Physics of Ultrasound Artifacts

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Objectives

• Identify common ultrasound artifacts
• Understand the physics behind 2D artifacts

Artifacts

• Definition: Any error in imaging
• Important to recognize
  – Object not real: wrong diagnosis
  – Object missing: miss real findings
  – Incorrect size, place: wrong measurements
• Causes
  – Equipment malfunction
  – Error: operator, viewer
  – Lack understanding of US physics
  – Violate sound assumptions

Sound Assumptions

1. Sound travels in a straight line
2. Sound is constant 1540 m/s
3. Sound goes directly to reflector + back
4. Thin imaging plane
5. Reflections only from beam's main axis
6. Reflections related to tissue characteristics

Types of 2D Artifacts

1. Propagation
   - Reverberation
   - Refraction
   - Multipath
   - Grating lobe
   - Range ambiguity
2. Attenuation
   - Acoustic shadow
   - Enhancement
   - Focal enhancement
3. Resolution
   - Axial, lateral
   - Beam thickness
   - Dropout
   - Speckle/noise
   - Near field clutter

Propagation Path

• Reverberation (Bounce)
  – Mirror image
  – Comet tail
  – Ringdown
• Refraction (Shift)
  – Ghosting
  – Speed error
  – Edge shadowing
• Side / Grating Lobe
• Range Ambiguity
Reverberation Artifacts

- Bouncing of US beam (reflections) between 2 strong reflectors
- Echoes of an echo
- Single or multiple artifacts
- Equally spaced lines ↓ amplitude
- Parallel to sound beam
- Deeper in straight line

Question 1

What artifact are the blue arrows pointing to in both of these TEE clips?
1. None, it is normal
2. Edge enhancement
3. Mirror image
4. Acoustic shadowing
5. Refraction

Mirror Image

- Reverberation artifact
- Single reflection between strong reflector + transducer on same path
- 2nd copy of reflector at twice distance
- Same structure more than one place
- Color Doppler also appears
- UE Aortic arch LAX, Desc Aorta SAX + LAX

Question 2

What artifact are the blue arrows pointing to in both of these TEE clips?
1. None, it is normal
2. Focal enhancement
3. Ringdown
4. Comet tail
5. Refraction

Comet Tail

- Reverberation artifact
- Small intense reflector repeatedly reflected in line with US beam
  - Aortic atheroma, mechanical valves
- Tail distal to object (long hyperechoic line)
- Thin closely spaced discrete (clean shadow)
- Parallel to sound beam

Question 3

What artifact (hyperechoic region) are the blue arrows pointing to in these 2 views?
1. None, it is normal
2. Focal enhancement
3. Ringdown
4. Comet tail
5. Refraction
**Ringdown**
- Reverberation artifact (?)
- Fluid trapped by air resonates
- Multiple reflections
- Numerous, thin, closely spaced — less discrete than comet tail
- Streaks at end scan line (dirty shadow)

**Refraction**
- Refraction is bending of transmitted + reflected waves
- Sound changes direction when
  - It strikes a boundary obliquely
  - Media have different propagation speeds
- US beam reflects off structures outside beam planes
- Examples
  - Ghosting
  - Speed error
  - Edge shadowing

**Question 4**

What artifact is shown in this ME AV LAX view?
1. Diffraction
2. Refraction
3. None, it is normal
4. Edge enhancement
5. Focal enhancement

**Ghosting**
- Refraction type
- Bending of sound striking curved boundary obliquely
- 2nd copy reflector side-by-side true anatomic structure
- Objects in different position than actually are
- Extra echoes present
- Degrades lateral resolution (edges appear blurred)

**Question 5**

What artifact (anechoic region) is the blue arrow pointing to in this ME Ascending Aorta view?
1. Shadowing
2. Edge shadowing
3. Dropout
4. Edge enhancement
5. None, it is normal

**Edge Shadowing**
- Refraction artifact (not attenuation)
- Beam bent edge of round structures, no returning echo
- Small dark areas under edges circular structure (anechoic)
- High to low velocity — narrow shadow, opposite is true
Example 6 Artifact

What artifact are the blue arrows pointing to in both of these TEE clips?
1. Enhancement
2. Ghosting
3. None, it is normal
4. Side lobe
5. Focal enhancement

Side-Grating Lobe

- Side lobes (single), Grating lobes (array) transducer
- US not in main beam
- Bounce off highly reflective structures (calcified aorta, mechanical valves, catheters)
- Multiple structures either side
- Curved arc same level of true object
- Hyperechoic, superimposed over structures

Example 7 Artifact


Range Ambiguity

- Propagation path
- Pulsed sound returns late, after 2nd pulse sent
- Late reflection from reflector beyond scan area
- Deeper structures closer then actual location unexpected intra-cardiac echo
- Changing depth (PRF) artifact may disappear/reposition

Question 6

Question 7

What artifact is shown in this ME 4 chamber view?
1. Enhancement
2. Echo contrast
3. None, it is normal
4. Range ambiguity
5. Focal enhancement

Attenuation Artifacts

- Acoustic Shadowing
- Enhancement
- Focal Enhancement

Example 8 Artifact

Question 8

What artifact (anechoic region) is the blue arrow pointing to in this ME 4 chamber view?
1. Shadowing
2. Edge shadowing
3. Dropout
4. Edge enhancement
5. Refraction

Shadowing

- Attenuation type artifact
- Lose US transmission from high reflection or absorption
- High density structures (calcium, prosthetic valves)
- Distal structures not seen (anechoic)
- Shadow shape follows US path
  - small structure close to transducer casts long shadow

Example 9 Artifact

Question 9

What artifact (hyperechoic region) is the blue arrow pointing to in this TG mid SAX view?
1. None, it is normal
2. Focal enhancement
3. Dropout
4. Edge enhancement
5. Refraction
Enhancement

• Attenuation type artifact
• Proximal structure low sound absorption (< soft tissue)
  distal structure more energy reflected
• Hyperechoic region under tissue of low attenuation
  – Distal structures brighter (hyperechoic)
  – Transmitted object darker (hypoechoic)
• Opposite of shadowing

Example 10 Artifact

Question 10

What artifact (hyperechoic region) is the blue arrow pointing to in this TG mid SAX view?
1. None, it is normal
2. Focal enhancement
3. Dropout
4. Edge enhancement
5. Refraction

Focal Enhancement

• Occurs around focal zone
• Increased side by side intensity, extra echoes
• Too much band brightness compared to other depth
• Same appearance as incorrect TGC settings

Resolution

• Axial Resolution
• Lateral Resolution: Beam width
• Elevational Resolution: Slice/Beam thickness
• Dropout
• Speckle/Noise
• Near Field Clutter

Example 11 Artifact
Question 11
What artifact (anechoic region) is the blue arrow pointing to in this TG mid SAX view?
1. None, it is normal
2. Acoustic shadowing
3. Dropout
4. Edge shadowing
5. Refraction

Example 12 Artifact

Question 12
What US machine knob was adjusted to eliminate the artifact the blue arrow is pointing to in this ME AV LAX view?
1. Focus
2. Overall Gain
3. TGC Gain
4. Contrast
5. Harmonics

Noise

Example 13 Artifacts
Question 13

What artifact is the blue arrow pointing to in this epiaortic image of the descending aorta in SAX?
1. Echo contrast
2. Noise
3. Near field clutter
4. Shadowing
5. Refraction

Near Field Clutter

- High amplitude oscillations of piezoelectric elements
- Extra echoes in near field
- Difficulty differentiating near field structures
- Common with epi-aortic probe
- Reduce by using stand-off with saline filled glove
- Harmonics for TTE/TEE

Summary

- Artifacts are common
- Learn to recognize
- Don’t misdiagnose
- Make pretty pictures

Selected Readings

3. Ohio State Physics Lecture Series on youtube: [http://www.youtube.com/watch?v=7iQe52pmbTQ](http://www.youtube.com/watch?v=7iQe52pmbTQ)

Thank You

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