Use of Computed Tomography to Guide Mitral Interventions

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KEYWORDS

• CTA • Fluoroscopy • 3D reconstruction • Virtual planning • Fusion

KEY POINTS

- Improved CTA temporal and spatial resolution have afforded the opportunity to evaluate cardiac structure and function and, now integral in characterizing MV disease.
- 3D cardiac reconstruction allows for anatomic evaluation of the MV apparatus including prosthetics devices and important surrounding structures.
- Fusion imaging allows for the merger of pre-procedural CTA with live fluoroscopy.
- Virtual procedural planning using fusion imaging enables the selection of best access approach(es) and device(s).
- Landmarks can be overlaid directly onto fluoroscopy for procedural guidance, particularly helpful during MV interventions where there is a lack of fluoroscopic mitral landmarks.

INTRODUCTION

Cardiac computed tomographic angiography (CTA) has focused traditionally on the evaluation of coronary artery disease. Overall, CTA has been underused owing to a multitude of reasons: the need for advanced equipment not universally available, the requirement for contrast media and ionizing radiation, the presence of limited reimbursement, and more important, the expertise required for the acquisition and postprocessing/reconstruction. It is not considered the gold standard imaging modality for the assessment of the mitral valve (MV) apparatus by most interventionalists and imaging specialists. However, its ability to provide high spatial resolution images compared with alternative modalities offers the unique potential for anatomic evaluation of the MV. With increasing use of CTA for structural heart disease and the widespread adoption of fusion imaging technology allowing the merger of preprocedural CTA with fluoroscopy, our ability to plan and guide complex MV interventions is now possible. This article details the role of CTA in imaging of MV disease and support for transcatheter therapies.

IMAGING FOR MITRAL VALVE INTERVENTIONS

Echocardiography, both transthoracic and transesophageal (TEE), is the gold standard imaging modality for the assessment of MV disease and guidance for intervention, whether surgical or transcatheter. TEE is the most widely accepted modality of choice.[1–4] It provides essential functional information while displaying blood flow (ie, color Doppler); advances in 3-dimensional

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(3D) TEE offer enhanced visualization cardiac of abnormalities, as well as interventional equipment in real time. Additionally, intraprocedural complications such as perforations, tamponade, and device embolization can be assessed without delay.

Interest in CTA for assessment and procedural guidance of MV disease has grown significantly with the evolution of this technology. With the advent of electron beam CTA, its major utility was quantification of calcification for coronary disease evaluation.[5,6] In 2000, the introduction of multidetector CTA further established its role in the assessment of coronary disease.[7,8] Subsequent improvements in temporal and spatial resolution have afforded the opportunity for CTA to evaluate cardiac structure and function and, more recently integral to characterize both native and prosthetic cardiac valves; in particular for the MV,[9–14] this includes the presence of mitral annular calcification, leaflet thickening and calcification, leaflet prolapse, and rupture and/or thickening of the chordae tendinae and papillary muscles. Although challenges remain, such as limited visualization of the MV owing to the relatively minor thickness of the leaflets and chordae tendinae, high-velocity cardiac motion, and significant artifacts from the surrounding calcification, the usefulness of the technology continues to mature.[15–18]

Currently, the predominant literature on CTA for guidance of structural heart interventions is dedicated to TAVR.[19–23] Three-dimensional volume rendering (VR) of the vasculature can assess for tortuosity, and measurements can accurately be performed to determine atherosclerotic disease and its ability to accommodate delivery sheath, as well as alternative access routes. Measurements of the valve complex are important to minimize complications particularly paravalvular regurgitation and coronary occlusion, with CTA providing more accurate measurements than 2-dimensional (2D) transthoracic echocardiography or TEE. Furthermore, manipulation of images can identify the optimal fluoroscopic views for transcatheter valve implantation. More recently, the use of CTA for MV has expanded to the treatment of paravalvular leaks (PVL)[24–28] and prosthetic valve dysfunction with valve-in-valve implantation. The most common MV intervention, the Mitraclip (Abbott, Abbott Park IL), continues to rely on the TEE for procedural planning and guidance.

The usefulness of CTA for the guidance of MV interventions can be divided into 3 categories:

- Image acquisition and diagnostics;
- Preprocedural planning; and
- Intraprocedural guidance.

Image Acquisition and Diagnostics

The importance of quality source CT data should not be underestimated; the reliability of measurements and quality of image reconstruction is proportionally dependent on the cross-sectional images. Factors affecting data quality include body habitus, increased and/or irregular heart rate (arrhythmia), and artifacts from extensive calcification and/or prosthetic devices such as postoperative metal clips or prostheses. Sufficient contrast enhancement in the area of interest, that is, the left atrium and ventricle in the case of MV assessment, during acquisition is essential.

Image acquisition starts with evaluation of the patient's personal data. Body size with an increased body mass index is usually the major component of a suboptimal study. Adjustments of the x-ray tube power setting (mA, KV) according to the scanner manufacturer's protocols can improve image quality. Heart rate is another equally important parameter. Coronary CTA acquisition protocols require a heart rate of approximately 60 bpm or less to reduce motion artifacts; structural CTA follows the same rules. Administration of β-blockers (oral or intravenous) is useful to decrease motion artifacts. The use of helical acquisition with retrospective electrocardiographic (ECG) gating allows for the reconstruction of multiple phases of the cardiac cycle in the search for the best possible, motion artifact–free image. Furthermore, adequate contrast enhancement depends on optimal transit time for the contrast to reach the left heart from the antecubital vein. This time can be calculated easily using the same protocol for the coronary CTA. The most common intravenous site is antecubital with an 18-G catheter and a contrast volume of 75 to 90 mL (1 mL/Kg) injected at the rate of 5 to 6 mL/s. A saline chaser is not required unless concomitant coronary evaluation is needed.

There are 2 main acquisition protocols, namely, retrospective ECG gating with multiple phase reconstruction and prospective ECG gating with acquisition during a preselected single phase of the cardiac cycle. Prospective ECG gating has a significantly lesser radiation dose compared with the helical acquisition (2–3 vs 12–15 mSv) and is typically used in younger patients and when repeat surveillance scans are likely to be required. Single phase acquisition for the MV, however, provides limited information; it is usually acquired in end-diastole and shows the MV leaflets during opening, with no information during valve systole. Helical