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# Medical instrumentation

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BIOEN 302

11/19/2010

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# Medical instrumentation

- Definition: instrument for sensing, diagnostics, therapeutics or surgery of human being.

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# Medical instrumentation

- ❑ Definition: instrument for sensing, diagnostics, therapeutics or surgery of human being.
- ❑ Fundamental purpose: to enhance the capabilities of human beings to help themselves and each other.



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# Medical instrumentation classification

- ❑ Diagnostic instrumentation
- ❑ Therapeutic instrumentation
- ❑ Clinical laboratory instrumentation

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Diagnosis



Therapy



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# Diagnostic instrumentation

- Definition: a device that gathers information leading to the identification of a disease or disorder.



Stethoscope  
(invented in 1819)



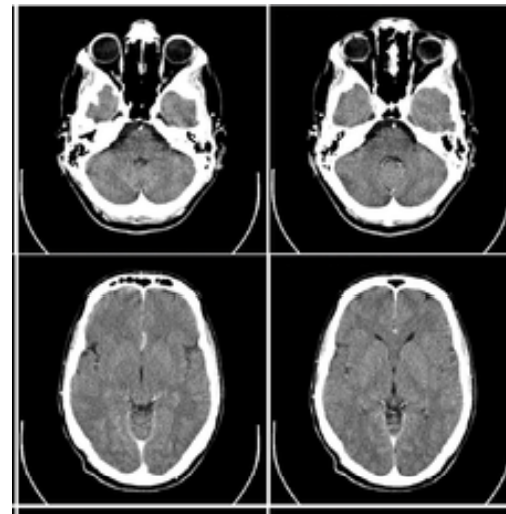
CT  
(X-ray computed tomography )

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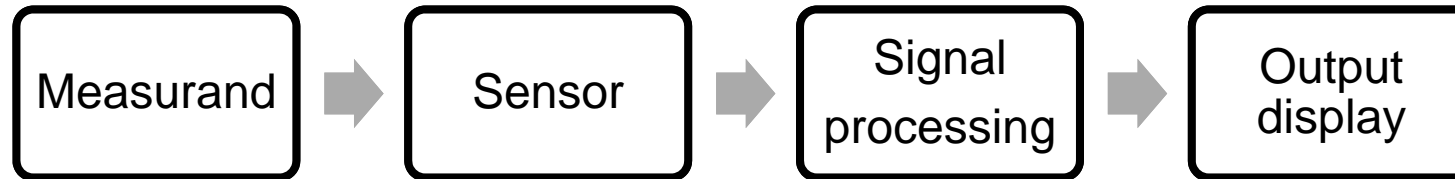
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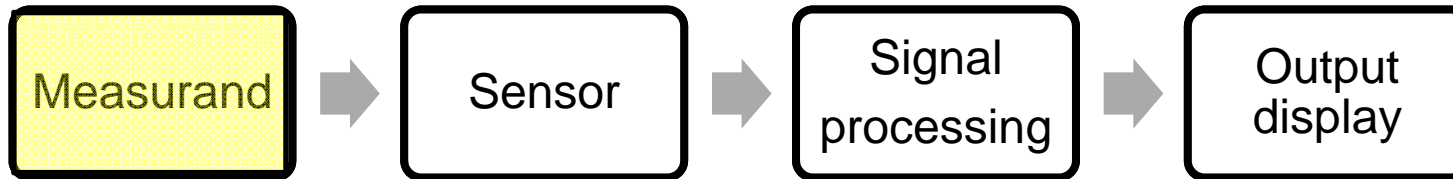
# Generalized composition of diagnostic instrument





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# Generalized composition of diagnostic instrument



- Measurand: physical quantity, property, or condition that the system measures.

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# Measurand

- Examples:
  - Blood oxygen saturation
  - Electrical activity of the heart
  - Tumor



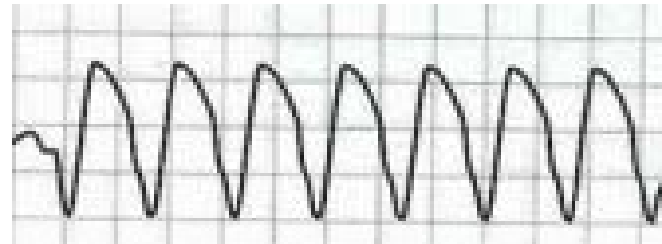
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# Measurand

- Examples:
  - Blood oxygen saturation
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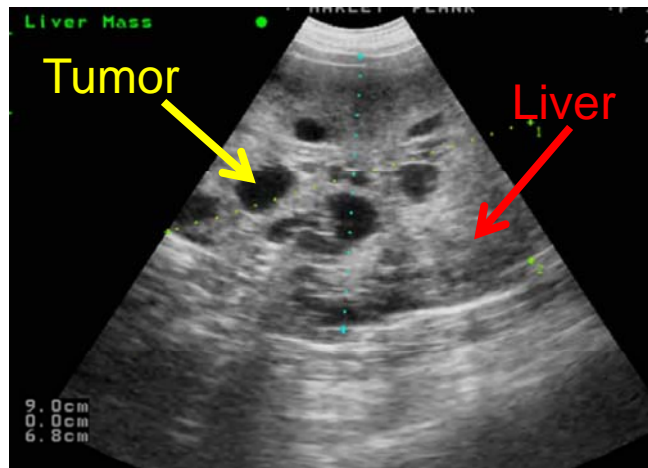
Normal ECG  
(Electrocardiography)



Abnormal ECG

# Measurand

- Examples:
  - Blood oxygen saturation
  - Electrical activity of the heart
  - Tumor



Ultrasound image of tumor in liver

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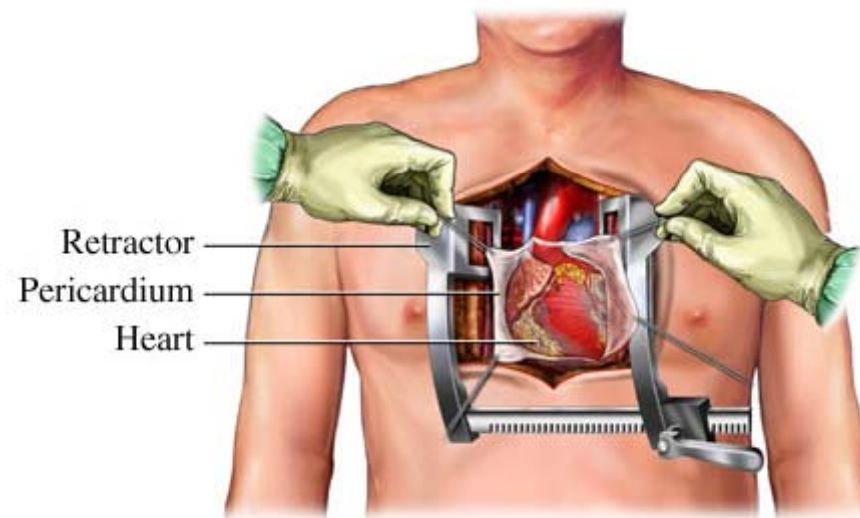
# Measurand

- Constrains:
  - Accessibility
  - Vary with time and among patients
  - Safety

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- Constrains:
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# Measurand

- Constrains:
  - Accessibility
  - Vary with time and among patients

Patient :		Date : 04-Jun -2005 12:01	
Client :			
Test	Results	Reference Range	Indicator
			LOW      NORMAL      HIGH
ALB	= 2.9 g/dl	2.2 - 3.9	
ALKP	= 136 U/L	23 - 212	
ALT	= 48 U/L	10 - 100	
AMYL	= 887 U/L	500 - 1500	
BUN	= 13 mg/dl	7 - 27	
Ca	= 9.9 mg/dl	7.9 - 12.0	
CREA	= 0.9 mg/dl	0.6 - 1.8	
GLU	= 123 mg/dl	74 - 149	
LIPA	= 613 U/L	200 - 1800	
PHOS	= 3.0 mg/dl	2.5 - 6.8	
TBIL	= 0.3 mg/dl	0.0 - 0.9	
TP	= 6.2 g/dl	5.2 - 8.2	
GLOB	= 3.3 g/dl	2.5 - 4.5	

# Measurand

- Constrains:
  - Accessibility
  - Vary with time and among patients
  - Safety:
    - Limitation of external applied signals
    - Electrical safety

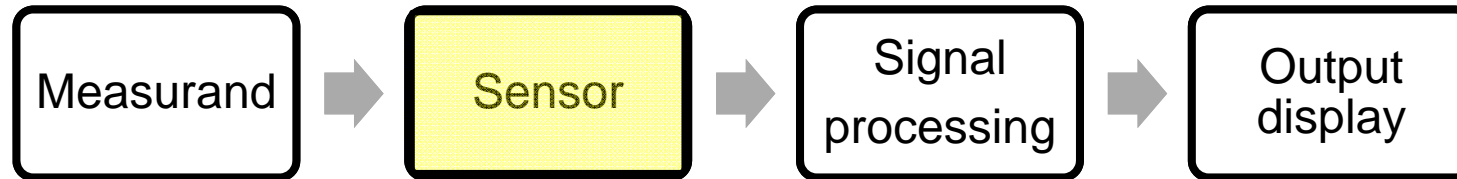


Radiation hazard



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# Generalized composition of diagnostic instrument



- Sensor: a device that converts the measurand into a signal carrying information.

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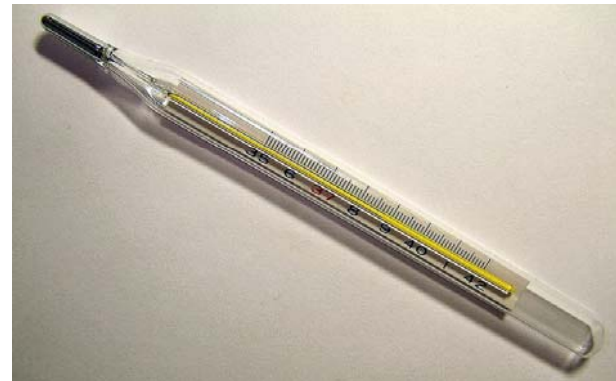
# Sensor

- Classification: according to the quantities to be measured
  - Thermal quantities
  - Mechanical quantities
  - Chemical quantities
  - Radiation intensity

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Blood glucose meter

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# Sensor

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# Sensor

- ❑ *Static characteristics*: the relationship between the output signal and the measurand.
- ❑ *Limit of detection*: the lowest value of measurand that can be detected by the sensor.
- ❑ *Sensitivity*: the smallest change it can detect in the quantity that it is measuring.
- ❑ *Repeatability*: ability of a sensor to reproduce output readings under the same input.

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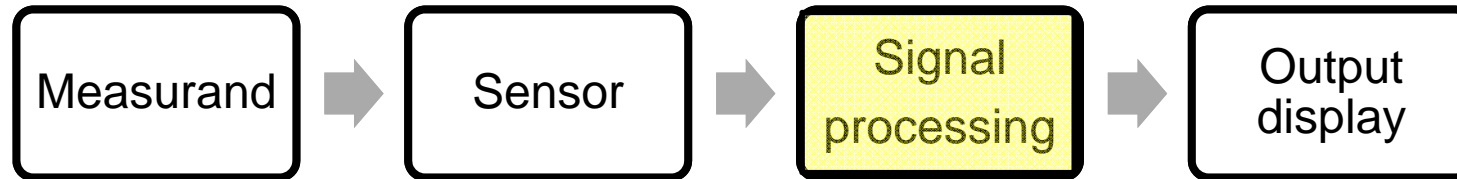
# Sensor

- Requirements:
  - Sensitive to the measured property
  - Accurate
  - Stable and reliable



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# Generalized composition of diagnostic instrument



- Signal processing: amplifies, filters, or in any other way changes the output of the sensor to prepare signals suitable for display.

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# Signal Processing

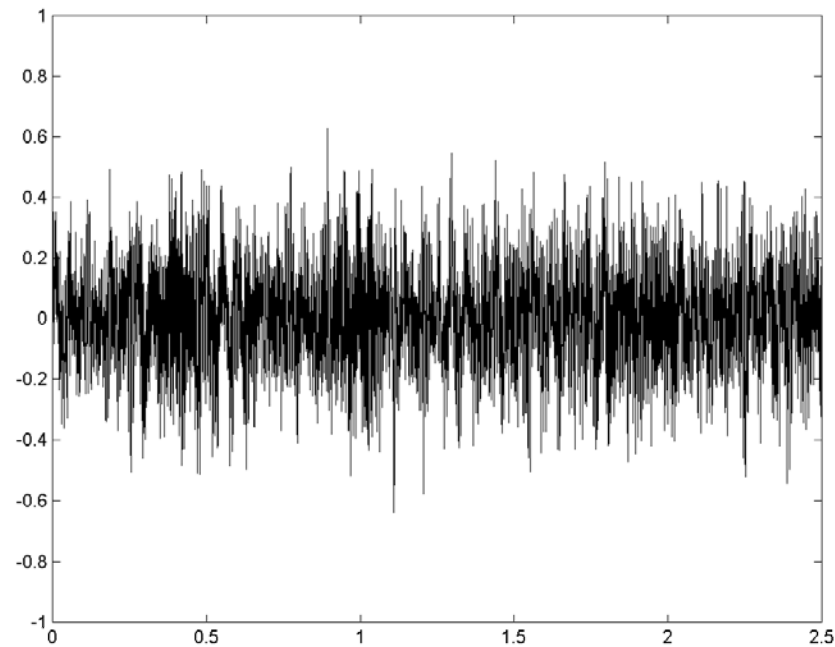
- Challenges:
  - Biological signal magnitudes are low
  - Any measurement includes noise

Parameter	Range
ECG	0.5 – 4 mV
Blood flow speed	1 – 300 ml/s

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# Signal Processing

- Challenges:
  - Biological signal magnitudes are low
  - Any measurement includes noise



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# Signal Processing

- Noise sources:
  - External: power lines, radio broadcast, cell phone ...
  - Internal: muscle noise, motion artifact...

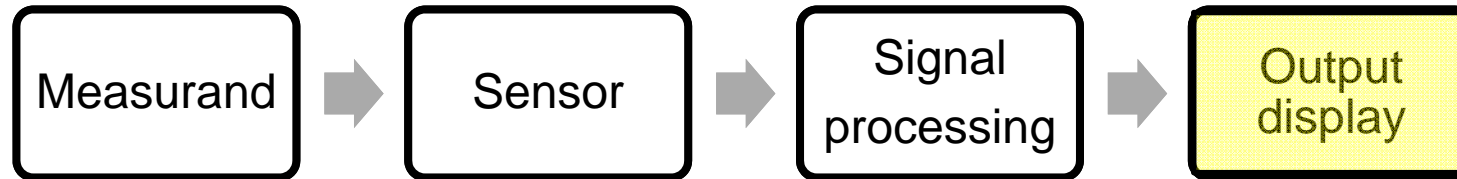
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# Signal Processing

- Eliminate noise:
  - Signal filtering: separate noise from the desired signal using their distinct property. e.g. separate high frequency noise from low frequency signal.
  - Opposing inputs: if noise is known, it can be removed from the signal by subtracting the noise from the signal.

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# Generalized composition of diagnostic instrument



- Output display: convey the information obtained by the measurement in a meaningful way (visual, audible)

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Question?

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# Therapeutic instrumentation

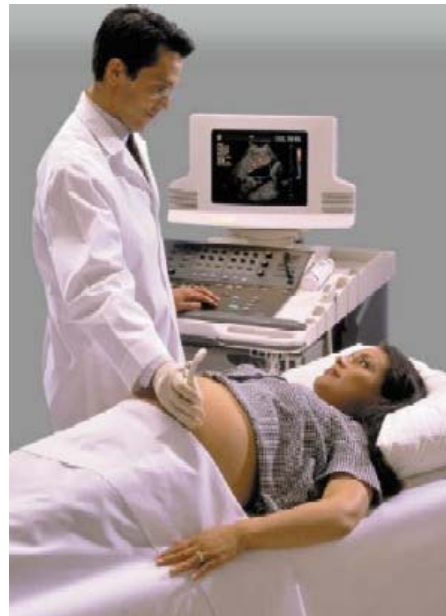
- Definition: a device that is used to treat a disease or disorder.
  - Example:
    - Ultrasound devices in therapy
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# Ultrasound

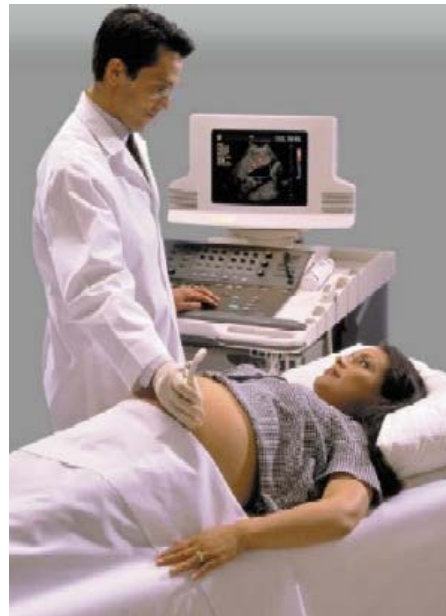
- Ultrasound: sound wave with a frequency beyond the upper limit of human hearing (>20 KHz).



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# Ultrasound

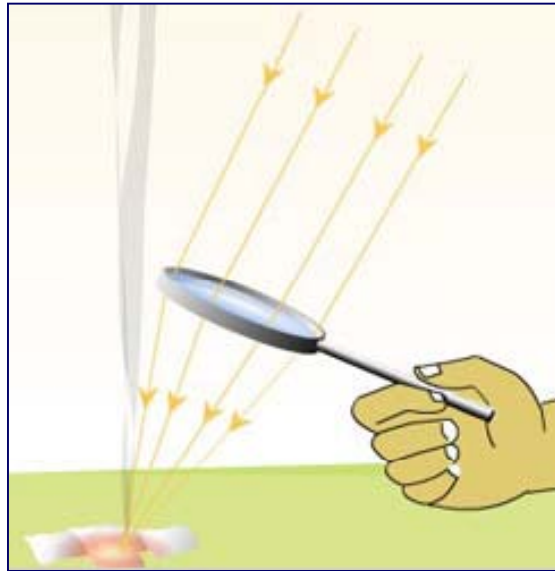
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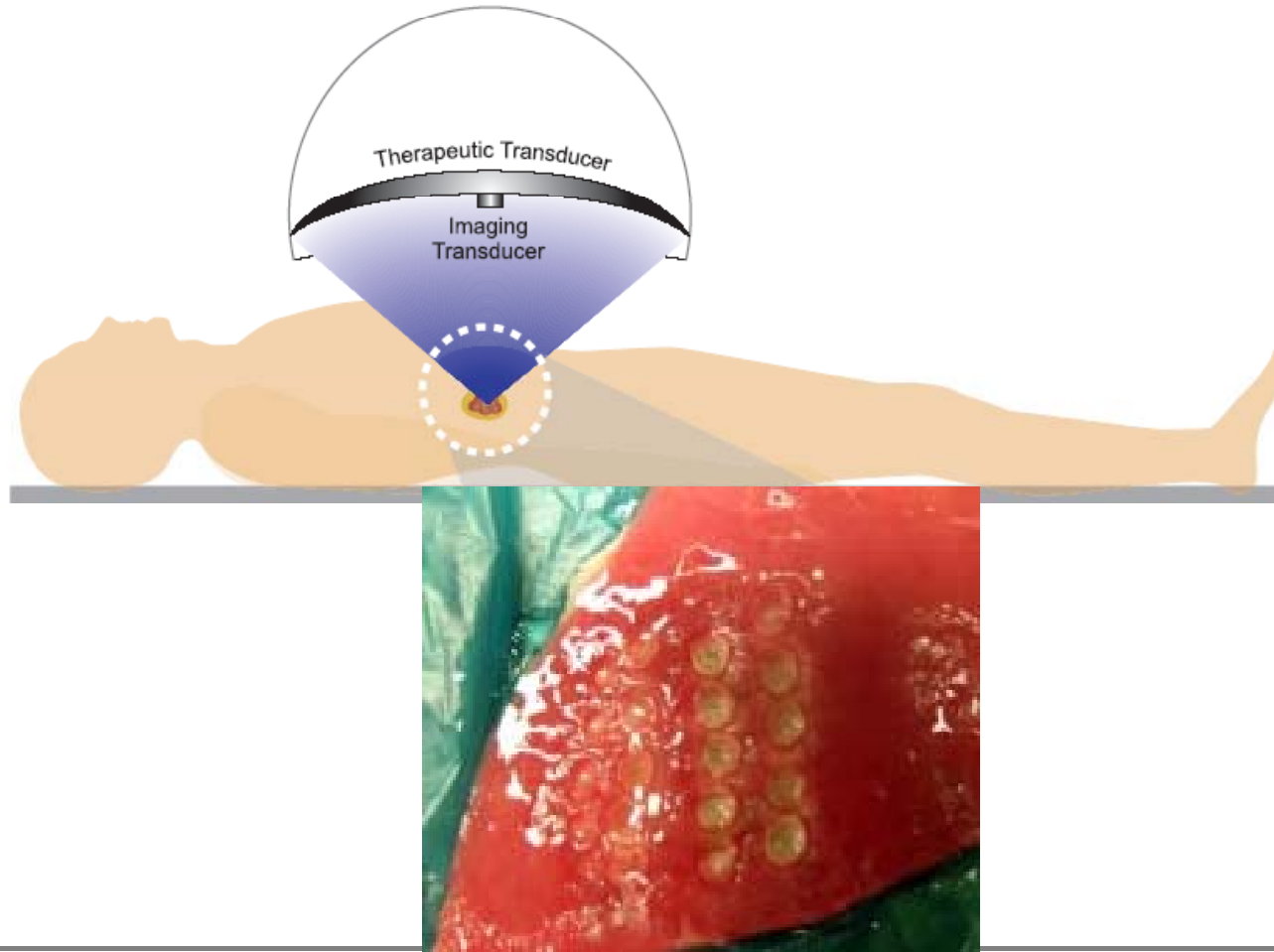
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# Ultrasound in cancer treatment

- High-intensity focused ultrasound (HIFU): Used to heat and destroy tumors.



# Cancer treatment instrument



# Clinical devices



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# Clinical applications

- Prostate cancer
- Liver cancer
- Breast cancer
- Pancreatic cancer
- ...

# Ultrasound in stop bleeding

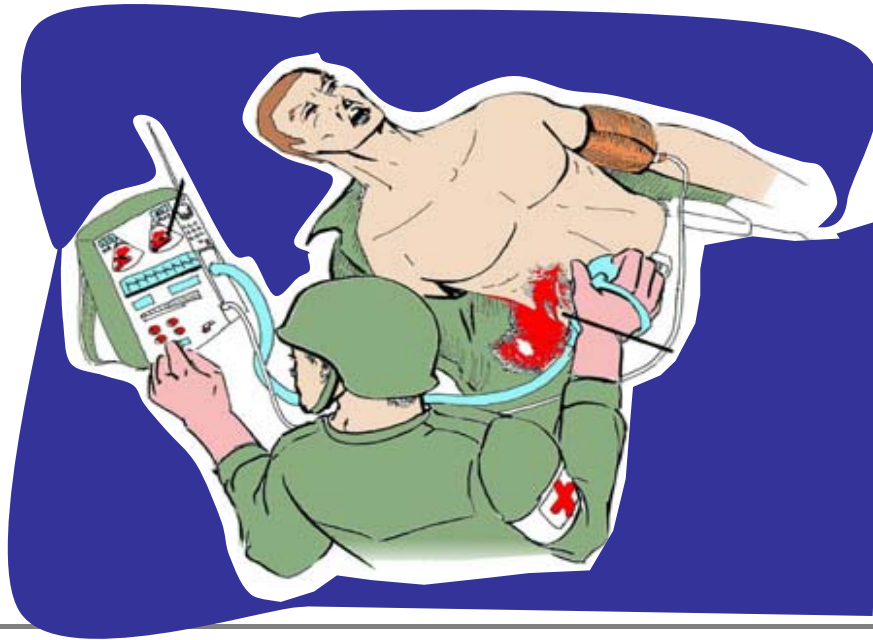
- Exsanguination (“bleeding to death”)  
= **80%** of early mortality in civilian injuries  
= **50%** of all battlefield mortality.



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# Ultrasound in stop bleeding

- Portable device that could be used near the site of trauma to reduce mortality from severe blood loss.

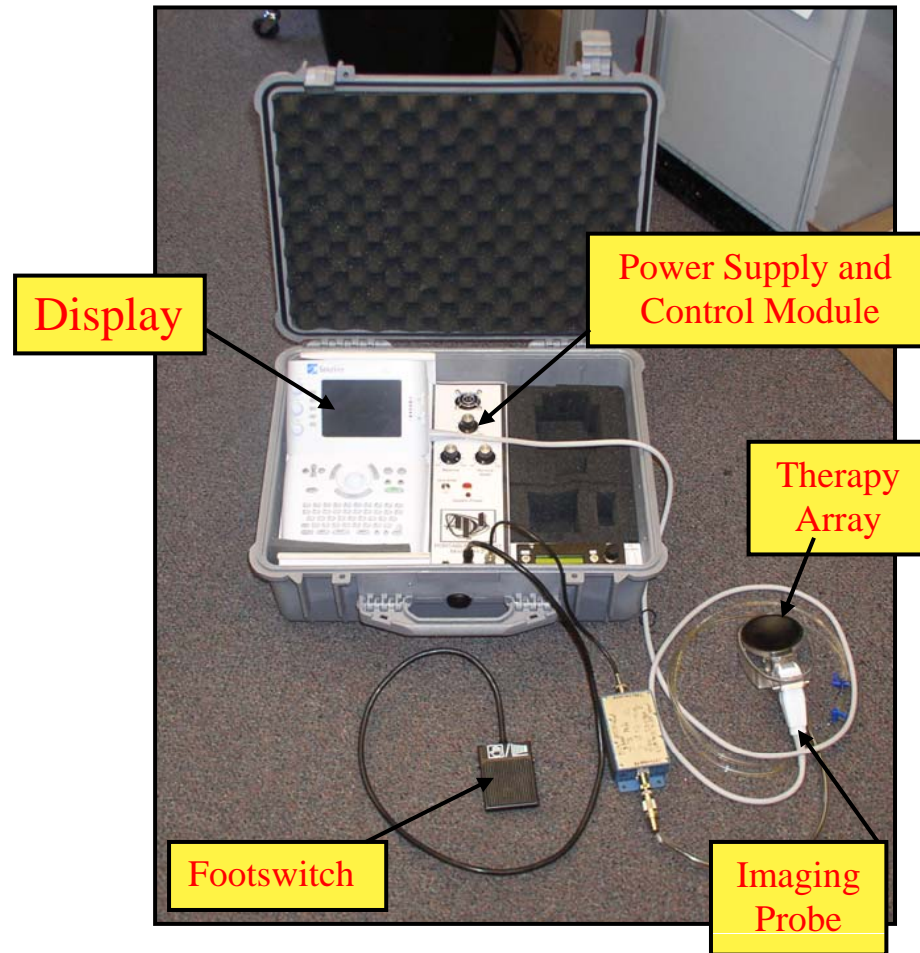




# Portable HIFU device

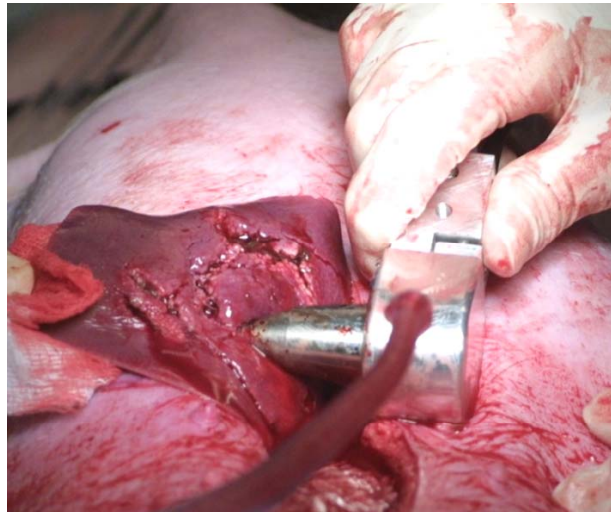


Dr. Myntti carrying a portable image-guided HIFU System



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# Ultrasound in stop bleeding



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# Summary

- ❑ Diagnostic
- ❑ Therapeutic

Diagnose



Therapy



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# Historical Perspective: 20<sup>th</sup> Century

- 1903 ECG – heart diagnostic
- 1924 EEG – brain waves
- 1928 ESU – cauterizing scalpel
- 1928 Iron Lung – respiration assist
- 1936 Nuclear Medicine
- 1956 Defibrillation
- 1957 Pacemaker (1960 implantable)
- 1957 Ultrasound Imaging (anatomical imaging)
- 1970 CT Scanner (anatomical imaging)
- 1975 Inter aortic balloon pump
- 1982 MRI (anatomical imaging)
- 1984 Artificial Heart
- 1990s PET - use radio isotopes (physiological imaging)