Al-Mustaqbal University

College of Science

Medical physics Department

Medical Physics II

Second Semester

3rd stage

Lesson 5

Sound in Medicine

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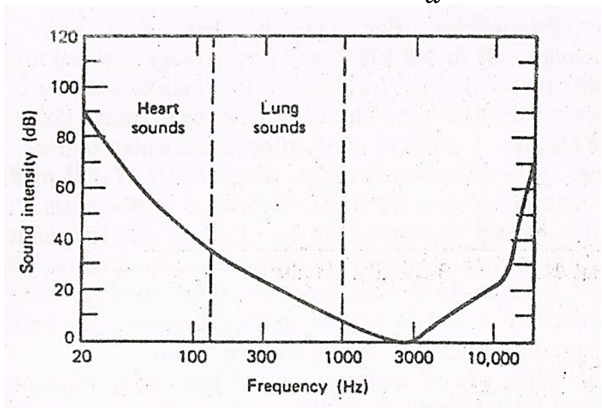
Stethoscope

Stethoscopes are diagnostic instruments that amplify sounds produced by the body from the heart, lungs, abdomen and other internal organs. Modern stethoscope consists of:

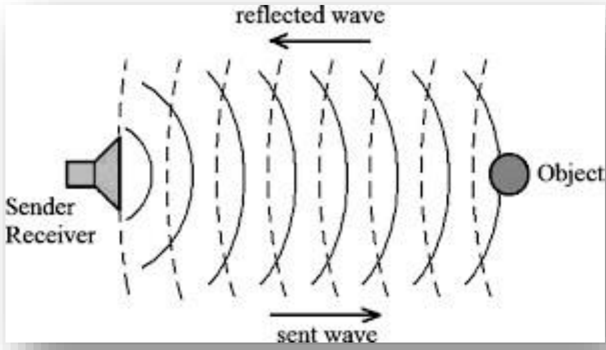
(1)Bell: (chest pies): which is open or closed by a thin diaphragm. The bell serves as impedance matcher between the skin and the air and accumulates sounds from the contacted area. The skin diaphragm has a natural resonant frequency at which it most effectively transmits sound. **(2)Flexible tubing:** 30 -45 cm long. **(3)The earpieces:** Should be fit tightly into the ear because any leak results in background noise entering the ear

The ***natural frequency*** F_{res} of the bell depends on bell diameter *d* and tension *T* of the diaphragm as following: $F_{res} \propto \frac{\sqrt{T}}{d}$

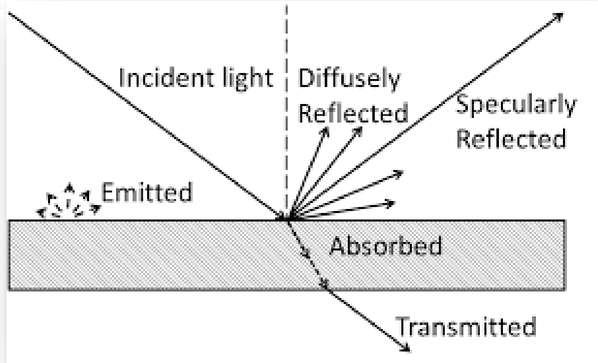


To selectivity pick up certain frequency ranges the appropriate bell size and diaphragm tension must be chosen. Most of the heart sound are of low frequency in the region where the sensitivity of the ear is poor. Lung sounds generally have higher frequencies. This curve represents the threshold hearing for good ear. Some of the heart and lung sounds are below this threshold.

Ultrasound Pictures of the Body



Ultrasound is sound whose frequency is above the range of human hearing. Principal reasons for its wide application are its ease of use, the relatively low cost of the instrumentation, and the lack of ionizing radiation.

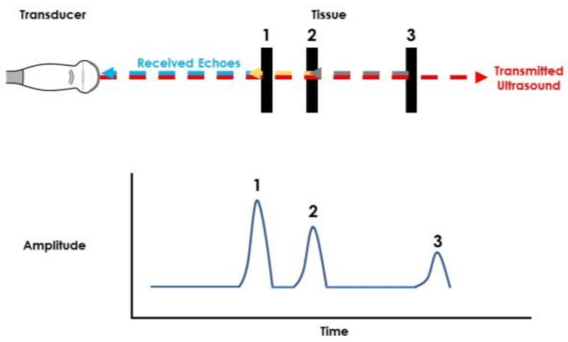


SONAR (SOund NAvigation and Ranging) - It is a device that uses an Ultrasound to generate an image of a particular soft tissue structure in the body. In medical diagnosis, pulses of ultrasound are transmitted into the body by placing the US transducer in close contact with the skin, using water or a jelly paste to eliminate the air and create a good impedance matching between the transducer and skin. Sound waves are transmitted into the body; then because the various internal structures reflect and scatter sound differently, returning echoes can be collected and used to form an image of a structure as in figure

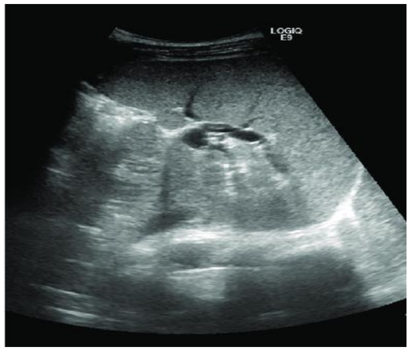
The backed echoes are detected as a weak signal that amplified and displayed on an oscilloscope.

A **transducer** is any device that converts energy from one form to another. An ultrasound transducer converts electric energy into ultrasound energy (mechanical energy) and ultrasound energy back into electric energy.

Types of US imaging



A-Mode (1D); It is used to obtain diagnostic information about the depth of structure (image with 1-dimention). In this mode an US waves send into the body and measure the time required to receive the reflected sound (*echoes*) from the interface between the different tissues. A-mode is used to detect the brain tumors and eye diseases. The transducer is constant without movement.



B-Mode (2D); It is used to obtain 2D images of the body. The principle is the same as in A-mode except that transducer is moving. A storage oscilloscope is usually used to form the image. B-mode provides information about the internal structure of the body, such as size, location and change with time of the eye, liver, heart, and fetus.

(B-mode image of the spleen)

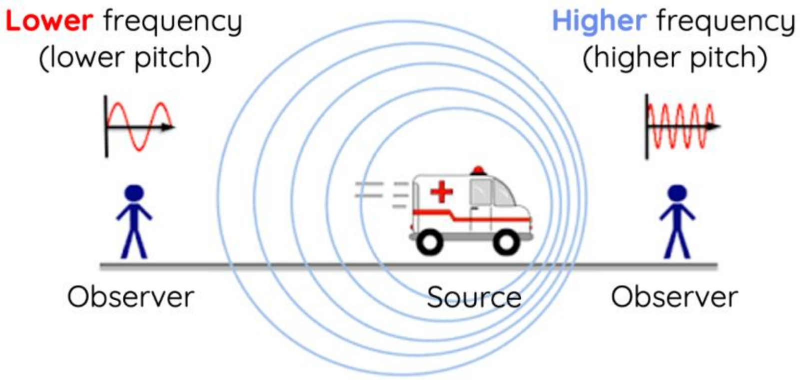
M-Mode (2D +motion); It is used to study motion such as that of heart and heart valves.

D-Mode (3D + motion; or 4D) (**Doppler Effect**); D- Mode takes 3-dimensional US images and adds the element of time to the process (image with 3D with motion).

Doppler Effect

The change in **pitch** due to the relative motion between a source of sound and the person hearing the sound is called the **Doppler Effect**. A common example of the Doppler Effect is the change in pitch from high to low as an emergency vehicle, drives by at high speed. In general, when a source of sound moves toward an observer, the frequency heard is higher than the frequency produced by the source. When a source of sound moves away from the observer, the frequency heard is lower than the frequency produced by the source.

As example when the truck moves toward the right, the wave crests become bunched up close together in the forward direction. This means that the observer ahead of the truck experiences more crests per second and hence a higher-frequency sound. An observer behind the truck experiences wave crests that are spread out, which results in a lower-frequency sound. *The Doppler technique is used for;*



- Study the blood motion in the circulatory system.
- To locate the point of the entry of the umbilical cord into the placenta to detect if there is bleeding due to misplaced placenta or if there is an intrauterine transfusion for Rh incompatibility

Quality of ultrasound imaging

The quality of ultrasound imaging is determined by the interaction of the acoustic wave with the body tissue, these interactions includes: spatial resolution, attenuation and reflection and transmission.

Spatial Resolution: The spatial resolution is limited by wavelength of sound, $\Delta S \approx \lambda = \frac{v_s}{f}$

Low f→ high ΔS → Bad resolution → Bad image

Attenuation: All media attenuate ultrasound (loss of energy) due to absorption and scattering effects as following:

$\mu = \mu_{abs} + \mu_{scat}$ μ depends on tissue characteristics (density) and on frequency.

So, high f→ high attenuation

Reflection and transmission: Perpendicular reflection originates the echo signal, while non-perpendicular reflection causes an intensity loss in echo signal.

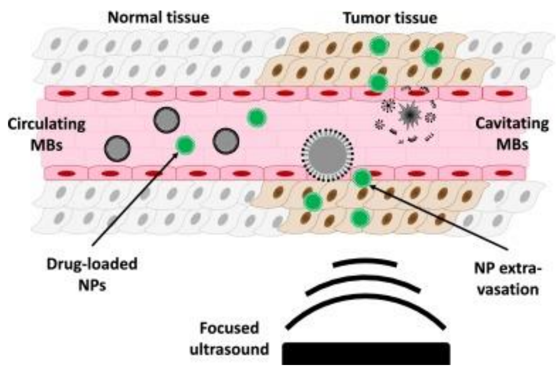
Smooth surface → low scattering → good image

Rough surface → high scattering → bad image

Physiological effects of ultrasound in therapy

Various physical and chemical effects occur when ultrasonic waves pass through the body, and they can cause physiological effects. The magnitude of physiological effects depends on the frequency and amplitude of sound.

1. Low intensity US (~ 0.01 W/cm^2) → no harmful effects are observed → used for diagnostic (as in the Sonar).
2. Continues US (~1 W/cm^2) → deep heating effect (diathermy) → temperature raise due to the absorption of acoustic energy in the tissue.
3. Continues US (1-10 W/cm^2) → sound moves through tissues → region of compression and rarefactions → pressure differences in adjacent regions of tissues (micromassage).
4. Continues US (~ 35 W/cm^2) → tissue destroying effect. 35 W/cm^2 → 10 atm over a very short distance → molecules cannot disperse the energy to its surrounding by vibration → breakage of chemical bonds → rupture DNA molecules.
5. Continues and focused US (~ 103 W/cm^2) → selective destroying of deep tissue using a focused ultrasound beam.



Exercises

1 The natural frequency F_{res} of the bell in the stethoscope depends on -------------- of the diaphragm

(a) Atmospheric pressure (b) Diameter of bell and tension of diaphragm (c) Patient and doctor (d) The long of the tubing

(e) None of them

2 SONAR is a device that uses an -------------to generate an image of a particular soft tissue structure in the body.

(a) Ultrasound (b) Sound wave (c) Light (d) Electromagnetic wave (e) Electrons

3 A ------------is any device that converts energy from one form to another

(a) Thermometer (b) Sonar (c) Stereo Celia (d) Cochlea (e) Transducer

4 ----------- is used to obtain diagnostic information about the depth of structure (image with 1-dimention).

(a) A-mode sonar (b) B-mode sonar (c) C-mode sonar (d) D-mode sonar (e) M-mode sonar

5 Continues and focused ultrasound with power of (~ 103 W/cm^2) is used for----------

(a) diagnostic (b) Destroying tumor cells (c) Heating tissues (d) Micromassage (e) None of them