TRENDS IN MEDICAL IMAGING

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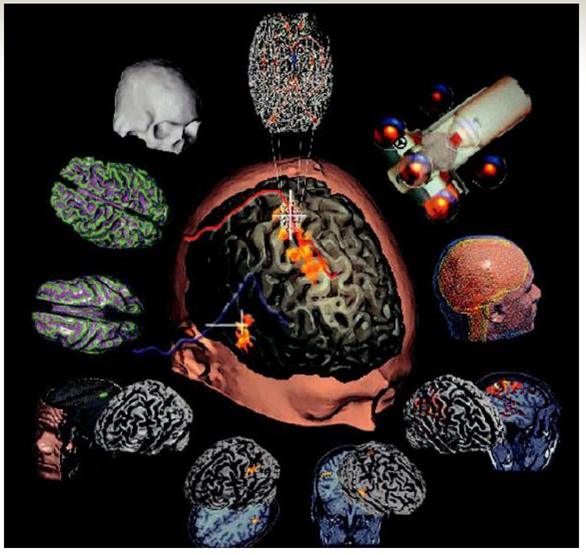
Medical Equipment I
Part II (2009)



Objective

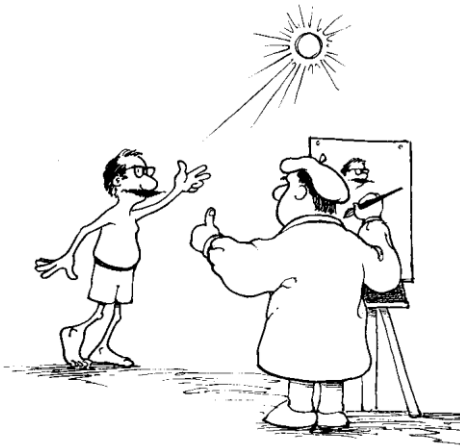
- Provide an overview of medical imaging to promote student interest and knowledge of its basic ideas and clinical applications

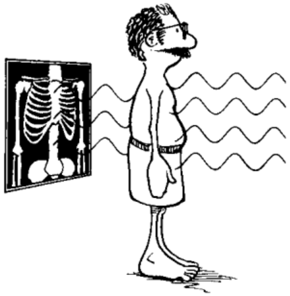
Contents

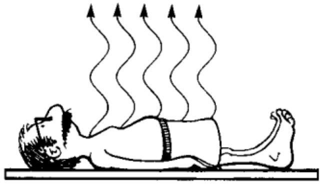
- Basic Ideas of Medical Imaging
- Brief history
- How it works: Examples for ultrasound, x-ray and MRI
- Applications
  - Imaging of anatomy
  - Imaging of flow
  - Imaging of function
  - Imaging of chemical composition
  - Image-guided interventions
- Challenges for biomedical imaging

Basic Ideas of Imaging

- To use a means to measure and map a useful property of the human tissues
- Non-invasive or minimally-invasive
- Examples:
  - Reflection – photography, ultrasound
  - Transmission – x-rays
  - Radiation – MRI, PET/SPECT







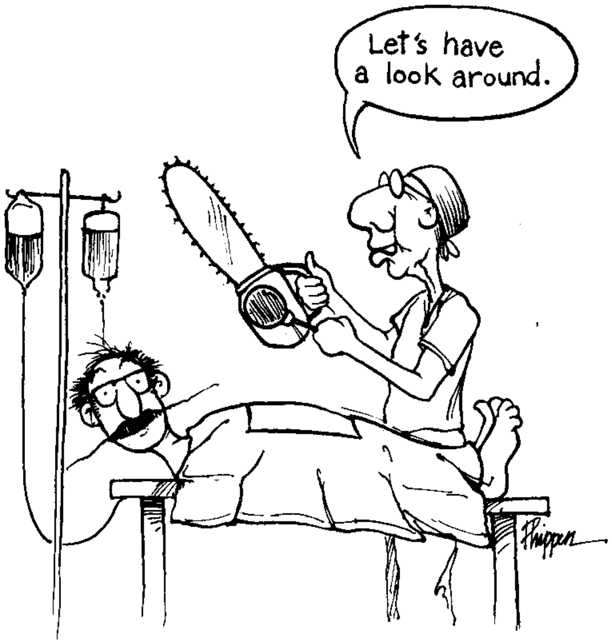
Imaging Methods

- A variety of energy sources can be used to measure one or many tissue properties

Energy Sources	*Tissue Properties*	*Image Properties*
X rays	Mass density	Transmissivity
γ rays	Electron density	Opacity
Visible light	Proton density	Emissivity
Ultraviolet light	Atomic number	Reflectivity
Annihilation Radiation	Velocity	Conductivity
Electric fields	Pharmaceutical Location	Magnetizability
Magnetic fields	Current flow	Resonance
Infrared	Relaxation	Absorption
Ultrasound	Blood volume/flow	
Applied voltage	Oxygenation level of blood	
	Temperature	
	Chemical state	

History of Medical Imaging

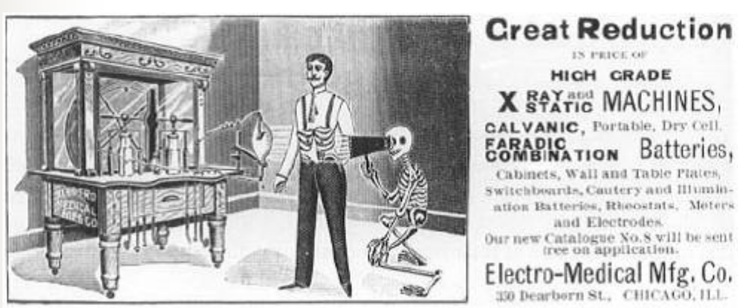
- In the 1800s and before, physicians were extremely limited in their ability to obtain information about the illnesses and injuries of patients.
  - They relied essentially on the five human senses



History of Biomedical Imaging

- 1895: physicist Wilhelm Röntgen, discovered x-rays
- A few months later, the use of x-rays in medical application started in several places

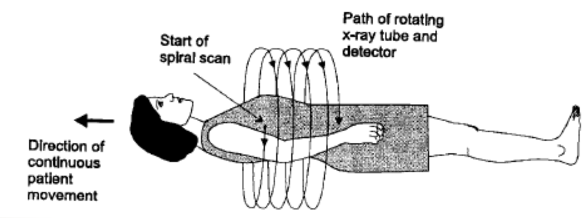
Poster for a public demonstration of x rays, 1896, Crystal Place Exhibition, London and an advertisement for x-ray studio

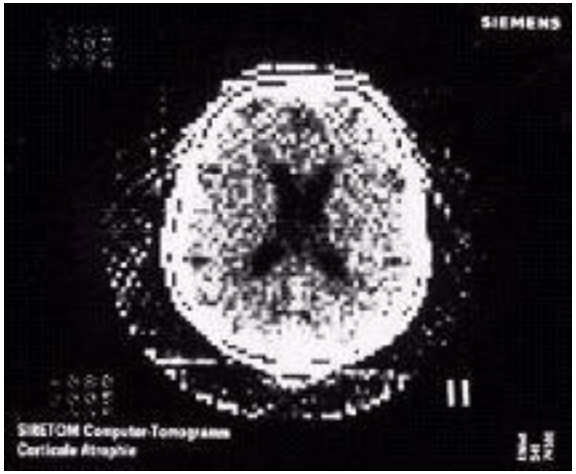


First x-ray "movie" showing 5 views of a frog's leg

History of Biomedical Imaging

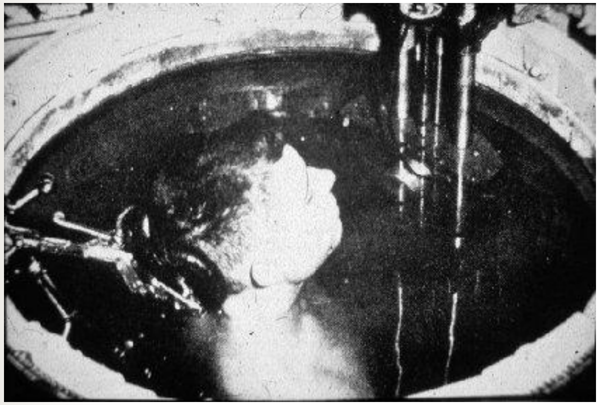
- 1972: CT was invented by Godfrey Hounsfield of EMI Laboratories
- 1989: Spiral CT was introduced

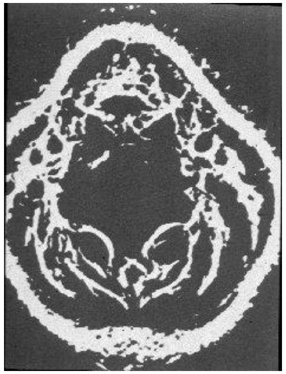


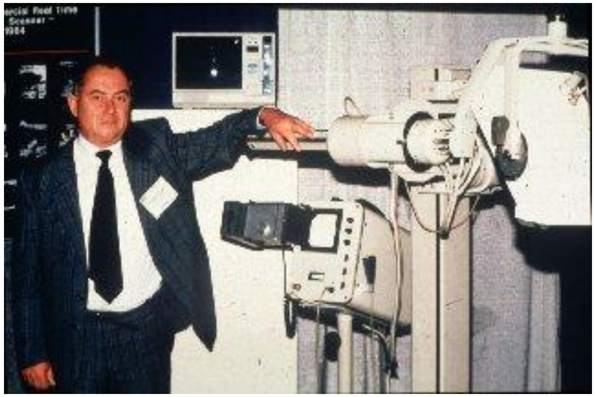


History of Biomedical Imaging

- WW-I: Sonar
- 1942: ultrasound in medicine
- 1963: Real-time ultrasound

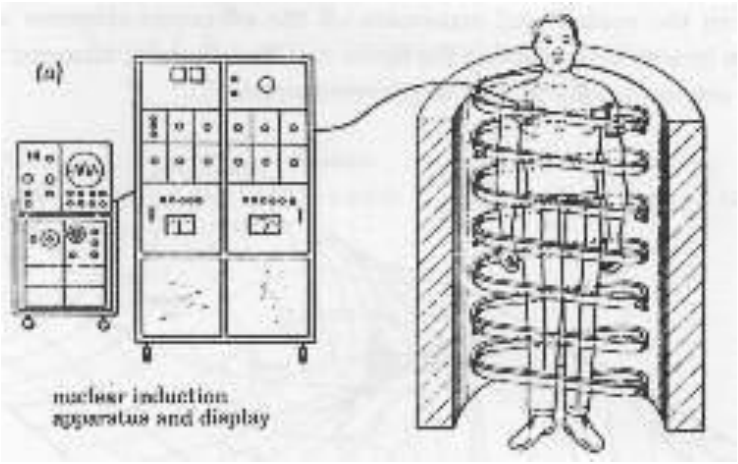


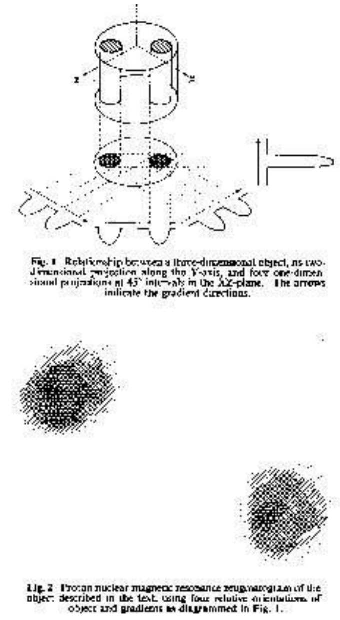




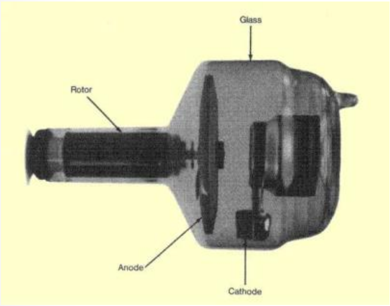
History of Biomedical Imaging

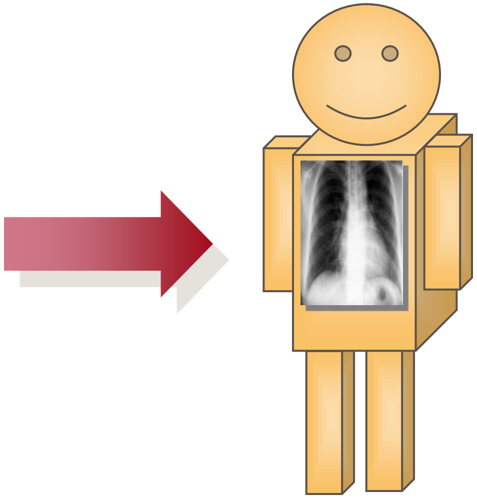
- 1946: Felix Bloch and Edward M. Purcell independently described the NMR phenomenon
- 1973: Magnetic resonance imaging was first demonstrated on small test tube samples by Paul Lauterbur.

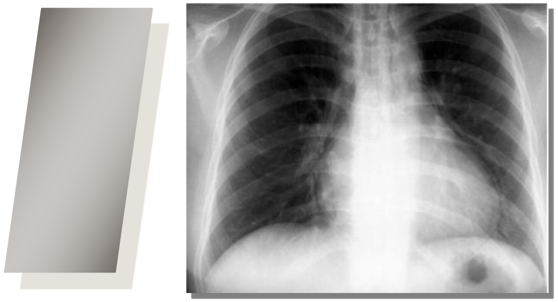




Plain X-Ray Imaging





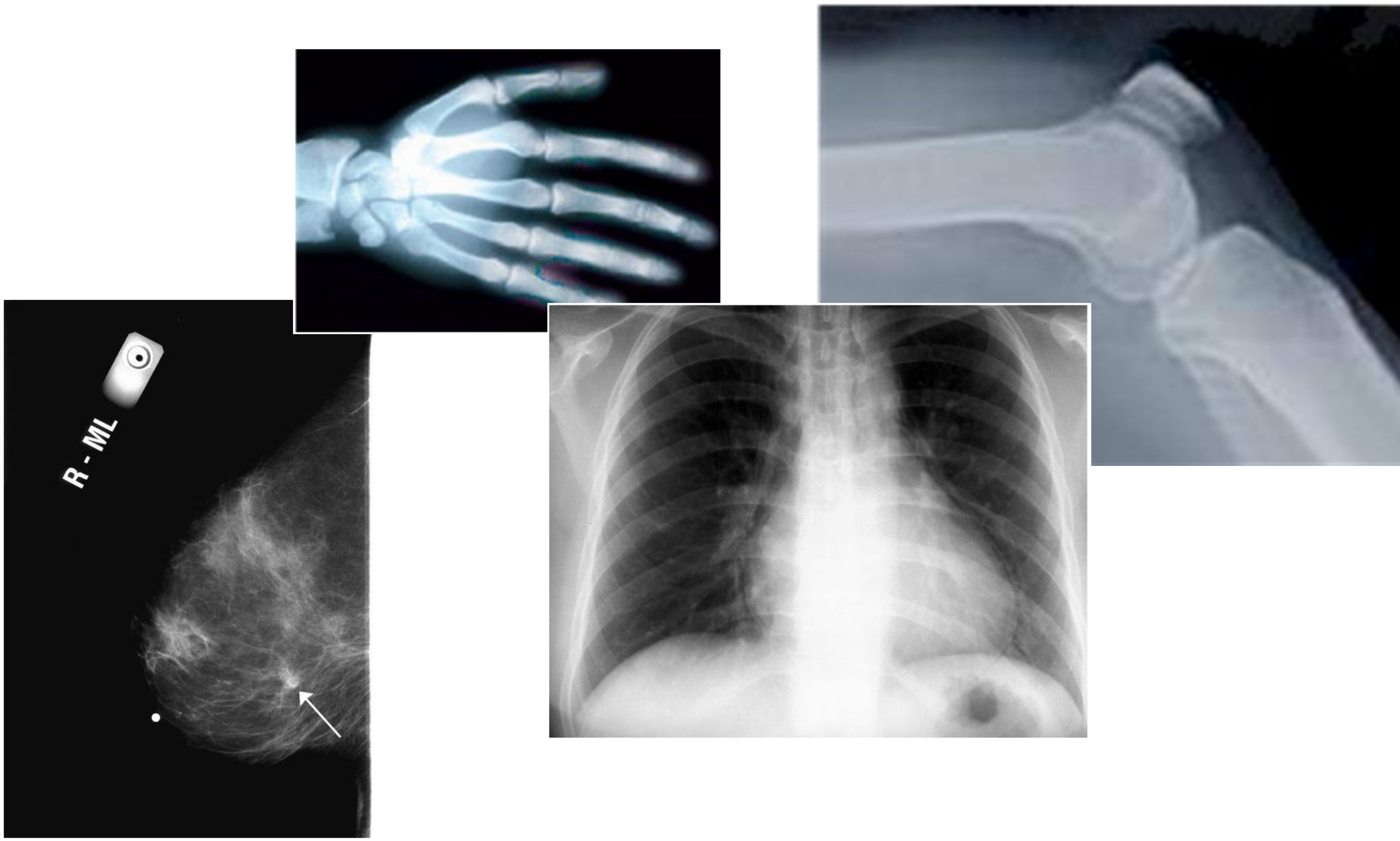


X-Ray Tube

Patient

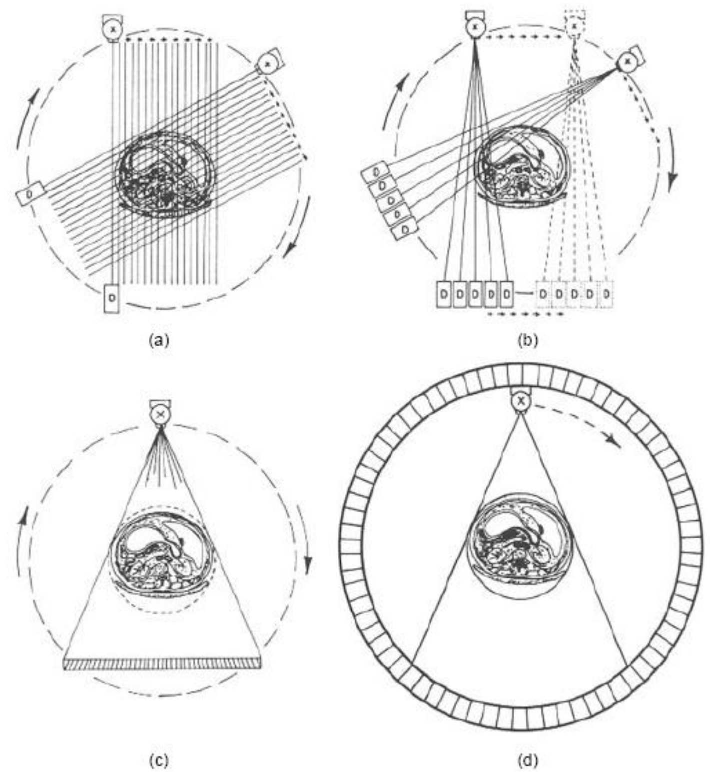
Film

X-Ray Imaging
Applications and Limitations



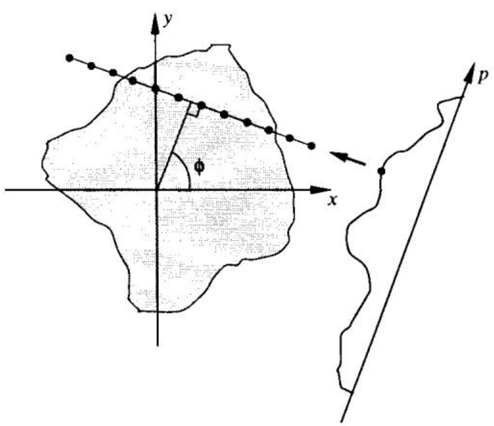
Computerized Tomography (CT)

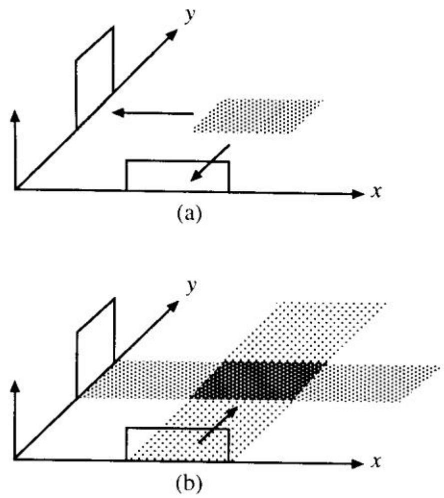
- Collect enough information to estimate and map x-ray attenuation



CT: Back-Projection Method

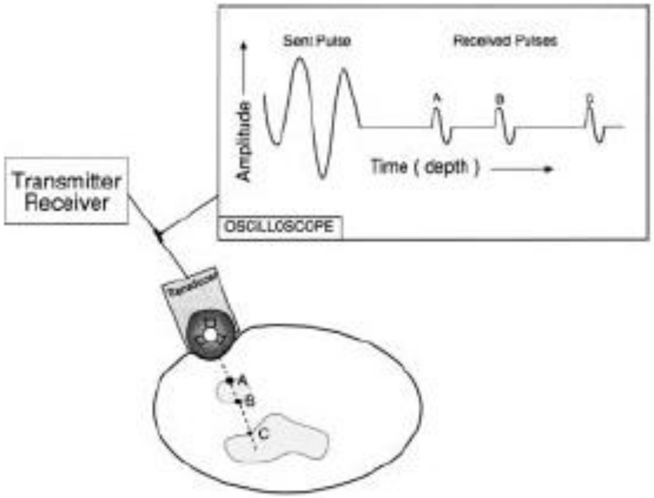
- Start from a projection value and back-project a ray of equal pixel values that would sum to the same value
- Back-projected ray is added to the estimated image and the process is repeated for all projection points at all angles
- With sufficient projection angles, structures can be somewhat restored

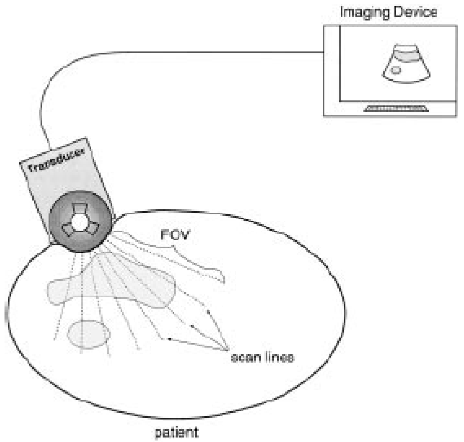


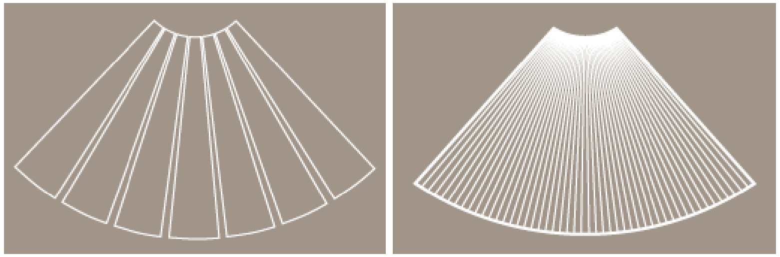


Ultrasound Imaging

- Acoustic energy is sent through the body
- Reflected energy is detected and used to construct an image

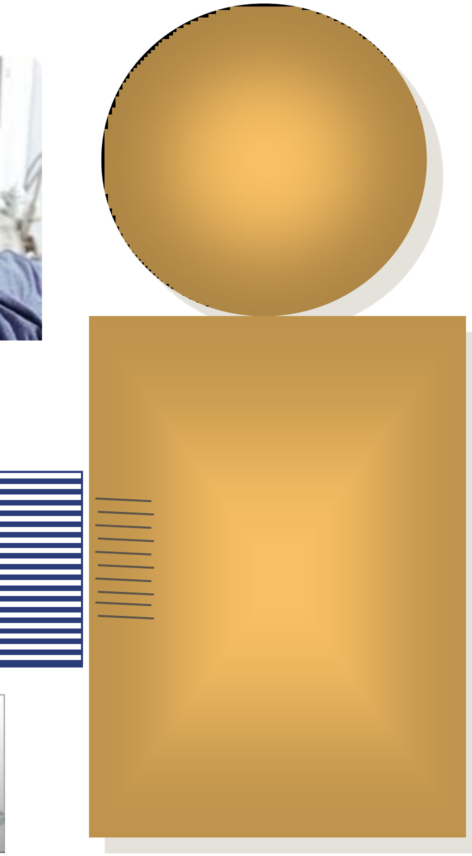






Ultrasound Imaging

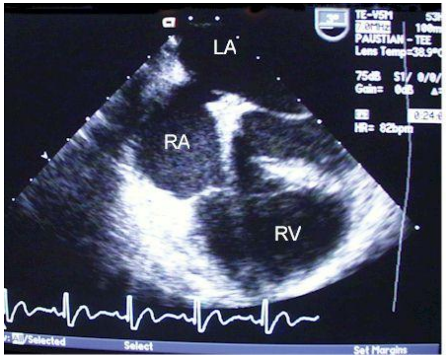
Probe



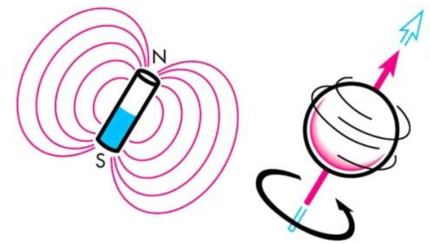
Patient

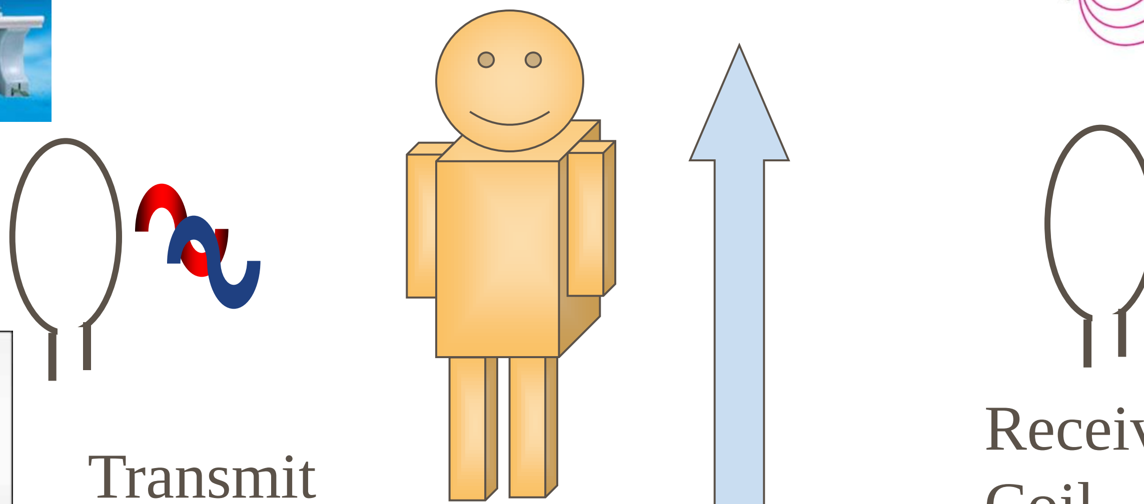
Image on Monitor

Ultrasound Imaging Applications and Limitations



Magnetic Resonance Imaging (MRI)





Transmit Coil

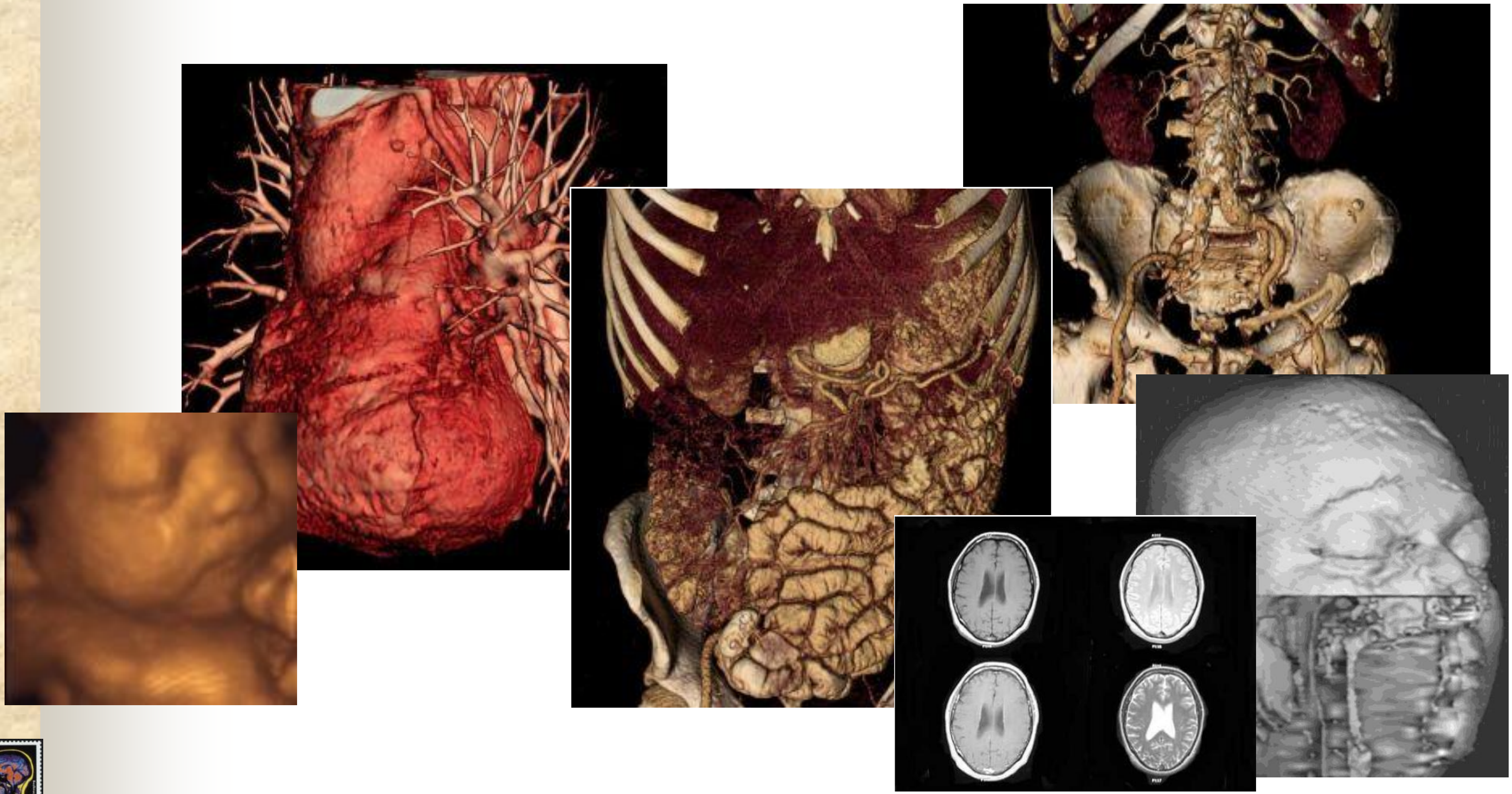
Strong Magnetic Field

Receive Coil

Applications of Medical Imaging

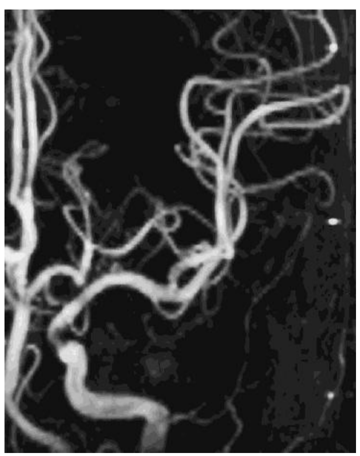
- Imaging of Anatomy
  - How internal organs look like
- Imaging of Flow
  - How blood vessels are doing
- Imaging of Function
  - How physiology is doing
- Imaging of Chemical Composition
  - Biochemical analysis of a location noninvasively
- Image Guided Interventions
  - Operation prepared or done using imaging

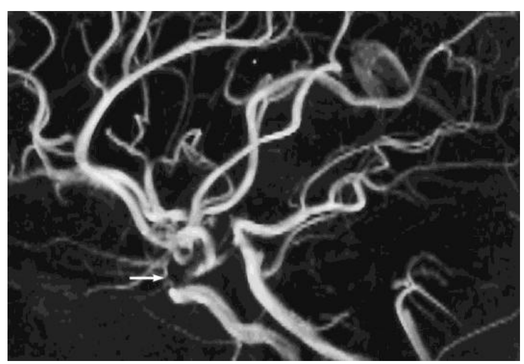
Imaging of Anatomy

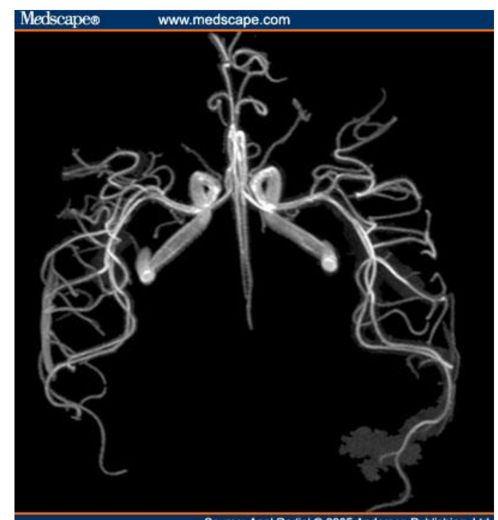


Imaging of Blood Flow: MRA

- Time-of-flight or phase contrast
- Velocity encoding for quantitative results
- Can be done with or without contrast agents
- MIP visualization

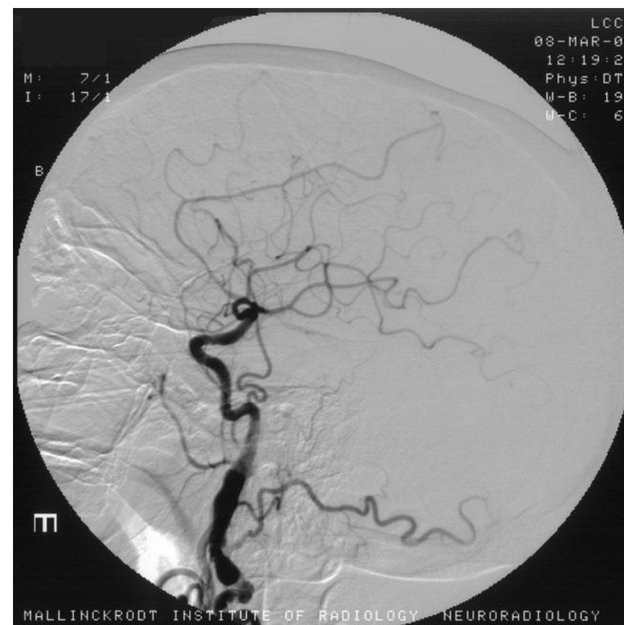






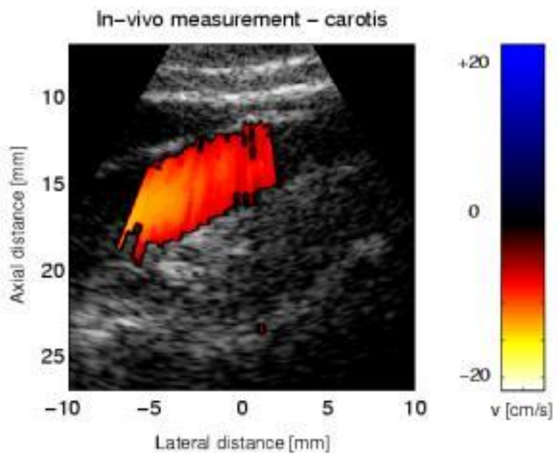
Imaging of Blood Flow: X-ray

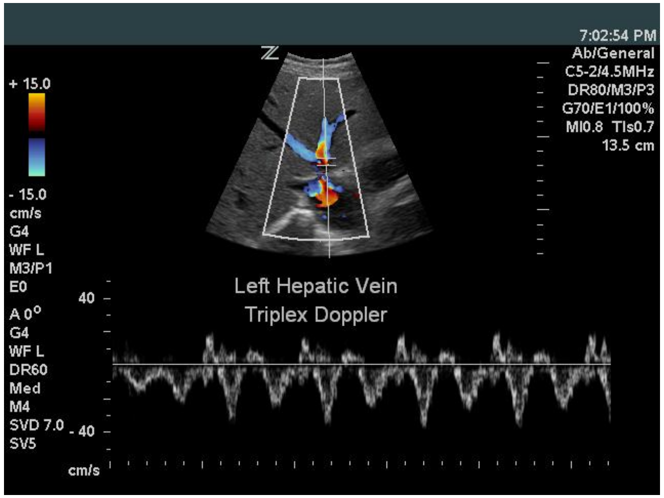
- Contrast agent must be injected
- Digital subtraction angiography



Imaging of Blood Flow: Ultrasound

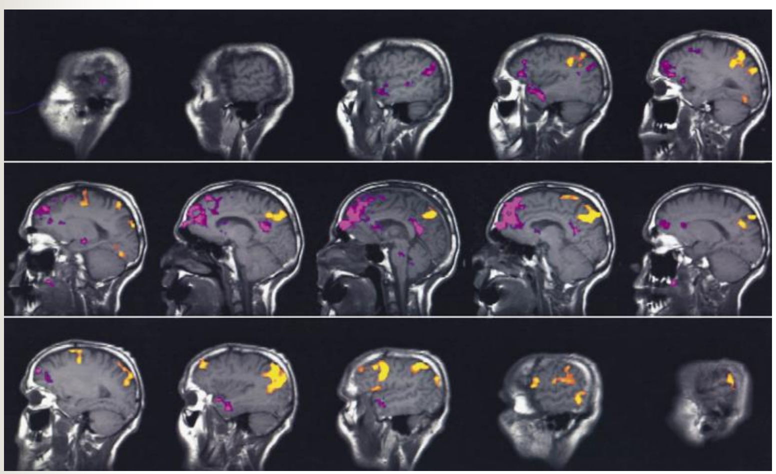
- Doppler effect
- Spectrogram display
- Color flow mapping
  - Spatial resolution vs. velocity accuracy

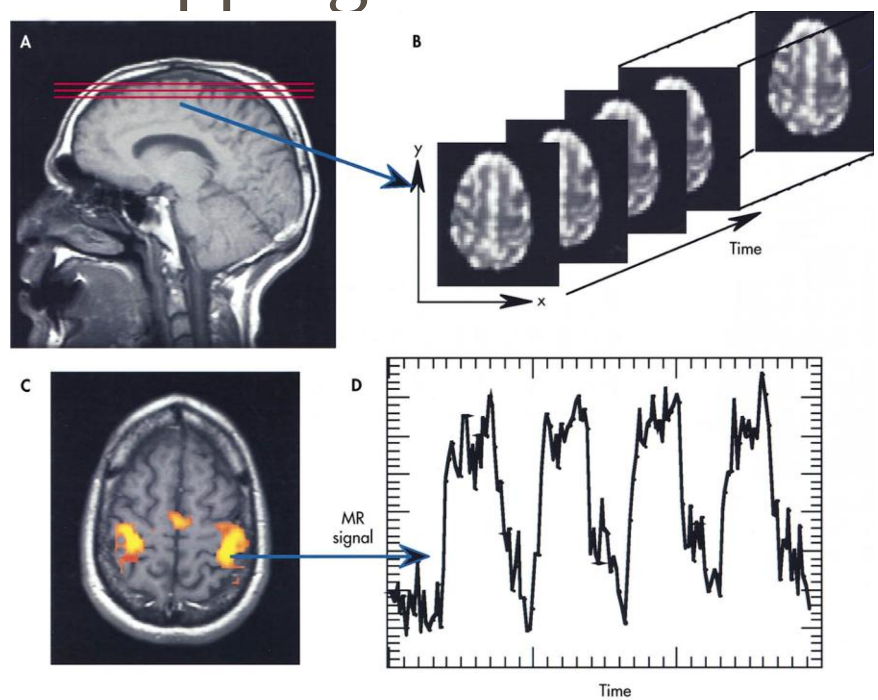




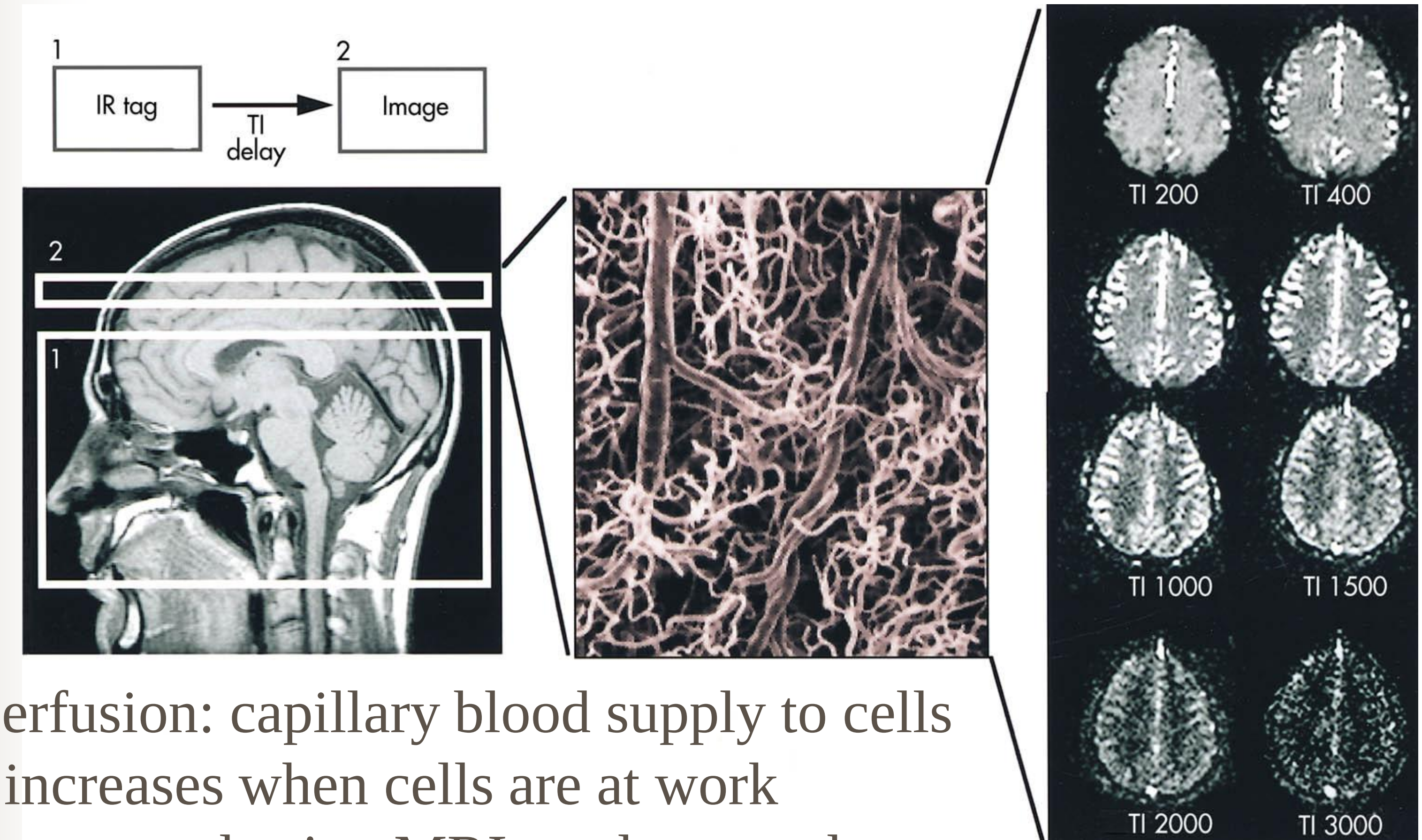
Imaging of Function: Blood Oxygen Level Dependent (BOLD)

- Map changes with a physiological function
- Neuronal activation mapping





Imaging of Function: Perfusion

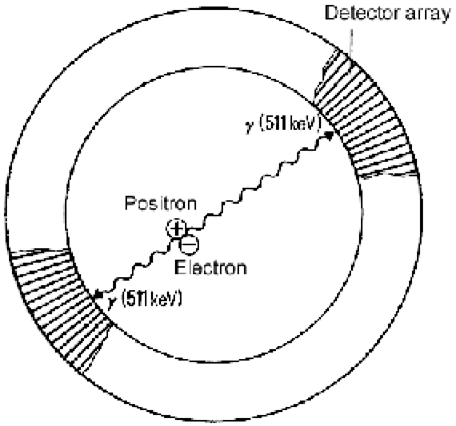


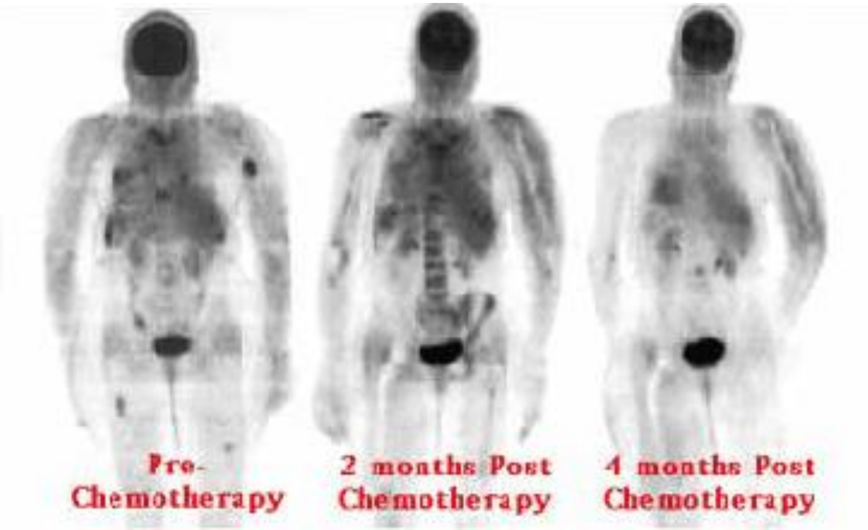
Perfusion: capillary blood supply to cells

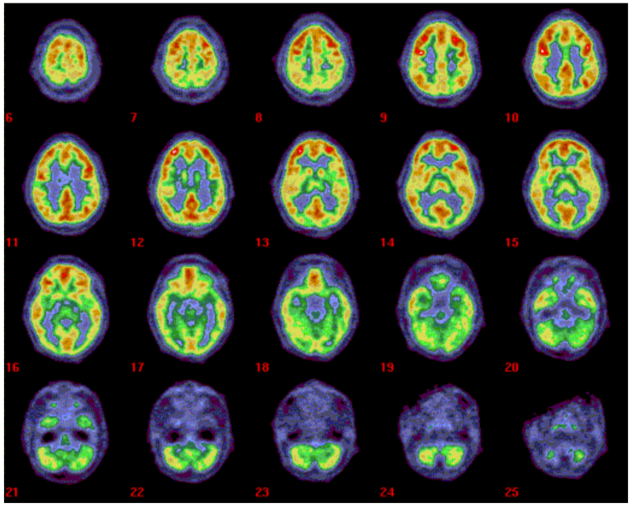
- increases when cells are at work
- measured using MRI or ultrasound

Imaging of Function: PET

- Radioactive isotopes related to a particular function (biomarkers)
  - e.g., Iodine necessary for thyroid
- Radioactive decay with positron generation (measured and mapped)

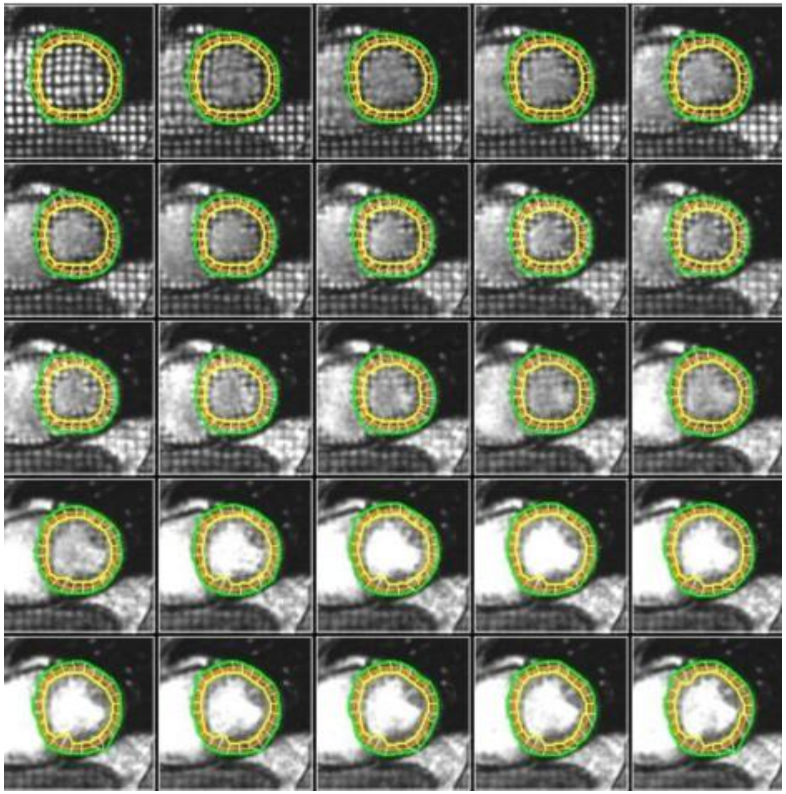






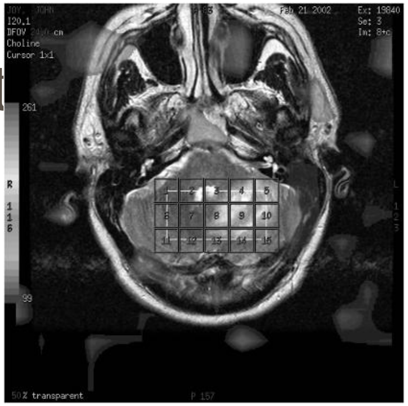
Imaging of Function: Cardiac MRI

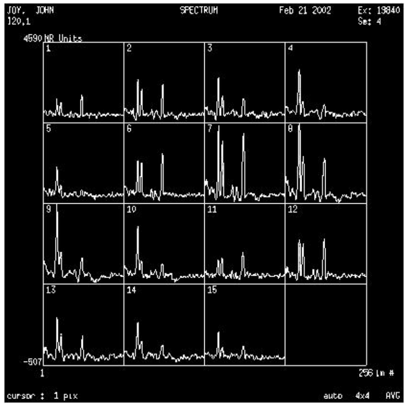
- SPAMM tagging
- Tag tracking
- Quantitative wall viability assessment
- Fast and accurate analysis is a challenge

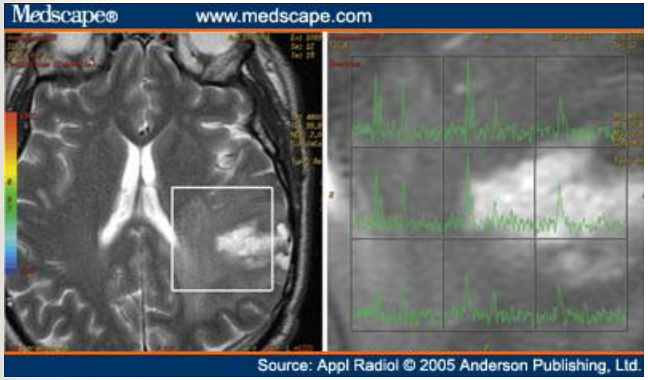


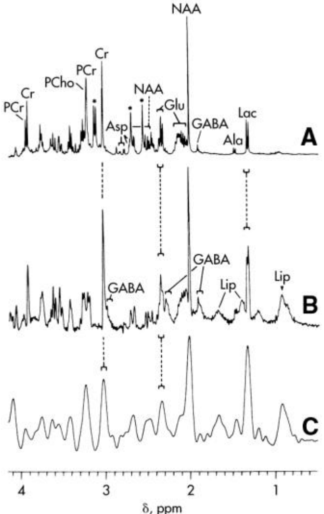
Imaging of Chemical Composition: MR Spectroscopy

- Quantitative measurement of different metabolites in a specific area in the image
- Multiple nuclei
  - e.g., Hydrogen, Phosphorus, etc









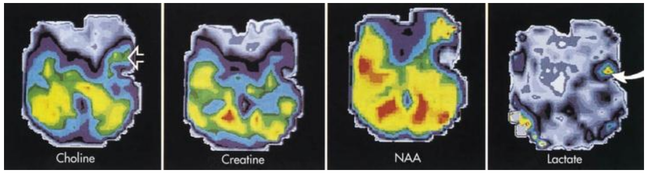
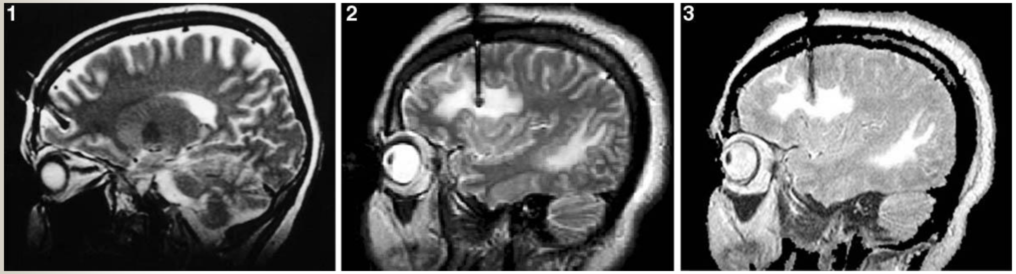


Image-Guided Interventions

- Image-guided surgical planning
  - Minimally invasive brain surgeries
- Image-guided surgical procedures
  - Cathlab
  - Needle-Biopsy



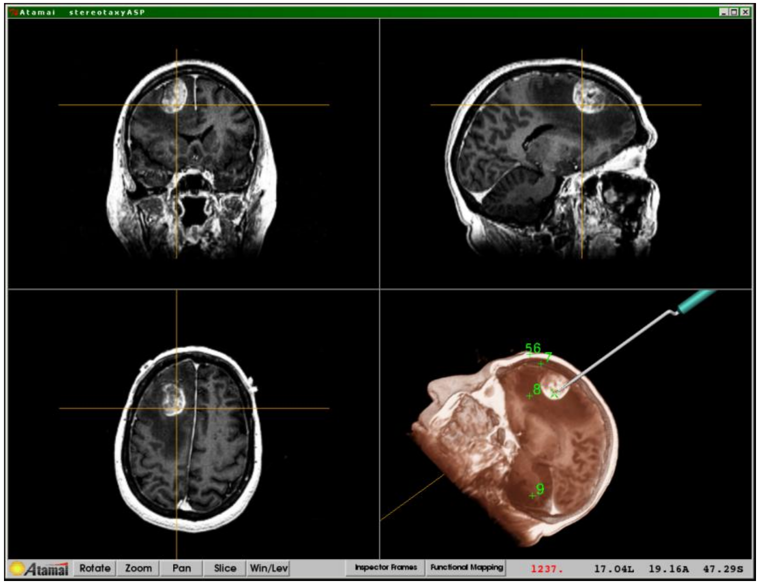
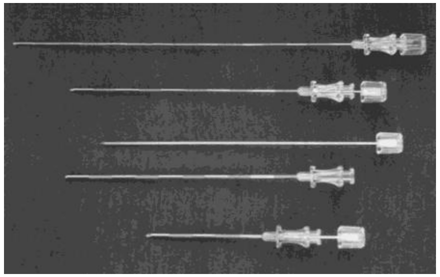
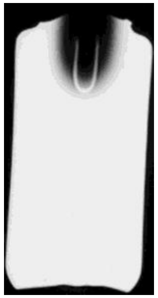


Image-Guided Interventions: Hardware Limitations

- Special surgical tools
- Custom suite designs
- Custom imaging equipment





Biomedical Imaging Trends

From

- Anatomic
- Static
- Qualitative
- Analog
- Nonspecific agents
- Diagnosis

To

- Physiobiochemical
- Dynamic
- Quantitative
- Digital
- Tissue-Targeted agents
- Diagnosis/Therapy

Summary

- Medical imaging is both a science and a tool to explore human anatomy and to study physiology and biochemistry.
- Medical imaging employs a variety of energy sources and tissue properties to produce useful images.
- Increasingly, clinical pull is the driving force in the development of imaging methods.
- Pushing the limits of resolution and accuracy is the focus of current research in this area
- Molecular biology and genetics are new frontiers for imaging technologies.