



# Nasjonalt Senter for Gastroenterologisk Ultrasonografi

National Centre for Ultrasound in Gastroenterology  
Haukeland University Hospital, Bergen, Norway

## Ultralyd-fysikk for leger

Odd Helge Gilja, MD, PhD

Department of Clinical Medicine

University of Bergen

Bergen, Norway



# The Champions of Ultrasound





We are often left to  
admire the skills of dolphins...





# The Dolphin was the first to utilise bubbles with ultrasound...



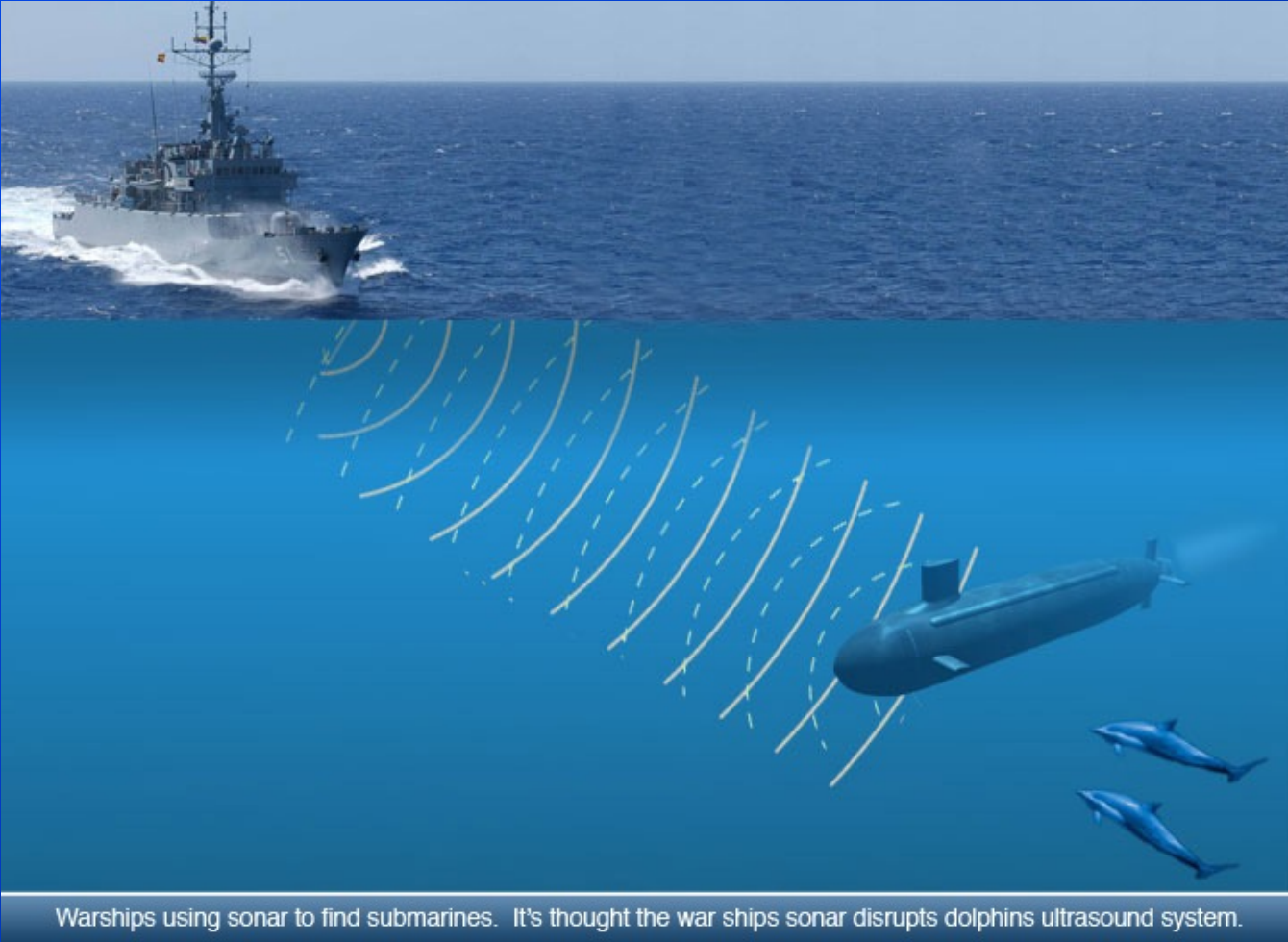


# The Humpback Whale hunts using "fishing-net" of gas-bubbles



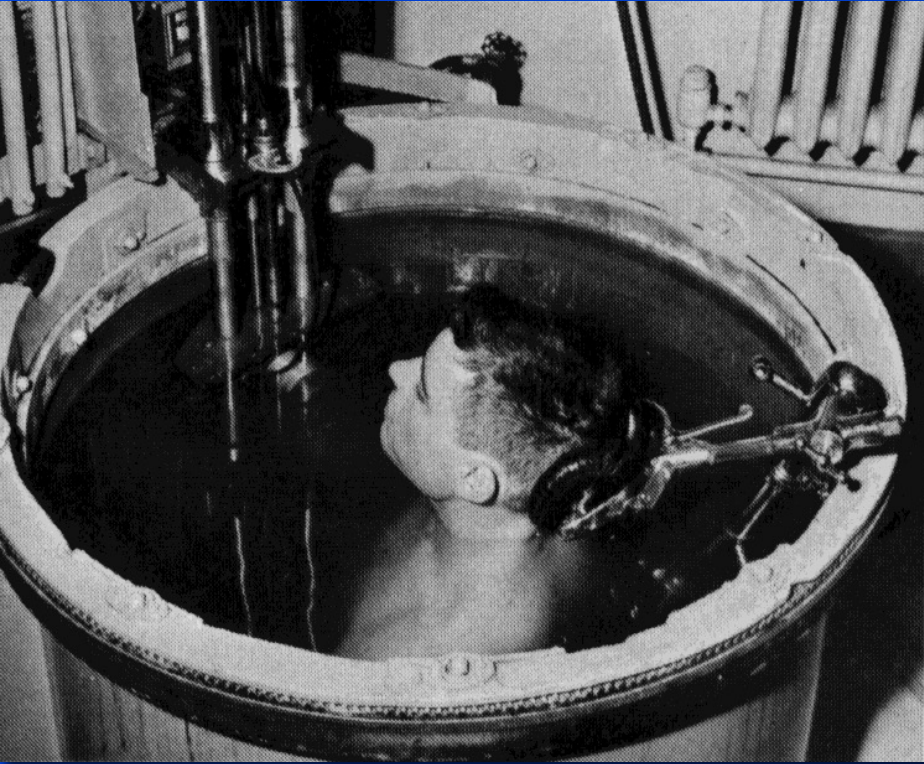


# The Sonar – 1912 Post-Titanic





# Technological Development in Ultrasonography



1954

The Denver group, USA



1989



2001



# Vscan – 2010 – Handheld US A gamechanger !







# The Future: From Stethoscope to Echoscope



1816

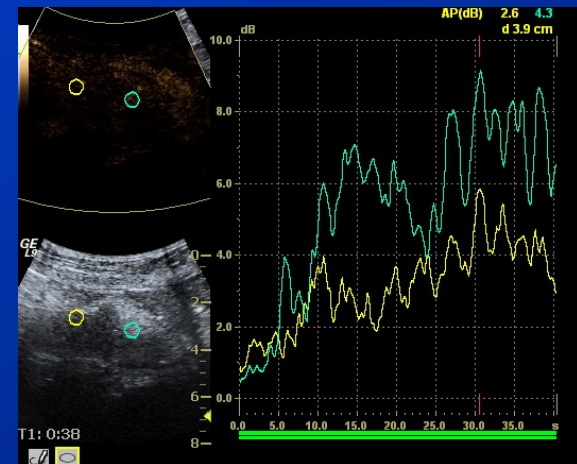
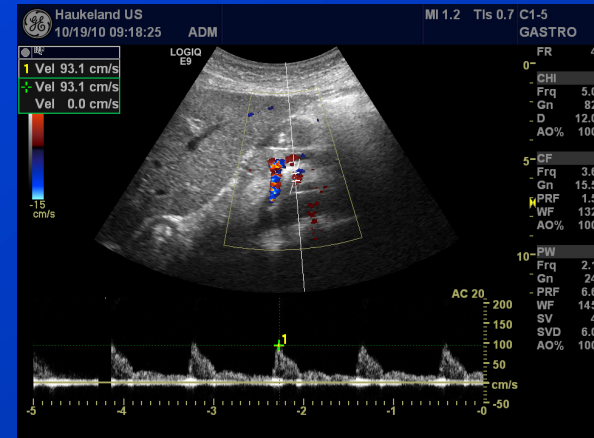


2009



# Ultrasound is more than an image

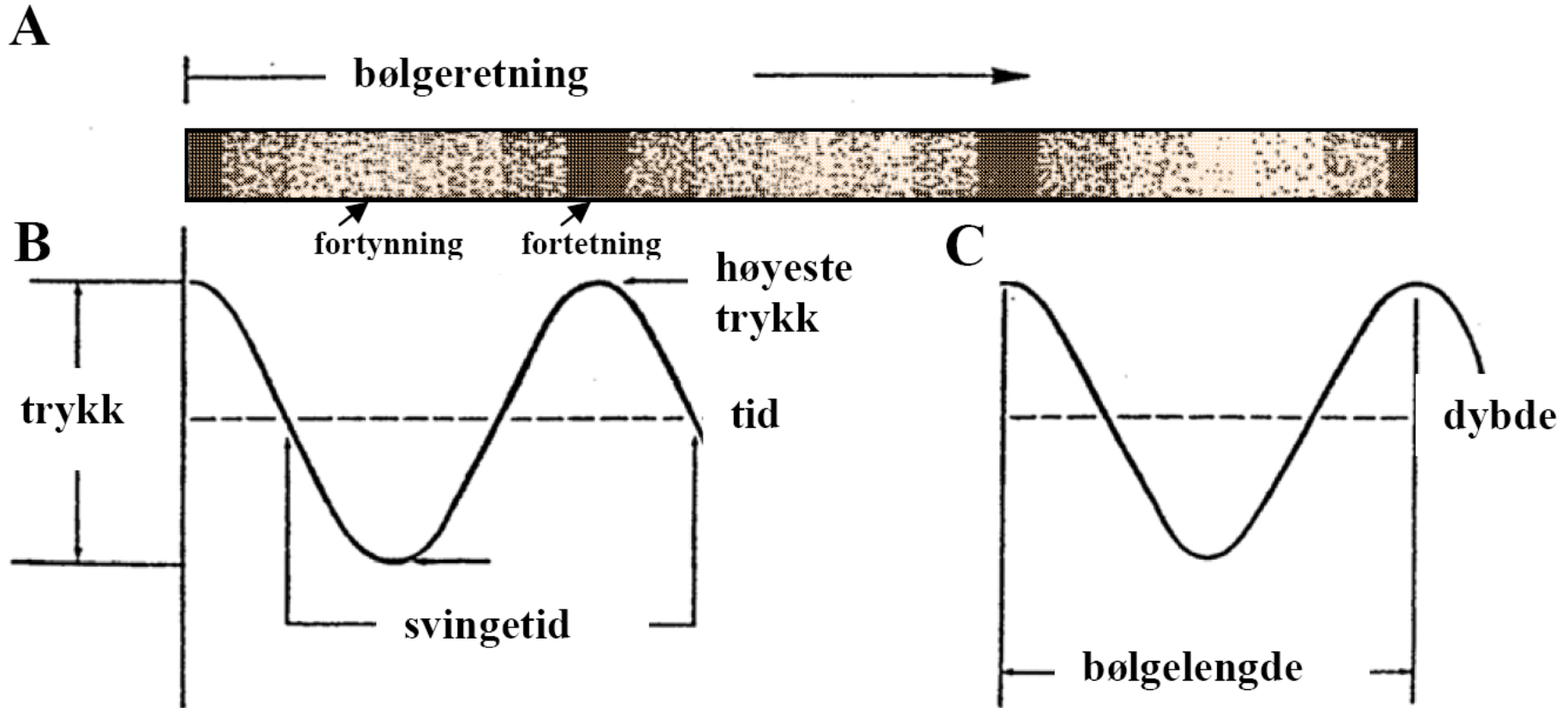
- A-mode
- B-mode
- M-Mode
- Doppler
  - Continuous
  - Pulsed
  - Color
  - Power / Angio
  - Tissue Doppler
  - Strain Rate Imaging
  - Duplex – Triplex
- 3D and 4D ultrasound
- Elastography
- Harmonic imaging
- Contrast-enhanced ultrasound (CEUS)
- Guiding of interventions
- Ultrasound therapy - sonoporation



A versatile  
Ultrasound Toolbox !



# Lydbølger



Longitudinale bølger: masselementene beveger seg langs bølgeretningen. Trykkbølger - akustiske bølger

(Ødegaard S, Gilja OH, Matre K (red). Innføring i abdominal ultrasonografi, Fagbokforlaget 2009).





# Egenskaper til ultralydbølger

Longitudinale bølger med frekvens over 20 000 Hz,  
20 kHz

1. Kan ledes i stråler
2. Følger de samme lover som lys mht refleksjon og brytning
3. Reflekteres av relativt små objekter
4. Dårlig gjennomgang i gassfylte medier



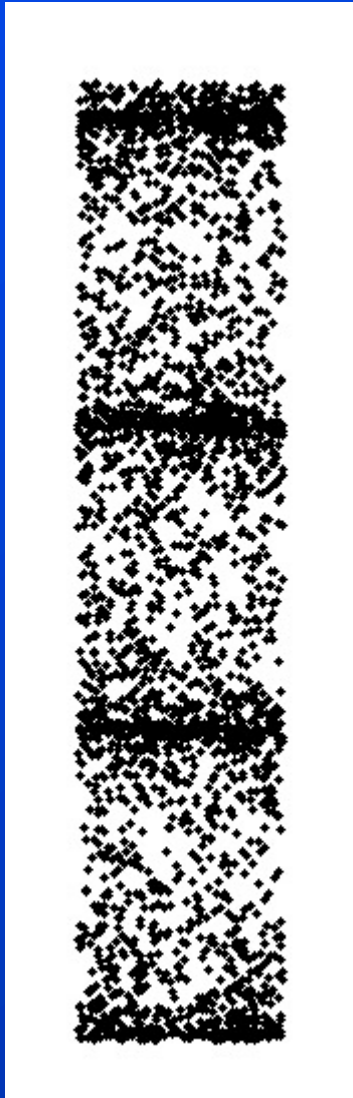


# Longitudinal and Shear Waves

Ultrasound  
Wave

$$c_l = \sqrt{\frac{K}{\rho}}$$

$c_l \sim 1540$  m/s  
in tissue



Shear Wave

$$c_t = \sqrt{\frac{E}{3\rho}}$$

$c_t = 1-10$  m/s in tissue



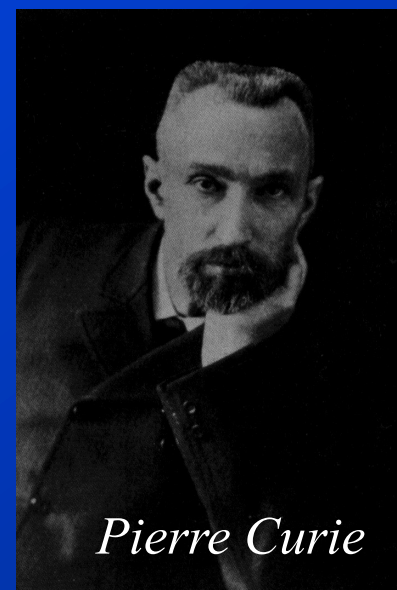
# UL-hastigheter i ulike vev

Ultralydhastighet i biologisk materiale i m/s:

Blod	1570
Lever	1547-1585
Nyre	1560
Myokard	1540
Fett	1440-1476
Bein	2700-4100
Luft	331

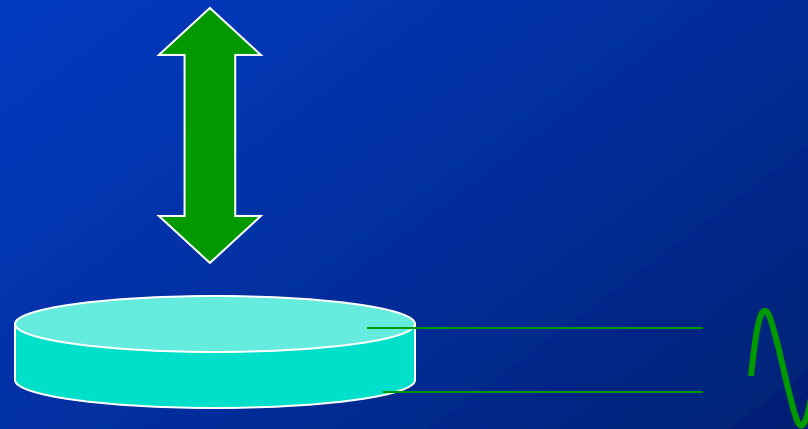


# Piezoelectric Effect



*Pierre Curie*

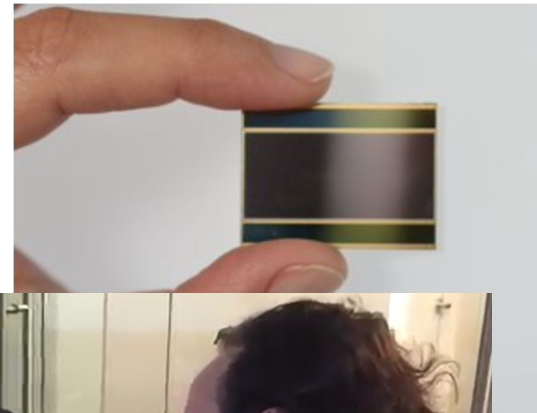
- Quartz, Barium, Titanate, Lead-ciconate
- Silicium oxide
- Electrical potential → Deformation of crystal
- Sound pressure → Electrical potential





# Ultrasound on a microchip

Butterfly's engineers replaced the piezoelectrics with a micromachine that acts like a tiny drum to generate vibrations. Inside this "capacitive micromachined ultrasound transducer" (CMUT), an applied voltage moves a membrane to send ultrasonic waves into the body. The waves that bounce back from various body tissues move the membrane and are registered as an electric signal, which creates the image. Butterfly based its technology on [research done](#) by Stanford professor [Pierre Khuri-Yakub](#), who serves on Butterfly's scientific advisory board.



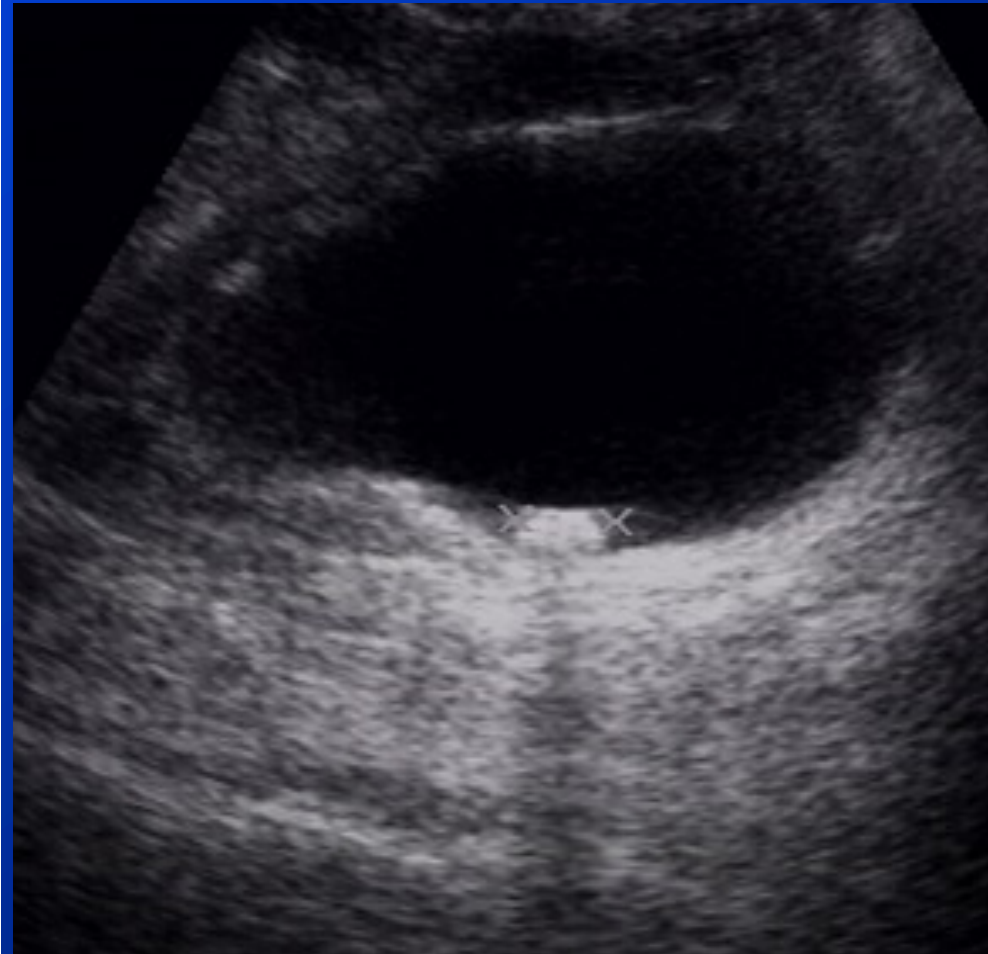
The butterfly system:  
US < 2k USD





# Pixels in the US-image

A	1	2	3	4	5	6	7	8	9	10	11
B	Dark	Black	Dark	Medium	Medium	Medium	Medium	Dark	Medium	Medium	Medium
C	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
D	Medium	Medium	Medium	Black	Black	Black	Black	Black	Black	Medium	Medium
E	Medium	Black	Black	Medium	Black	Black	Black	Black	Black	Dark	Medium
F	Medium	Black	Black	Black	Black	Black	Black	Black	Black	Dark	Medium
G	Medium	Medium	Medium	Black	White	Black	Black	Black	Medium	Medium	Medium
H	Medium	Medium	White	Light	Dark	White	Light	Medium	Medium	Medium	Dark
I	Medium	Medium	Medium	White	Black	White	White	Medium	Medium	Dark	Medium
J	Blue	Medium	Medium	Medium	Black	Black	White	Medium	Dark	Blue	Blue





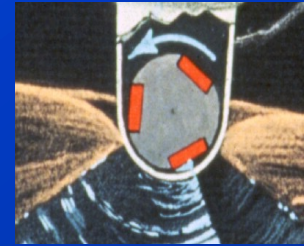
# Dynamic Range (dB)





# Ultrasound Transducers

## Mechanical Transducers



## Electronic Array Transducers

— Convex

— Linear

— Phased



Parallel scanlines



Diverging scanlines



# Hva betyr frekvensen for bildet?

Konsekvenser av økt ultralydfrekvens:

**1) oppløsning går opp**

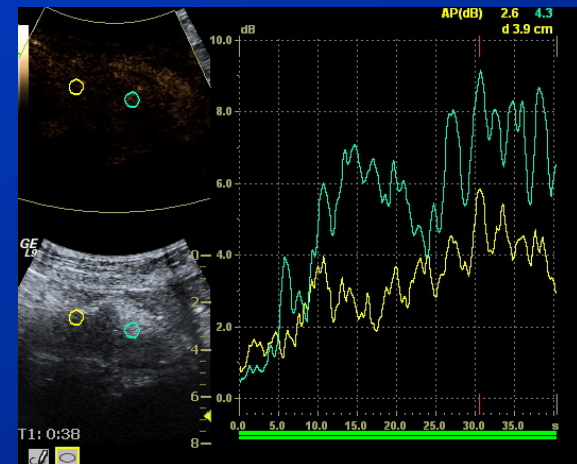
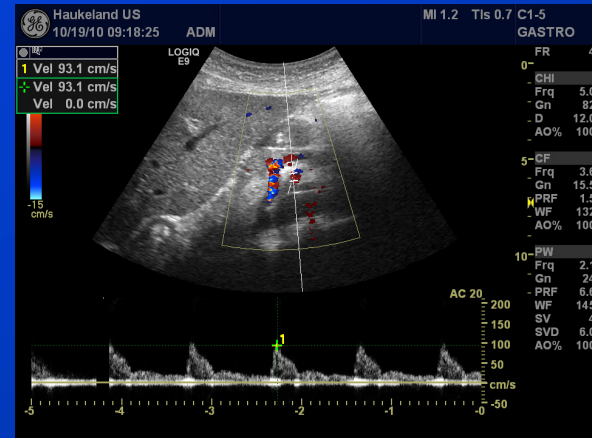
**2) penetrasjon går ned**

Moderne skannere: frekvensen på en valgt probe kan varieres noe, på bekostning av følsomhet (sensitivity)



# Ultrasound is more than an image

- A-mode
- B-mode
- M-Mode
- Doppler
  - Continuous
  - Pulsed
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- CEUS
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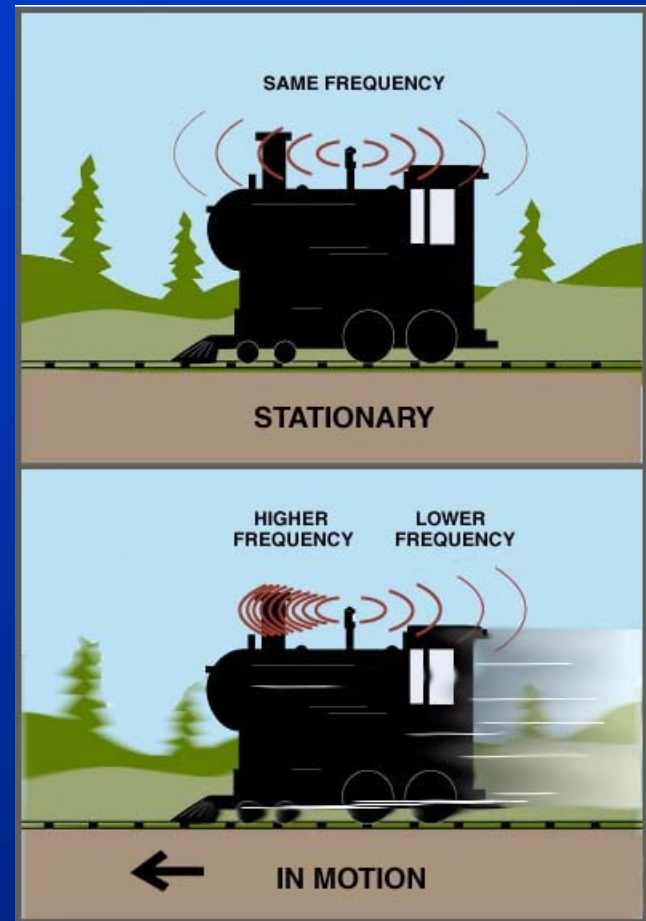


# Christian Doppler



**Born: 29 Nov 1803 in Salzburg, Austria**  
**Died: 17 March 1853 in Venice, Italy**

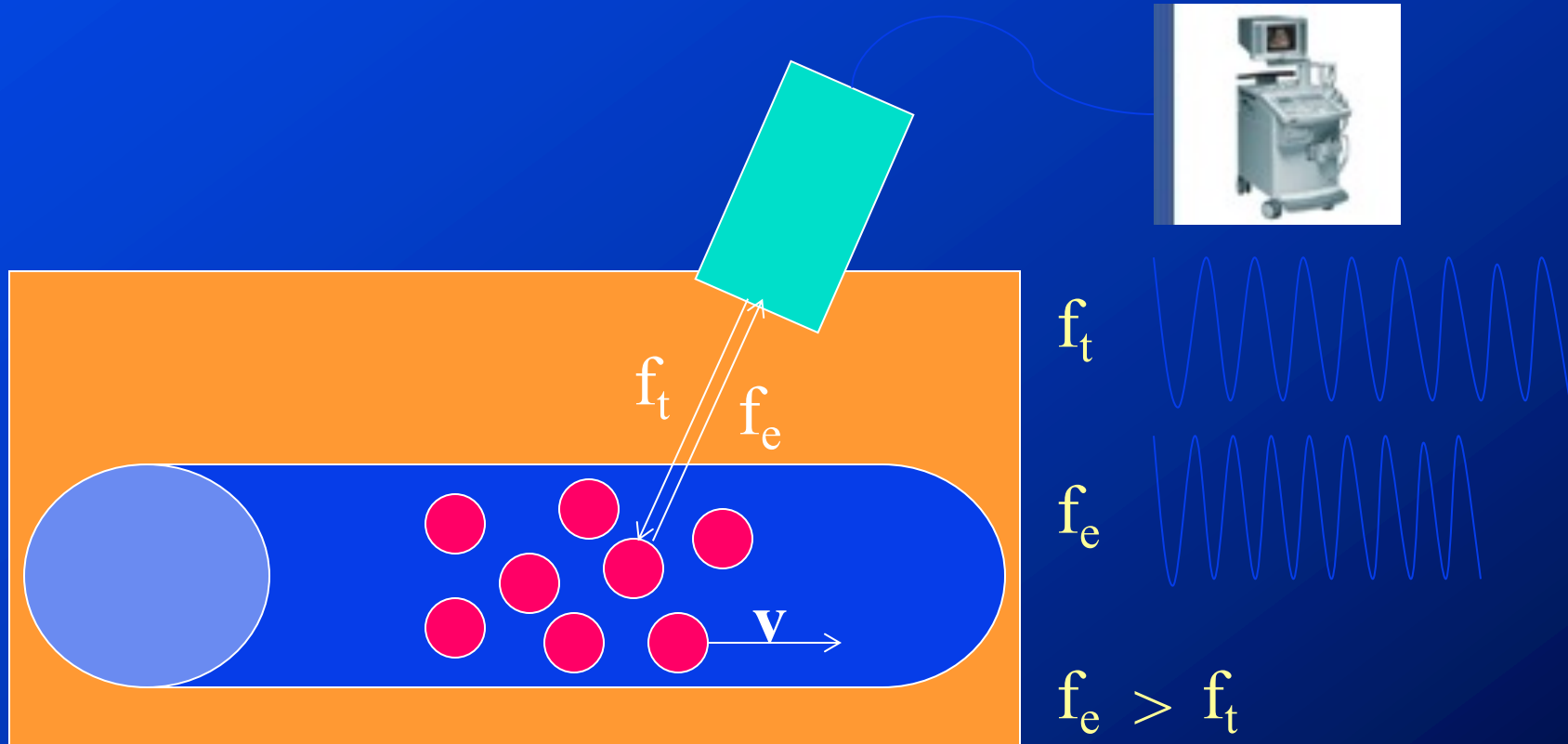
## The Doppler effect (1842)





# The Doppler effect in medical ultrasound

$$f_d = f_e - f_t = 5\,002\,000 \text{ Hz} - 5\,000\,000 \text{ Hz} = 2\,000 \text{ Hz}$$



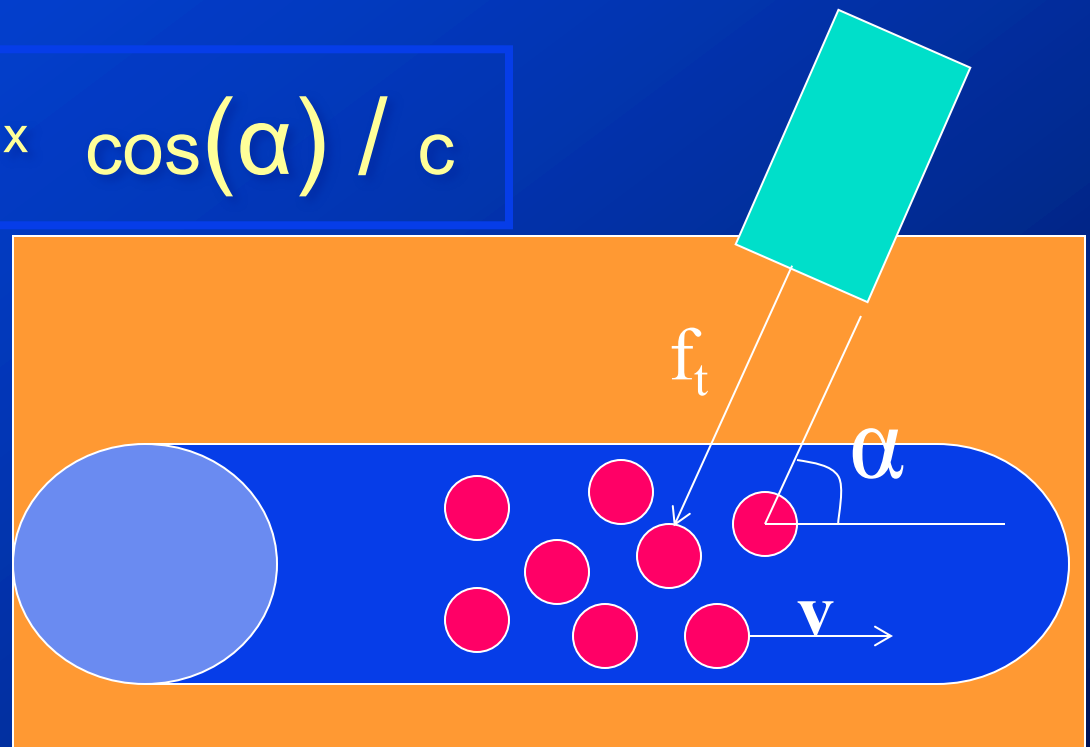


# The Doppler equation

- Doppler frequency  $f_d \approx v, \alpha, f_t$

- $f_d = 2 \times f_t \times v \times \cos(\alpha) / c$

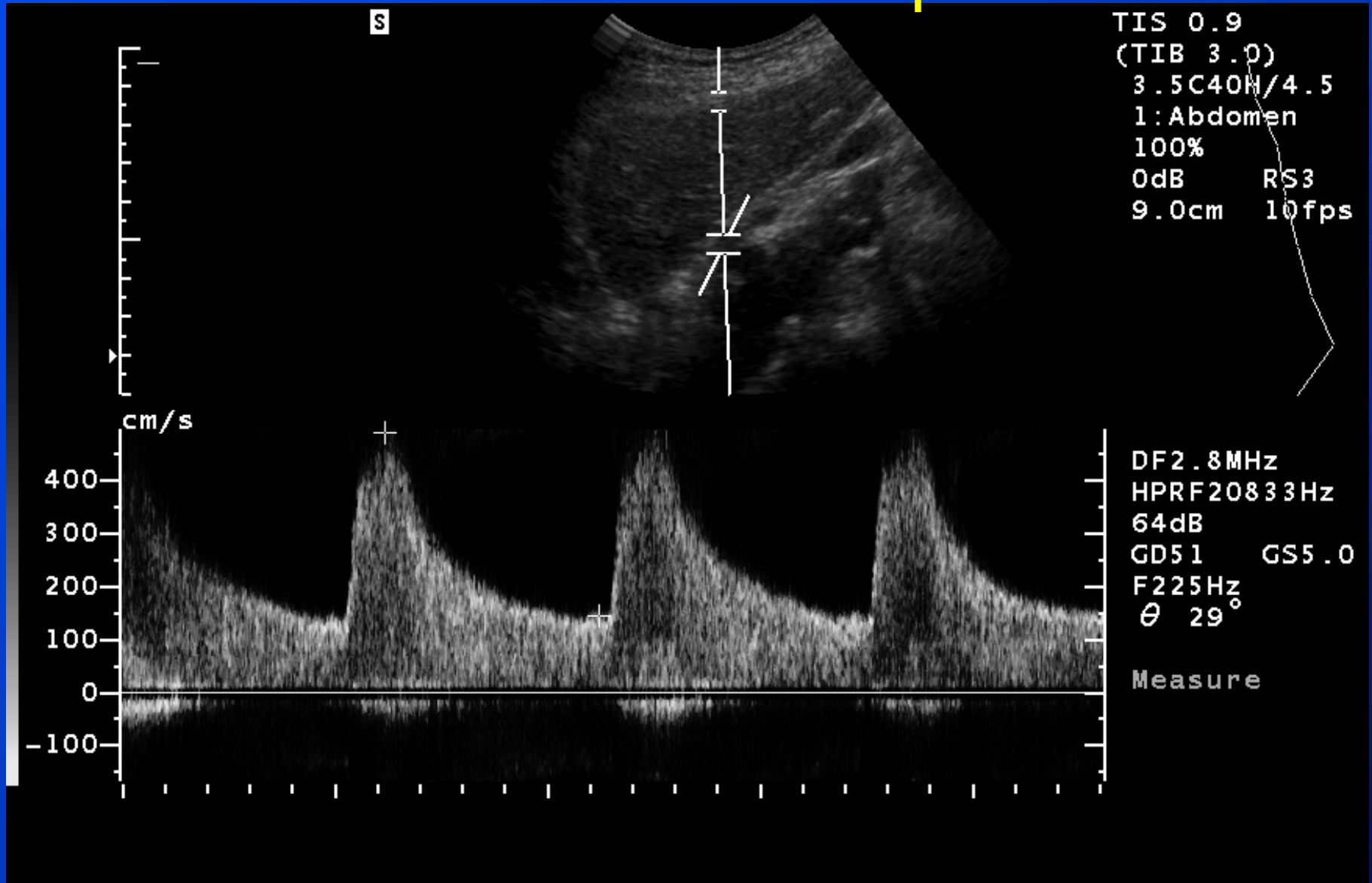
- $c = 1\,500 \text{ m/sec}$







# Pulsed Doppler of arteria mesenterica sup

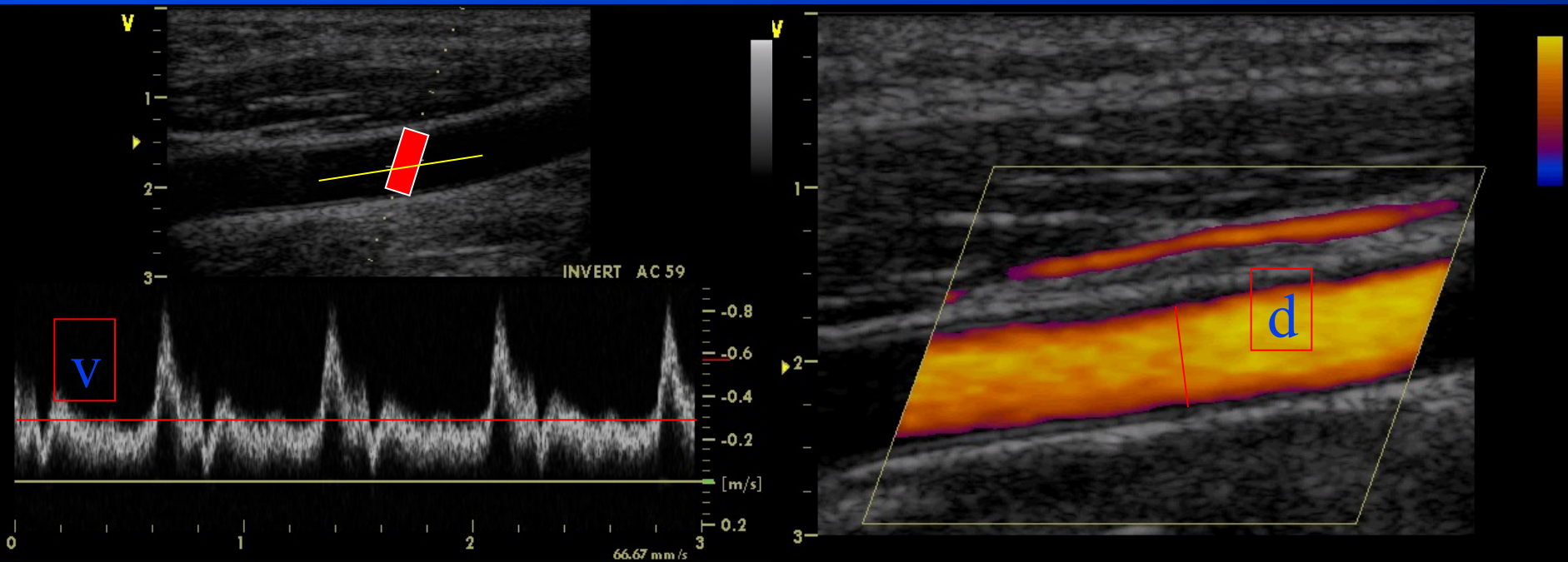




# Flow Measurement (ml/min)

$$Q = v A \quad (\text{Condition: Small or known angle})$$

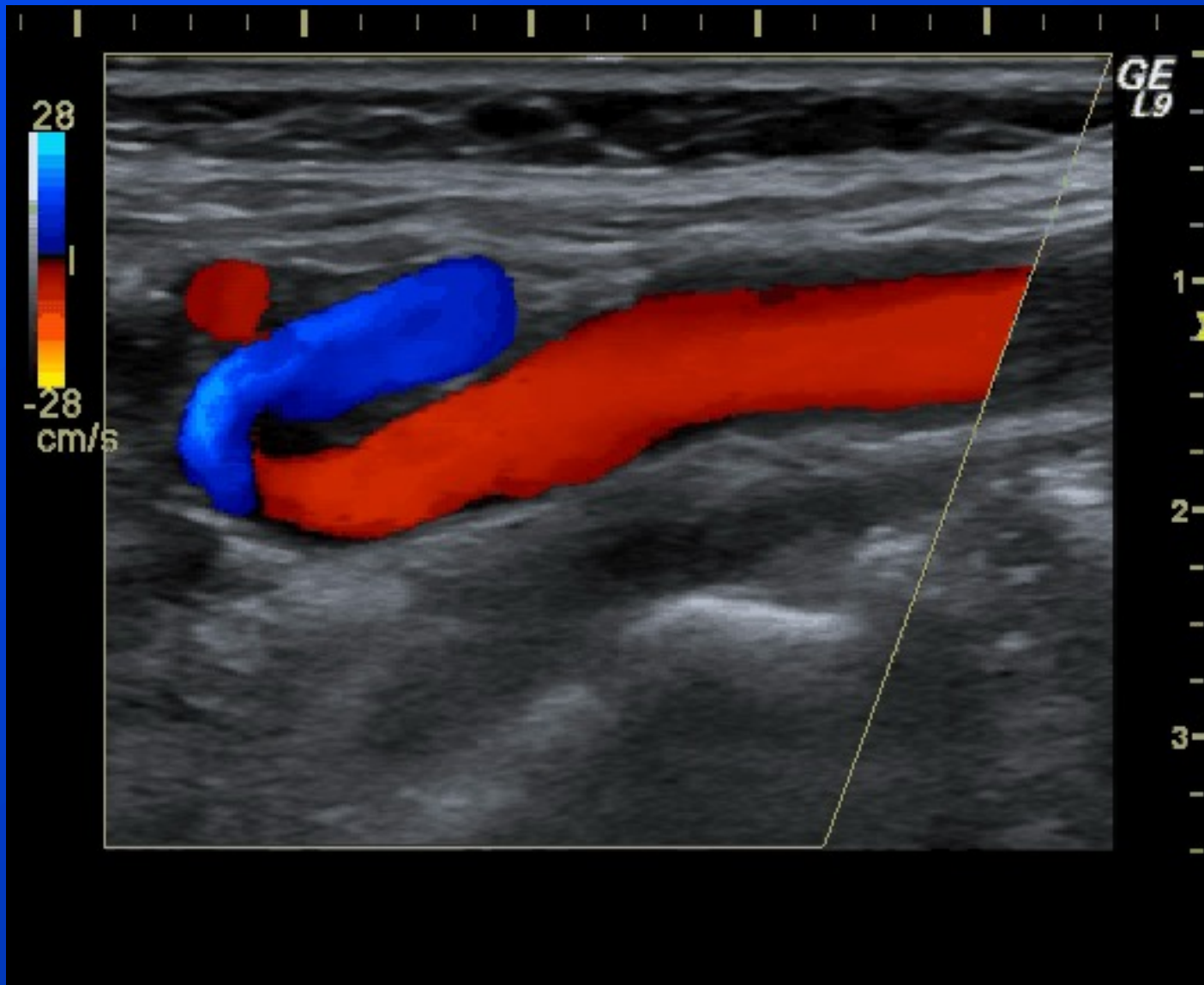
$v$  = mean velocity,  $A$  = area at locus of measurement



$d=0.6, r=0.3$  cm,  $v=25$  cm/s gives  $Q=424$  ml/min

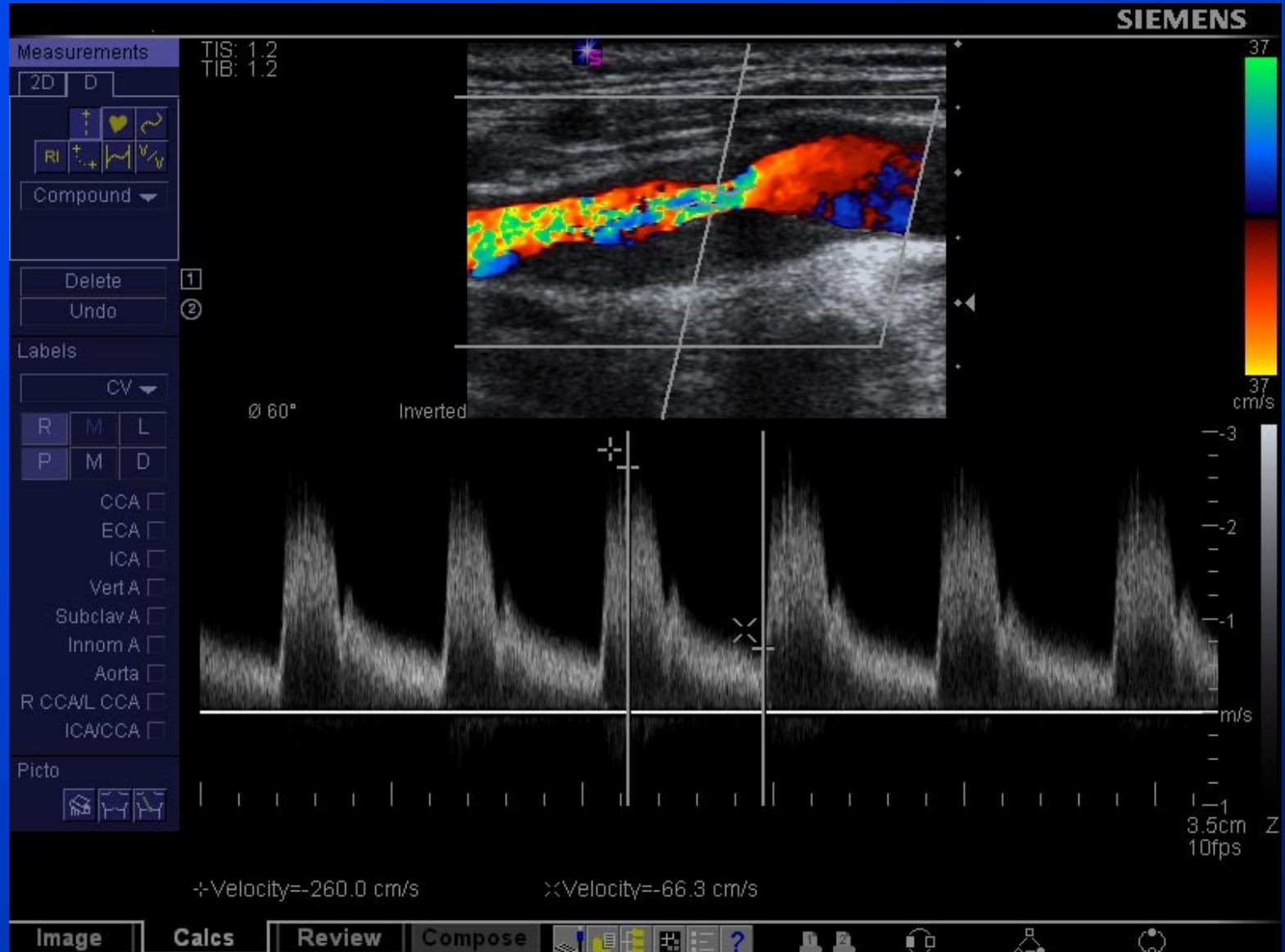


# Color Doppler



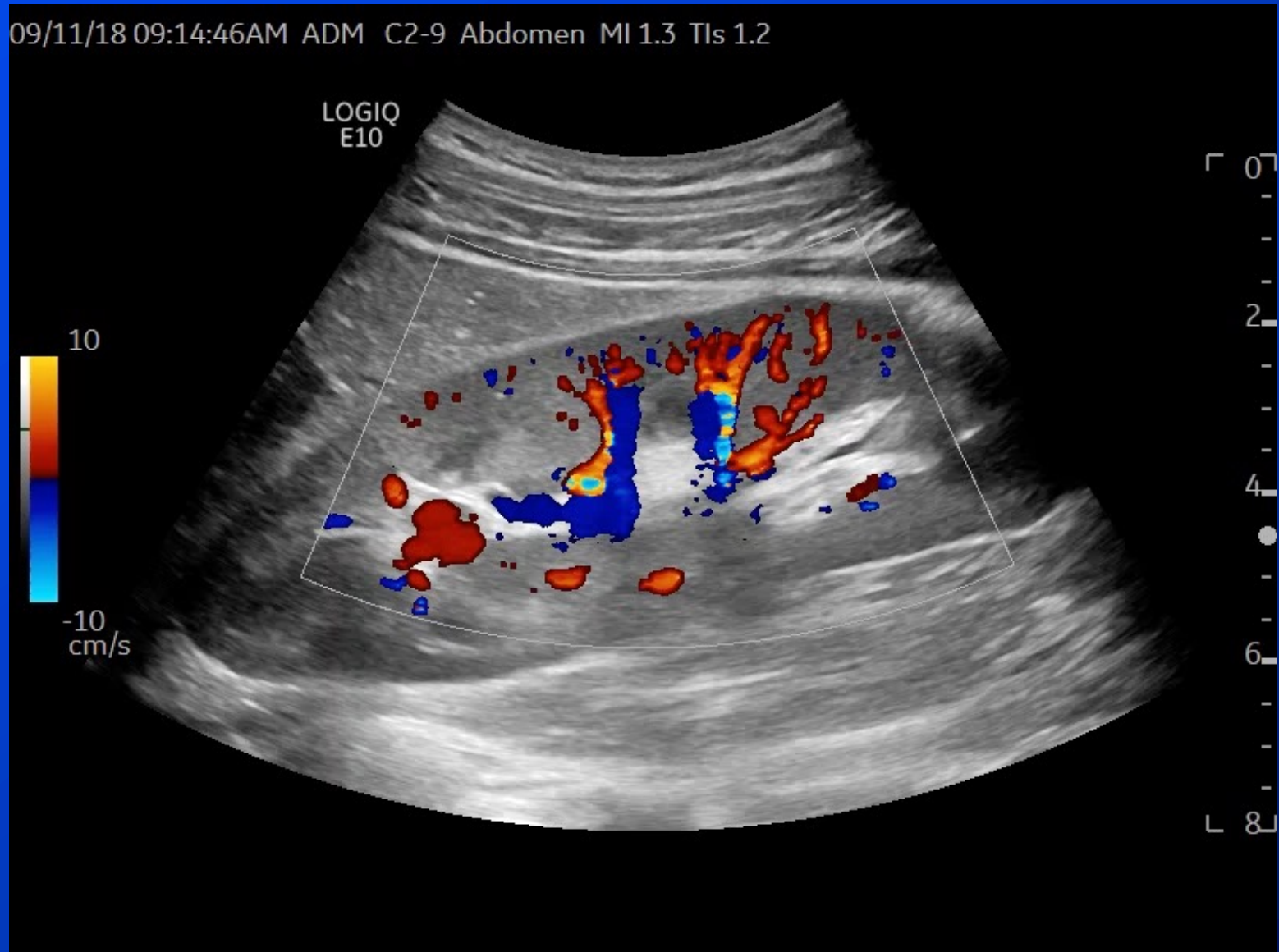


# Triplex – B-mode+Pulsed+Color



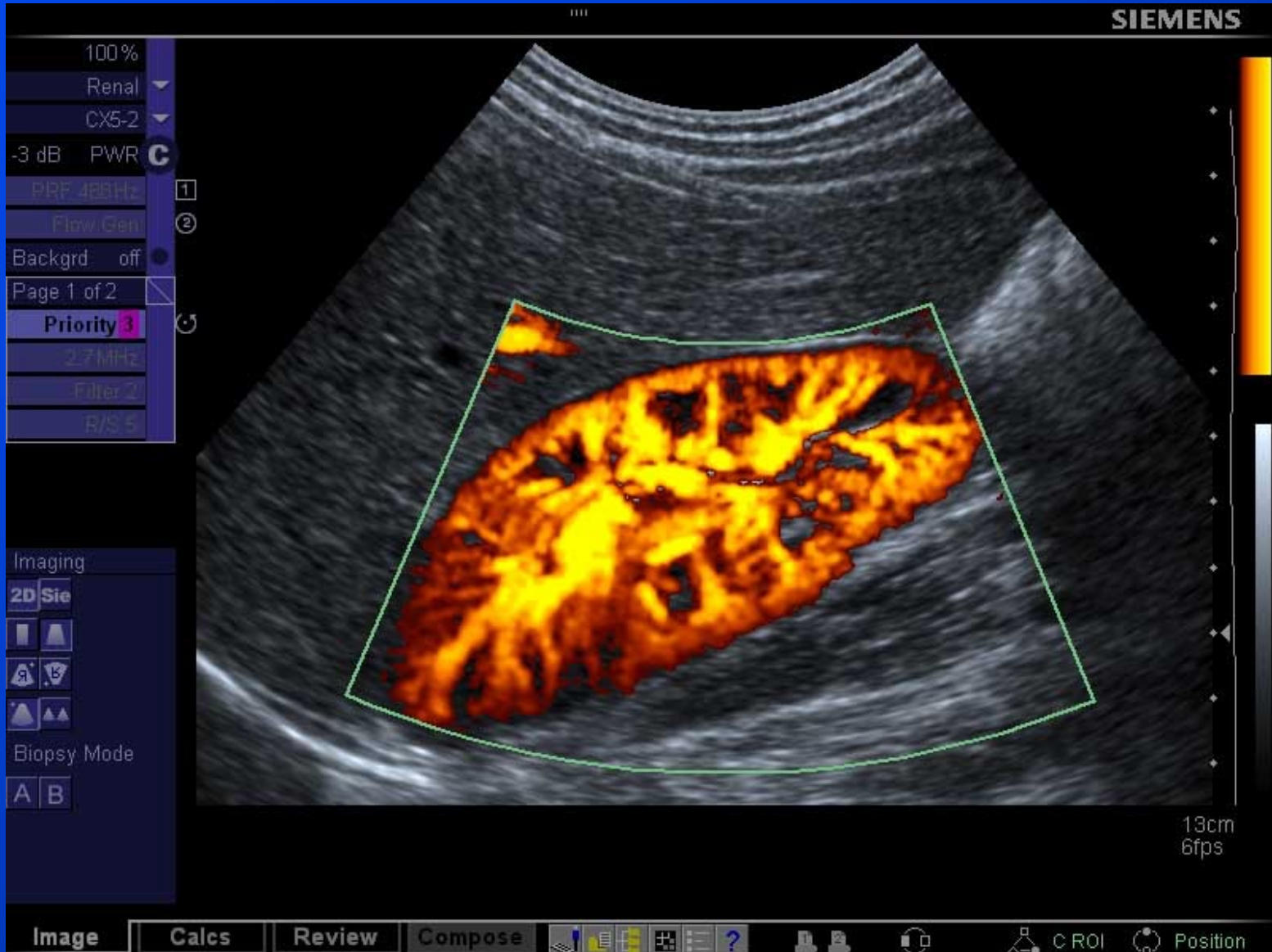


# Real-time flow evaluation





# Power Doppler





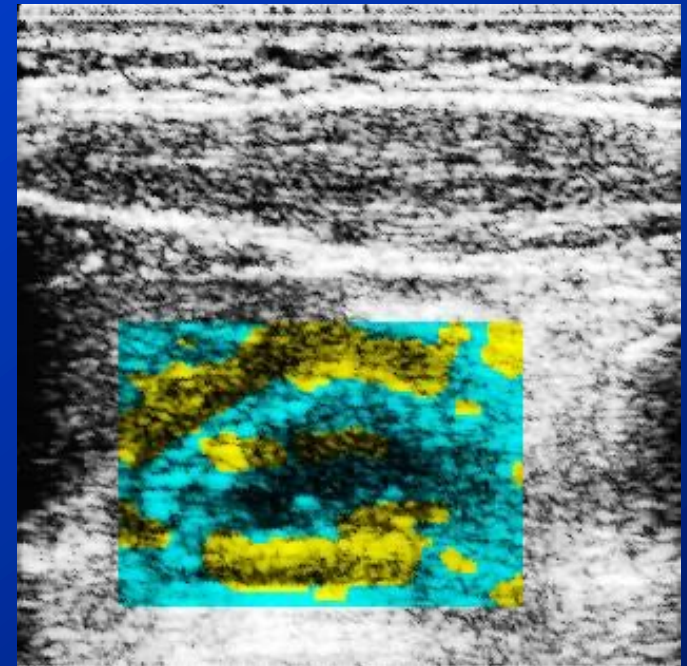
# B Flow real-time dynamics





# Tissue Doppler Imaging

- Tissue Doppler imaging (TDI) enables estimation of slow velocities
- TDI can map local tissue velocities (point velocities) in large organs
- The point velocity of tissue, however, does not differentiate between actively contracting and passively following tissue



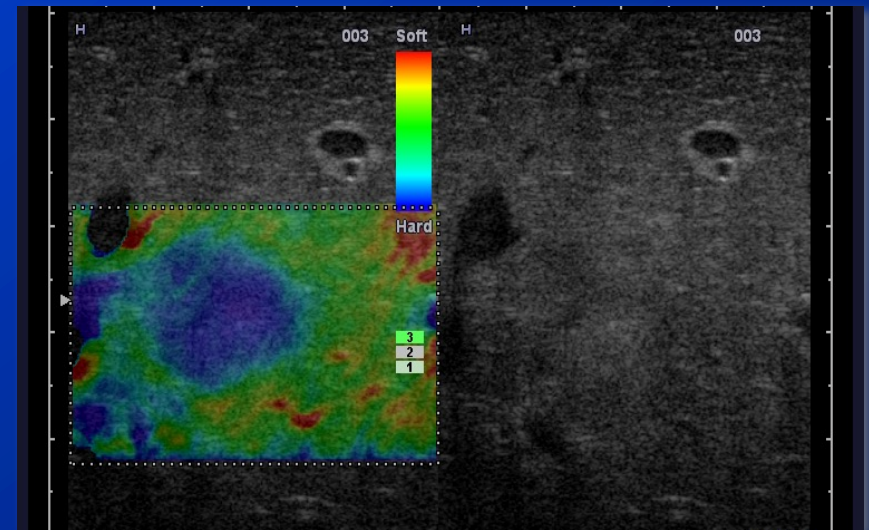




# Strain is Deformation of Tissue



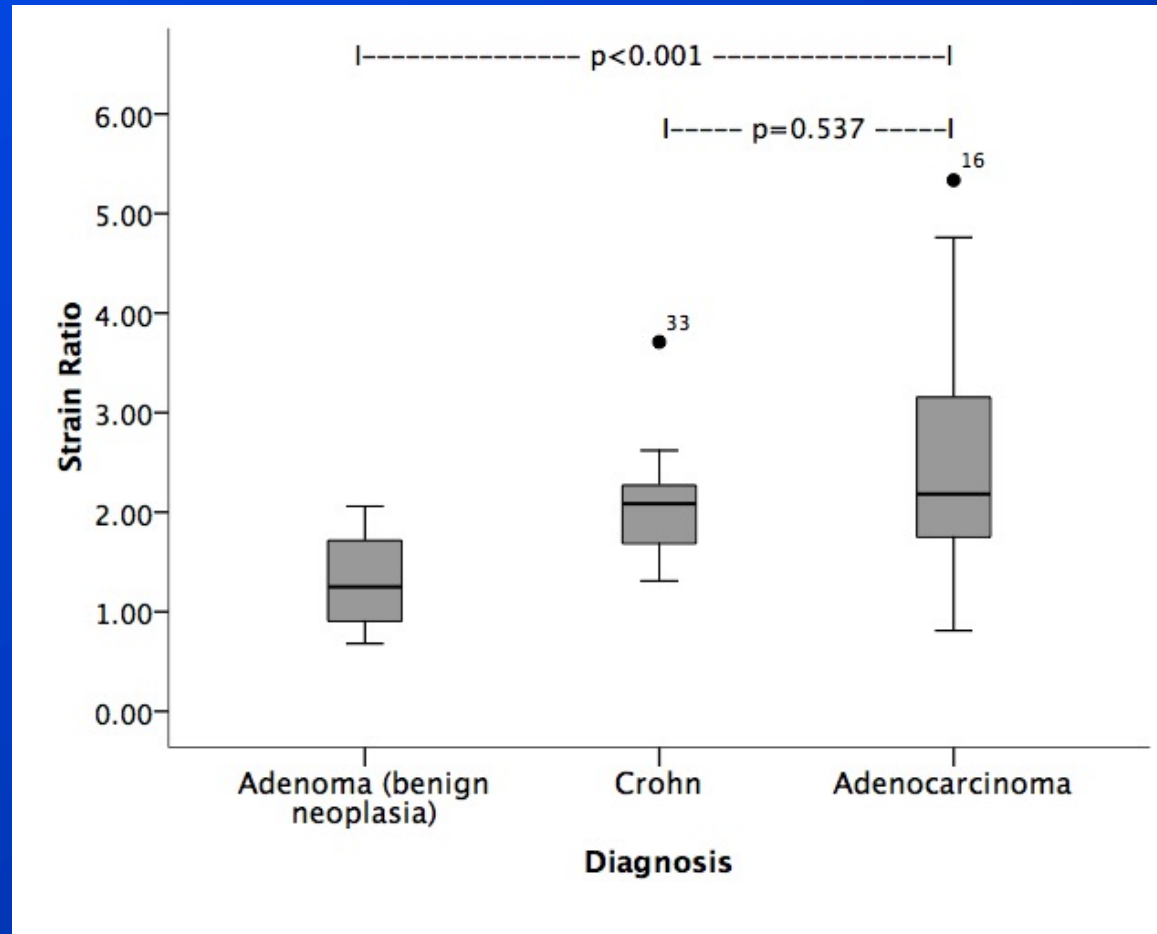
Deformation by the fist



Deformation by the probe during liver surgery

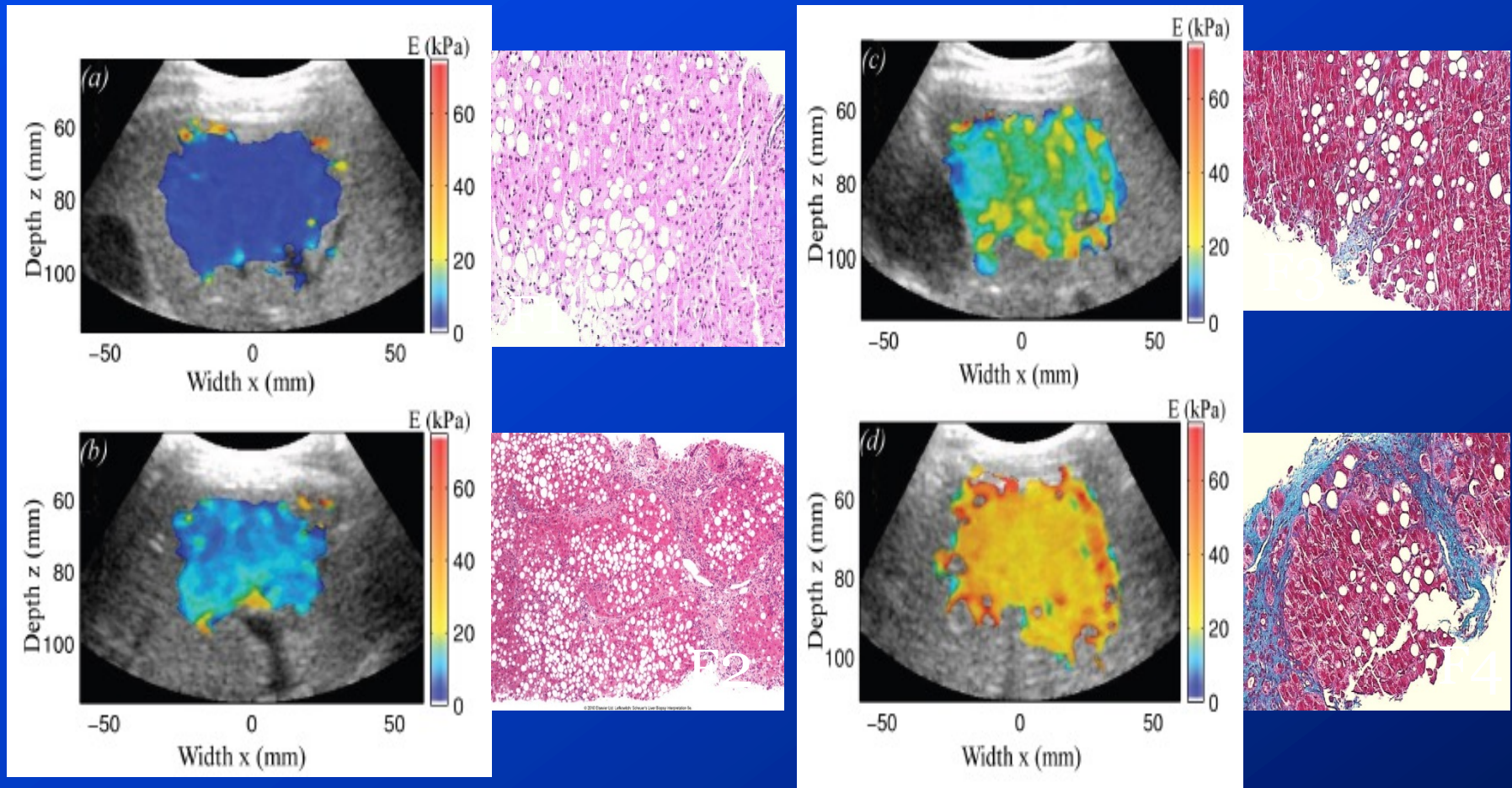


# Elastographic Association between Strain Ratio and Pathology





# Shear Wave Elastography compared to histological findings and Liver Fibrosis



*Ultrasound Med Biol.* 2011 Sep;37(9):1361-73. Epub 2011 Jul 2011 Noninvasive in vivo liver fibrosis evaluation using supersonic shear imaging: a clinical study on 113 hepatitis C virus patients. Bava E, Gennisson JL, Couade M, Bercoff J, Mallet V, Fink M, Badel A, Vallet-Pichard

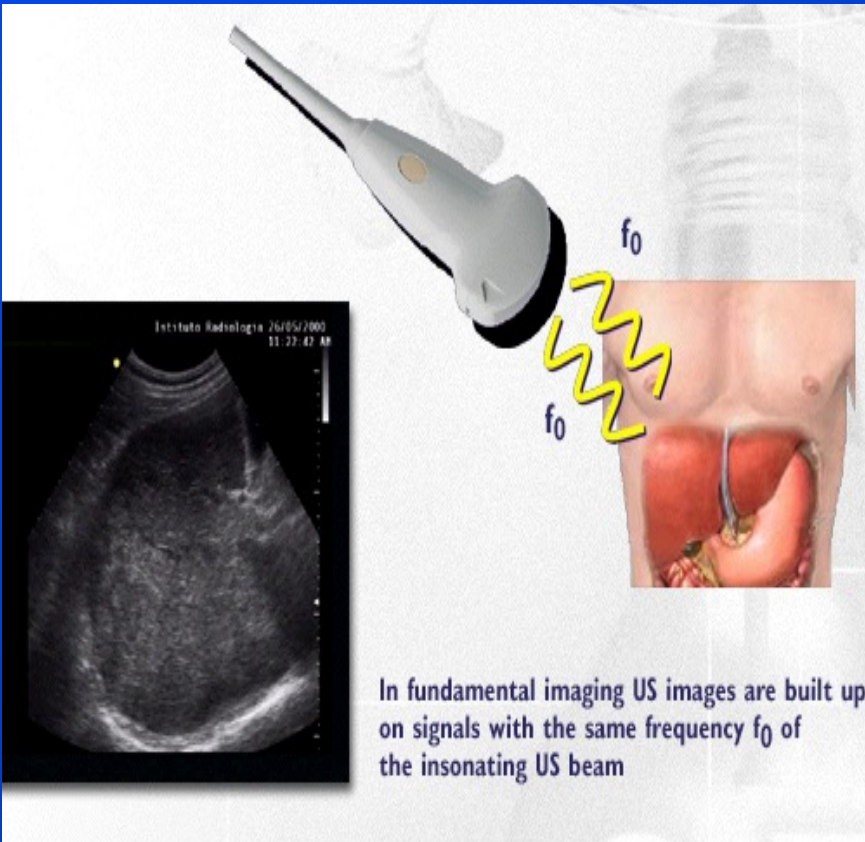


# Ultrasound elastography

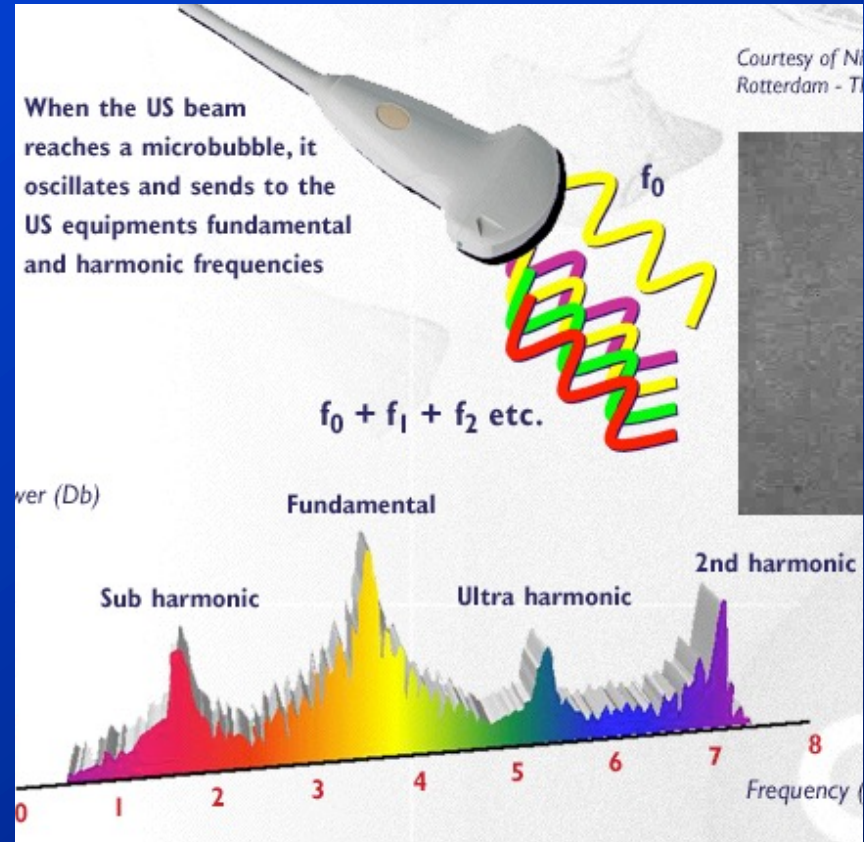
- Correlates well with histology regarding fibrosis
- Easy to perform
- Prolongs the US exam only with 2 min
- Provides valuable information to the clinician
  
- CT does not give data on liver stiffness
- MR elastography has low availability, is expensive and time consuming



# Harmonic Imaging



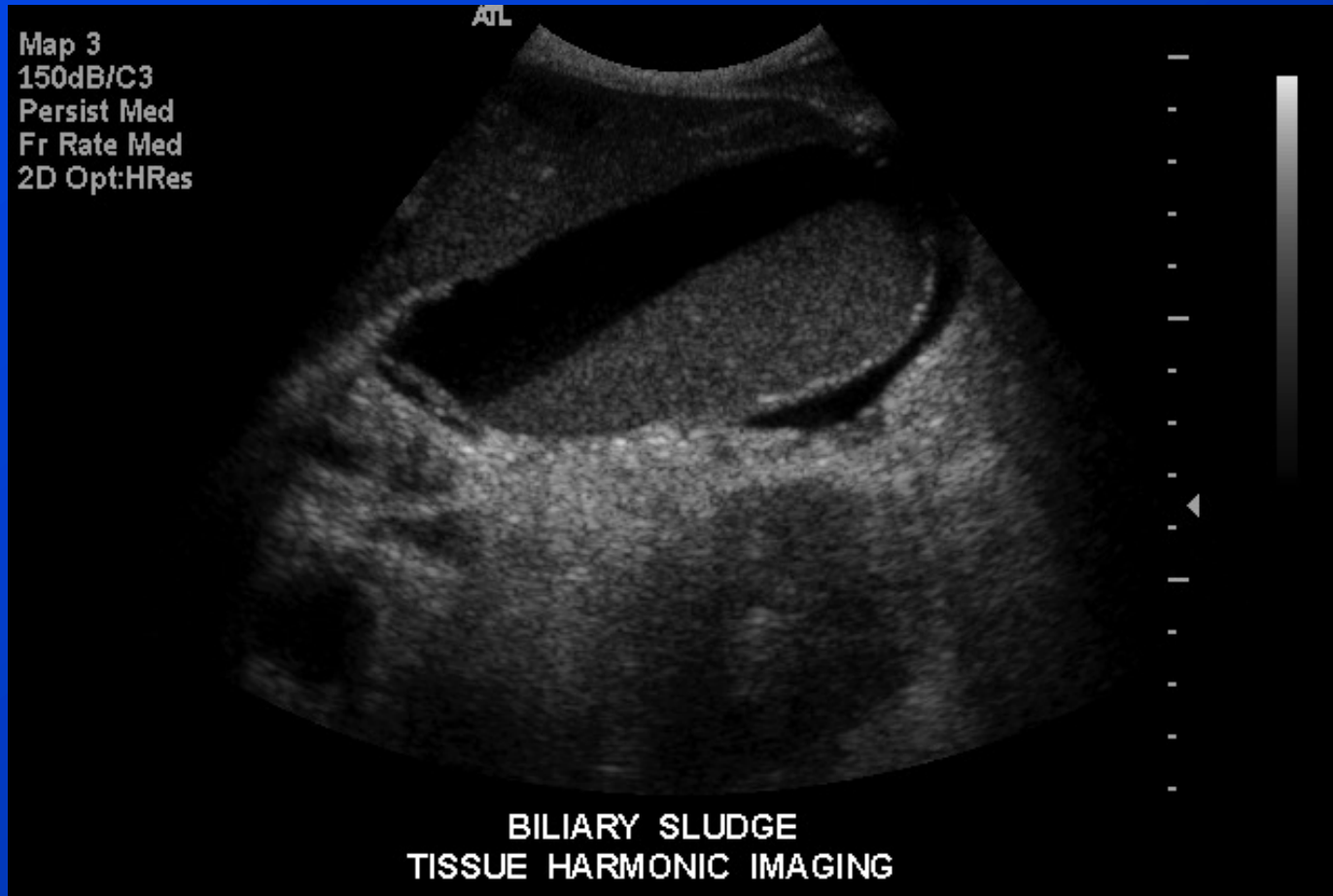
Fundamental Imaging



Harmonic Imaging

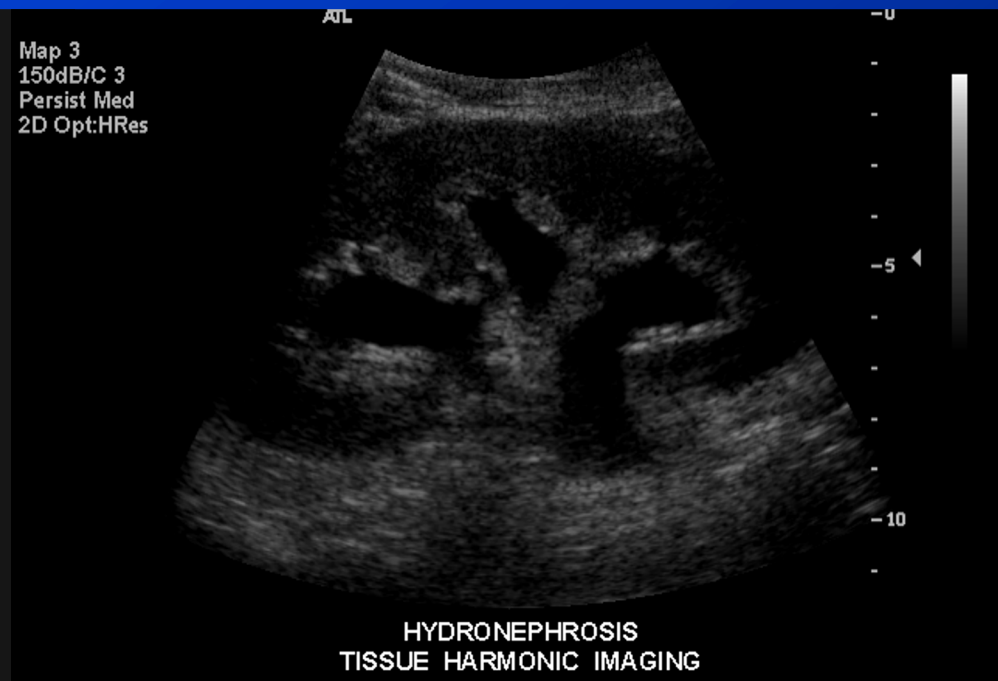
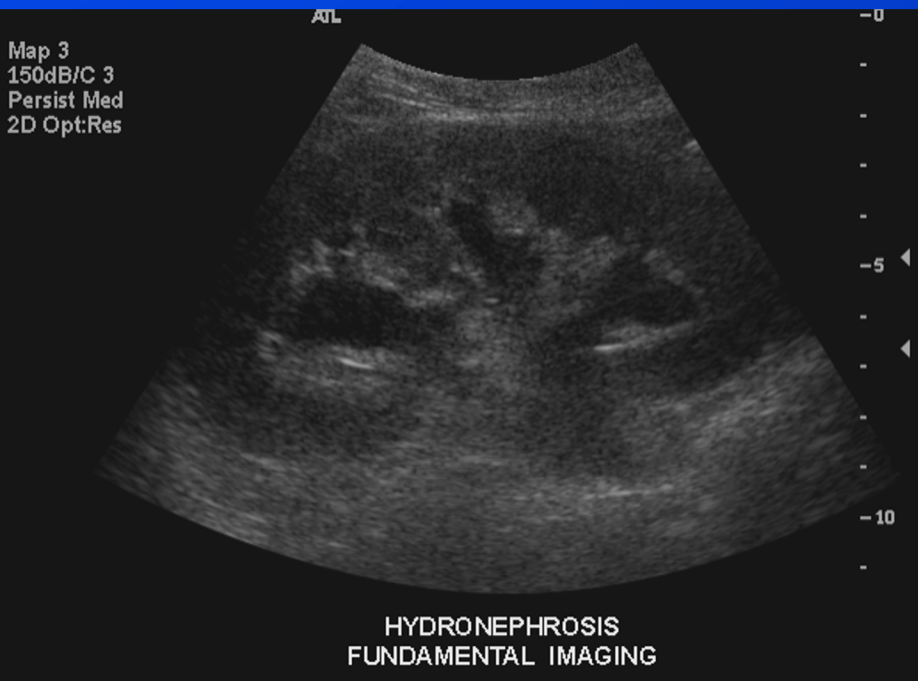


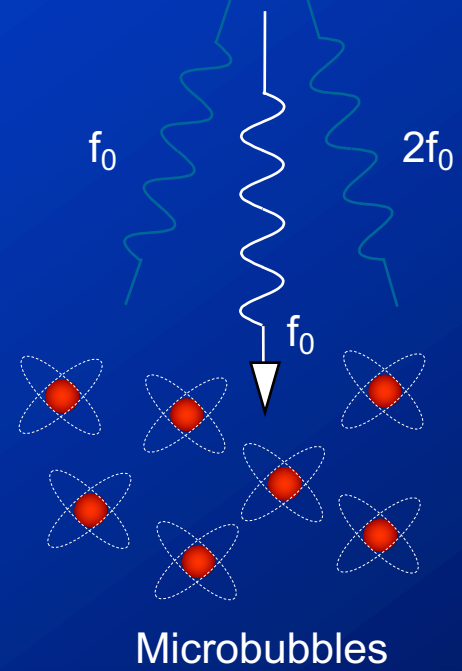
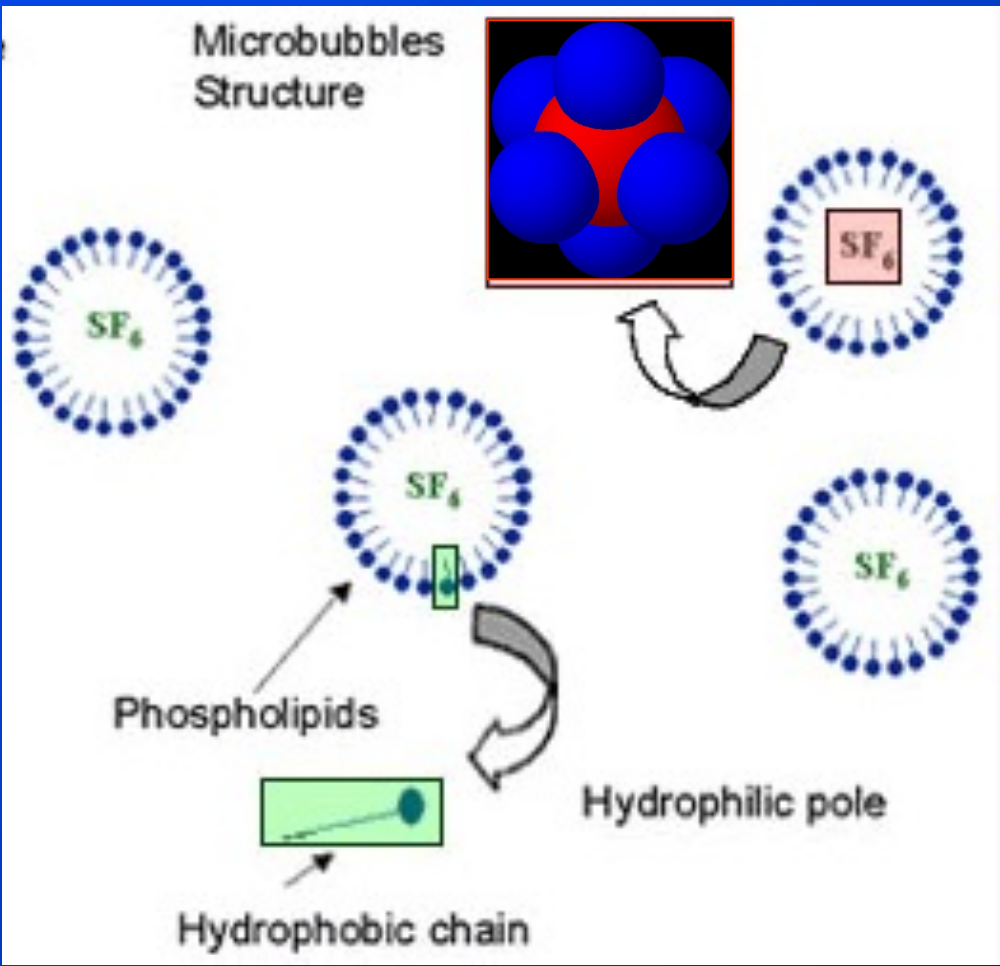
# Harmonic Imaging





# Harmonic Imaging Hydronefrose

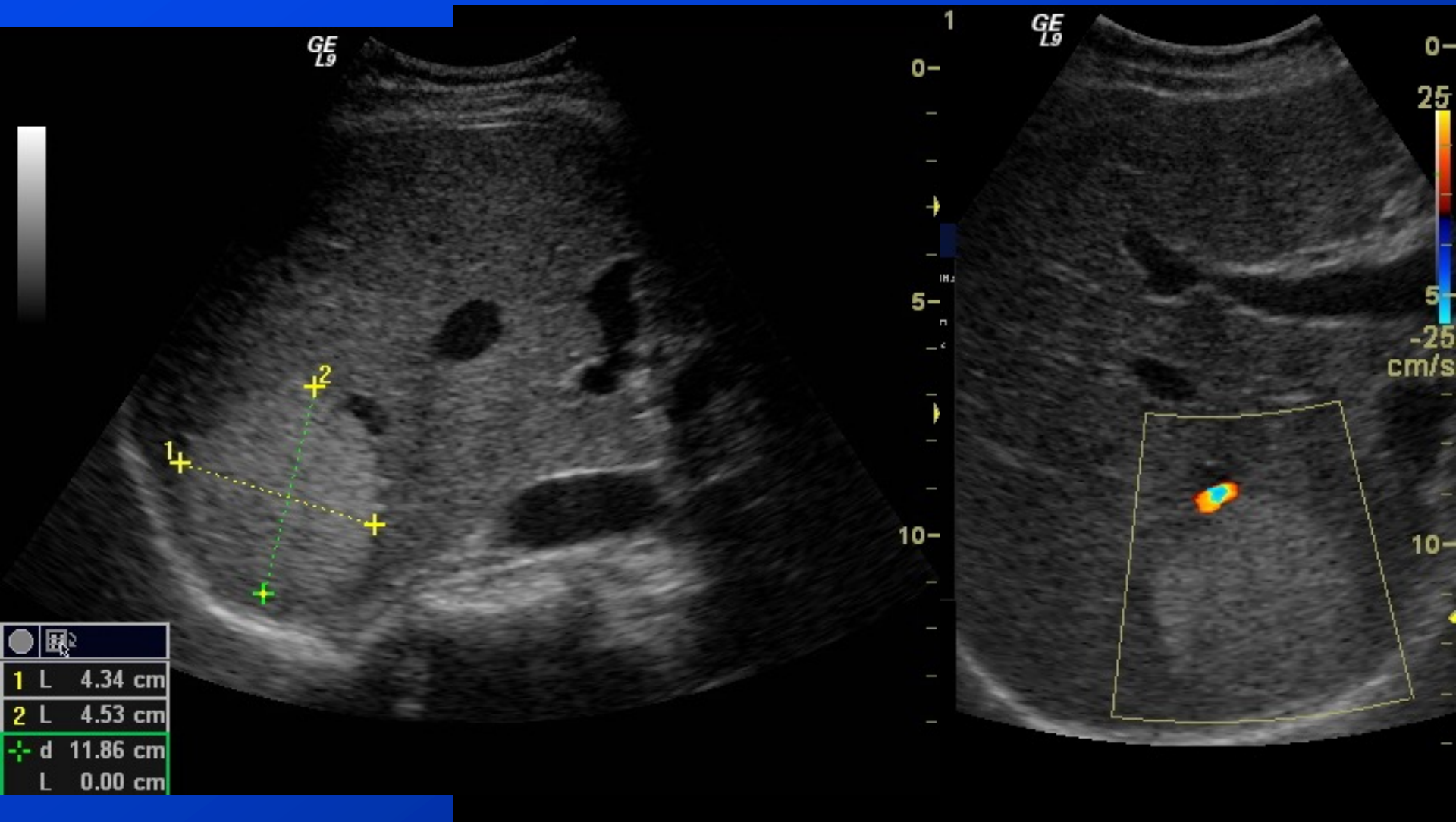








# Referred from the CT-Lab Haemangioma ?





# Peripheral Globular Enhancement



...with slow sentripetal filling



# EFSUMB Guidelines for CEUS

## The EFSUMB Guidelines and Recommendations on the Clinical Practice of Contrast Enhanced Ultrasound (CEUS): Update 2011 on non-hepatic applications

### Authors

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### Affiliations

Affiliation addresses are listed at the end of the article.

### Bibliography

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### Correspondence

### Thematic sections

	Thematic Section	Chairperson
1	Introduction	F. Piscaglia – C. Nolsøe
2	Generalities	D. Cosgrove
3	Equipment	H. P. Weskott
4	Investigator's training	O. H. Gilja

### List of Abbreviations

AAA = Abdominal Aortic Aneurysm  
 AUC = Area Under the Curve  
 CE = Contrast Enhanced  
 CECT = Contrast Enhanced Computed Tomography  
 CEMRI = Contrast Enhanced Magnetic Resonance Imaging

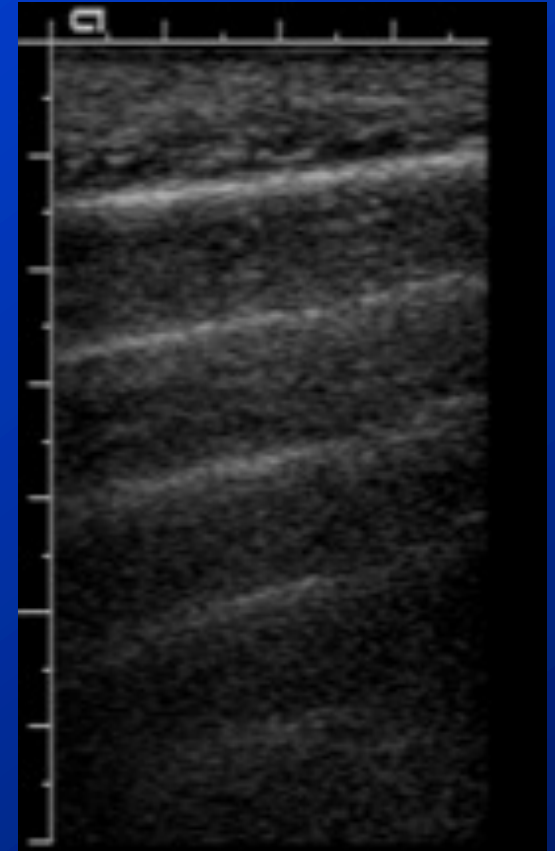
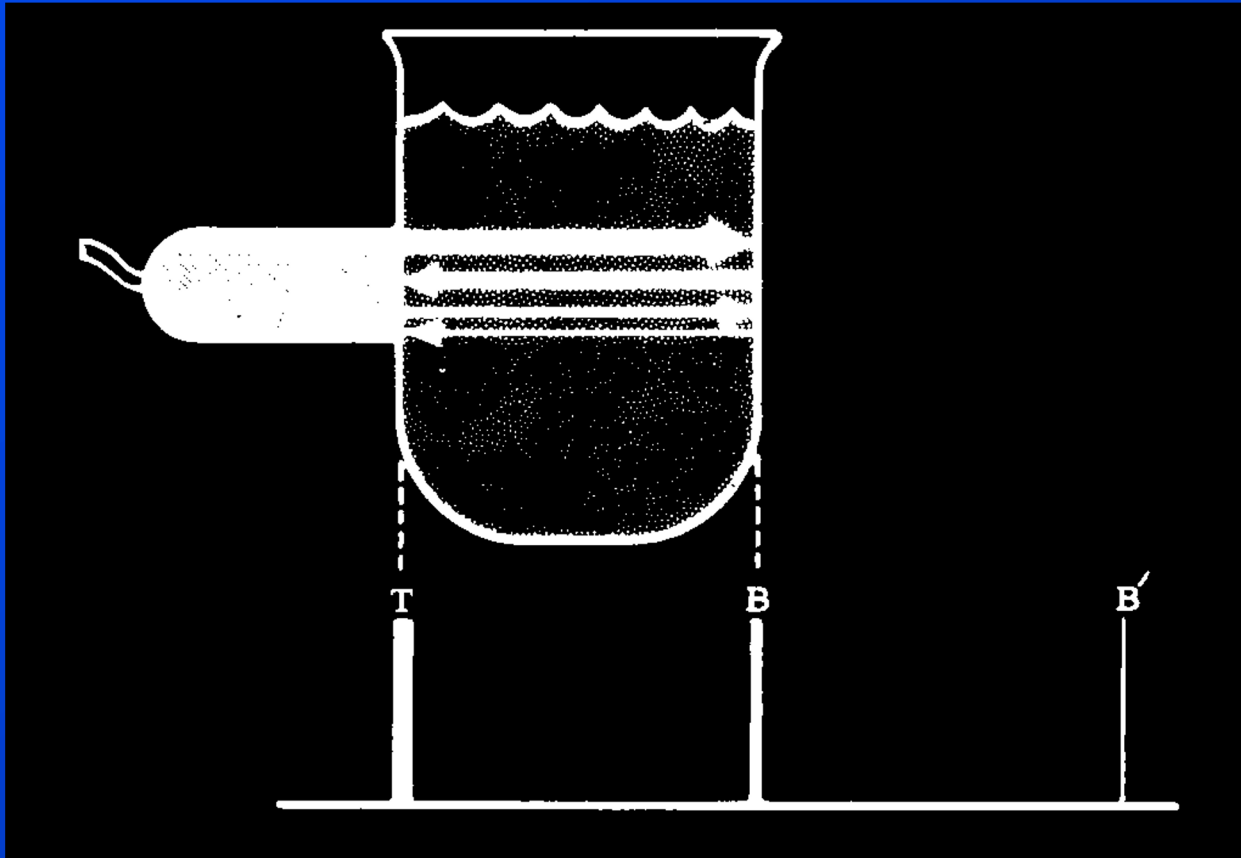
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Over 1200 citations

*Ultraschall Med / EJU Aug. 2011*

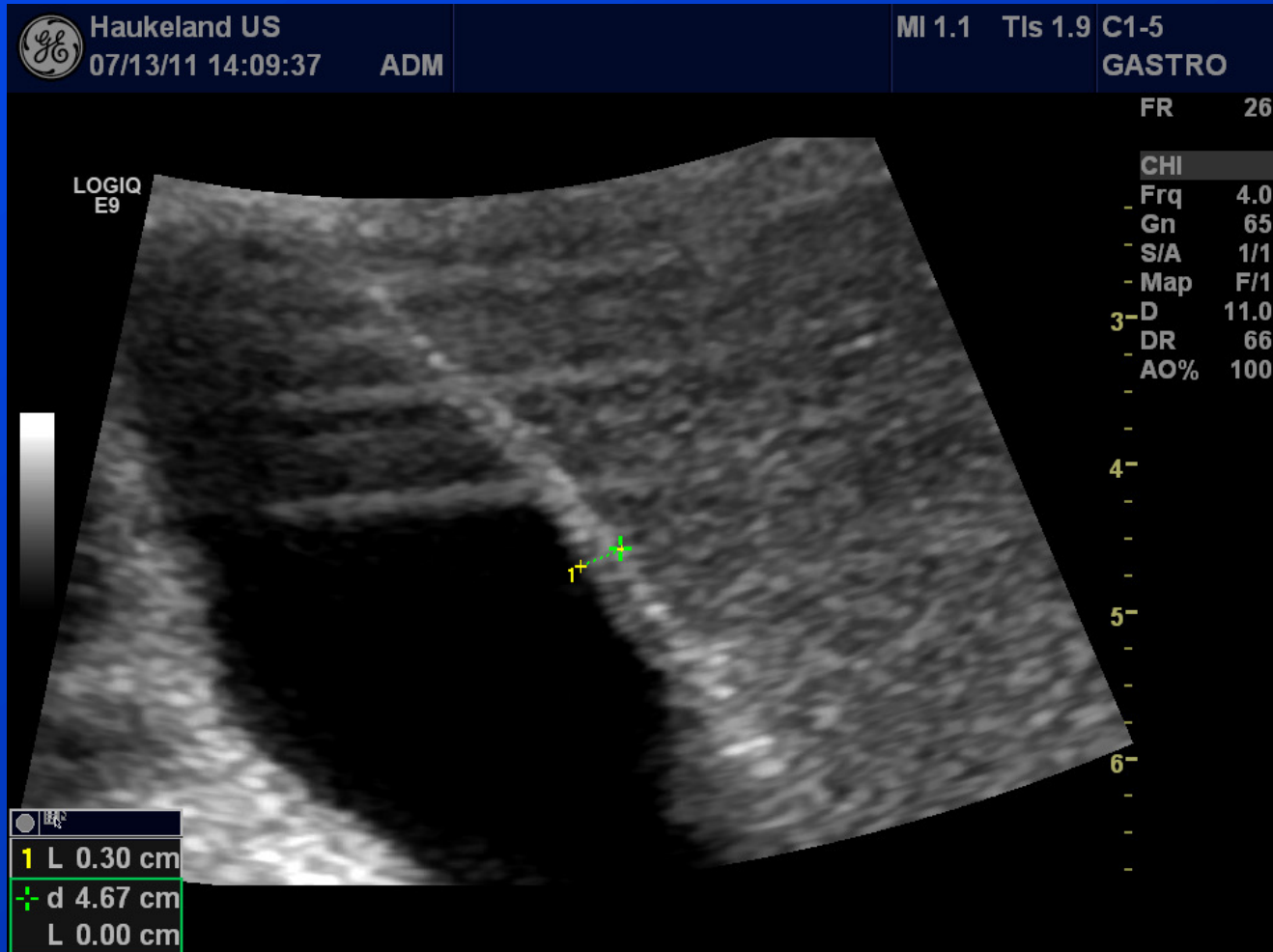


# Artifacts - Reverberations





# Reverberations in Gallbladder



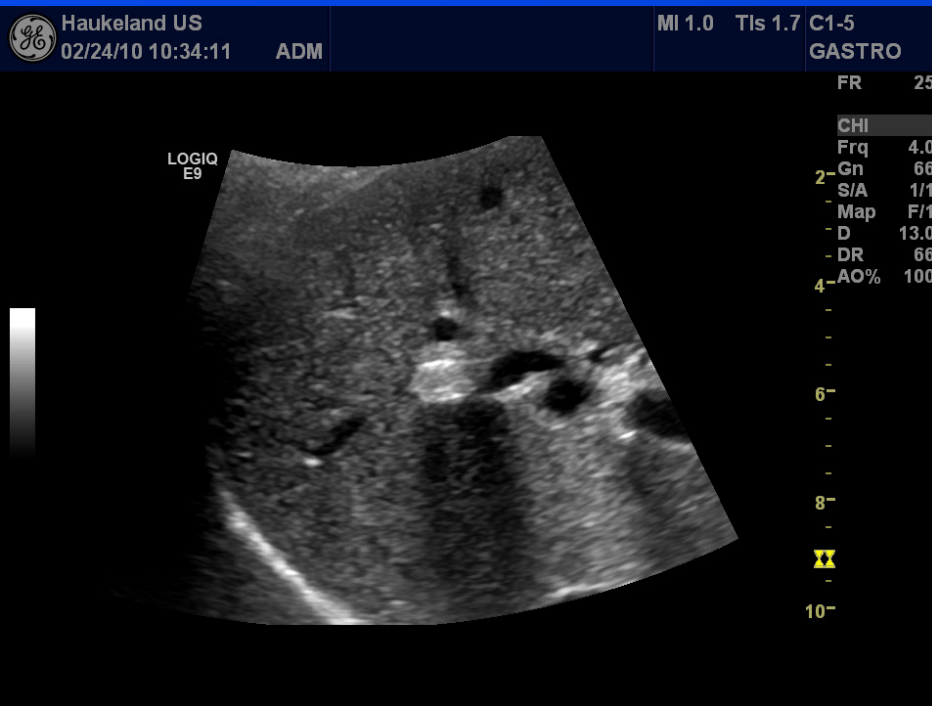


# The Mirror Artifact



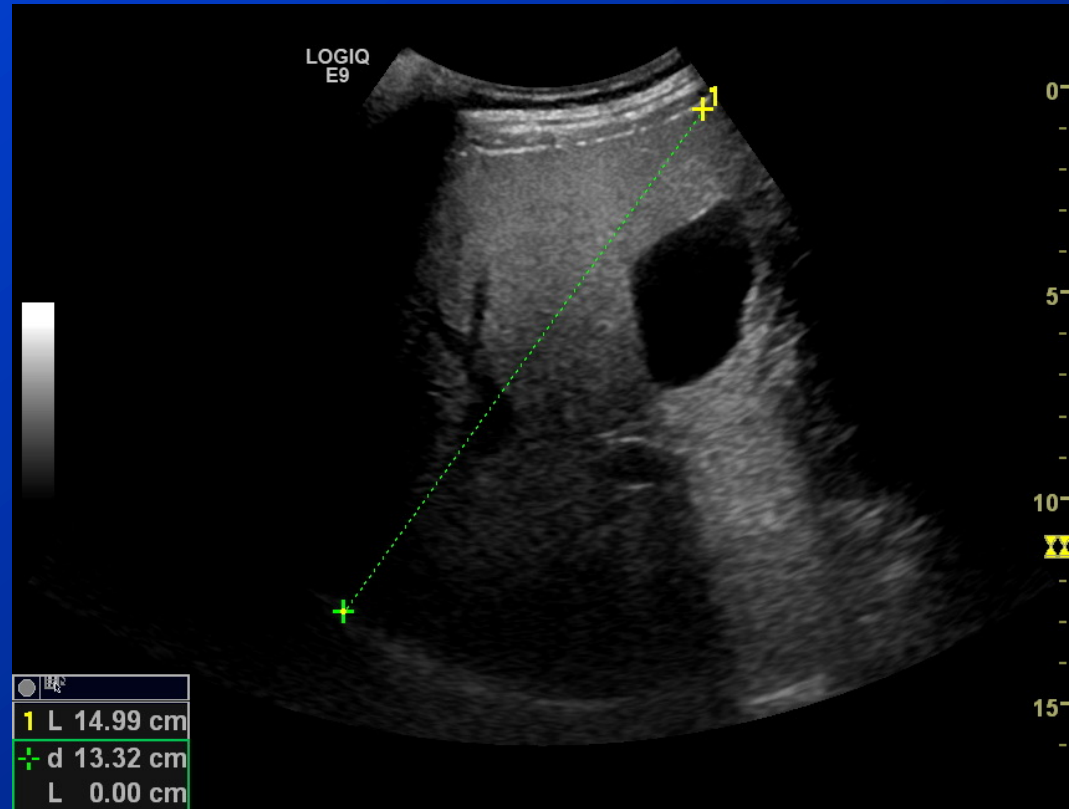


# Artifacts is often clinically helpful





# Acoustic Enhancement





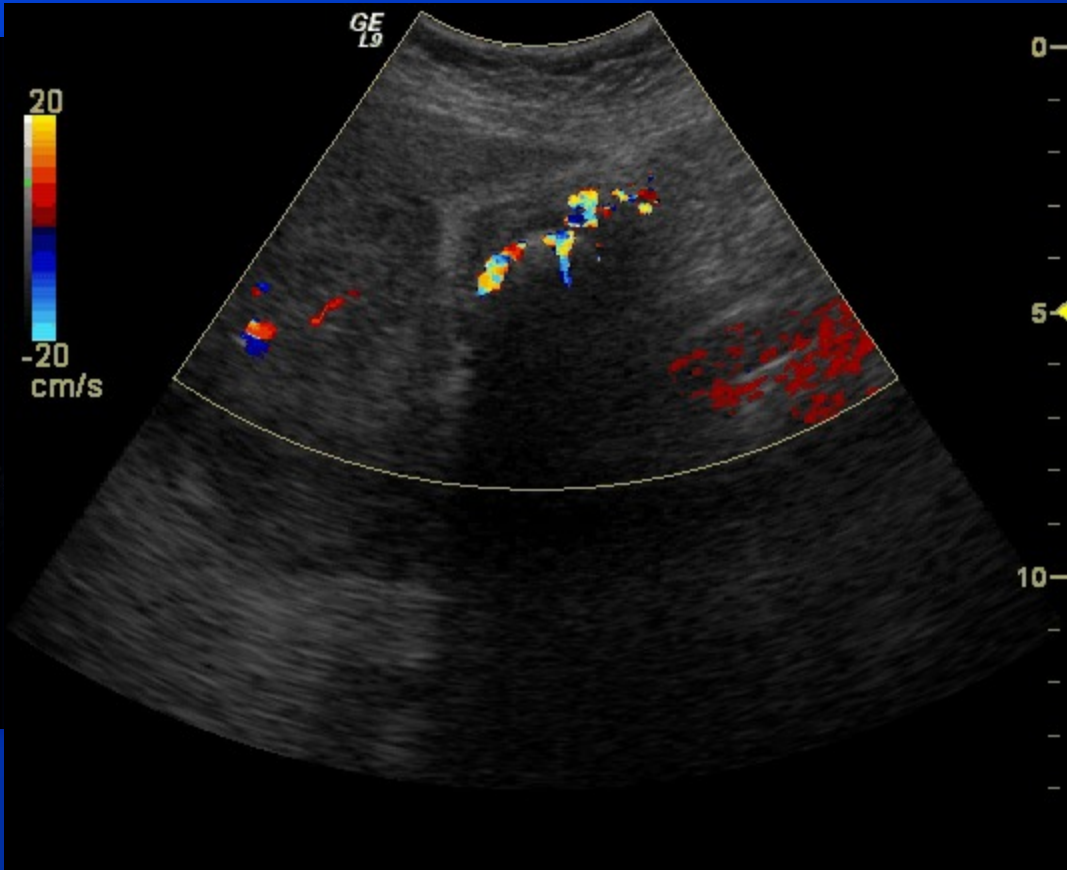
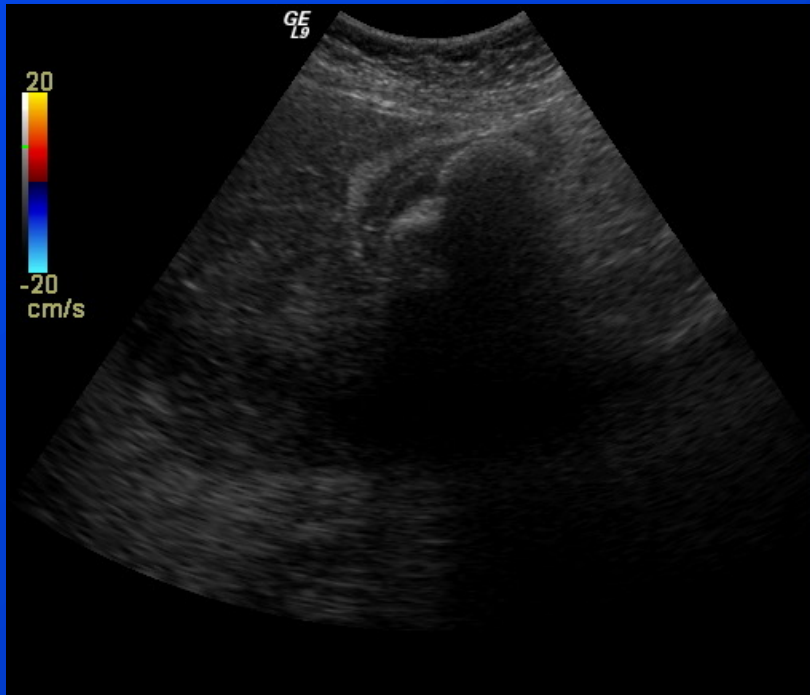


# Shadowing and Comet tail





# Cholecystitis – twinkling artifact





# "Yes, we scan"





US first...



It's not FAKE news!



# Biden ?





# «Green Deal»



Ultrasound is “green”:

- No radiation
- Safe to repeat
- Low cost
- Widely available
- Short travel