Ultrasound in Internal Medicine

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FADOI
Ultrasound Definition and Physics
Short History of Ultrasound
Basic features of US images
Ultrasound Exam Performance
Clinical Use of BEDSIDE Ultrasound
Potentially redefine physical exams...

Quick look

Potentially redefine physical exams...

Quick look

Potentially redefine physical exams...

Quick look

...quick and immediate visualization.

consider another product'dual probe' with expanded indications
### Differences between ultrasound approaches

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Examples of point-of-care ultrasound
WHAT IS ULTRASOUND?
Basic Physics of Ultrasound

- **Ultrasound** is a medical imaging technique that uses **high frequency sound waves and their echoes**.

- The technique is similar to the echolocation used by bats, whales and dolphins, as well as **SONAR** used by submarines etc.
Why Ultrasound...?

- As an extension of clinical examination and of clinical skills
- It provides real time useful clinical answers
- It can be performed bedside
- It is a noninvasive technique
- Can be repeated to monitor the patient
- It is relatively cheap
In ultrasound, the following events happen

1. The ultrasound machine transmits **high-frequency** (1 to 12 megahertz) sound pulses into the body using a probe.

2. The sound waves travel into the body and hit a boundary between tissues (e.g. between fluid and soft tissue, soft tissue and bone).

3. Some of the sound waves reflect back to the probe, while some travel on further until they reach another boundary and then reflect back to the probe.

4. The reflected waves are detected by the probe and relayed to the machine.
5. The machine calculates the distance from the probe to the tissue or organ (boundaries) using the speed of sound in tissue (1540 m/s) and the time of each echo's return (usually on the order of millionths of a second).

6. The machine displays the distances and intensities of the echoes on the screen, forming a two dimensional image.
Sound waves consist of mechanical vibrations containing condensations (compressions) & rarefactions (decompressions) that are transmitted through a medium.

- Sound is mechanical energy.
- Sound is not electromagnetic.
- Matter must be present for sound to travel.
Piezoelectric effect

- To produce an ultrasound, a **piezoelectric crystal** has an alternating current applied across it. The piezoelectric crystal grows and shrinks depending on the voltage run through it. Running an alternating current through it causes it to vibrate at a high speed and to produce an ultrasound.
• This conversion of electrical energy to mechanical energy is known as the piezoelectric effect. The sound then bounces back off the object under investigation.

• The sound hits the **piezoelectric crystal** and then has the reverse effect - causing the mechanical energy produced from the sound vibrating the crystal to be converted into electrical energy.

• By measuring the time between when the sound was sent and received, the amplitude of the sound and the pitch of the sound, a computer can produce images, calculate depths and calculate speeds.
Categories of Sounds

- Infrasound (subsonic) below 20Hz
- Audible sound 20-20,000Hz
- **Ultrasound above 20,000Hz**
- Nondiagnostic medical applications <1MHz
- **Medical diagnostic ultrasound >1MHz**
ULTRASOUND PULSES
MAKING THE IMAGE

• Echoes occur when pulses of U/S hit reflectors
• A stream of echoes from each pulse return to transducer
• Deeper echoes from deeper tissues arrive later
• Stronger echoes arrive from stronger reflectors

All the energy comes from the transducer
All we “see” are reflections and scatter.
Treatment of gastric ulcers (left) and arthritis (right) in the 1940s.
DIAGNOSTIC ULTRASOUND

➢ Ultrasound diagnostics started to develop in early 40's of 20th century. It allows to obtain cross-sectional images of the human body which can also include substantial information about its physiology and pathology.

➢ Ultrasound diagnostics is based mainly on reflection of ultrasound waves at acoustical interfaces.
History of Ultrasound

- George Ludwig, 1940s, **Naval Medical Research Institute** in Bethesda, Maryland.
- Classified experiments with the Navy
- Gall stones

In a 1949 paper, he wrote:

"The possibility of detecting neoplasms by use of ultrasound has been considered. As with foreign bodies, the detection of a tumor would depend upon the impedance mismatch between it and the surrounding normal tissue. Tumors vary in composition and physical properties. It is reasonable to assume that in most cases, the density, elasticity, and velocity of sound would differ but slightly from that of normal tissue..."
A-mode

• A-mode ultrasound
• A = amplitude

Echo amplitude is proportional to the intensity of reflected waves (Amplitude modulation)

Distance between echoes shown on the screen is approx. proportional to real distance between tissue interfaces.
B-mode ultrasound
• B = brightness
• Intensity of echoes in grey scale

- Brightness of points on the screen represents intensity of reflected US waves (Brightness modulation).
Transducers

- 3.5MHz convex probe 
  Application: Abdomen, GYN, OB

- 7.5MHz linear probe 
  Application: Vascular, Small Parts

- 6.5MHz micro-convex probe 
  Application: Pediatric, Cardiac

- 6.5MHz trans-vaginal probe 
  Application: Vaginal
Basic characteristics of US images

Degree of reflectivity – echogenity. The images of cystic (liquid-filled) and solid structures are different. According to the intensity of reflection in the tissue bulk we can distinguish structures:

- isoechogenic
- hyperechogenic
- Hypoechogenic
- anechogenic.
Degree of reflectivity – echogenity.

- **Echogenic**: the ability of a structure to produce echoes
- **Anechoic**: no echoes: appears black on ultrasound
- **Hypoechoic**: less reflective and low amount of echoes when compared with neighboring structures, appears as varying shades of darker gray
- **Hyperechoic**: highly reflective and echo rich: when compared with neighboring structures appears as varying shades of lighter gray
- **Isoechoic**: having similar echogenicity to a neighboring structure
Figure 1-1  Anechoic. A transabdominal sagittal image of the female pelvis demonstrating the anechoic distended urinary bladder (UB) anterior to the uterus (U). Note the lack of echoes within the urinary bladder since it is filled with urine.
Figure 1-2 Hypoechoic. A transabdominal transverse image of the liver (L) demonstrating a hypoechoic (H) mass within the right lobe of the liver. Also, note the anechoic fluid (arrows) representing a right-sided pleural effusion.
Hyperechoic and isoechoic

Figure 1-3  Hyperechoic and isoechoic. A transabdominal sagittal image of the right upper quadrant. The liver (L) contains two areas (arrows) that are hyperechoic when compared with the rest of the moderate echogenicity of the liver parenchyma. The kidney (K) is isoechoic to the liver.
ULTRASOUND TEXTURE

- Homogeneous: organ parenchyma is UNIFORM in echogenicity
- Inhomogeneous or heterogeneous: organ parenchyma is not uniform in echogenicity
Ultrasound Artifacts:

Artifacts may be caused by the following:

- US waves interacting with tissue
- Machine malfunction
- Improper machine settings
- Motion of the patients
Common Artifacts, examples...

- Acoustic shadow caused by absorption and reflection of US by a kidney stone

**THIS CAN BE USEFUL!!!**

Hyperechogenic area below a cyst (low attenuation of US during passage through the cyst compared with the surrounding tissues)
PROBE ORIENTATION

- Epigastrum - Aorta, IVC, pancreas, vena portae... (transverse)
- Liver + right kidney (sagittal)
- Spleen + left kidney (sagittal)
- Abdominal aorta + aortic branches, liver, caput pancreatis (sagittal)
- Hepatic veins flow into IVC
- Liver hilum
- Urinary bladder (transverse)
IMAGE ORIENTATION
CONVEX TRANSDUCER 3,5-5 MHz
TRANSVERSAL SECTION
Like CT SCAN VIEW!!! THINK TO LOOK PATIENT FROM HIS FEET...
Transverse

Liver
Left renal artery
IVC
Superior mesenteric artery
Splanic vein
Aorta
Vertebral body
Human Liver Anatomy

- Inferior vena cava
- Aorta
- Hepatic artery
- Gall bladder
- Portal vein
- Common bile duct
IMAGE ORIENTATION
CONVEX TRANSDUCER 3,5-5 MHz
LONGITUDINAL SECTION
LONGITUDINAL ANTERIOR VENTRAL SCAN

VENTRAL

HEAD

DORSAL

FEET
PRESSURE APPLIED TO PROBE

GRADUAL BUT EFFECTIVE !!!
CONDITIONS FOR A GOOD ABDOMINAL ULTRASOUND EXAMINATION

CORRECT PREPARATION
(fasting, activated charcoal…)

PATIENT’S COOPERATION
(POSITION, DEEP BREATH)
Palpation of the gall bladder

- **Murphy’s symptom**
The pain is increased at pressing in Kehr’s point while child inhales (diseases of gall bladder)
Clinical Scenario

- A 46 year old woman presents to the clinic complaining of epigastric pain that she experiences after eating a large meal.

On examination, the patient is an obese female who does not appear to be in any acute distress. She is afebrile, with stable vital signs. The exam is only significant for the patient experiencing mild tenderness upon palpation of the right upper quadrant of her abdomen.
ACR Appropriateness Criteria

• For a patient with acute right upper quadrant pain, who is afebrile with a normal WBC count:

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<tr>
<th>Radiologic Exam Procedure</th>
<th>Appropriateness Rating</th>
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<td>CT, abdomen</td>
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<tr>
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Ultrasound Abdomen

- The imaging modality of choice for the gallbladder is ultrasound. It is fast, real-time, non-invasive, and does not utilize ionizing radiation.
- **95% sensitivity** for detection of cholelithiasis. Diagnosis based on visualization of a mobile, hyperechoic, intraluminal mass with acoustic shadowing.
- **>90% sensitivity** for detection of acute cholecystitis. Diagnosis based on presence of cholelithiasis, gallbladder wall thickening, pericholecystic fluid, and a sonographic Murphy sign.
- Limited by skill of operator, and pt’s body habitus.
Normal Gallbladder
Gallbladder, with numerous stones present
Clinical Scenario

Acute cholecystitis – notice increased gallbladder wall thickness.
Palpating the Spleen

A spleen is not palpable unless it is enlarged. Use your left hand under left lower rib cage, position finger tips so they point to axilla and press inwards and upwards. You can also ask the patient to take a deep breath and feel again.
LINEA PLEURICA → «Bat Sign» - «Sliding» – «Lung pulse»

LINEE A: orizzontali e statiche, artefatti da riverbero della linea pleurica


Segno della stratosfera o del codice a barre. Modificata da Lichtestein DA, Chest 2008;

Figura 6: Sopra: posizione sonda per la finestra apicale 4 camere con sonda settoriale. Notare il marker della sonda (freccia).
Sotto: cuore normale.
RV=ventricolo dx, LV=ventricolo sx
RA=atrito dx, LA=atrito sx
**Globo vescicale**

Vescica in scansione longitudinale e trasversale. Sono misurati i tre diametri: longitudinale, trasversale ed antero-posteriore. Il volume calcolato con la formula dell’ellissoide (prodotto dei tre diametri x0.5) evidenzia un volume > 1.000 ml.

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**Cistite acuta**

Pareti vescicali ispessite ed irregolari, nel lume sedimento ecogeno con livello modificato dalle variazioni di decubito.
**Calcolosi vescicale**
Formazione iperecogena con attenuazione distale nel lume vescicale (mobile con le variazioni di decubito).

**Carcinoma vescicale**
Formazione esogena aggettante nel lume dalla parete vescicale sn (fissa con le variazioni di decubito).
Carcinoma vescicale
Formazione ecogena ad impianto osteso ed aggettante nel lume della parete vescicale dx (fissa con le variazioni di decubito).

Carcinoma vescicale avanzato
Formazione ecogena disomogenea a carico della parete vescicale sn, a sviluppo intra o (prevalentemente) extra vescicale.
CONCLUSION

- Ultrasound are produced using the Piezoelectric effect.
- US can be considered an extension of clinical examination and of clinical skills.
- It provides real time useful clinical answers.
- It can be performed bedside.
- It is a noninvasive technique and can be repeated.
- It is relatively cheap.
- All we “see” are reflections... not real images.
- Basic features of US images allow to identify different tissue and organs.
- Correct Probe orientation is mandatory.
- US is an operator-dependent technique.
Thanks for your attention