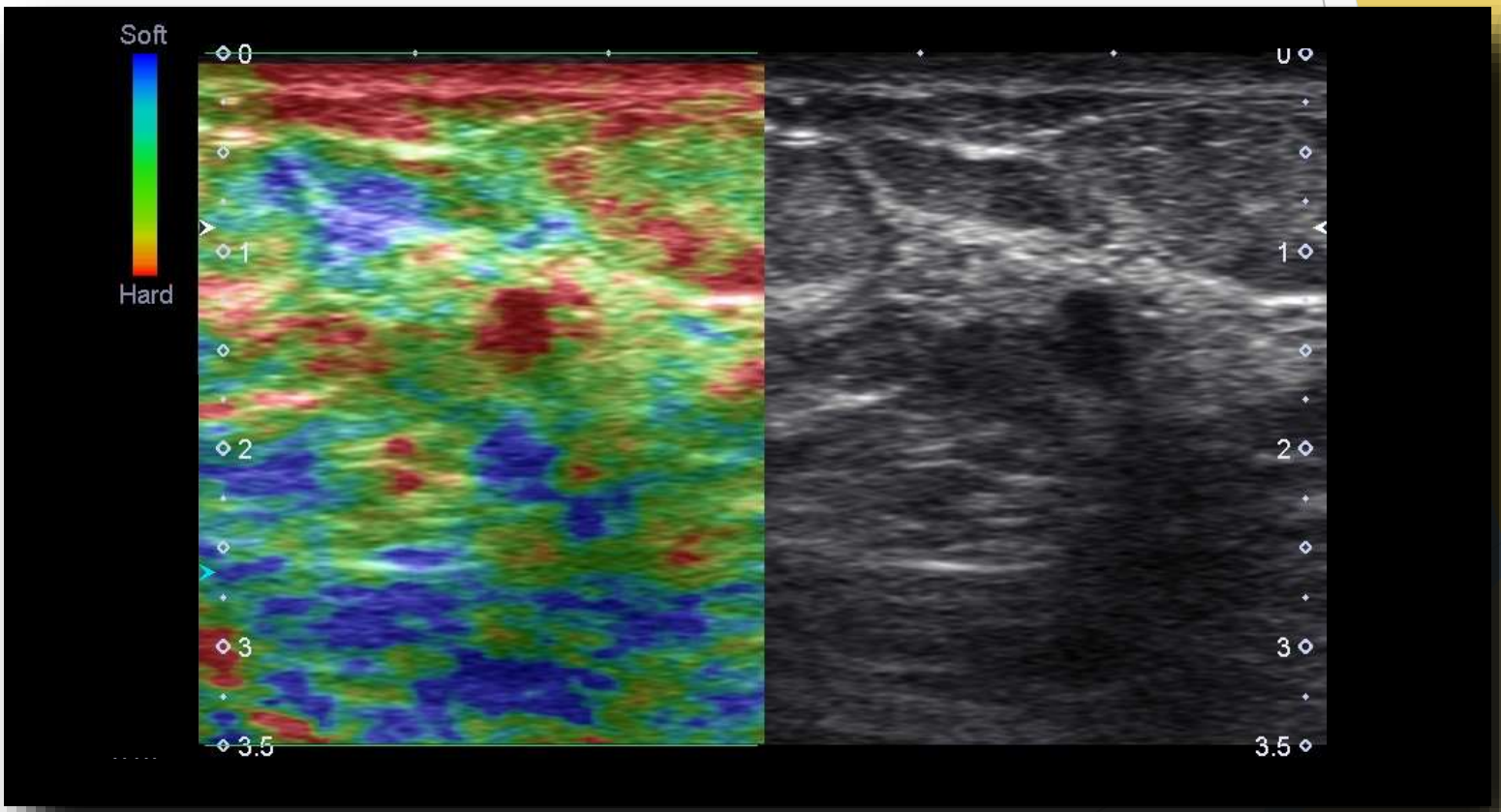
Case #1



Case #2



Case #3



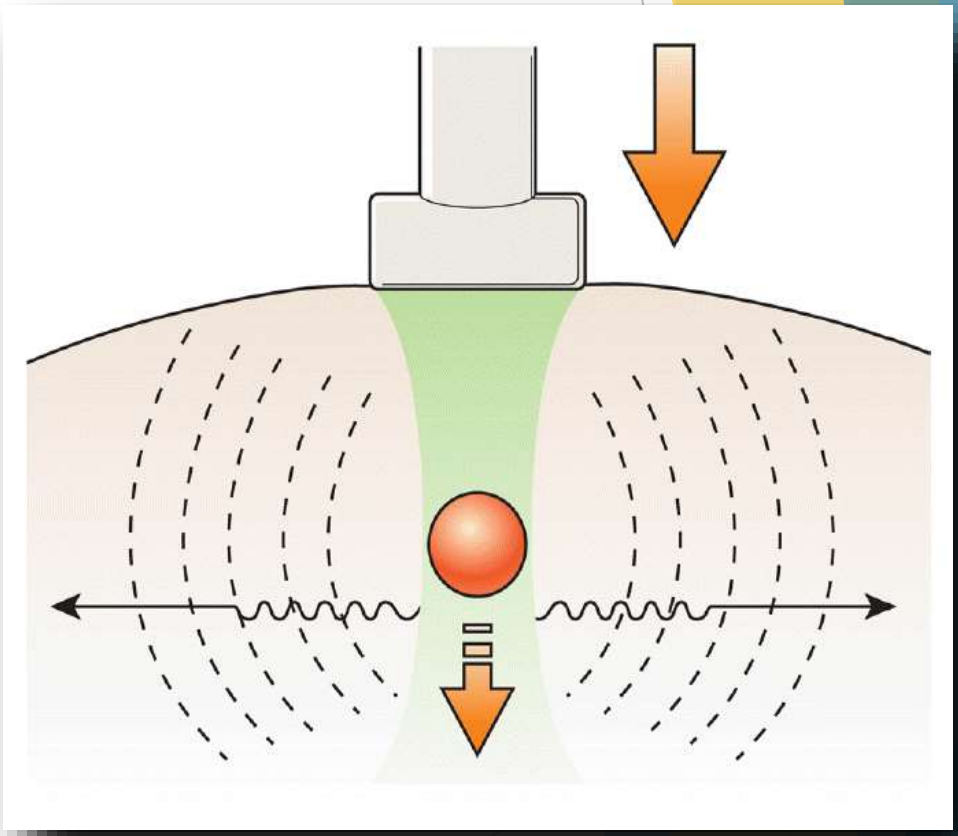
Strain Elastography

- **Advantages**
  - Simple to use
  - Cost effective
  - Useful for focal disease in the breast
- **Disadvantages**
  - Qualitative results, not Quantitative
  - Requires a reference region for comparison
  - Not useful in diffuse disease

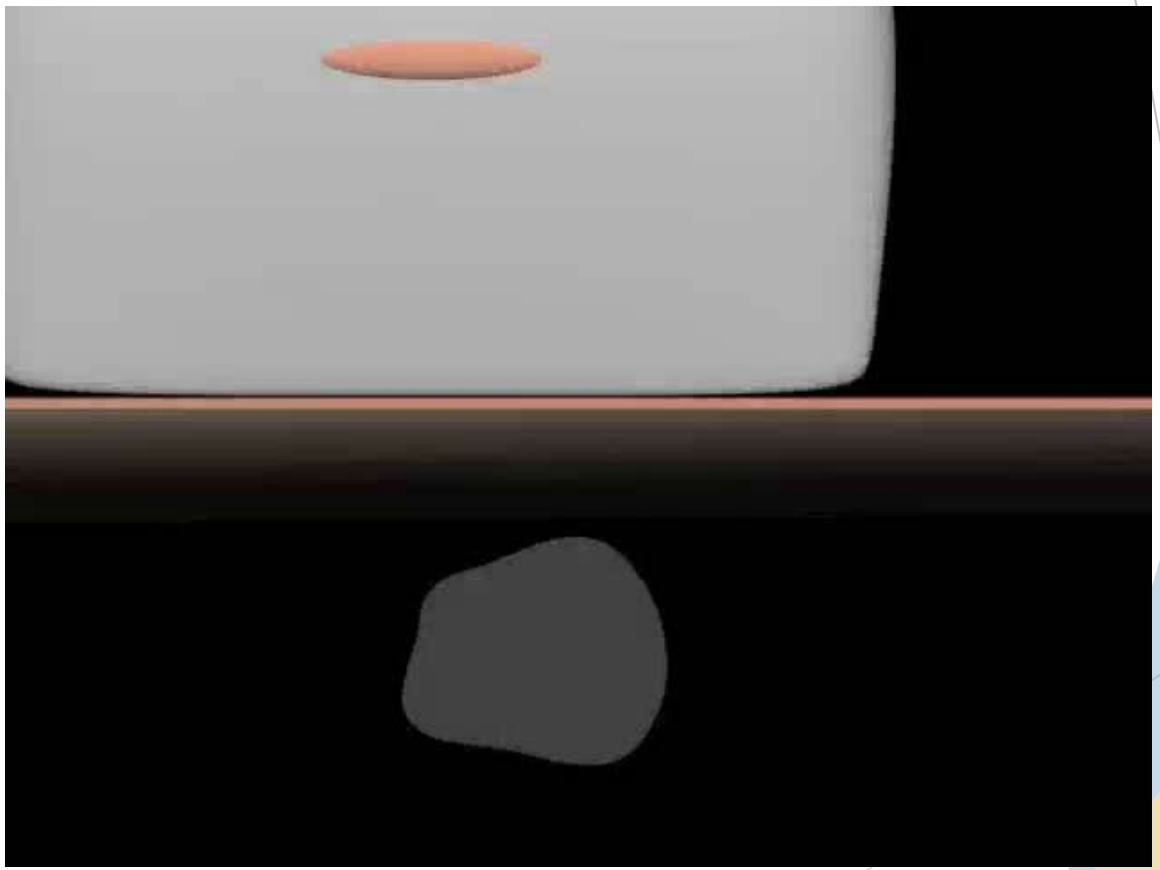
Shear Wave Elastography

- Uses a push-pulse or force that causes shear waves to propagate perpendicularly
- Can measure elasticity or stiffness of tissue using Young's Modulus

$$E \approx 3\rho v^2$$

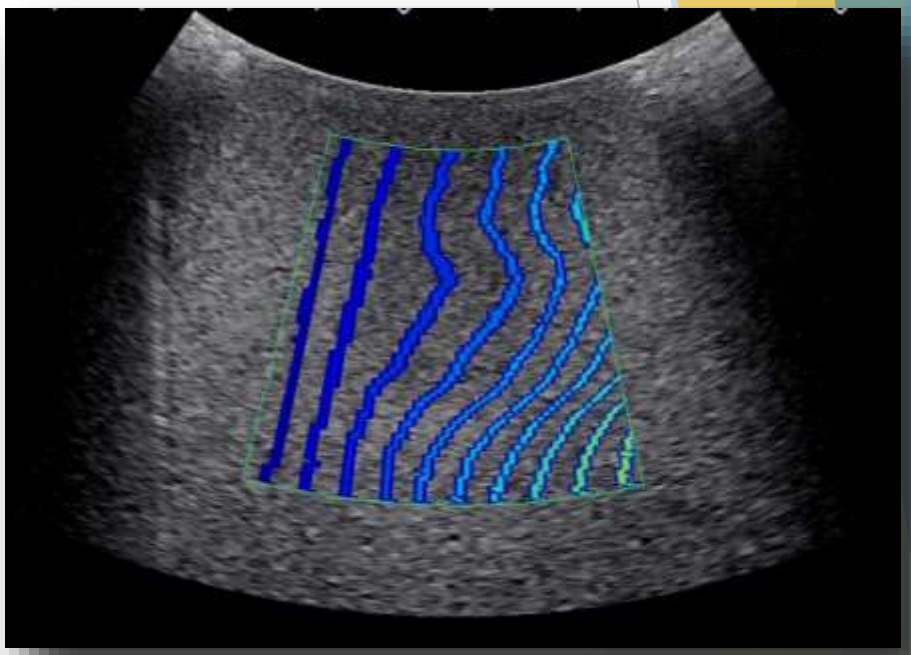


Shear Wave Elastography



Shear Wave Elastography (SWE)

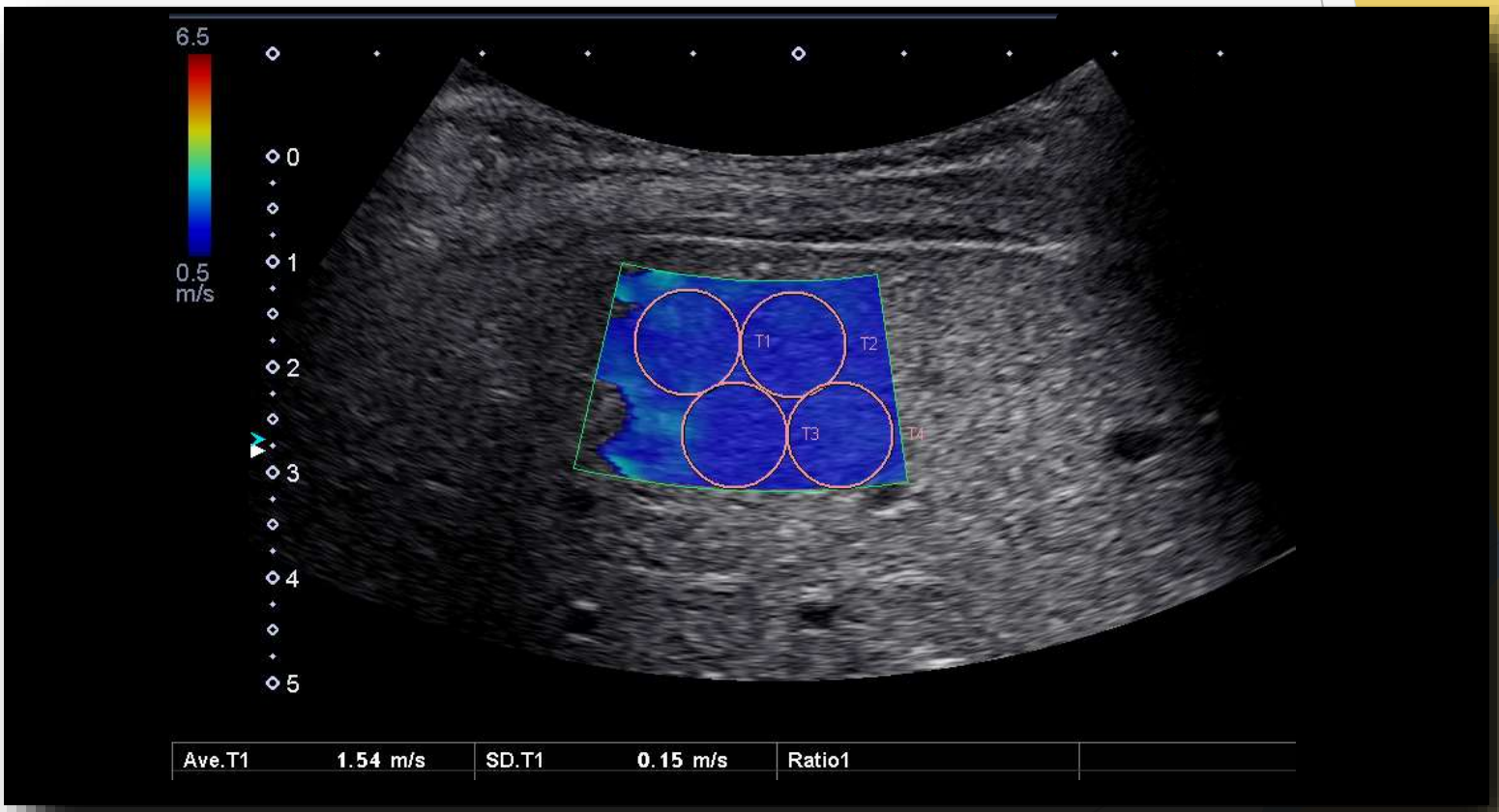
- Shear waves travel much slower than longitudinal waves
- Speed is 1 to 10 m/s
- Can measure absolute stiffness
- Can identify stiffness of focal lesions or diffuse disease



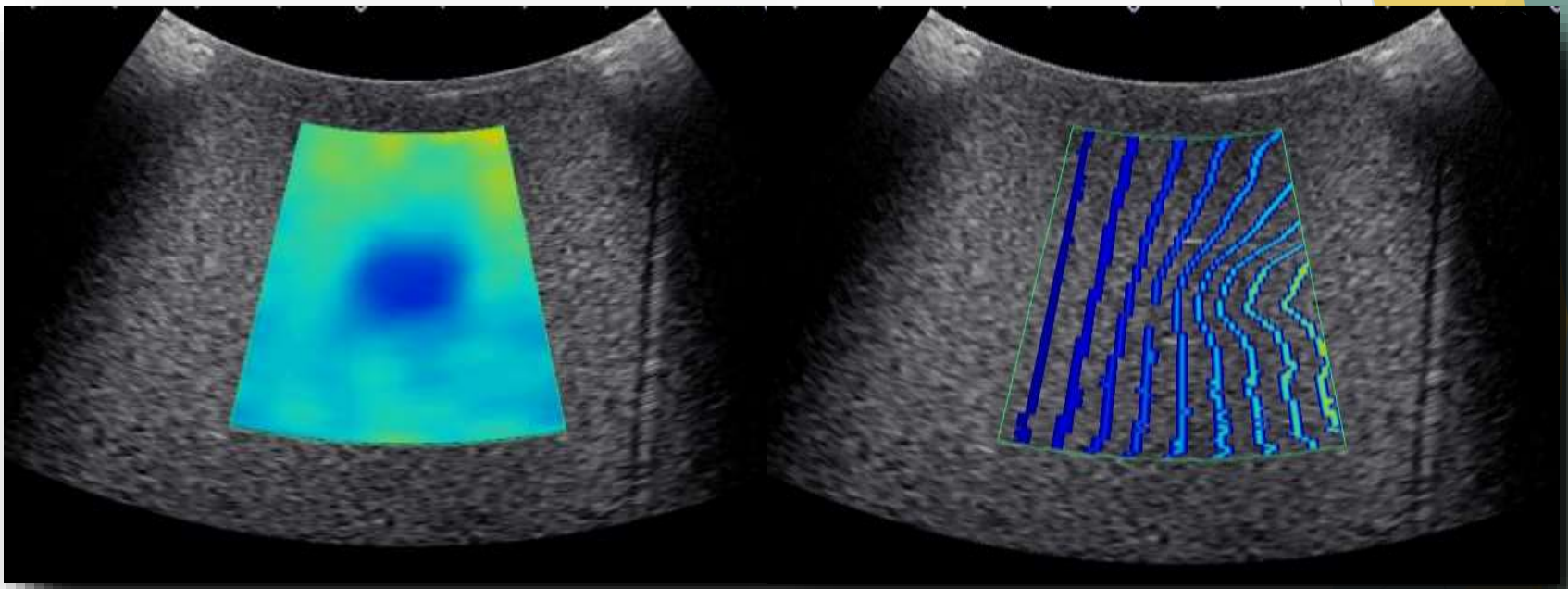
SWE for Liver Fibrosis

- Hepatitis C is the leading indication for liver transplantation with over 150 million people affected worldwide
- Liver biopsy is considered gold standard for fibrosis assessment in patients with diffuse liver disease
- Shear Wave Elastography offers a non-invasive alternative
  - *Quantitative stiffness value
  - Lower cost
  - Evaluate liver disease progression
  - Screen and monitor antiviral treatment

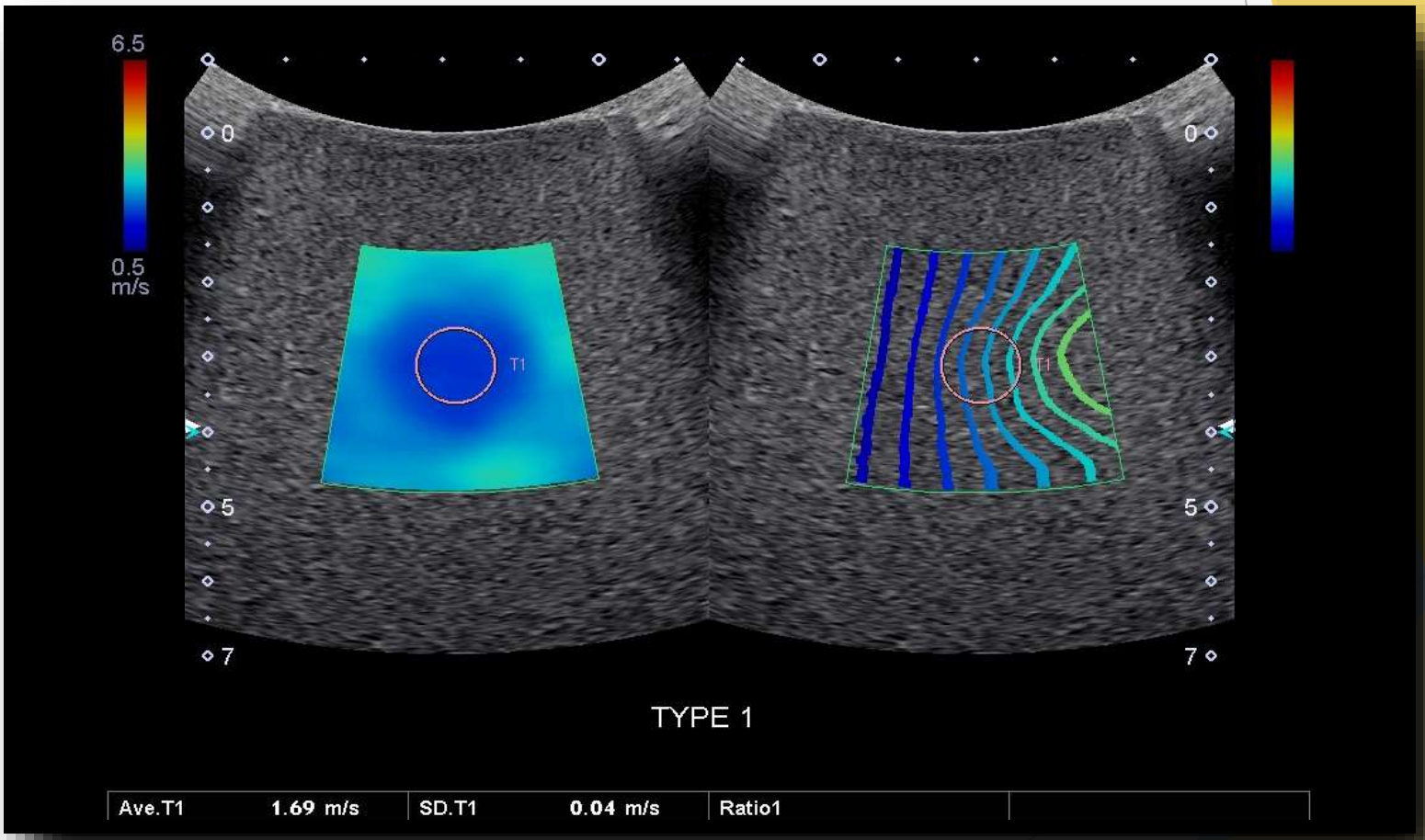
Shear Wave Normal Liver



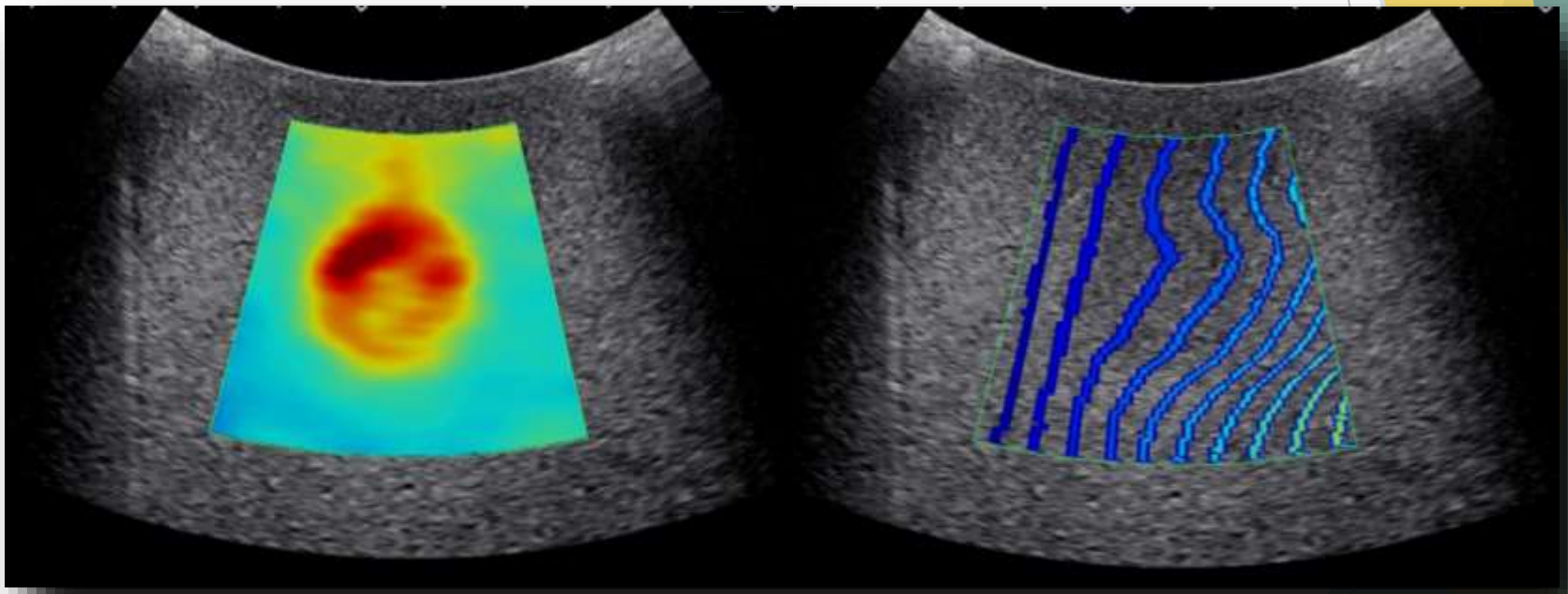
SWE – Soft Lesion



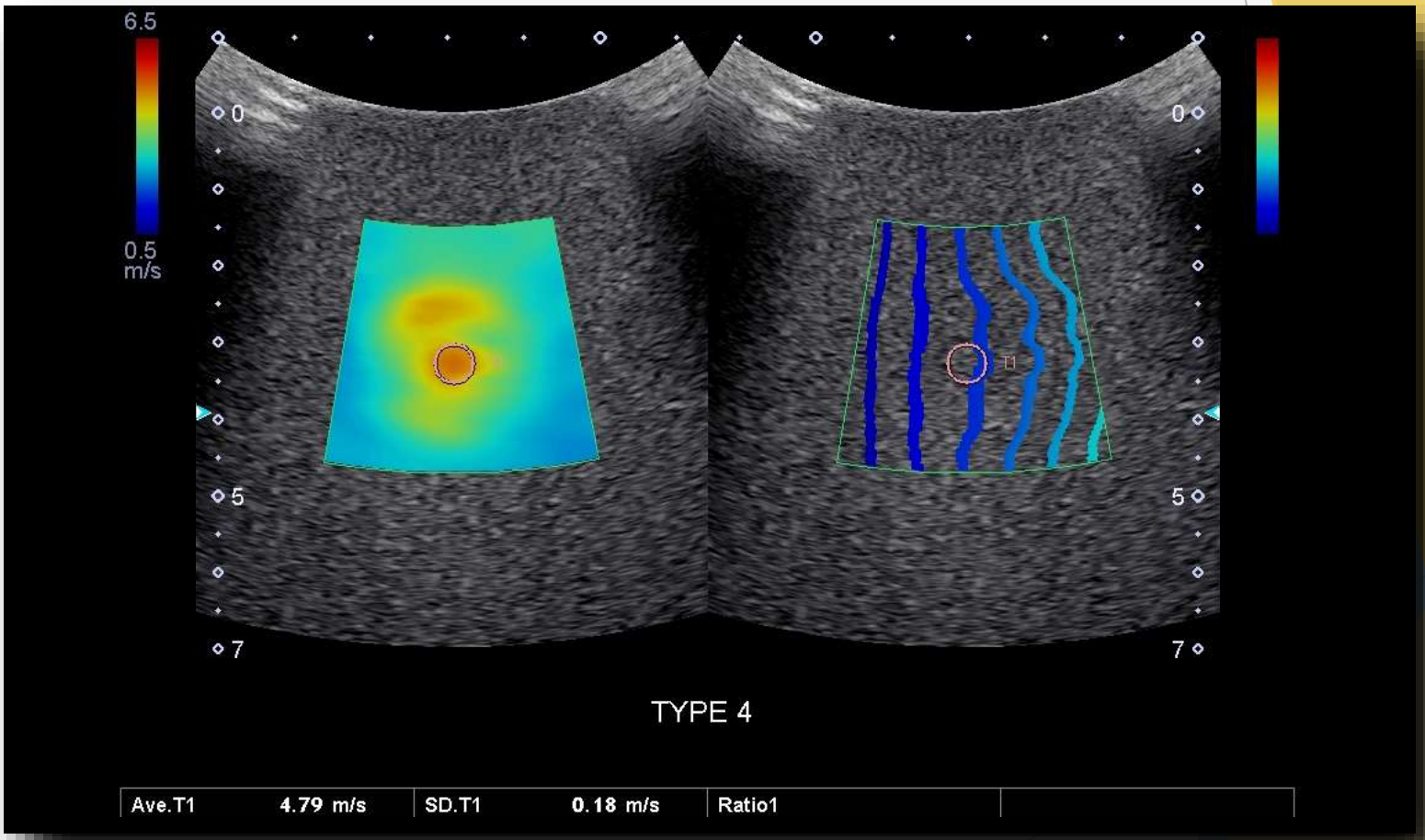
SWE – Soft Lesion



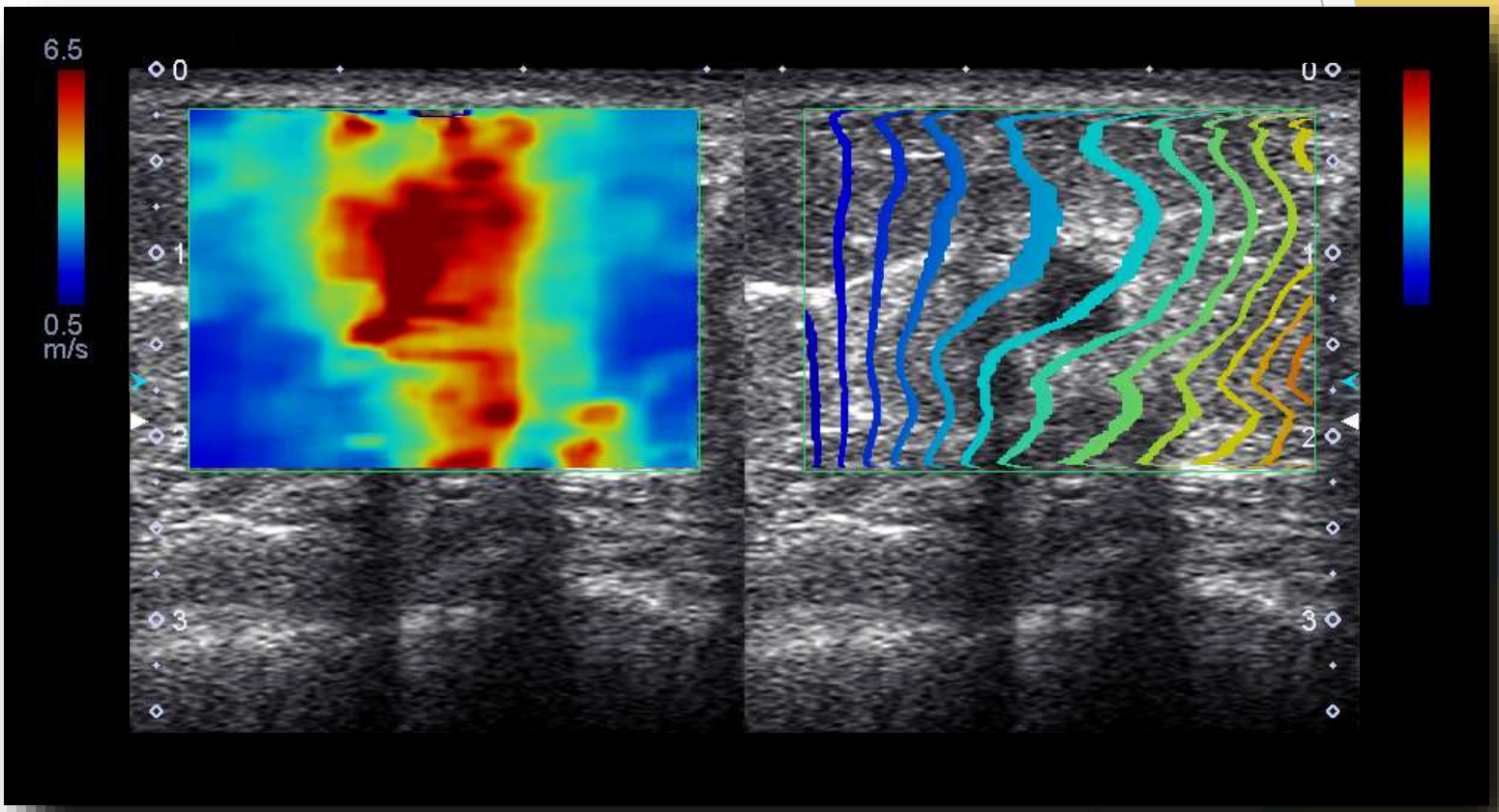
SWE – Stiff Lesion



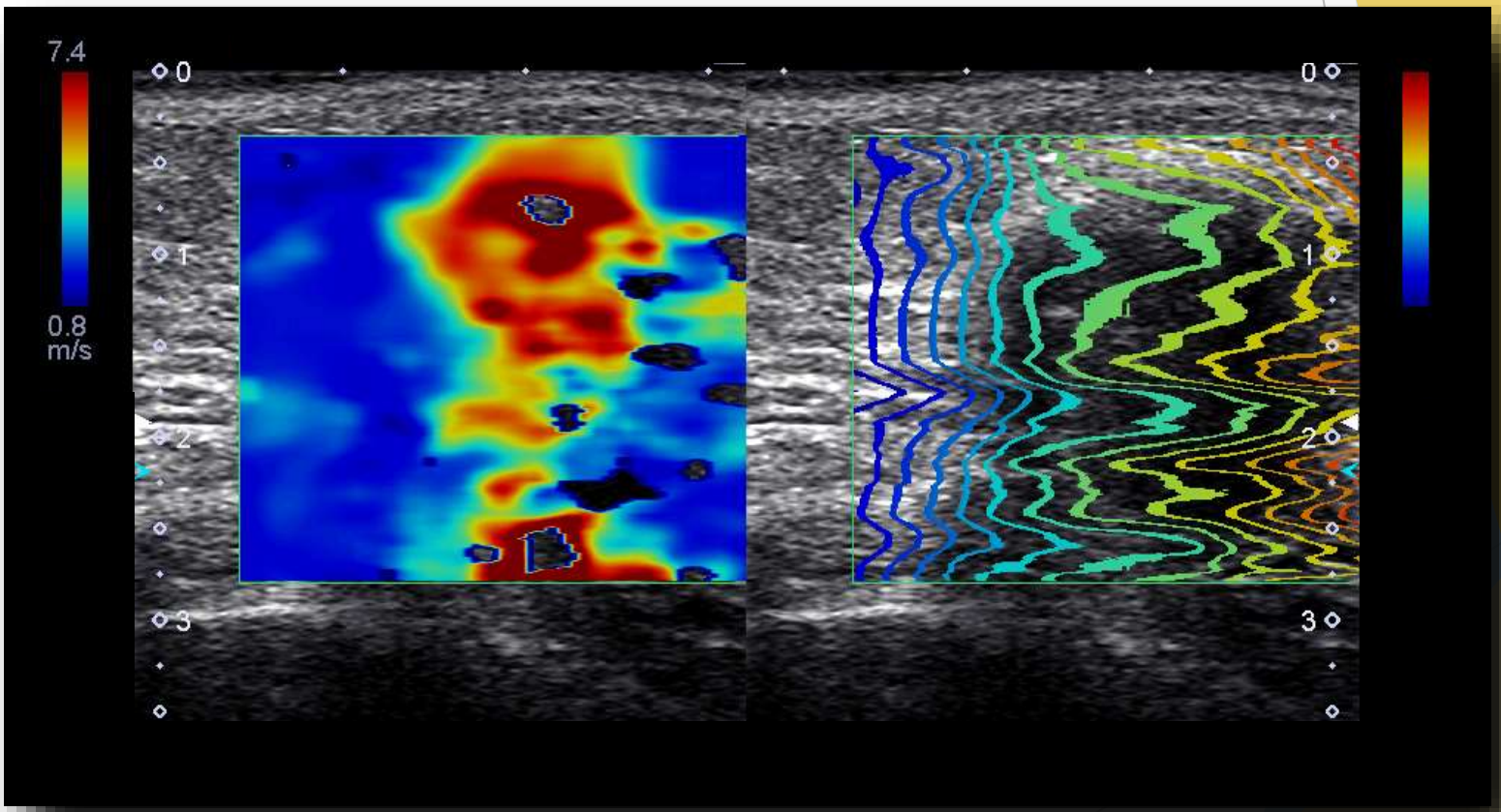
SWE – Stiff Lesion



SWE - Breast



SWE - Breast



Shear Wave Elastography - Breast

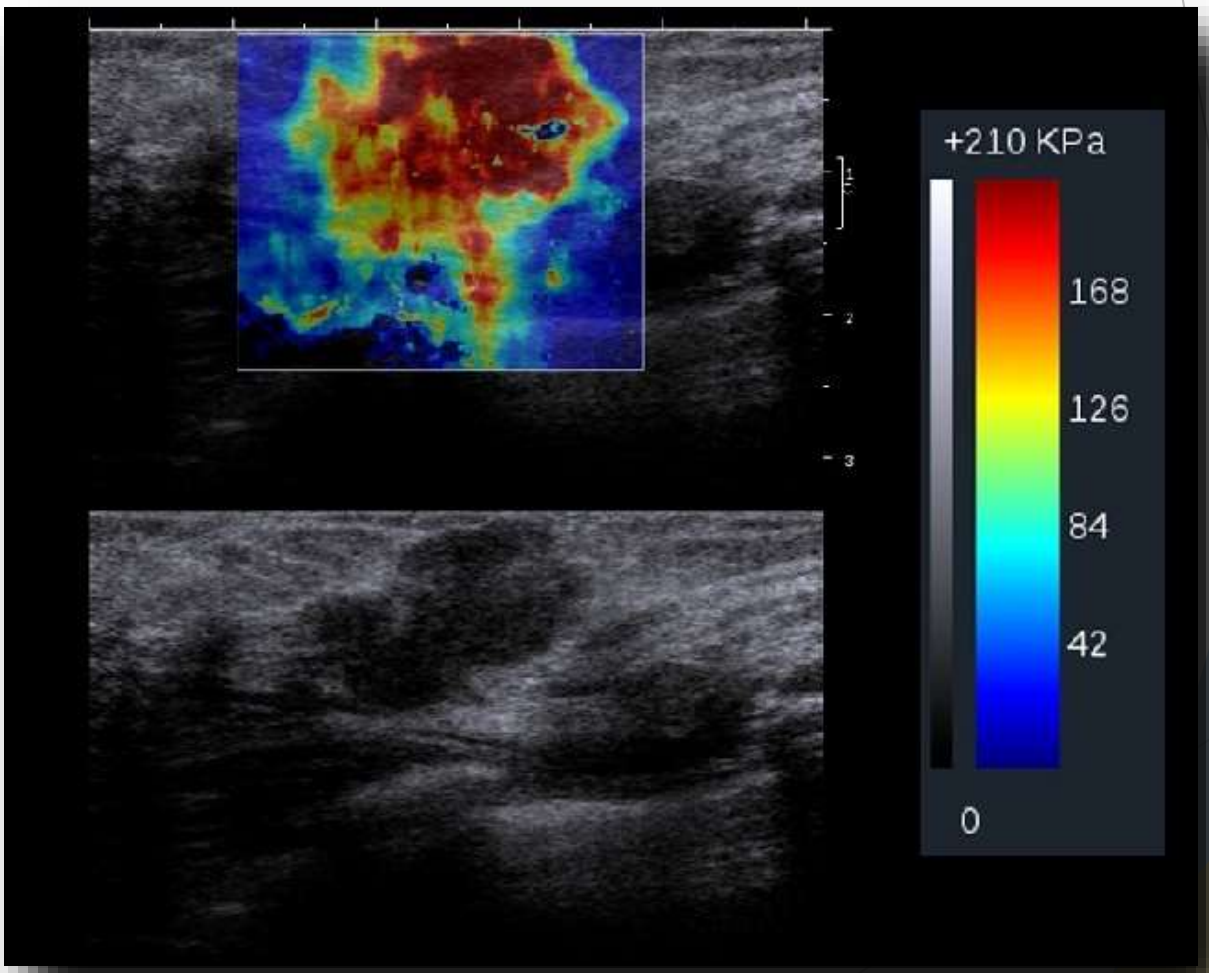
Table 1 Young's modulus of breast tissue samples [1]

Breast tissue type	Young's modulus (kPa)
Normal fat	3.25±0.91
Normal fibroglandular tissue	3.24±0.61
Fibroadenoma	6.41±2.86
DCIS (ductal carcinoma in situ)	16.38±1.55
Low-grade IDC (invasive ductal carcinoma)	10.40±2.60
High-grade IDC	42.52±12.47

Benign

Malignant

SWE - Breast

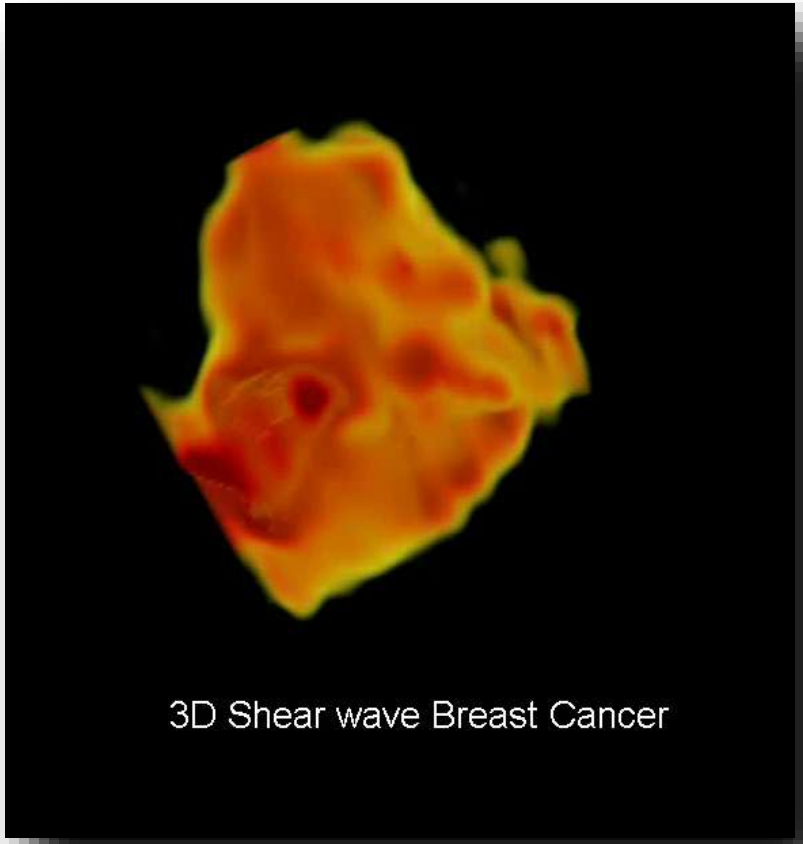


Shear Wave Elastography

	Speed[m/s]		Elasticity[kPa]		Depth[cm]
	Average	SD	Average	SD	
1	1.31	0.06	5.0	0.6	3.9
2	1.34	0.10	5.3	0.9	5.0
3	1.38	0.07	5.6	0.6	4.0
4	1.32	0.06	5.1	0.6	3.6
5	1.27	0.08	4.7	0.6	3.5
6	1.31	0.06	5.0	0.5	3.8
7	1.47	0.10	6.4	0.9	4.3
8	1.31	0.05	5.0	0.5	3.8
9	1.24	0.04	4.5	0.4	4.3
10	1.32	0.06	5.1	0.5	3.7

Mean	1.33	5.2
SD	0.06	0.5
Median	1.32	5.1
IQR	0.03	0.3

SWE - Breast



Shear Wave Elastography

- **Advantages**
  - Can calculate an absolute value in velocity (m/s) or kPa
  - Does not require a reference region
  - Useful for focal and diffuse disease

- **Disadvantages**
  - Depth limitations of 6 – 8 cm
  - Challenging with obese patients
  - FDA limits on push-pulse intensity

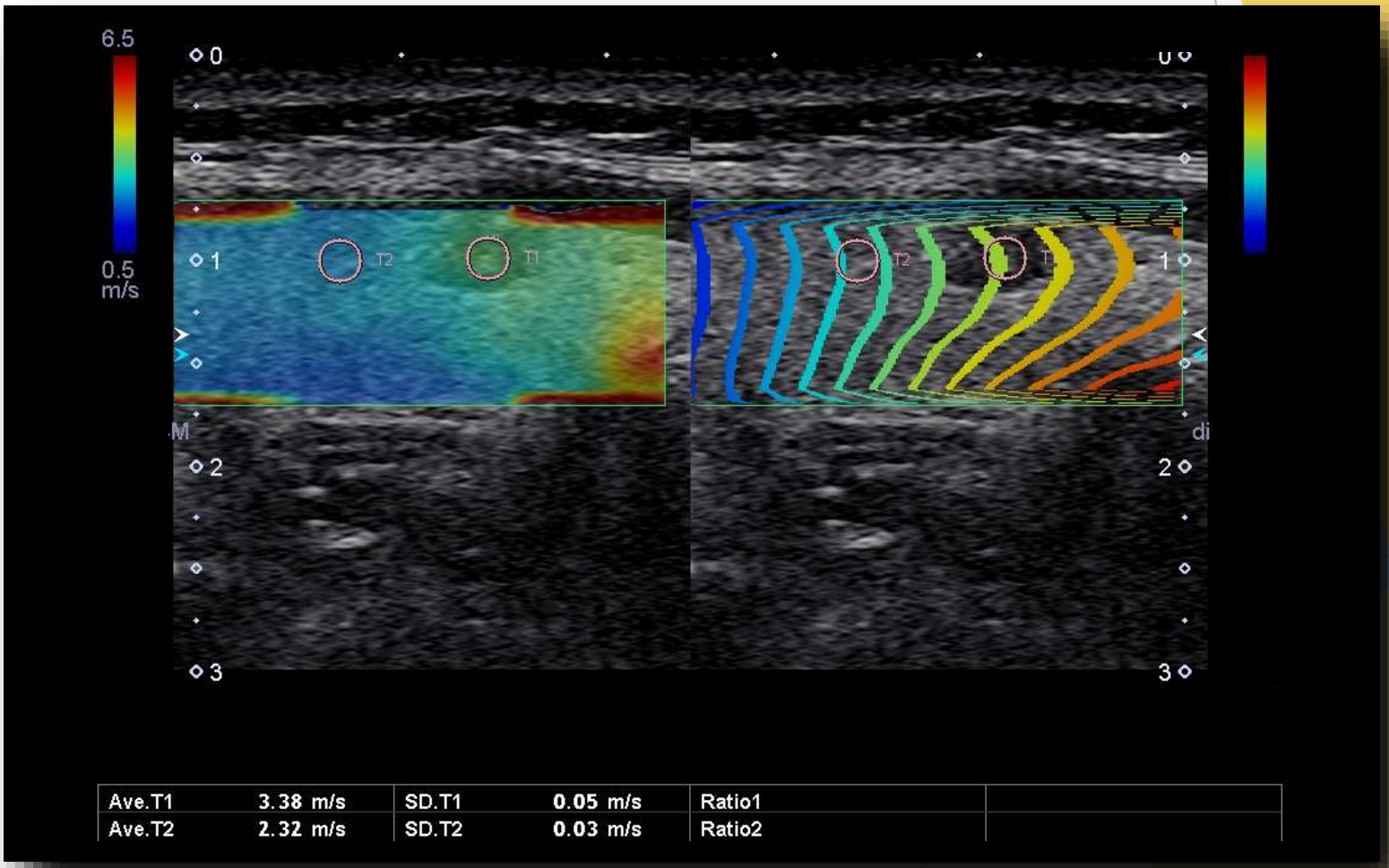
Strain vs Shear Wave Elastography

	Advantage	Disadvantage
Strain	• Strong clinical evidence for breast lesions • High spatial resolution • Better frame rates	• Absolute stiffness not available • Requires compression • Operator dependent • Not suitable for tissue when manual compression is difficult
Shear wave	• Absolute stiffness • Compression not required • Less operator dependent • More reproducible	• Penetration is limited by acoustic power regulations • Structural boundaries might yield substantial artifact

What's Next for Shear Wave?

- New Structures
  - Thyroid – lesion characterization
  - Prostate – tumor characterization
  - MSK – tendon/muscle softening
  - Uterine fibroids
- Stiffness Correlation per Vendor
  - Each vendor will develop elasticity charts specific to imaging algorithms
  - … and specific to each organ structure

SWE - Thyroid


6.5
0.5
m/s
T2
T1
T2
T1
Ave.T1 3.38 m/s SD.T1 0.05 m/s Ratio1
Ave.T2 2.32 m/s SD.T2 0.03 m/s Ratio2

Thank You!

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