Physics and Artifacts

SK Edelman       NJ Skubas MD, FASE, DSc
Director         Professor of Clinical Anesthesiology
ESP Ultrasound   Chief, Cardiac Anesthesiology
Weill Cornell Medical College
New York, NY

Objectives
At the conclusion of this lecture, the participant should be able to
1. describe the artifacts on the basis of 2D ultrasound principles
2. classify the anatomic pitfalls by location in the heart
3. differentiate pitfalls from true findings with manipulation of settings

Echocardiographic imaging results from the interaction between the ultrasound beam and biologic tissues (blood and myocardium). These interactions include reflection, transmission (and refraction) and absorption. The travel time and attenuation (loss of acoustic energy) of the returning echo is used to generate the two-dimensional (2D) image. In soft tissue (myocardium, blood), the ultrasound travels with a speed of 1540 m/s. A structure (reflector) at a distance (D) from the transducer will generate a reflection; this reflection will be timed after a time equal to 2 x D/1540 s or D/770 s from the time the transmitted ultrasound was produced by the transducer. The ultrasound system processes the returning echoes to generate a 2D image based on the following principles:

a. ultrasound travels in a straight line
b. a structure (reflector) generates a single reflection (echo)
c. echoes are generated only from reflectors located within the main ultrasound beam
d. the intensity of the echoes is related to the acoustic characteristics of the reflector
e. the position of the reflector on the display monitor is proportional to the round trip travel time of the ultrasound beam
f. the speed of sound in human tissue is constant (1540 m/s)

An echocardiographic imaging artifact does not convey anatomic information. This is the case when the displayed structure is not real, or a real structure is misplaced, absent, or distorted, enhanced or attenuated.

Artifacts

A. Multiple artifacts (not real structures)
These artifacts are produced from the violation of “one echo per reflector” principle.

Reverberations are artifacts produced distal to a real reflector, along a straight path. Their position is at multiples of the distance of the reflector from the transducer, and they appear as a “ladder”. This is how, in the ME ascending aorta LAX view, a pulmonary artery catheter inside the right pulmonary artery is reproduced distally inside a dilated aorta and, together with side lobes (see below), may appear as a dissection flap. Reverberations become fainter with decreasing the gain and disappear in alternate views.
Comet tail, ring-down or near-field artifacts are produced with the same back-and-from mechanism as reverberations; for these artifacts, the reflected ultrasound travels between closely spaced surfaces (microbubbles, calcified plaques) between returning back to the transducer.

Mirror image is a duplicate (triplicate, etc.) of the reflector at twice (thrice, etc.) the distance from the transducer. The most common example is the double-barrel descending aorta. Mirror imaging occurs with Doppler and 3D echocardiography.

B. Misplaced reflections
These artifacts occur from reflections off objects that are imaged with the lateral part of the ultrasound beam (less acoustic energy than the main beam) when they are incorrectly imaged as if they had originated from the main beam.

Side (or grating) lobe artifacts are produced from a highly reflecting object (wire or catheter) that is imaged with the side beam. The oscillating transducer is scanning the object multiple times and the strong reflections appear on both sides of the reflector, at equal distance from the transducer, placed in an arc.

C. Missing reflections
A highly reflected surface will decrease the energy of the propagated ultrasound and the reflections will be attenuated or missing distal to the surface.

Acoustic shadowing is the lack of reflections distal to a metal, calcified or other strongly reflective surfaces. The lack of echoes appears as a shadow, which traverses anatomic structures. Alternative views are mandatory to image distal to such strong reflectors. Examples are calcified mitral annulus or a mitral prosthesis (the acoustic shadowing traverses the inter-ventricular septum or lateral left ventricular walls in the ME views; alternate view: TG) or a prosthetic aortic valve in the ME views (the acoustic shadowing traverses the tricuspid valve or the free right ventricular wall; alternate view: TG). Acoustic shadowing in 3D produces holes traversing structures and lack of reflections distal to it.

Enhancement is the opposite of acoustic shadowing. It occurs when the ultrasound beam encounters a weaker reflector, is attenuated less than anticipated and the returning echoes from distal structures appear brighter. The corrective action is to use the time-gain compensation to “balance” the reflections.

Alternate views (from ME to TG and vice versa) and imaging techniques (i.e., epiaortic or epicardial) are necessary to remove artifacts. 3D echocardiography or Doppler are prone to same artifacts and pitfalls.

D. Doppler artifacts
Aliasing occurs when the Nyquist limit is unable to resolve the blood velocity. The use of high pulse repetition frequency or continuous wave Doppler will resolve high velocities at the expense of spatial resolution (particularly when using continuous wave Doppler). Mirroring or “crosstalk” is the appearance of a symmetric spectral image on the opposite side of the zero baseline from the true signal. It is less intense than the actual signal and can be reduced by decreasing the power output and optimizing the alignment of the Doppler beam with the flow direction.
Beam width artifact is produced by a sample volume that is placed in the far field that is recording simultaneously more than one velocities.

Anatomic pitfalls

Anatomic pitfalls are real structures that are confused with artifacts or other structures. A list of them is shown below.

<table>
<thead>
<tr>
<th>Right Atrium #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crista Terminalis #</td>
</tr>
<tr>
<td>Located at the junction of SVC and RA (ME bicaval view); mimics a firmly attached thrombus #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chiari network #</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Flimsy” linear, “floating” structure (RA in ME views); attached to crista terminalis and Thebesian valve #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eustachian Valve #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Located at the junction of IVC and RA (ME 4C view); elongated thin structure; may “divide” RA #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coronary Sinus #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Located on the RA side of the septal TCV leaflet (ME 4C or bicaval views); always on the atrial side of the mitral annulus plane (ME 2C view); DDx from abscess #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Persistent left superior vena cava #</th>
</tr>
</thead>
<tbody>
<tr>
<td>dilated CS orifice (diagnose with i.v. saline infusion in a left upper extremity vein); retrograde cardioplegia administration is not effective #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thebesian Valve #</th>
</tr>
</thead>
<tbody>
<tr>
<td>“guards” the orifice of CS; may impede cannulation #</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RAA trabeculations, RA pectinate muscles #</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDx: thrombus is larger and moves freely Prominent echo dense “mass” at lateral tricuspid annulus/atrio-ventricular groove (adipose tissue) #</td>
</tr>
</tbody>
</table>

| Interatrial septum # |
| Location during cardiac cycle influenced by RA and LA pressure; Aneurysm (maximum excursion >1.5 cm; ME 4C and bicaval views); associated with PFO; lipomatous hypertrophy (“dumbbell”) spares the fossa ovalis (DDx from tumor)
| Devices: Catheters, cannulae, wires
| Reverberations, side lobes and shadowing

**Right Ventricle**

**Moderator Band**

Between RV free wall and IVS; ME 4C

**Left atrium**

**Ligament of Marshall**

Junction of left upper pulmonary vein and left atrial appendage (ME 4C view); “Coumadin ridge” (misdiagnosed thrombus)

**Smoke**

Swirling due to low flow state; DDx from high gain (immobile)

**LAA**

Multilobar (ME 4C to 2C views); dilated in LA hypertension or AFib; thrombosis possible

Trabeculations are equally spaced, with equal echogeneity and move in synchrony with the LAA; may be confused with thrombosis (unequal spacing/size/echogeneity, relatively immobile, fill the LAA cavity)

**Transverse sinus**

Potential space (better image in pericardial effusion) between LA and great arteries; ME AV SAX (LA – PA), ME AV LAX (LA – Aorta)

**Oblique sinus**

Behind aorta and PA, adjacent to SVC; ME AA SAX

**Aortic Valve**

**Lambl’s excrescences**

Thread-like filaments on either side of AV cusps (middle part); DDx from endocarditis or fibroelastoma (tumor, irregular shaped, with stalk)

**Nodes of Arantius**

At point of cusp periphery, confused with mass (DDx: endocarditis)
Aorta

| Mass (echo-dense) at intervalvular fibrosa post-AVR (ME views); DDx from abscess (echo-lucent) |
| Atheroma” at junction of arch and descending aorta |

References:


Skubas NJ, et al. Diagnostic dilemma: a pacemaker lead inside the left atrium or an echocardiographic beam width artifact? Anesth Analg 2006;102:1043-4
