Medical Imaging

Presented by

Lec. Dr. Sarah Mahdi Obaid

Department of Medical Physics,

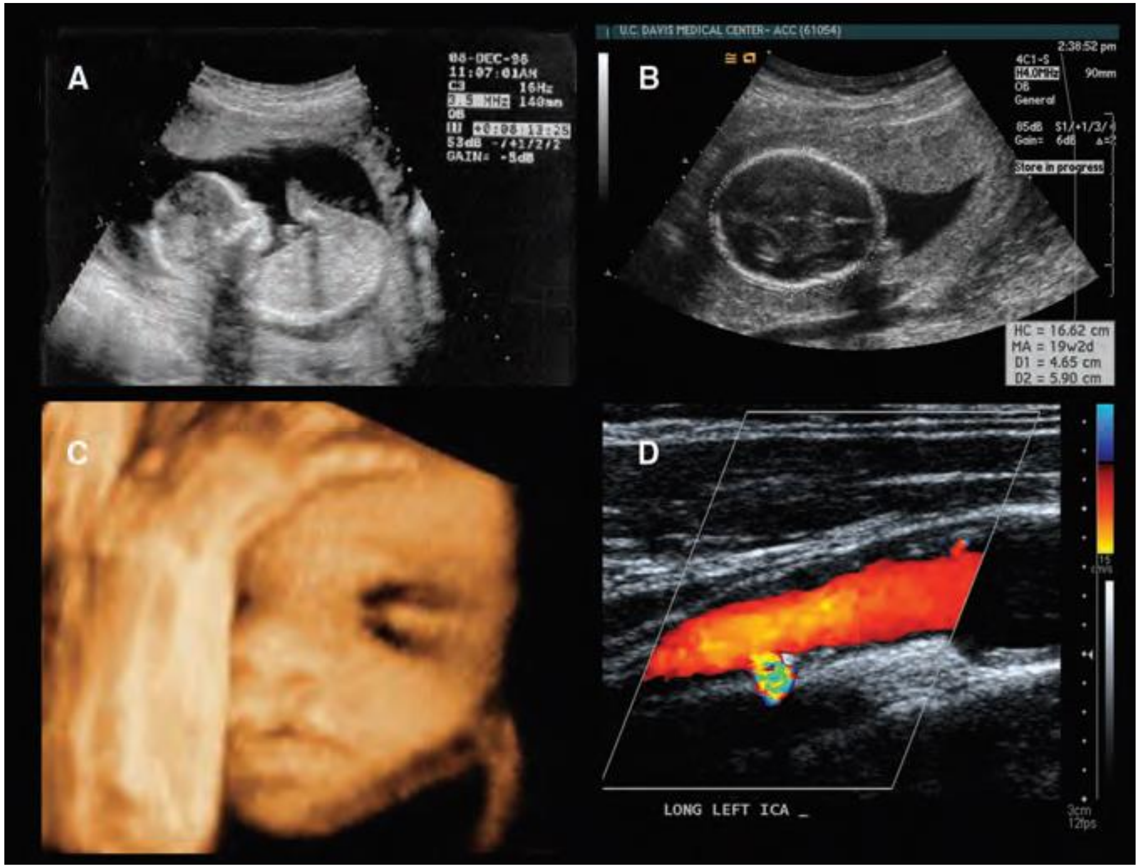
Al-Mustaqbal University,

Babil, Iraq

Email: sarah.mahdi@uomus.edu.iq

Second-year students

Ultrasound Imaging – Equipment and Image



Ultrasound Medical Imaging

- What is medical ultrasound?
- How does it work?
- What is ultrasound used for?
- Are there risks, advantages and disadvantages?

Ultrasound Imaging

- Mechanical energy in the form of high-frequency ("ultra") sound can be used to generate images of the anatomy of a patient.
- The sound waves travel into the tissue, and are reflected by internal structures in the body, creating echoes. The reflected sound waves then reach the transducer, which records the returning sound.
- Because each ultrasound image represents a tomographic slice, multiple images spaced a known distance apart represent a volume of tissue, and with specialized algorithms, anatomy can be reconstructed with volume rendering methods.

What is ultrasound used for?

- Medical ultrasound falls into two distinct categories: diagnostic and therapeutic.

1. ***Diagnostic ultrasound***

   - A non-invasive diagnostic technique used to image inside the body.
   - Ultrasound probes (transducers), produce sound waves that have frequencies above the threshold of human hearing (above 20KHz), but most transducers in current use operate at much higher frequencies (in the megahertz (MHz) range). Most diagnostic ultrasound probes are placed on the skin.
   - However, to optimize image quality, probes may be placed inside the body via the gastrointestinal tract, vagina, or blood vessels. In addition, ultrasound is sometimes used during surgery by placing a sterile probe into the area being operated on.

What is ultrasound used for?

Diagnostic ultrasound.

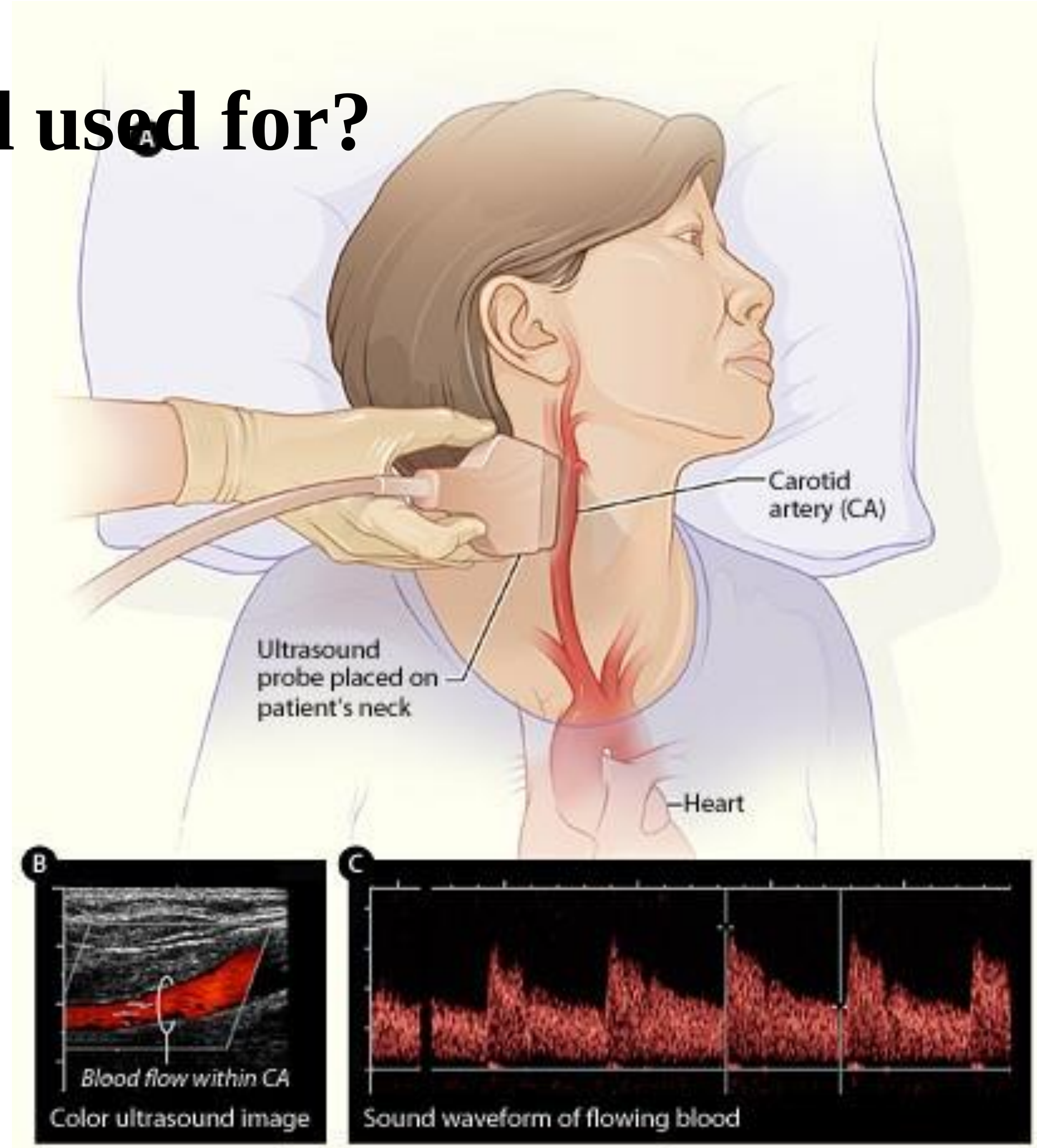


Figure A shows how the ultrasound probe (transducer) is placed over the carotid artery. Figure B is a color ultrasoundimage showing blood flow (the red color in the image) in the carotid artery. Figure C is a waveform image showing the sound of flowing blood in the carotid artery.

What is ultrasound used for?
Diagnostic Applications:

- Endocrinology
  - In abdominal Sonography, the solid organs of the abdomen are imaged such as the pancreas, aorta, inferior vena cava, liver, gall bladder, bile ducts and spleen..
- Obstetrics & Gynecology
  - Measuring the size of fetus.
  - Determining the position of the fetus to see if it is in the normal head down position.
  - Checking the position of placenta to see if it is improperly developing.
  - Seeing the number of fetuses in uterus.
  - Checking the fetus growth rate by making many measurements.
  - Seeing tumors of breast.
- Cardiology
  - To diagnose the dilation of parts of the heart and the function of heart ventricles and valves.
  - Measuring blood flow through the heart and major blood vessels.

What is medical ultrasound?

- Diagnostic ultrasound can be further sub-divided into anatomical and functional ultrasound.
  - **Anatomical ultrasound** produces images of **internal organs or other structures**.
  - **Functional ultrasound** combines information such as **the movement and velocity of tissue or blood, softness or hardness of tissue, and other physical characteristics**, with anatomical images to create "**information maps**." These maps help doctors visualize changes/differences in function within a structure or organ.

What is ultrasound used for?

Functional ultrasound.

- Functional ultrasound applications include Doppler and color Doppler ultrasound for **measuring and visualizing blood flow** in vessels within the body or in the heart.
- It can also measure the **speed of the blood flow and direction** of movement.
- This is done using **color-coded maps** called color Doppler imaging.
  Doppler ultrasound is commonly used to determine whether plaque build-up inside the carotid arteries is blocking blood flow to the brain.
- Another functional form of ultrasound is **elastography**, a method for **measuring and displaying the relative stiffness of tissues**, which can be used to differentiate tumors from healthy tissue. This information can be displayed as either color-coded maps of the relative stiffness; black-and white maps that display high-contrast images of tumors compared with anatomical images; or color-coded maps that are overlayed on the anatomical image. Elastography can be used to test for liver fibrosis, a condition in which excessive scar tissue builds up in the liver due to inflammation.
- Ultrasound is also an important method for **imaging interventions** in the body. For example, ultrasound-guided needle **biopsy** helps physicians see the position of a needle while it is being guided to a selected target, such as a mass or a tumor in the breast.
- Also, ultrasound is used for **real-time imaging** of the location of the tip of a catheter as it is inserted in a blood vessel and guided along the length of the vessel.
- It can also be used for **minimally invasive surgery** to guide the surgeon with real-time images of the inside of the body.

What is ultrasound used for?

2. Therapeutic ultrasound

- Also uses sound waves above the range of human hearing but does not produce images.
- Its purpose is to interact with tissues in the body such that they are either modified or destroyed.
  - Among the modifications possible are: moving or pushing tissue, heating tissue, dissolving blood clots, or delivering drugs to specific locations in the body.
  - These destructive, or ablative, functions are made possible by use of very high-intensity beams that can destroy diseased or abnormal tissues such as tumors.
- The advantage of using ultrasound therapies is that, in most cases, they are non-invasive. No incisions or cuts need to be made to the skin, leaving no wounds or scars.

What is ultrasound used for?

Therapeutic Applications

- Therapeutic applications use ultrasound to bring heat or agitation into the body.

- Ultrasound may be used to clean teeth in dental hygiene.
- Ultrasound sources may be used to generate regional heating and mechanical changes in biological tissue, e.g. in physical therapy and cancer treatment.
- However the use of ultrasound in the treatment of musculoskeletal conditions has fallen out of favor.
- Focused ultrasound may be used to generate highly localized heating to treat cysts and tumors (benign or malignant).
- Focused ultrasound may be used to break up kidney stones by lithotripsy.
- Ultrasound may be used for cataract treatment by phacoemulsification.

What is ultrasound used for?

3. **<u>Therapeutic or interventional ultrasound</u>**.

- Therapeutic ultrasound produces high levels of acoustic output that can be focused on specific targets for the purpose of heating, ablating, or breaking up tissue.
- One type of therapeutic ultrasound uses high-intensity beams of sound that are highly targeted, and is called High Intensity Focused Ultrasound (HIFU).
- HIFU is being investigated as a method for modifying or destroying diseased or abnormal tissues inside the body (e.g. tumors) without having to open or tear the skin or cause damage to the surrounding tissue.
- Either ultrasound or MRI is used to identify and target the tissue to be treated, guide and control the treatment in real time, and confirm the effectiveness of the treatment. HIFU is also being investigated as a way to close wounds and stop bleeding, to break up clots in blood vessels, and to temporarily open the blood brain barrier so that medications can pass through.

Other Applications Of Ultrasound

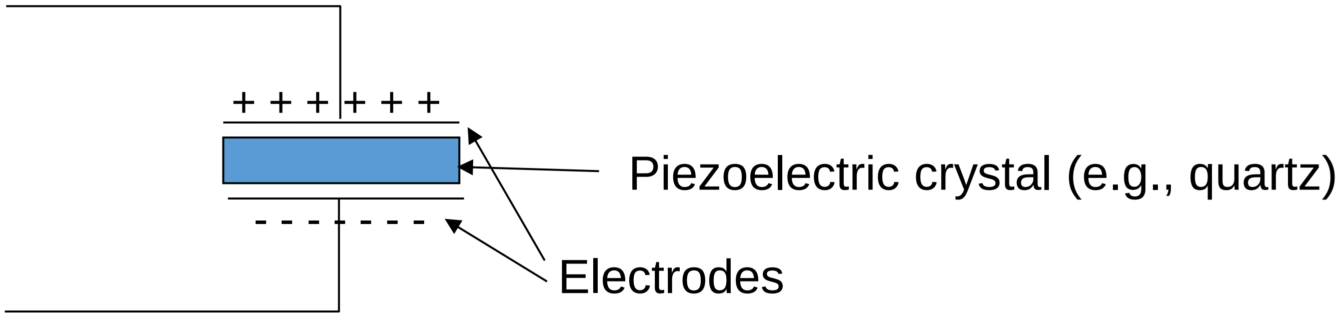
- Cleaning
  - This includes the removal of grease, dirt, rust and paint from metal, ceramic, glass and crystal surfaces of parts used in the electronic, automotive, aircraft, and precision instruments industries.
- Flow Metering
  - It can be used to monitor closed systems, such as a coolant in a nuclear power plant.
- Soldering and Welding
  - Ultrasound has also proved to be very useful for joining plastic materials. It can be used for both soldering and welding.
- Livestock
  - Ultrasound has been used to measure the thickness of fat layers on pigs and cows as part of livestock management.
  - It has also been used in improve the quality of homogenized milk.
  - A related application is pest control, including killing insects.
- Oceanography
  - In addition to the tracking of submarines.
  - Oceanographic applications include mapping the contour of the sea bottom, discovering sunken ships.

How does it work?

Piezoelectric Effect in Crystals

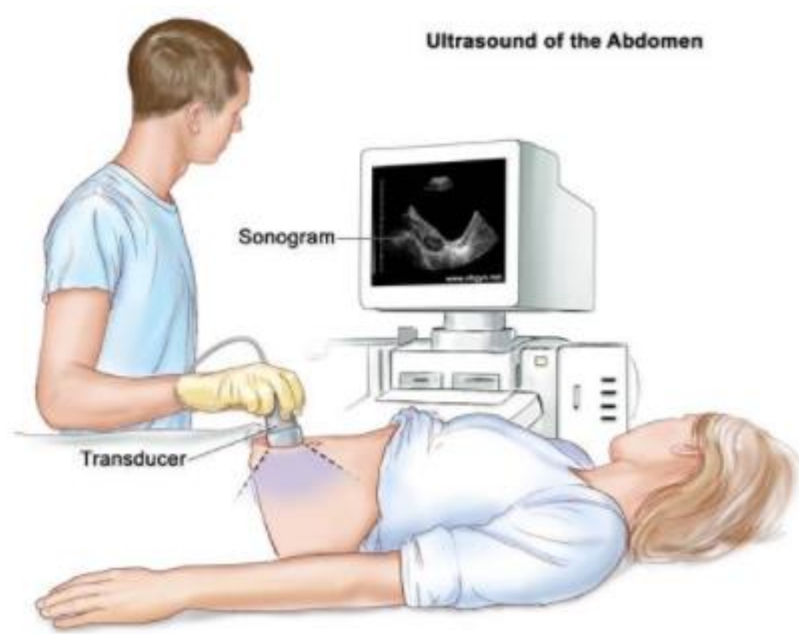
- Applied electric field produces mechanical vibration
- Also, mechanical vibration produces electrical signal

- Single crystal can be both ultrasound source and detector
  - Not at exactly same time
  - Mechanical vibration moves at same frequency as electrical vibration (1 MHz to 20 MHz)



How does it work?

- Ultrasound waves are produced by a transducer, which can both emit ultrasound waves, as well as detect the ultrasound echoes reflected back.
- In most cases, the active elements in ultrasound transducers are made of special ceramic crystal materials called piezoelectrics.



How does it work?

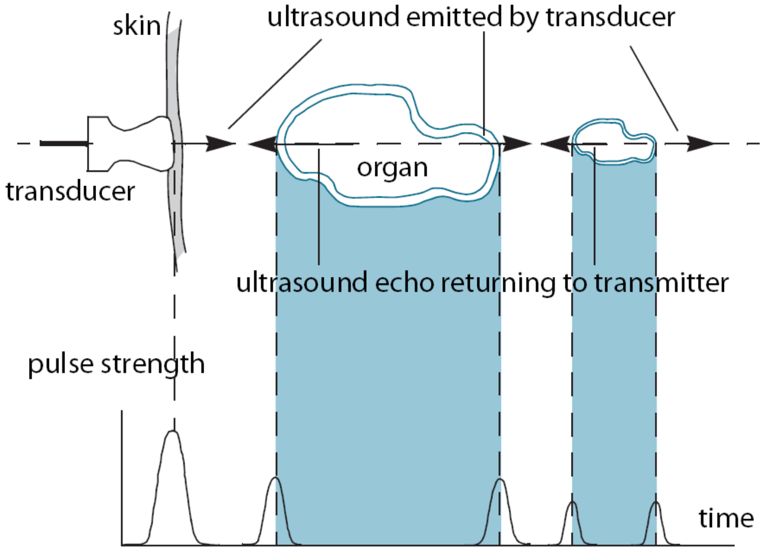
- When used in an ultrasound scanner, the transducer sends out a beam of sound waves into the body. The sound waves are reflected back to the transducer by boundaries between tissues in the path of the beam (e.g. the boundary between fluid and soft tissue or tissue and bone).
- When these echoes hit the transducer, they generate electrical signals that are sent to the ultrasound scanner.
- Using the speed of sound and the time of each echo's return, the scanner calculates the distance from the transducer to the tissue boundary. These distances are then used to generate two-dimensional images of tissues and organs.
- During an ultrasound exam, the technician will apply a gel to the skin. This keeps air pockets from forming between the transducer and the skin, which can block ultrasound waves from passing into the body.

Scan Modes with Ultrasound

- A-mode- amplitude modulation mode.
- B-mode- brightness mode.
- M-mode- motion mode.
- Doppler (Doppler imaging).

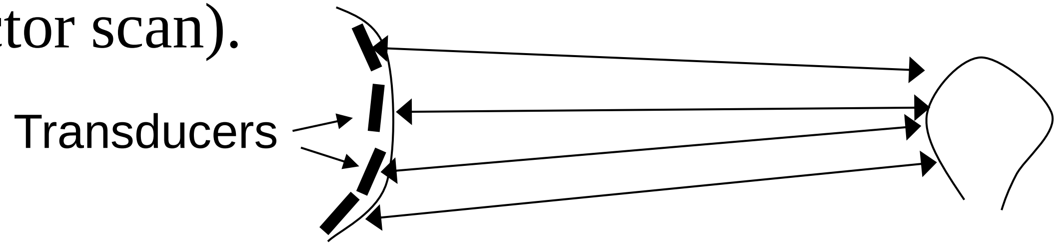
A-mode

- A-mode (Amplitude-mode) ultrasound is used to judge the depth of an organ, or otherwise assess an organ's dimensions.
- The A-mode scan had also been used for early pregnancy assessment (detection of fetal heart beat), and placental localization.
- Also used to test the symmetry between left and right hemispheres of the brain: R-L then L-R.
- Display of echo amplitude (Y-axis) versus distance (X-axis) into the tissue, which is related to elapsed time and the speed at which ultrasound propagates in the tissue.
- Sometimes used to calibrate the other modes.



B-Mode

- Several transducers on handgrip record travel time simultaneously
- B-mode ultrasound (Brightness-mode) is the display of a 2D-map of B-mode data, currently the most common form of ultrasound imaging.
- Brightness of image on screen is proportional to strength of reflection
- This form of display (solid areas appear white and fluid areas appear black) is also called gray scale.
- The B-mode scan is the basis of 2D scanning. The transducer is moved about to view the body from a variety of angles. The probe can be moved in a line (linear scan), or rotated from a particular position (sector scan).



Real Time B-mode

- Used phased array transducer called a real-time scanner.
- Used most often to scan abdomen and to check the fetus in pregnant women.
- System scans 15-60 frames/s.
- Hand-held transducer moved to different positions or held at different angles to get complete picture.
- Transducer can be moved and angles so that get 3-D information.
- Real-time B-scans allow body structures which are moving to be investigated.
- The simplest type of scanner is just a speeded up version of the 2-D B-scan , allowing a rapid series of still pictures to be built up into a video of the movement.

M-mode

- The M-mode (Motion-mode) ultrasound is used for analyzing moving body parts (also called time-motion or TM-mode) commonly in cardiac and fetal cardiac imaging.
- Used for studying the motion of interface.
- The high sampling frequency (up to 1000 pulses per second) is useful in assessing rates and motion, particularly in cardiac structures such as the various valves and the chamber walls.

Ultrasound Imaging – Doppler shift scans

- Determine blood flow speed
- High speed – indication of blockage
  - ✓ Moving ultrasound (M Scan)
    - Real-time image of moving objects
    - E.g., heart beating
  - ✓ Fetus

Ultrasound Frequency Choice

- High frequency - high resolution
  - Get more detail with a higher frequency scan than a lower frequency scan
- High frequency – high attenuation
  - Higher frequencies are attenuated faster than lower frequencies
  - Get more penetrating images using lower frequencies

Advantages Of Ultrasound

- Ultrasound scanning is noninvasive (no needles or injections) and is usually painless.
- Ultrasound is widely available, easy-to-use and less expensive than other imaging methods.
- Ultrasound imaging uses non ionizing radiation.
- Ultrasound scanning gives a clear picture of soft tissues that do not show up well on x-ray images.
- Ultrasound causes no health problems and may be repeated as often as is necessary if medically indicated.
- There are no hazards for the patient and operator.

Disadvantages Of Ultrasound

- The major disadvantage is that the resolution of images is often limited.
- Still in many situations where x-rays produce a much higher resolution.
- Bone absorbs ultrasound so that brain images are hard to get.
- Attenuation can reduce the resolution of the image.
- Sonography performs very poorly when there is a gas between the transducer and the organ of interest
- Images of tissues on the far side of lungs are impossible to get.

Ultrasound (US)

- Year discovered: 1952 (clinical: 1962)
- Form of radiation: Sound waves (non-ionizing)
  NOT EM radiation!
- Frequency / wavelength of radiation: 1 – 10 MHz / 1 – 0.1 mm
- Imaging principle: Echoes from discontinuities in tissue density/speed of sound are registered.
- Imaging volume: < 20 cm
- Resolution: High (mm)
- Applications: Soft tissue, blood flow (Doppler)