# Physics of Ultrasound Artifacts

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http://pie.med.utoronto.ca/TEE/



## **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 1540m/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**

Propagation
Reverberation
Refraction
Multipath
Grating lobe
Range ambiguity

#### 2Attenuation

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  $\downarrow$  amplitude
- Parallel to sound beam
- Deeper in straight line









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

![](_page_7_Picture_8.jpeg)

![](_page_7_Picture_9.jpeg)

## Mirror Image

![](_page_8_Figure_1.jpeg)

- 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

![](_page_8_Picture_8.jpeg)

![](_page_8_Picture_9.jpeg)

![](_page_9_Figure_1.jpeg)

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

![](_page_9_Picture_8.jpeg)

![](_page_9_Picture_9.jpeg)

## **Comet Tail**

![](_page_10_Figure_1.jpeg)

![](_page_10_Picture_2.jpeg)

![](_page_10_Picture_3.jpeg)

- 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

![](_page_10_Picture_10.jpeg)

![](_page_10_Picture_11.jpeg)

![](_page_10_Picture_12.jpeg)

![](_page_11_Picture_1.jpeg)

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

![](_page_11_Picture_8.jpeg)

![](_page_11_Picture_9.jpeg)

# Ringdown

![](_page_12_Figure_1.jpeg)

- 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)

![](_page_12_Picture_8.jpeg)

![](_page_12_Picture_9.jpeg)

## 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

![](_page_13_Picture_10.jpeg)

![](_page_13_Picture_11.jpeg)

![](_page_13_Picture_12.jpeg)

![](_page_14_Figure_1.jpeg)

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

![](_page_14_Picture_8.jpeg)

Denault A, Couture P, Vegas A, et al. Transesophageal Echocardiography Multimedia Manual 2<sup>nd</sup> ed

![](_page_14_Picture_10.jpeg)

# Ghosting

![](_page_15_Picture_1.jpeg)

![](_page_15_Picture_2.jpeg)

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

![](_page_15_Picture_9.jpeg)

![](_page_15_Picture_10.jpeg)

![](_page_16_Figure_1.jpeg)

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

![](_page_16_Picture_8.jpeg)

![](_page_16_Picture_9.jpeg)

## Edge Shadowing

![](_page_17_Figure_1.jpeg)

- 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

![](_page_17_Picture_6.jpeg)

![](_page_17_Picture_7.jpeg)

#### Example 6 Artifact

![](_page_18_Figure_1.jpeg)

Lossy Compression - not intended for diagnosis

![](_page_18_Figure_3.jpeg)

![](_page_18_Picture_4.jpeg)

![](_page_18_Picture_5.jpeg)

![](_page_19_Figure_1.jpeg)

![](_page_19_Figure_2.jpeg)

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

![](_page_19_Picture_9.jpeg)

![](_page_19_Picture_10.jpeg)

## Side-Grating Lobe

![](_page_20_Picture_1.jpeg)

- 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

![](_page_20_Picture_8.jpeg)

![](_page_20_Picture_9.jpeg)

![](_page_20_Picture_10.jpeg)

#### Example 7 Artifact

![](_page_21_Figure_1.jpeg)

![](_page_21_Picture_2.jpeg)

Denault A, Couture P, Vegas A, et al. Transesophageal Echocardiography Multimedia Manual 2<sup>nd</sup> ed

![](_page_21_Picture_4.jpeg)

![](_page_22_Figure_1.jpeg)

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

![](_page_22_Picture_8.jpeg)

Denault A, Couture P, Vegas A, et al. Transesophageal Echocardiography Multimedia Manual 2<sup>nd</sup> ed

![](_page_22_Picture_10.jpeg)

## **Range Ambiguity**

![](_page_23_Figure_1.jpeg)

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

![](_page_23_Picture_7.jpeg)

![](_page_23_Picture_8.jpeg)

#### **Attenuation Artifacts**

- Acoustic Shadowing
- Enhancement
- Focal Enhancement

![](_page_24_Picture_4.jpeg)

![](_page_24_Picture_5.jpeg)

![](_page_24_Picture_6.jpeg)

#### **Example 8 Artifact**

![](_page_25_Figure_1.jpeg)

![](_page_25_Picture_2.jpeg)

![](_page_25_Picture_3.jpeg)

![](_page_26_Figure_1.jpeg)

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

![](_page_26_Picture_8.jpeg)

![](_page_26_Picture_9.jpeg)

## Shadowing

![](_page_27_Picture_1.jpeg)

- 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

![](_page_27_Picture_8.jpeg)

![](_page_27_Picture_9.jpeg)

#### Example 9 Artifact

![](_page_28_Figure_1.jpeg)

53 bpm

![](_page_28_Picture_3.jpeg)

![](_page_28_Picture_4.jpeg)

![](_page_29_Figure_1.jpeg)

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

![](_page_29_Picture_8.jpeg)

![](_page_29_Picture_9.jpeg)

## Enhancement

![](_page_30_Figure_1.jpeg)

![](_page_30_Picture_2.jpeg)

- 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

![](_page_30_Picture_9.jpeg)

![](_page_30_Picture_10.jpeg)

## Example 10 Artifact

![](_page_31_Figure_1.jpeg)

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51 bpm

![](_page_31_Picture_4.jpeg)

![](_page_31_Picture_5.jpeg)

![](_page_32_Figure_1.jpeg)

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

![](_page_32_Picture_8.jpeg)

![](_page_32_Picture_9.jpeg)

## Focal Enhancement

![](_page_33_Picture_1.jpeg)

![](_page_33_Picture_2.jpeg)

- 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

![](_page_33_Picture_7.jpeg)

![](_page_33_Picture_8.jpeg)

## Resolution

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

![](_page_34_Figure_7.jpeg)

![](_page_34_Picture_8.jpeg)

![](_page_34_Picture_9.jpeg)

## Example 11 Artifact

![](_page_35_Figure_1.jpeg)

![](_page_35_Picture_2.jpeg)

![](_page_35_Picture_3.jpeg)

![](_page_36_Figure_1.jpeg)

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

![](_page_36_Picture_8.jpeg)

![](_page_36_Picture_9.jpeg)

### Dropout

![](_page_37_Picture_1.jpeg)

- Structures not seen, anechoic
- Signal attenuation from
  - Inadequate TGC/brightness or power
  - High frequency transducer
- Imaging beam parallel to structure (anistrophy)
- TG SAX view poorly seen lateral + septal wall

![](_page_37_Picture_8.jpeg)

![](_page_37_Picture_9.jpeg)

#### Example 12 Artifact

![](_page_38_Figure_1.jpeg)

![](_page_38_Picture_2.jpeg)

![](_page_38_Picture_3.jpeg)

![](_page_39_Picture_1.jpeg)

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

![](_page_39_Picture_8.jpeg)

![](_page_39_Picture_9.jpeg)

## Noise

![](_page_40_Picture_1.jpeg)

![](_page_40_Picture_2.jpeg)

![](_page_40_Picture_3.jpeg)

#### Acoustic (acoustic speckle)

- Interference of scattered sound waves reflection from tissues
- Small amplitude echoes, grainy image
- Improves with harmonic imaging

#### Electrical

• Repetitive geometric pattern

![](_page_40_Picture_10.jpeg)

![](_page_40_Picture_11.jpeg)

## **Example 13 Artifacts**

![](_page_41_Picture_1.jpeg)

![](_page_41_Picture_2.jpeg)

![](_page_41_Picture_3.jpeg)

![](_page_42_Figure_1.jpeg)

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

![](_page_42_Picture_8.jpeg)

![](_page_42_Picture_9.jpeg)

## Near Field Clutter

![](_page_43_Picture_1.jpeg)

- 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

![](_page_43_Picture_8.jpeg)

![](_page_43_Picture_9.jpeg)

## Summary

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

![](_page_44_Picture_5.jpeg)

![](_page_44_Picture_6.jpeg)

![](_page_44_Picture_7.jpeg)

## **Selected Readings**

- 1. Feldman MK et al. US Artifacts. RadioGraphics 2009; 29:1179-89.
- 2. Hindi A, et al. Artifacts in Diagnostic Ultrasound. Reports in Medical Imaging 2013; 6:29-48.
- Ohio State Physics Lecture Series on youtube: <u>http://www.youtube.com/watch?v=7iQe52pmbTC</u>
- 4. Le HT, et al Imaging Artifacts in Echocardiography. Anesth Analg 2016;122:633-46.

![](_page_45_Picture_5.jpeg)

![](_page_45_Picture_6.jpeg)

#### Thank You annette.vegas@uhn.ca

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