# Medical diagnostic systems

**(Orvosbiológiai képalkotó rendszerek)**

# Ultrasound – its place in medical diagnostics

**(Az ultrahang helye az orvosi diagnosztikában)**

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# Radiography (X-ray, CT)

- EM attenuation = mass attenuation coefficient × density

# Magnetic resonance imaging (MRI)

- density, relaxation times $T_1$,$T_2$ of (proton) magnetic dipoles

# Nuclear medicine (PET)

- emissions from radioisotopes (e.g. fludeoxyglucose $^{18}F$)

# Ultrasound (B-mode, Doppler)

- level of backscatter from different depths (arrival times)
- frequency shift in received signal

# Radiography (X-ray, CT)

- photoelectric effect, Compton scattering

# Magnetic resonance imaging (MRI)

- resonance, relaxation, shielding, tumbling

# Nuclear medicine (PET)

- metabolic uptake of radioisotopes

# Ultrasound (B-mode, Doppler)

- density, compressibility contrast → scattering
- moving scatterers → Doppler effect
- density and compressibility → speed of sound (SoS)
- absorption and scattering → attenuation

# Radiography (X-ray, CT)

- 30 keV(≈41 nm), ½-value thickness [Akar *et al.* 2006]:

  bone: 2.7 mm; muscle: 17.4 mm; water 18.5 mm

# Magnetic resonance imaging (MRI)

- 1.5 T, spin-lattice relaxation time $T_1$ [Nitz and Reimer 1999]:

  normal liver: 493 ms; malignant liver: 905 ms

# Nuclear medicine (PET)

- 5 μg/g/min glucose metabolic rate in bone marrow [Yao *et al.* 1995]

# Ultrasound (B-mode)

- backscatter/stiffness/attenuation/SoS/density/non-linearity...

# Advantages of ultrasond

- cheap (~$20k machine, personnel, electricity, gel)
- portable
- fast (10-100 Hz)
- *relatively* safe

# Disadvantages of ultrasound

- qualitative
- poor image quality (speckle)
- depth/resolution trade-off


"Ultrasound image of normal 24 week fetus"
http://images.wellcome.ac.uk N0019385
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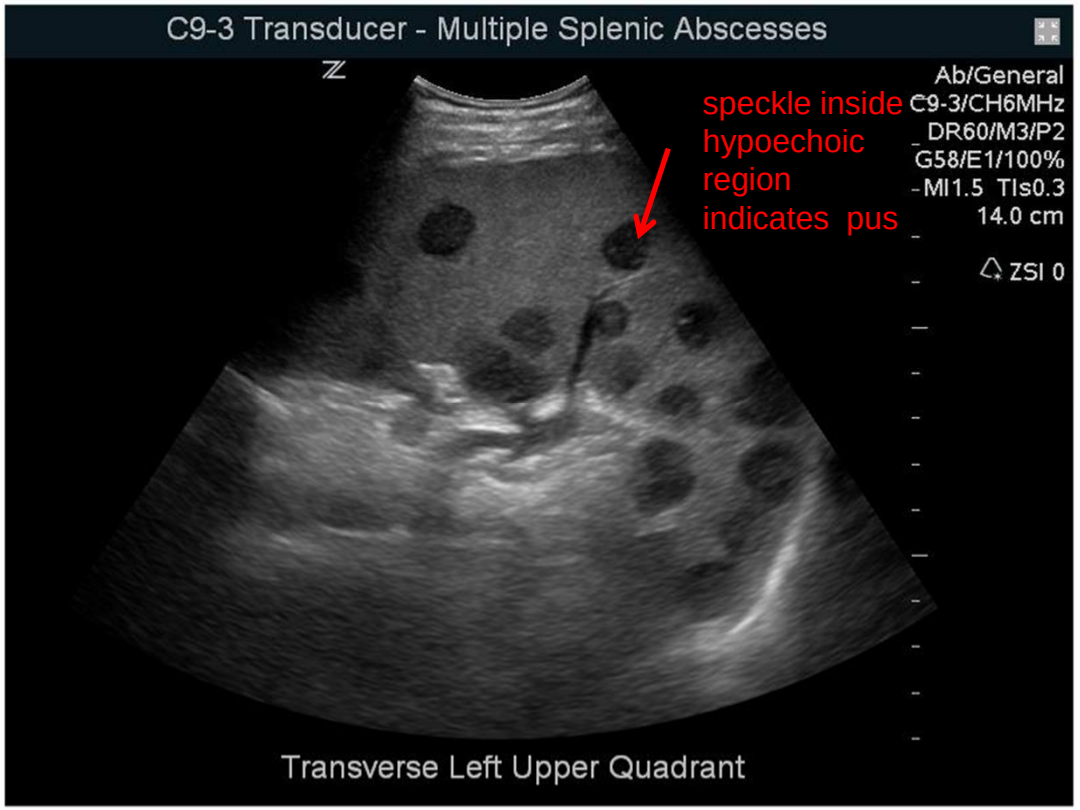
# Applications of ultrasound

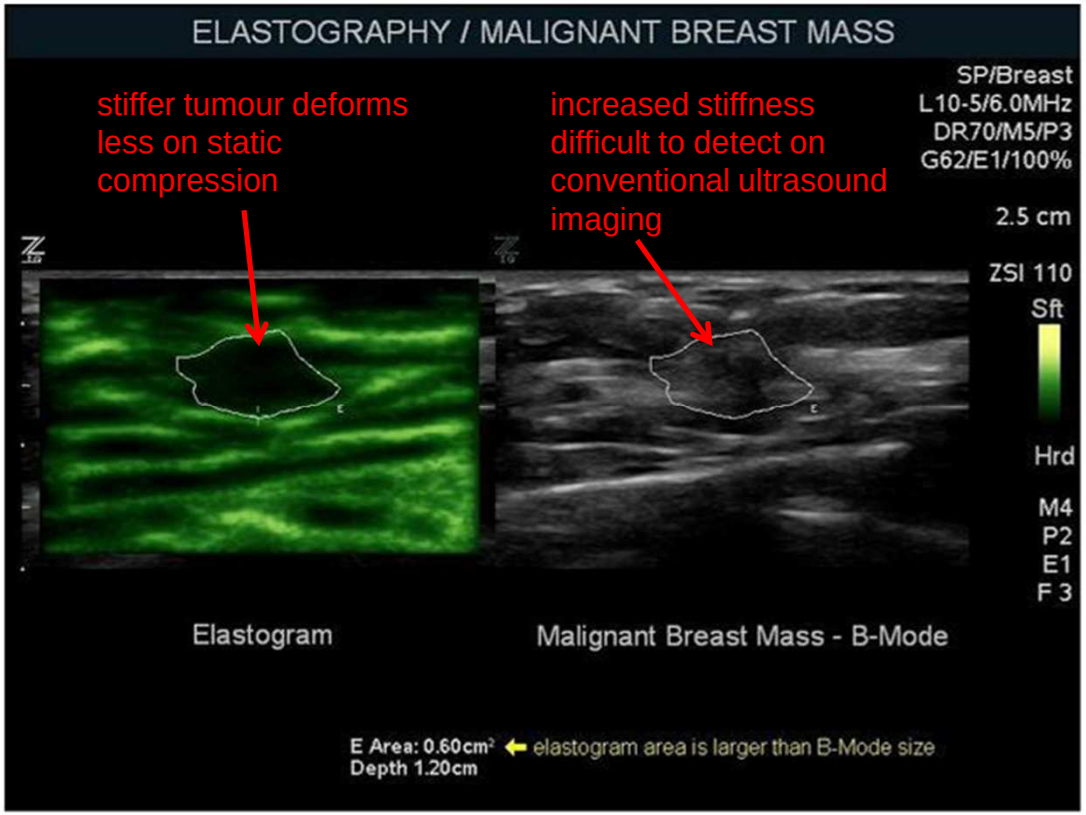
| Application | Example | Why ultrasound? |
|---|---|---|
| Abdominal organs | Cysts | Water-filled cysts very hypoechoic; speckle indicates pus |
| Cancer diagnosis | Hard lumps | Ultrasound elastography for detecting stiff inclusions |
| Cardiovascular system | Heart motion | High frame rate; Doppler effect |
| Eye | Biometry | Strong echoes from boundaries; accurate distance measurement |
| Foetus | Measure size | Safety; easy delineation of baby from hypoechoic amniotic fluid |

# Abscess (pus) in the spleen



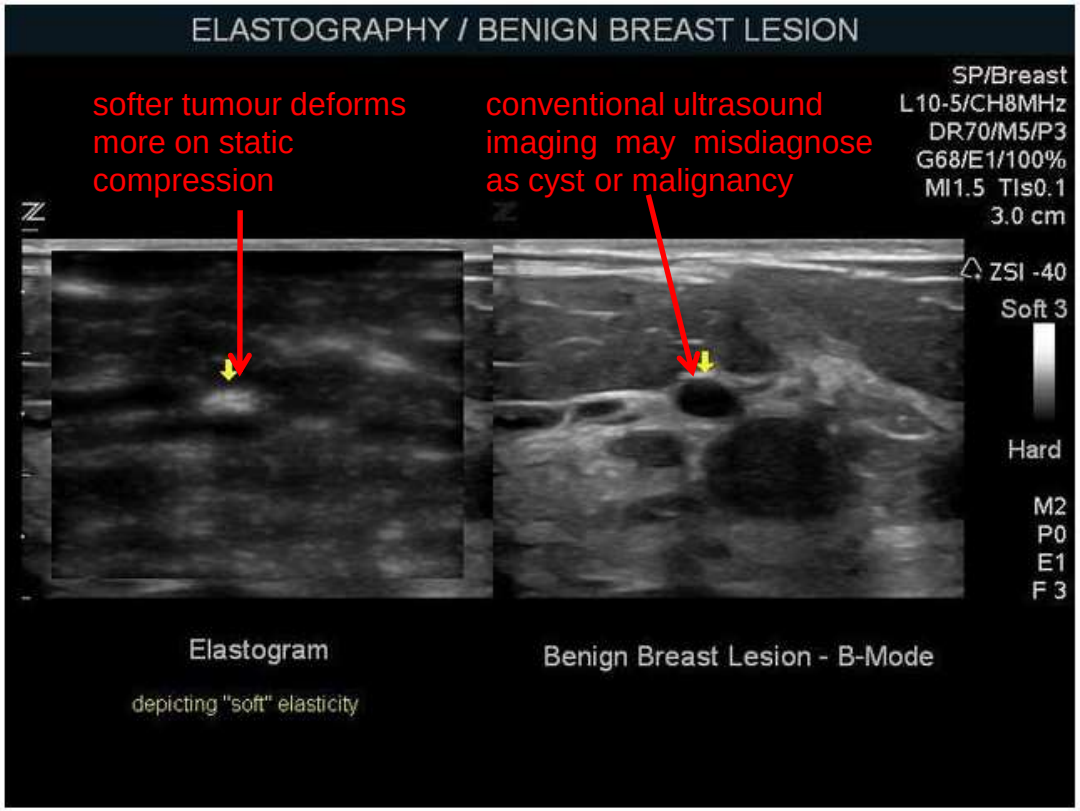

Courtesy of Zonare Medical Systems
http://www.zonare.com/products/clinical-images/id_2/

# Cancerous (malignant) breast tumour




Courtesy of Zonare Medical Systems
http://www.zonare.com/products/clinical-images/id_4/

# Benign breast tumour

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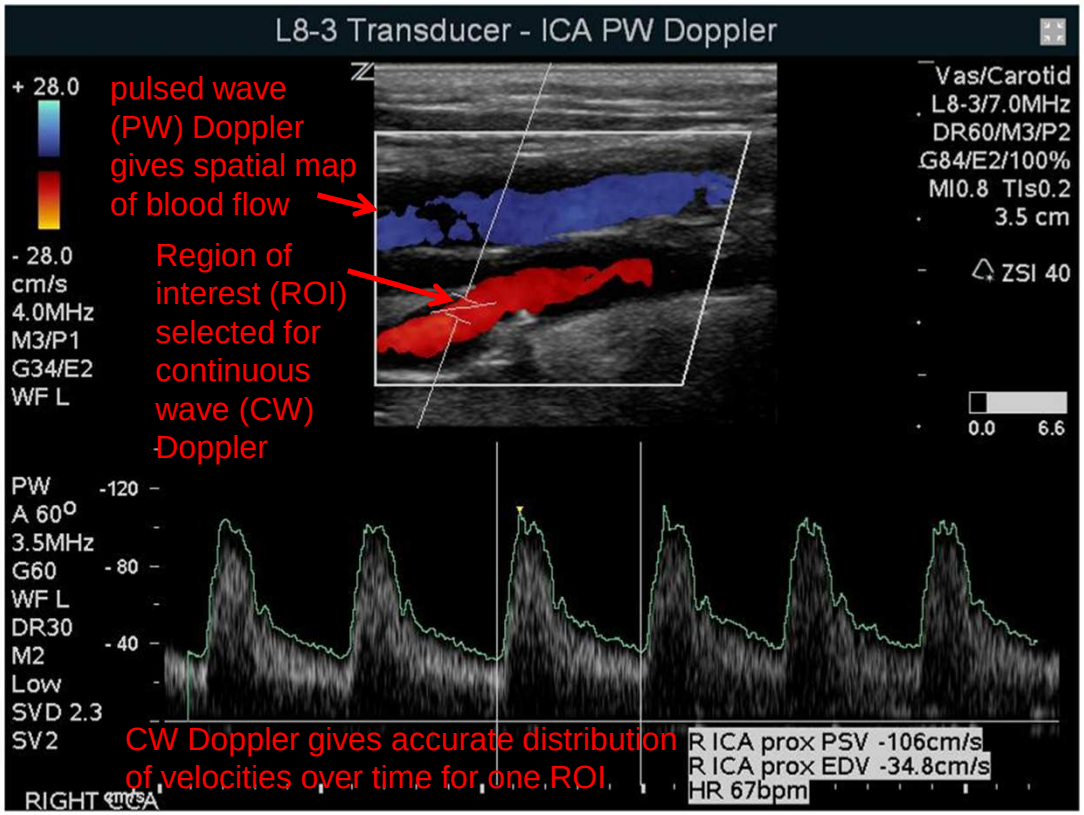
http://www.zonare.com/products/clinical-images/id_4/

# Internal carotid artery blood flow

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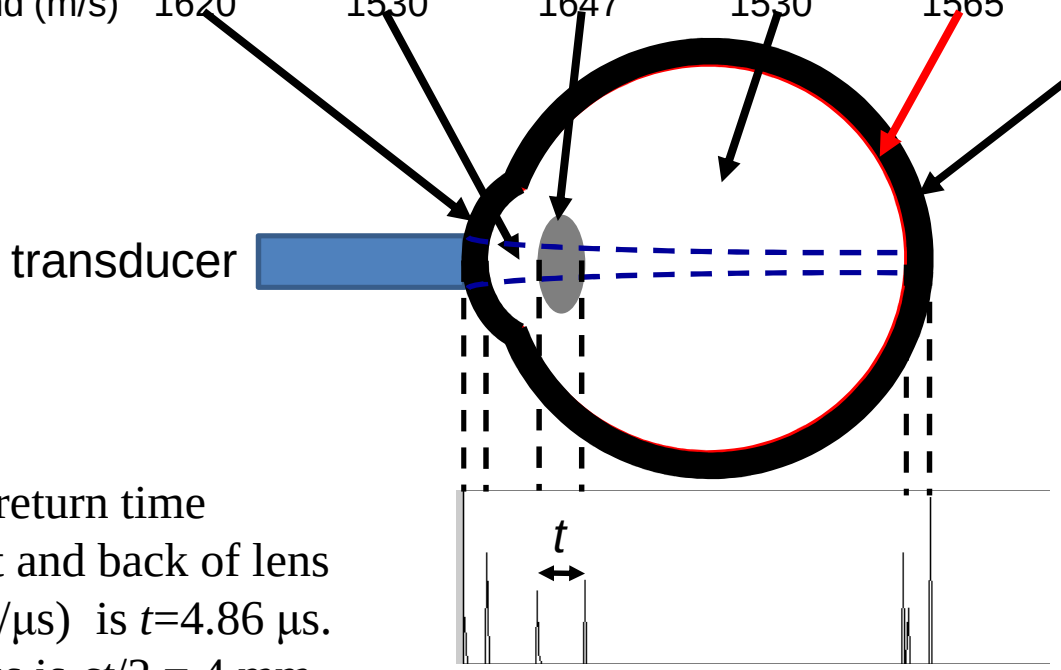
http://www.zonare.com/products/clinical-images/id_10/

# Eye biometry

[Thijssen1993]

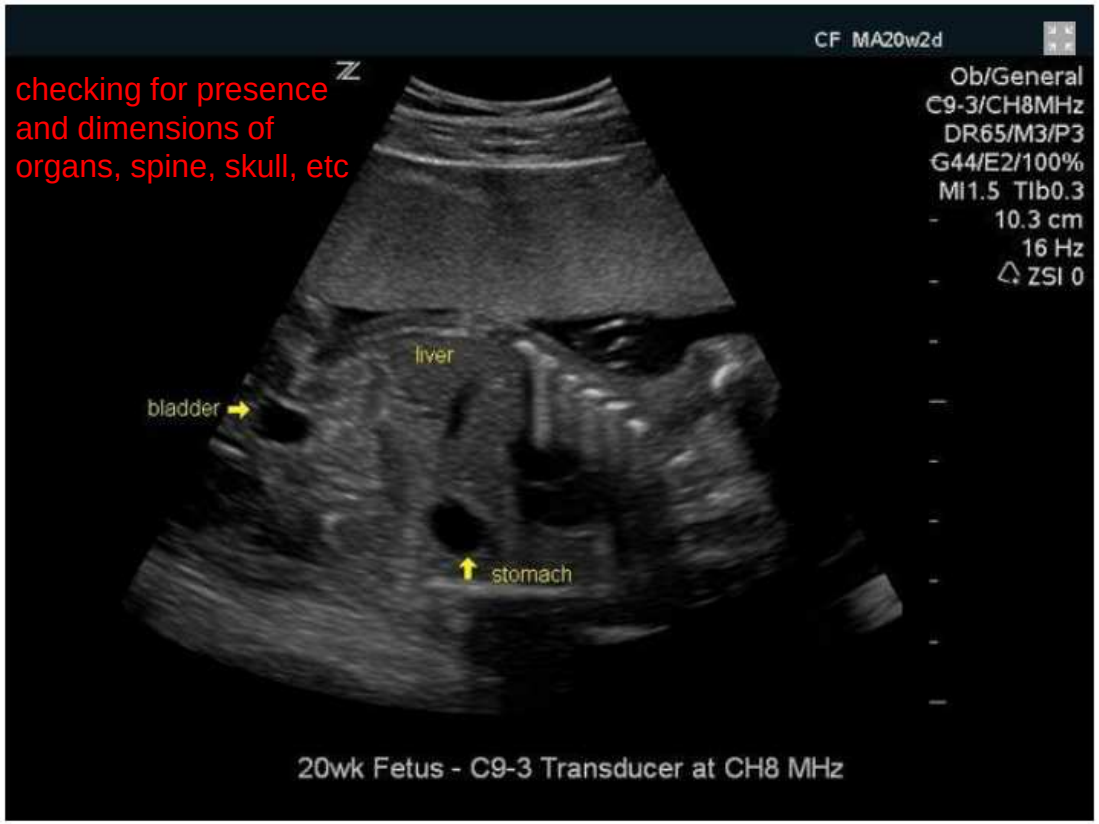
| | cornea | aqueous humour | lens | vitreous humour | retina | sclera |
|---|---|---|---|---|---|---|
| speed of sound (m/s) | 1620 | 1530 | 1647 | 1530 | 1565 | 1650 |




simulated echoes from eye based on image above

Example:
difference in return time between front and back of lens (c=1.647 mm/μs) is $t$=4.86 μs.
Lens thickness is $ct/2$ = 4 mm.

# Foetus




Courtesy of Zonare Medical Systems
http://www.zonare.com/products/clinical-images/id_7/

# References

[Akar *et al.* 2006] Measurement of attenuation coefficents for bone, muscle, fat and water at 140, 364 and 662 keV γ-ray energies. http://enformatik.ktu.edu.tr/eakademik/1703/articles/makale_25.pdf

[Nitz and Reimer 1999] Contrast mechanisms in MR imaging

[Thijssen 1993] The history of ultrasound techniques in ophthalmology

[Yao *et al.* 1995] Quantitative PET imaging of bone marrow glucose metabolic response to hematopoietic cytokines