SP.718 Special Topics at Edgerton Center: D-Lab Health: Medical Technologies for the Developing World
Spring 2009

Massachusetts Institute of Technology

D-LAB HEALTH

sp 718/755

Brian Tracey

Ultrasound and other Imaging Systems - Outline

- Types of Medical Imaging
- Ultrasound
  - Types of ultrasound (US) systems
  - Clinical applications of ultrasound
  - How ultrasound works (in 2 slides!)
- Global health-related technology development
  - Dartmouth tele-ultrasound system
  - Chest X-ray telemedicine system

Comparison of Imaging Modalities
(adapted from Szabo, 2004)

	Ultrasound	X-ray	CT	MRI
What's imaged	Mechanical properties (density, c)	Absorption (soft tissues difficult)	Absorption (hard and soft tissues)	H_2O resonances
Spatial resolution	0.3 – 3 mm	~1 mm	~1 mm	~1 mm
Penetration	3-25 cm	Excellent	Excellent	Excellent
Safety	High	Ionizing	Ionizing	High
Cost	$	$	$$$$	$$$$$$$
Portability	Excellent	Good	Poor	Poor
Skill needed to acquire	High	Lower	Lower	High
Skill needed to interpret	High	High (varies)	High	High

Why focus on ultrasound?

- Advantages of ultrasound include its relatively low cost, portability, and safety (non-ionizing nature)

- Disadvantages include lower resolution and higher operator skill (compared to X-ray)

- In the developed world, ultrasound is typically reserved for specialized uses (fetal imaging, echocardiograms, vascular studies, surgical monitoring)

- In developing world clinics, cost/benefit tradeoff means ultrasound may be the first line of imaging

Form Factors of Ultrasound Systems

Photo courtesy of redjar on Flickr.

SonoSite MicroMaxx®

Courtesy of SonoSite, Inc.
Used with permission.

Siemens ACUSON P10

Photo removed due to copyright restrictions.
See http://medgadget.com/archives/2007/06/acuson_p10_an_ultrasound_system_that_fits_in_a_pocket.html

- First systems available around 1980
- Wide range of features and costs ($10-$300k)

- First portable systems available circa 1999
- May have fewer features
- Costs range from ~$8-$50k (most units) to $4k (USB stick unit)

Clinical uses: Obstetrics

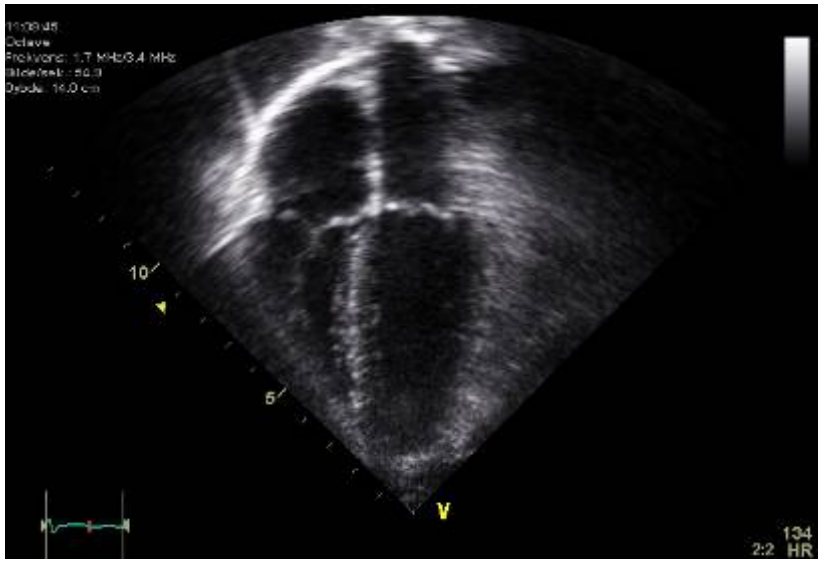
- Fetal imaging accounts for 45% of ultrasound usage in UK (UK Dept. of Health, 2005-2006, from Wikipedia)
  - X-ray imaging of fetus was linked to childhood cancer in 1950's

- Fetal imaging is used to determine:
  - Due date (important for planning, if travel to clinic is difficult)
  - Viability and development of fetus
  - Position of fetus and placenta (ectopic pregnancy)
  - Number of fetuses (twins mean higher-risk birth)

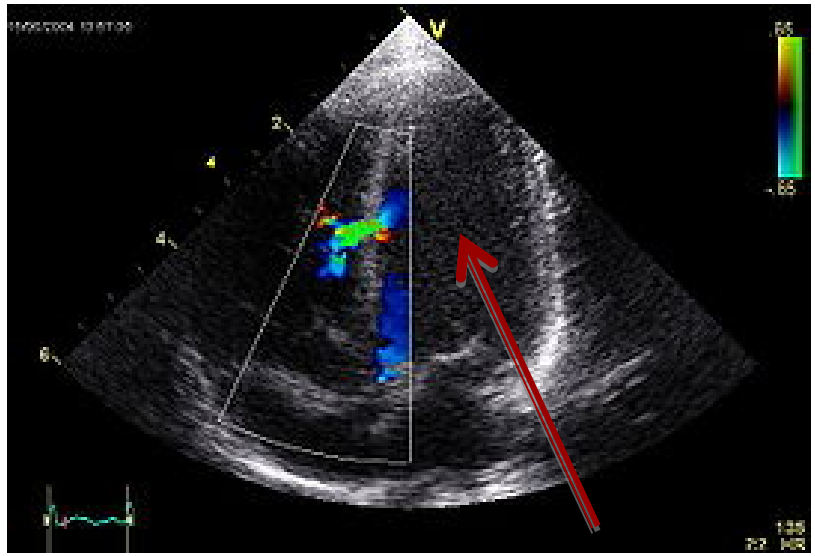
Images: Left courtesy of Sam Pullara on Flickr; right courtesy of jencu on Flickr.

Clinical uses: Cardiology

Structure of Heart



Blood flow in Heart



Leakage between chambers

- Echocardiogram used to image structure and blood flow in heart
  - Detect enlargement of heart or thickening of walls
  - Abnormal blood flow or leakage through heart valves
  - Estimate of cardiac output
- Vascular ultrasound used to detect turbulent flow / blockages in vessels

- 4-D heart imaging example: http://en.wikipedia.org/wiki/File:Apikal4D.gif

Images: Wikipedia, public domain by Kjetil Lenes. Echocardiogram_4chambers.jpg and Ventricular_Septal_Defect.jpg

How Ultrasound works (in 2 slides)

- Piezoelectric crystal transducer transfers electric signal into vibration (transmit) and vice versa (receive)

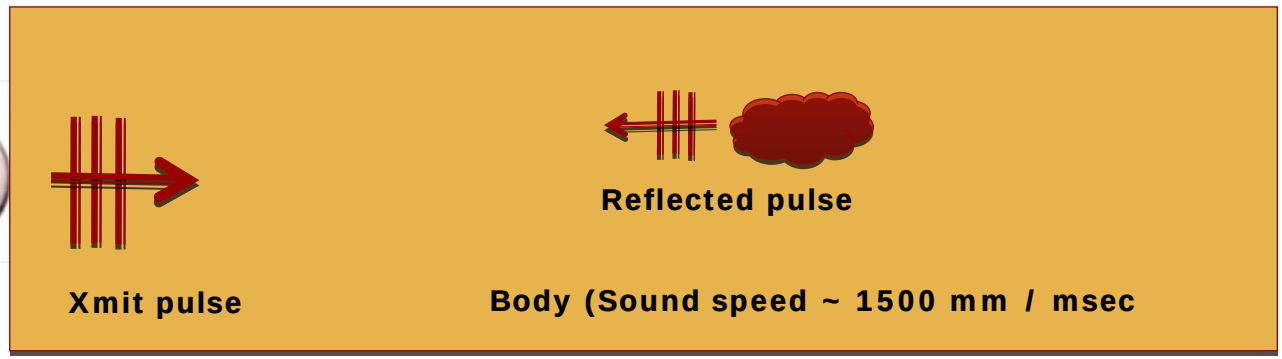
- Depth of echo-generating object is determined from round-trip travel time

- Typical center frequencies of pulse are 3.5 MHz or 5 MHz
  - Higher freq -> better resolution but shorter penetration

- Pulse repetition frequency (PRF) is limited by round-trip travel time
  - Higher PRF -> better motion resolution but shorter depths

- Moving reflectors (blood, heart) will Doppler-shift the returned echo

Xmit/Rcv Transducer (many elements)



Beam Scanning and Beamforming (Focusing)

SCANNING

- Narrow beams are sent/received that image a small sector
- Beams are swept mechanically or electrically to "paint" a picture in a short period of time

BEAMFORMING

- Signals are sent/received on an array of small elements
- Signals on the elements are time-delayed to steer beam to desired direction and distance

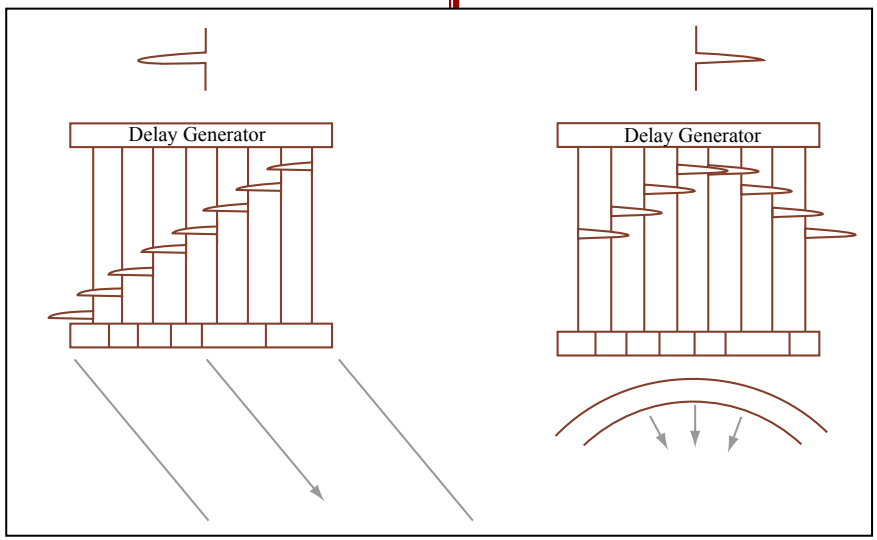


Figure by MIT OpenCourseWare.

Ultrasound in Global Health: Challenges and Thoughts on Solutions

Challenge	Possible solutions
Patient is not near clinic	Portable system; if system is non-portable, then ?
MD (image interpreter) is not locally available	Telemedicine system - is real-time feedback from MD needed?
MD is nearby but not currently available	Store images for playback and later review
Ultrasound tech is not well trained	1) real-time feedback during image acquisition 2) Telemedicine system for training
Your ideas?	

Example: Dartmouth Tele-Ultrasound System

- System links portable imaging units to a laptop running video-conferencing software
- Laptop connects to medical center via satellite communication for real-time consultation
- Radiologist in center can review data at 30 frames/sec and direct tech via audio link

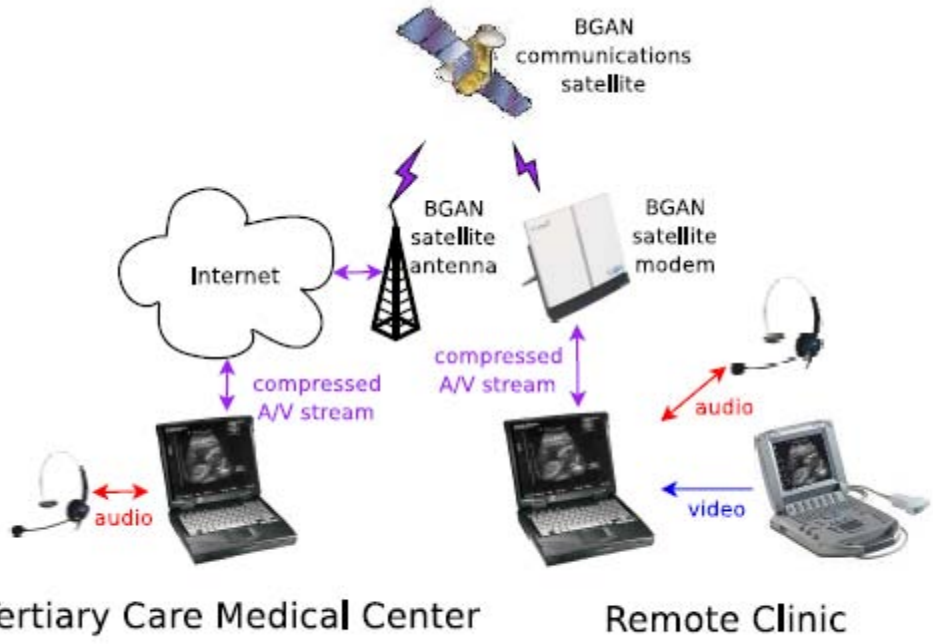


Fig. 1. System Structure

Courtesy of IEEE. Used with permission.

- Successfully tested and units donated in Vietnam and Nicaragua
- Problems (in 2007) with cost of satellite coverage, some freeze-ups

"A Tele-ultrasound System for Real-time Medical Imaging in Resource-limited Settings", J Pyke, M Hard, V Popov, R Harris, S McGrath, proceedings of IEEE EMBC 2007.

Telemedicine system for Chest X- rays (class reading)

- Problem: Difficult to get a 2nd opinion on X-ray diagnosis
- Proposed solution:
  - Use viewing box and digital camera to photograph images
  - Compress images so they are can be emailed to remote expert
- Results:
  - Compressed images are diagnostically useful

Discussion?

References / Further Reading

Diagnostic Ultrasound,(4th Ed) F Kremkau, Saunders, 1993

Diagnostic Ultrasound Imaging, TL Szabo, Elsevier, 2004

“A Tele-ultrasound System for Real-time Medical Imaging in Resource-limited Settings,” J Pyke, M Hard, V Popov, R Harris, S McGrath, proceedings of IEEE EMBC 2007.

“Through the looking glass,” R. Keefer, International Radiology, Vol. 63(7), 2008.

“Diagnostic accuracy of chest X-rays acquired using a digital camera for low-cost teleradiology,” A Szot et al, Jour Med Informatics 73, 2004 (class reading)