Real-time Three-dimensional Echocardiography

From Diagnosis to Intervention

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KEYWORDS

- Real-time three-dimensional echocardiography • Congenital heart disease
- Interventional cardiology • Transesophageal echocardiography
- Myxomatous degeneration

KEY POINTS

- Real-time three-dimensional echocardiography (RT3DE) is a clinically relevant technique that provides direct evaluation of the cardiac chambers, noninvasive realistic views of the valves, and anatomic details of congenital defects.
- Left ventricular volume, ejection fraction, mass, and wall motion can be calculated with minimal postprocessing analysis.
- Identification and characterization of masses and thrombi can be enhanced with RT3DE.
- Real-time three-dimensional (RT3D) transesophageal echocardiography (TEE) permits visualization of catheters, balloons, and devices, in addition to the structure undergoing intervention.
- RT3D TEE may become the technique of choice for guidance of certain interventional cardiology procedures.

INTRODUCTION

Advances in ultrasonography techniques have made echocardiography one of the most clinically relevant diagnostic modalities in veterinary cardiology. The evolution occurred from M-mode, pulsed-wave, and continuous-wave Doppler; color flow Doppler; two-dimensional (2D) echocardiography; and transesophageal echocardiography (TEE) to real-time 3D echocardiography (RT3DE) and more recently real-time 3D (RT3D) TEE.

New discoveries in electronic and computer technology created a fully sampled matrix array transducer and workstation for 3D display of acquired images, with the possibility of postprocessing and quantification.

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The matrix array transducer provides a full volume and 360° samples, with real-time acquisition and excellent image quality. The 3D projections are constituted by voxels instead of pixels as in the case of a 2D (flat plane) image. Voxels are pixels in a cube, which creates the perception of depth. This technology results in surface-rendered or wire-framed reconstructions of the cardiac chambers that allow more accurate calculations of the ventricular volumes and mass.[1] Visualization and quantification of color flow jets in 3 dimensions is also possible using this technique.

RT3DE is a new ultrasonography modality that provides comprehensive views of the cardiac valves and congenital heart defects. RT3DE is also potentially a more accurate echocardiographic means of evaluating chamber volumes and a more precise interventional and postoperative tool.

The most recently introduced RT3D transesophageal imaging may overcome the technical and image quality limitations of transthoracic techniques.

CLINICAL APPLICATIONS

Echocardiography is one the most important diagnostic tools in veterinary cardiology, and one of the greatest recent developments is real-time three-dimensional imaging.

ASSESSMENT OF CHAMBER SIZE AND FUNCTION

Left Ventricular Volumes, Mass, and Wall Motion

RT3DE allows direct evaluation of the cardiac chambers without the need for geometric assumptions, preventing mistakes caused by foreshortened views and ultimately creating a more accurate and reproducible measurement.[2] Left ventricular (LV) wall motion and LV volume are acquired at the same time, resulting in the complete dynamic information on LV contraction, which can be used not only to calculate the standard LV function parameters such as ejection fraction but also to assess shape and asynchrony (**Figs. 1** and **2**). Measurement of LV mass is also possible and it is generated based on endocardial and epicardial visualization (**Fig. 3**). This method is rapid and reproducible, and has a better agreement with MRI and cardiac computed tomography (CT) compared with conventional M-mode and 2D methods in people and in dogs.[3–6]

Left Atrial Volume and Function

Left atrial enlargement is associated with the most commonly diagnosed cardiovascular diseases in dogs and cats and is a well-known predictor of adverse outcomes, including heart failure.[7] Accurate assessment of the size of the left atrium (LA) is therefore crucial. Two-dimensional echocardiography is the most commonly used imaging technique in veterinary medicine to evaluate left atrial size.[8–11] A recent study in normal dogs compared the left atrial volume and functional indices using transthoracic one-dimensional M-mode, 2D, and 3D echocardiography; and another study performed in normal dogs and dogs with myxomatous valve degeneration calculated left atrial fractional shortening with RT3DE, both showing feasibility and reproducibility.[12,13]

In humans, RT3DE has been validated against MRI and shown to be more accurate and reproducible than 2D echocardiography for LA volume assessment.[14]

Right Ventricular Volume and Function

The right ventricular crescent shape has made the estimation of right ventricular volumes and function extremely challenging, because most of these values are calculated based on geometric modeling from 2D images. RT3DE has introduced the