Artifacts in Three-Dimensional Transesophageal Echocardiography

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Three-dimensional (3D) transesophageal echocardiography (TEE) is subject to the same types of artifacts encountered on two-dimensional TEE. However, when displayed in a 3D format, some of the artifacts appear more "realistic," whereas others are unique to image acquisition and postprocessing. Three-dimensional TEE is increasingly used in the setting of percutaneous catheter-based interventions and ablation procedures, and 3D artifacts caused by the metallic components of catheters and devices are particularly frequent. Knowledge of these artifacts is of paramount relevance to avoid misinterpretation of 3D images. Although artifacts and pitfalls on two-dimensional echocardiography are well described and classified, a systematic description of artifacts in 3D transesophageal echocardiographic images and how they affect 3D imaging is still absent. The aim of this review is to describe the most relevant artifacts on 3D TEE, with particular emphasis on those occurring during percutaneous interventions for structural heart disease and ablation procedures. (J Am Soc Echocardiogr 2014;27:453-62.)

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Three-dimensional (3D) transesophageal echocardiography (TEE) provides high-quality images of cardiac structures in a 3D format that appear identical to anatomic specimens.[1-3] In percutaneous catheter-based interventions and ablation procedures, 3D TEE is increasingly used for its ability to intersect long segments of catheters, tips, and devices without excessive probe manipulations; moreover, in most cases, the entire scenario in which catheter-based interventions and electrophysiologic procedures take place can be shown in a single 3D view.[4-9]

Three-dimensional TEE is subject to the same types of artifacts encountered on two-dimensional (2D) TEE. However, when displayed in a 3D format, some of the artifacts appear more "realistic" (i.e., dropout artifacts of the atrial septum or aortic leaflets resemble real holes), whereas others are unique to 3D image acquisition and postprocessing. In the setting of percutaneous interventions and ablation procedures, artifacts caused by the metallic components of catheters and devices are particularly frequent. Reverberations, shadowing, and blooming may alter 3D images of catheters or cover surrounding structures. Moreover, excessive undergain or overgain may significantly distort 3D images and reduce their quality. Knowledge of these artifacts is of paramount relevance to avoid misinterpretation of 3D images. Artifacts and pitfalls on 2D echocardiography are well described and classified.[10-12] However, despite several exhaustive reviews of 3D echocardiography,[13-16] a systematic description of artifacts on 3D TEE and how they affect images is still absent. The aim of this review is to describe the most relevant artifacts on 3D TEE, with particular emphasis on those occurring during percutaneous interventions for structural heart disease and ablation procedures. Table 1 summarizes these artifacts, their mechanisms, their impact on images, and how to avoid or minimize them.

STITCHING (RECONSTRUCTION) ARTIFACTS

The full-volume data set acquisition in most instruments uses electrocardiographic gating to capture a large volumetric data set over sequential cardiac cycles by advancing sector by sector (or subvolume). A correct acquisition requires regular heart rhythm and breath-holding to obtain the highest 3D spatial and temporal resolution with a volume rate > 50 Hz. This is due to the inverse relationship between volume rate (i.e., the number of volumes scanned per second), volume width, and spatial resolution (high number of ultrasound lines). Because decreasing the volume width automatically increases volume rate and the number of ultrasound lines, narrow subvolumes have high temporal and spatial resolution. In full-volume acquisition, the final image is a summation of these narrow subvolumes. The large full volume maintains the same high temporal and spatial resolution (Figure 1, Video 1; available at www.onlinejase.com). The price paid, however, is the lack of true real-time imaging (because the full image is unavailable until the last cycle is acquired) and the frequent occurrence of stitching artifacts. Stitching (or motion) artifacts are due to incorrect juxtaposition at the interface of the subvolumes. The positions of subvolumes may vary between sequential beats because of translation after respiration, different lengths of cardiac cycle, irregular heart rhythm, or any transducer or patient movement (Figure 2; Videos 2 and 3; available at www.onlinejase.com). Such artifacts not only affect comprehension of

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Abbreviations

IAS = Interatrial septum

TEE = Transesophageal echocardiography

3D = Three-dimensional

2D = Two-dimensional

structures but also can result in difficulties in quantification. Thus, in any electrocardiographically gated full-volume acquisition, the patient must stay very still, suspending breathing for a few seconds, and the operator must stabilize the probe during the entire acquisition.

DROPOUT ARTIFACTS

Dropout artifacts may be defined as a loss of ultrasound data on 3D surface images due to poor echocardiographic signal strength. They typically appear as a lack of tissue on 3D images. The most common dropout artifacts occur in the interatrial septum (IAS) and aortic leaflets and may be misinterpreted as real holes simulating atrial septal defects and leaflet perforations.

Dropout Artifacts of the IAS

The unique ability of 3D TEE is to image the surface of the IAS (the en face view). One of the easiest ways to obtain the IAS in an en face view is from the midesophageal 2D transesophageal bicaval view. From this position, the septum is nearly perpendicular to the ultrasound beam, and any 3D modality of acquisition (zoom mode, full-volume single beat, and full-volume multibeat) provides high-quality images of the left and right aspects of the septum.[2]

Not infrequently, the area of the fossa ovalis may appear to have a lack of tissue (Figure 3A, Video 4; available at www.onlinejase.com). This happens when the fossa ovalis is not completely perpendicular to the ultrasound beam (Figure 3B) and consequently reflects scattered, weak echoes, which create apparent holes in the tissue. These artifacts may be more evident in 3D than 2D format, because they also broaden in the third dimension. A second reason may be the thinness of the fossa ovalis compared with the surrounding structures, which may contribute to producing echocardiographic signals of low intensity. Fine tuning the gain setting and/or a slight change in probe position to optimize the biplane preview with the fossa ovalis perpendicular to the ultrasound beam may reduce these artifacts. However, dropouts usually disappear only when the gain is slightly overset and fine static noises cover the hole. This might result in poor-quality display. Borders of these apparent holes are rather indistinct, which may be one clue in distinguishing them from real atrial septal defects.

Table 1 Types of 3D artifacts

Type of artifact	Acquisition	Mechanism	Impact on images	How to avoid/minimize
Stitching artifacts	Full volume	Incorrect juxtaposition at the interface of sequential subvolumes (because of arrhythmias, breathing, probe/patient motion)	Strong demarcation between subvolumes leading to a “broken” image	Ask for breath holding and maintain still the position of probe
Dropout artifacts	Any	Poor echocardiographic signal strength due to weak echoes	These artifacts can be misdiagnosed as true holes/ perforations	Maintain slightly oversetting the gain and surfaces perpendicular to ultrasound beam
Blurring artifacts	Any	Indistinct edges of structures due to the assembly of nonisotropic voxels	Thin structures (i.e., chordae tendineae) appear thicker than they actually are	Use perspectives in which the 3D image is created using mostly the axial resolution
Blooming artifacts	Any	Metallic structures when intersected by ultrasound produce fringes extending beyond the borders of the metallic devices/catheters	Metallic structures appear with irregular, thick edges	No suggestions
Railroad-shaped artifacts	Any	In large catheters with wide lumens, two surfaces are perpendicular to the ultrasound beam, producing strong echoes, while the other two are tangential, producing very weak echoes	Single catheter appears as two linear structures	Obtain the most favorable perspective (i.e., the “en face” view of the surface perpendicular to the beam), and increase compression to merge boundaries
Reverberations	Any	Multiple reflection of metallic component of catheters	Depending on the perspective and the position of catheter, reverberations may appear to lengthen the catheter	No suggestions
Shadowing	Any	Inability of ultrasound to pass through strong reflecting catheters/devices	Lack of tissue posterior to catheters/devices that may appear as a “tear” of cardiac structures	Cover the shadowing by properly rotating/angulating the volumetric data set
Gain	Any	Variation of gain may produce significant variation in the size of structures	Orifices may appear larger or smaller according to gain variation	No suggestions