

## Physics of Ultrasound Artifacts

Annette Vegas MD, FRCPC, FASE  
Professor Anesthesiology



Toronto General Hospital Department of Anesthesia  
Perioperative Interactive Education  
<http://pie.med.utoronto.ca/TEE/>



## Objectives

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



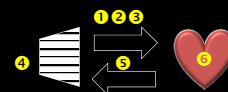
## Artifacts

- 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

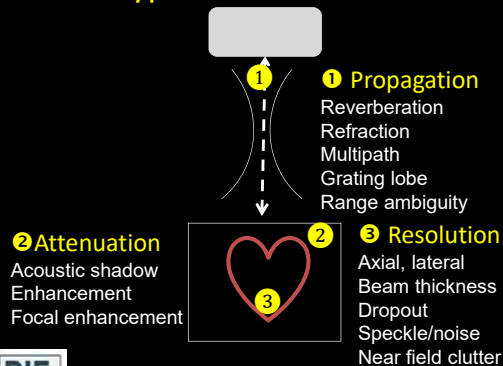


## Sound Assumptions

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

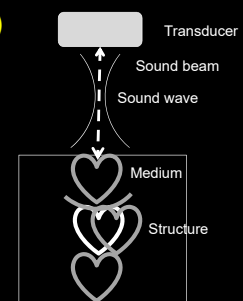


## Types of 2D Artifacts



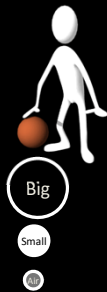
## Propagation Path

- **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

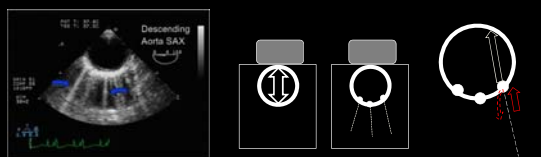


What artifact are the blue arrows pointing to in both of these TEE clips ?

1. None, it is normal
2. Focal enhancement
3. Ringdown
4. Comet tail
5. Refraction



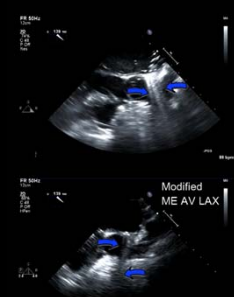
## Comet Tail



- 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

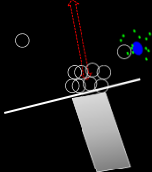
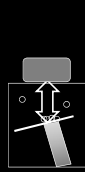
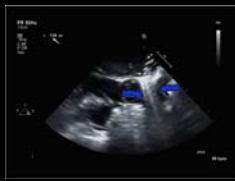


What artifact (hyperechoic region) are the blue arrows pointing to in these 2 views ?

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)

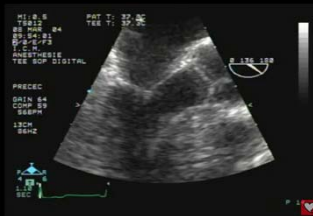


## Refraction

- 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 ?

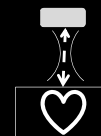
1. Diffraction
2. Refraction
3. None, it is normal
4. Edge enhancement
5. Focal enhancement



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



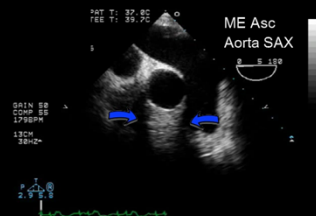
## Ghosting



- 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)



## Question 5

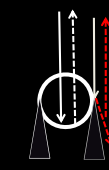
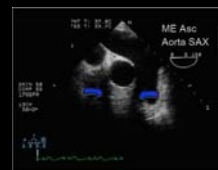


What artifact (anechoic region) is the blue arrow pointing to in this ME Ascending Aorta view ?

1. Shadowing
2. Edge shadowing
3. Dropout
4. Edge enhancement
5. None, it is normal



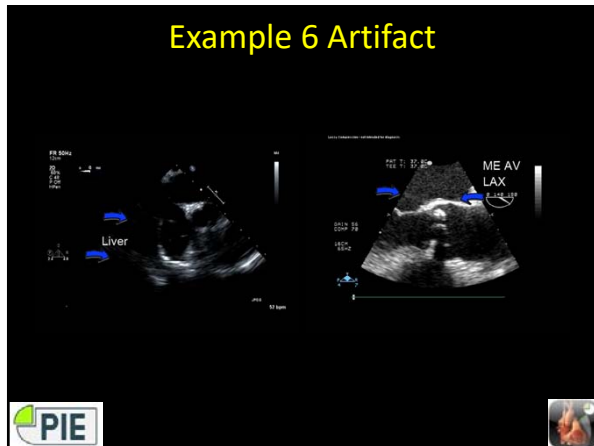
## Edge Shadowing



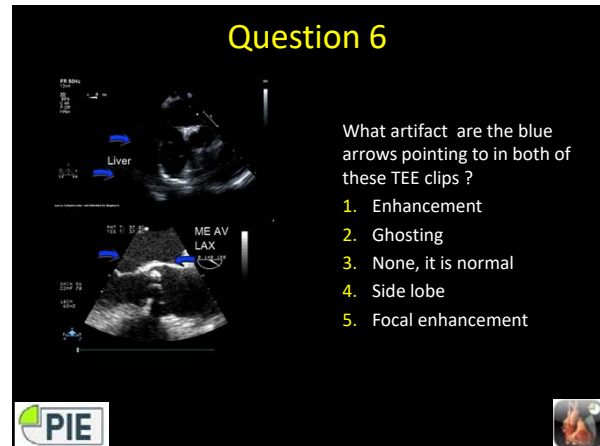
- Refraction artifact (not attenuation)
- Beam bent edge of round structures, no returning echo
- Small dark areas under edges circular structure (anechoic)
- High to low velocity = narrow shadow, opposite is true



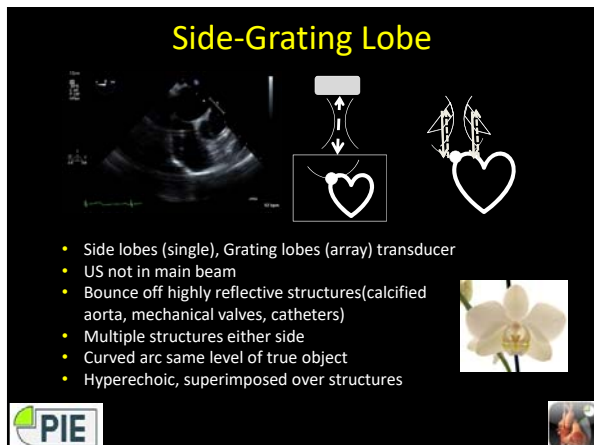
### Example 6 Artifact



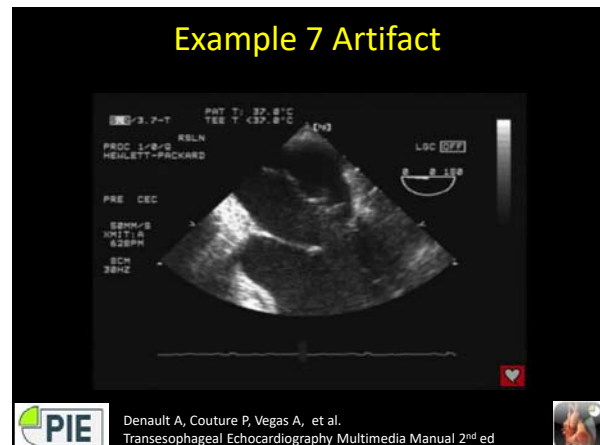
### Question 6



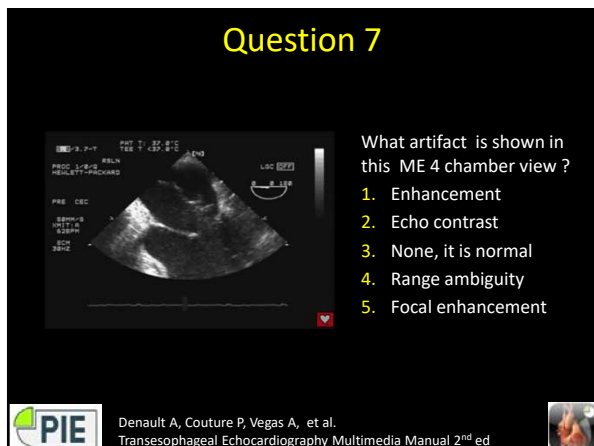
### Side-Grating Lobe



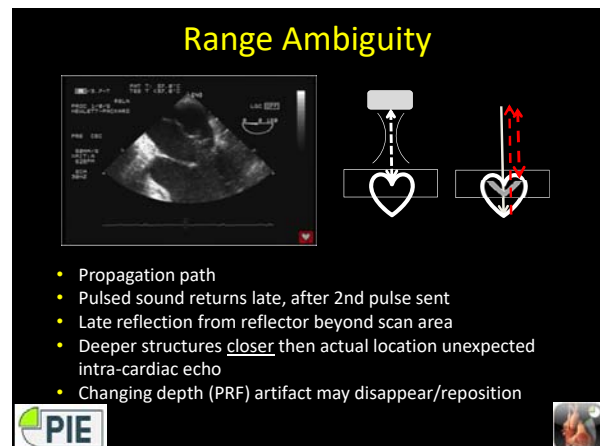
### Example 7 Artifact



### Question 7



### Range Ambiguity

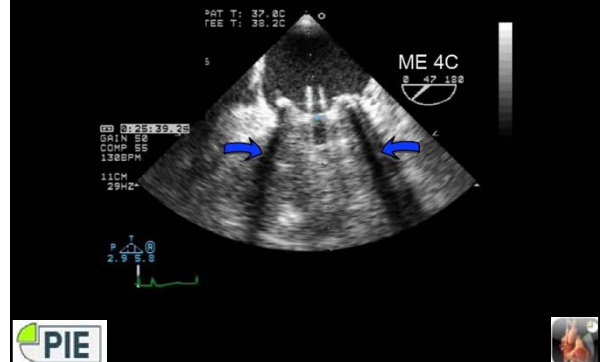


## Attenuation Artifacts

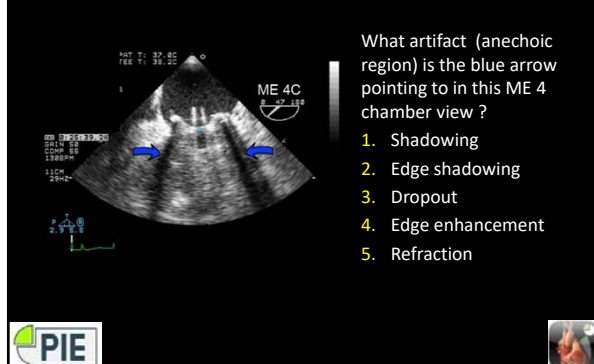
- Acoustic Shadowing
- Enhancement
- Focal Enhancement



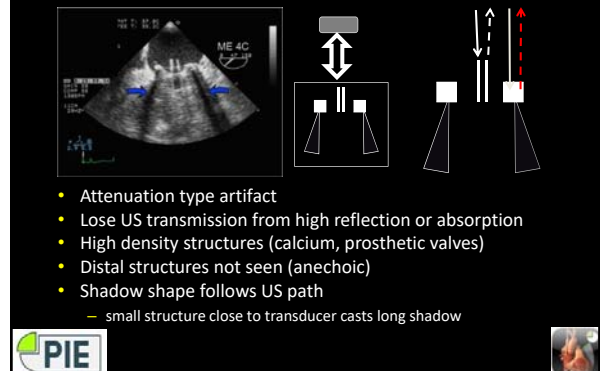
## Example 8 Artifact



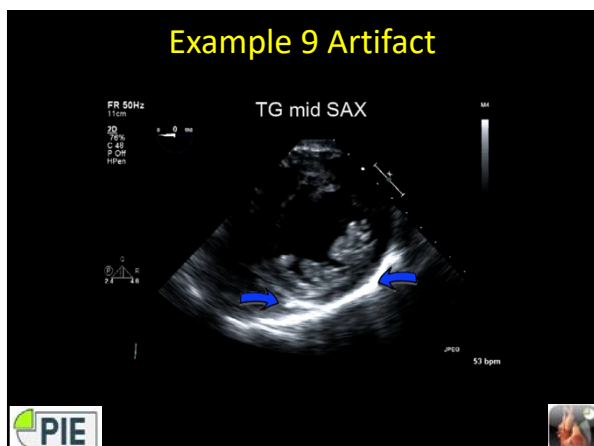
## Question 8



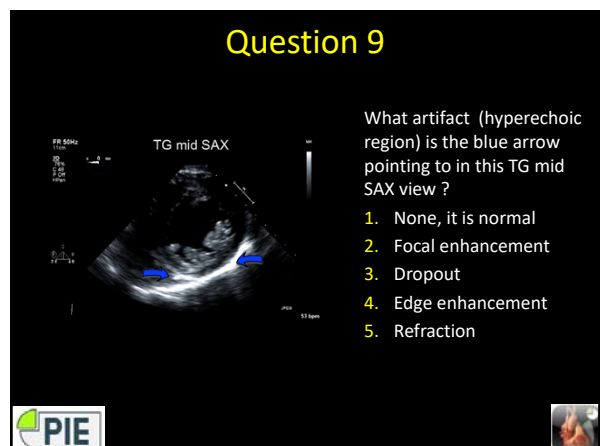
## Shadowing



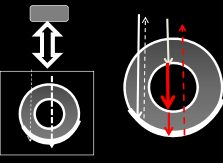
## Example 9 Artifact



## Question 9



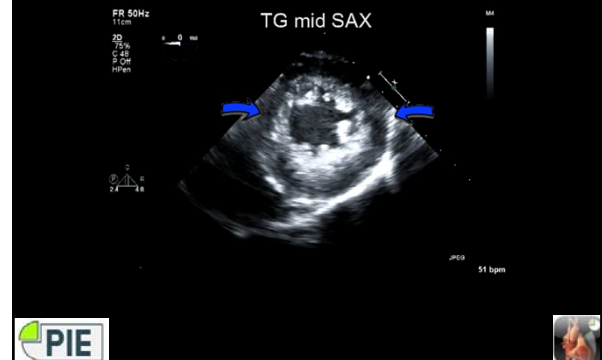
## Enhancement



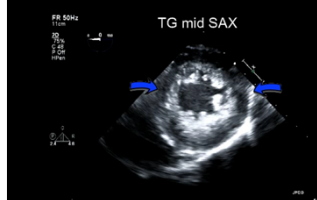
- Attenuation type artifact
- Proximal structure low sound absorption (< soft tissue)  
distal structure more energy reflected
- Hyperechoic region under tissue of low attenuation
  - Distal structures brighter (hyperechoic)
  - Transmitted object darker (hypoechoic)
- Opposite of shadowing



## Example 10 Artifact



## Question 10

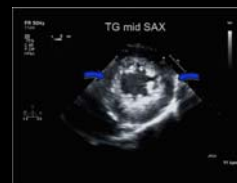


What artifact (hyperechoic region) is the blue arrow pointing to in this TG mid SAX view?

1. None, it is normal
2. Focal enhancement
3. Dropout
4. Edge enhancement
5. Refraction



## Focal Enhancement

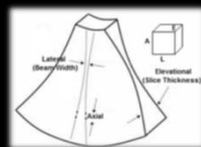


- Occurs around focal zone
- Increased side by side intensity, extra echoes
- Too much band brightness compared to other depth
- Same appearance as incorrect TGC settings

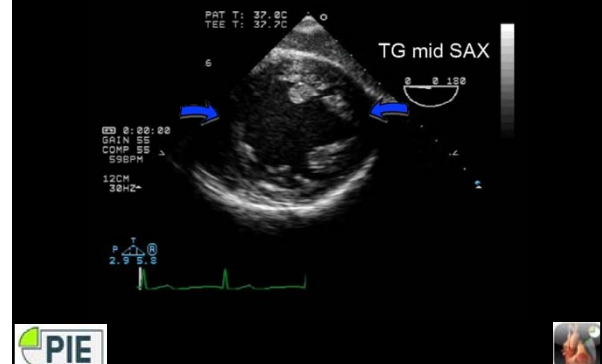


## Resolution

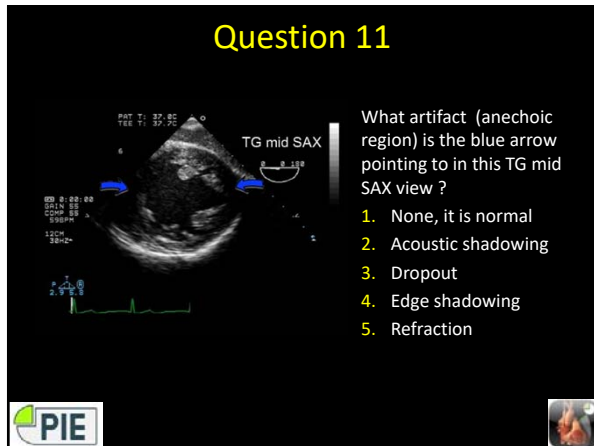
- Axial Resolution
- Lateral Resolution: Beam width
- Elevational Resolution: Slice/Beam thickness
- Dropout
- Speckle/Noise
- Near Field Clutter



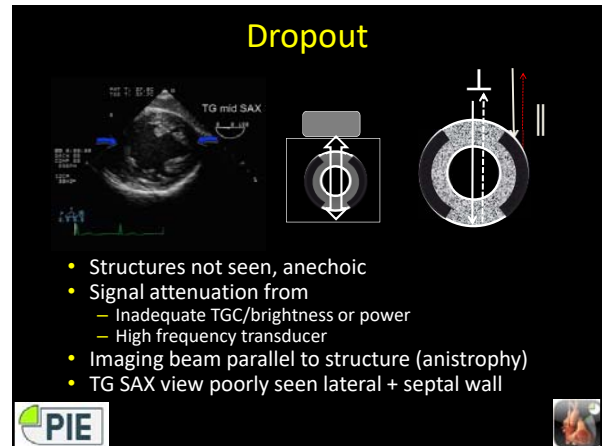
## Example 11 Artifact



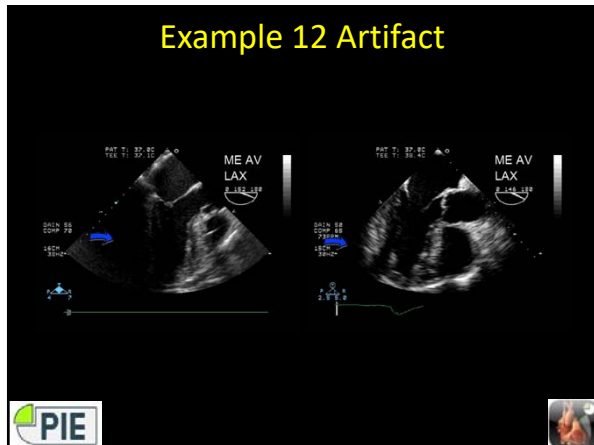
### Question 11



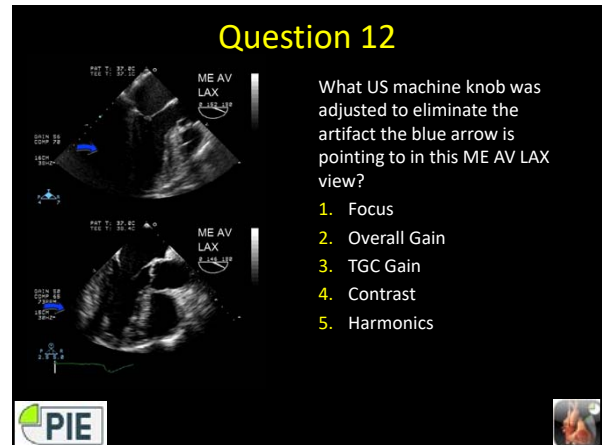
### Dropout



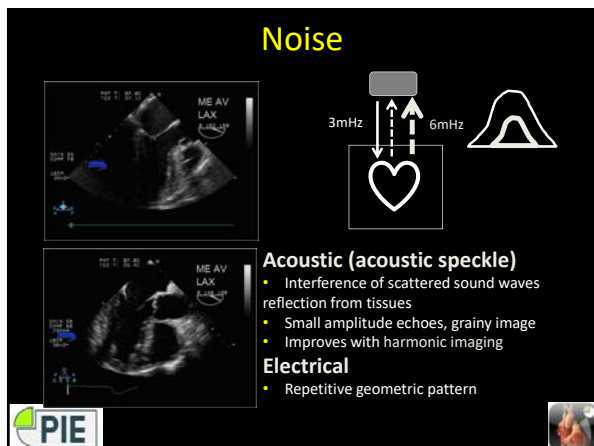
### Example 12 Artifact



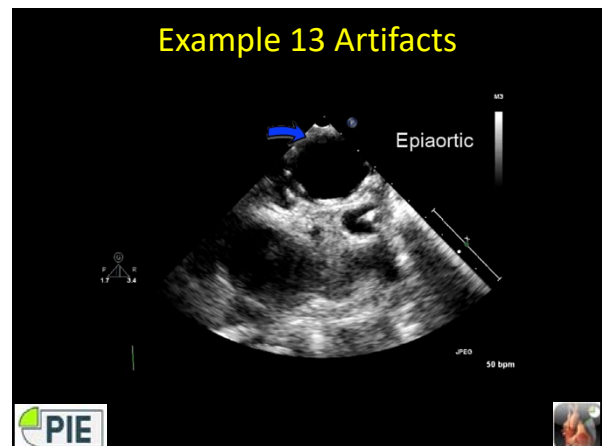
### Question 12



### Noise

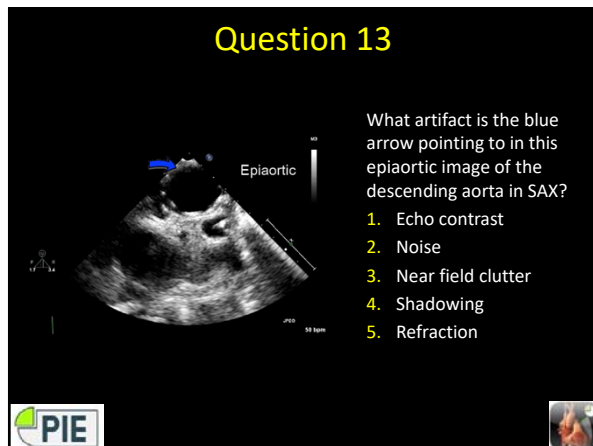


### Example 13 Artifacts

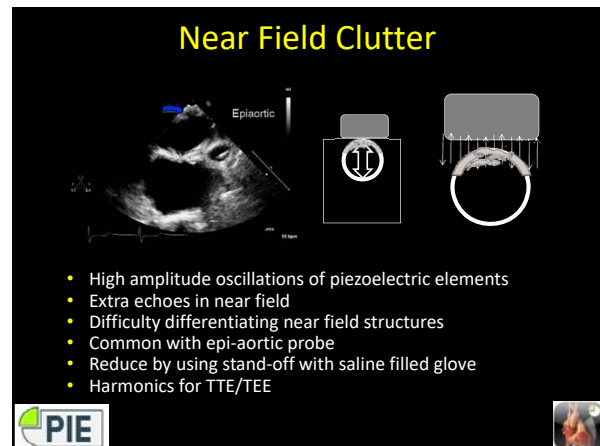




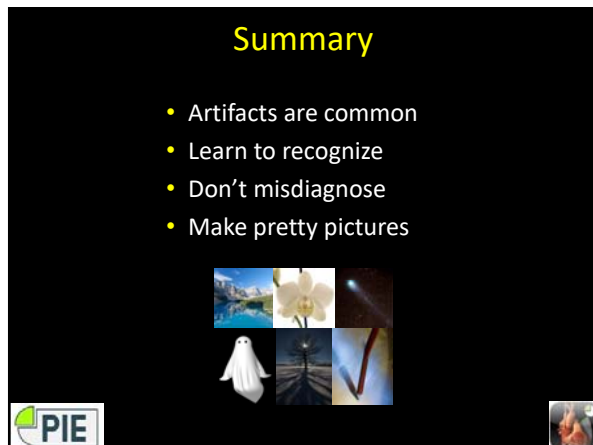
### Question 13



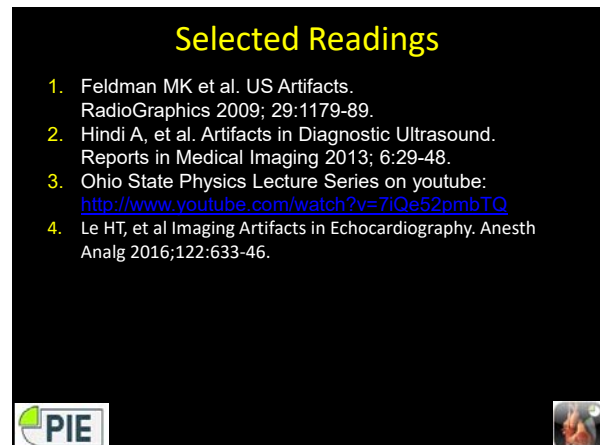
### Near Field Clutter



### Summary



### Selected Readings



Thank You  
annette.vegas@uhn.ca

