Postprocessing Techniques for Cardiac Computed Tomographic Angiography

Pamela T. Johnson, MD[a], Elliot K. Fishman, MD[b]

KEYWORDS

- CT angiography • Postprocessing techniques
- Two-dimensional multiplanar reformations
- Three-dimensional reconstruction • Volume rendering
- Maximum intensity projection

Implementation of 64-slice multidetector computed tomography (MDCT), with unprecedented temporal resolution, made coronary artery computed tomographic angiography (CTA) a realistic and reliable diagnostic tool. Recent investigations using a range of protocols describe per patient sensitivities of 83% to 100%, specificities of 84% to 100%, negative predictive values (NPV) of 81% to 100%, and positive predictive values of 64% to 100%.[1–5] In a recent meta-analysis,[6] the high per segment and per patient NPV of 96.5% with 64-MDCT technology was noted, which has defined a role for coronary CTA in assessing patients with low clinical suspicion. The emergence of newer generation scanners with even larger numbers of detector arrays and dual tubes promises to expand the utility of CT to a broader group of patients.

Despite the volume of literature on coronary CTA, even with 64-slice MDCT, there is a paucity of published information on postprocessing and analysis of CT datasets. This article presents experience-based guidance on postprocessing techniques, from axial review to two-dimensional (2D) renderings to three-dimensional (3D) reconstructions, for interpretation of coronary CTA data. An understanding of each technique is essential to optimally use these tools in practice; pearls and pitfalls derived from our experience are also presented.

BACKGROUND

Careful protocol design is essential to successfully perform coronary CTA, from patient preparation, to gating, to contrast infusion, to data acquisition, to data reconstruction parameters. Unlike other forms of CTA, cardiac computed tomography (CT) presents the challenge of imaging a moving target; although this is becoming less of an issue because of the speed with which newer scanners acquire data. However, the tenet holds true that the quality of the display is directly related to the quality of the dataset, regardless of the postprocessing tools used. This necessitates an understanding of how to maximize spatial, temporal, and contrast resolution for the highest-quality images. Similarly, once the data are acquired, interpretation requires hands-on training to master each technique. Workflow is maximized by implementation of reliable and streamline filming, archiving, and networking.

[a] The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins Hospital, 601 North Caroline Street, Room 3140D, Baltimore, MD 21287, USA
[b] The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins Hospital, 601 North Caroline Street, Room 3251, Baltimore, MD 21287, USA
E-mail address: pjohnso5@jhmi.edu

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A workstation equipped with tools for cardiac evaluation and investing the time to learn how to use these for coronary artery analysis are mandatory. This includes the standard 2D and 3D rendering programs and software specific to vascular imaging such as automated vessel segmentation, stenosis calculation software, vessel tracking software, and four-dimensional motion analysis.

Automated Vessel Segmentation

Several automated segmentation algorithms exist. Use of segmentation is generally obligatory with maximum intensity projection (MIP) rendering to isolate the vasculature from the dense contrast in the cardiac chambers, which would otherwise obscure visualization of the arteries. Our 3D rendering platform uses a region-growing algorithm to perform automated tagging of the aorta and coronary arteries, with the capacity for manual refinement (**Fig. 1**).[7] Following automated segmentation of arteries, additional analysis can be performed with any rendering algorithm and vessel tracking.

Automatic arterial segmentation using a corkscrew algorithm was described by Khan and colleagues,[8] who used 16-MDCT to evaluate 50 subjects. Color-coded volume renderings (VRs) are generated with diameter reflected by color variation from red to blue; the technique also plots vessel diameter along an x-y axis. Compared with manually generated MIP, multiplanar reconstructions (MPR), VR, and curved planar reconstructions (CPR), diagnostic accuracy and vessel detection rates were similar, but the automatic technique required significantly less time.[8]

Stenosis Calculation Software

The means by which an arterial stenosis can be quantified include visual, manual, and automated techniques. Automated calculation of the percent stenosis is performed on the CPRs (**Fig. 2**). Cardiac-specific software packages and many vessel analysis packages typically require the user to select the area of maximum narrowing and normal vessel proximal and distal to the stenosis. Once these are selected, percent stenosis is calculated automatically. These programs are not without error.

Initial studies comparing visual and automated techniques in the literature suggested that automated quantification could improve diagnostic accuracy.[7,9]

However, more recent data suggest the contrary. Using 4 vascular phantoms with stenoses between 33% and 72%, Dikkers and colleagues[10] compared the accuracy of manual measurements with those performed by 5 cardiac software packages using a 64-slice scanner. Manual measurements correlated more accurately with true diameter than any automated program, such that the authors concluded "Manual stenosis measurements are significantly more accurate compared with automatic measurements, and therefore, manual adjustments are still essential for noninvasive assessment of coronary artery stenosis."[10]

Vessel Tracking Software

Most software programs currently used for vessel tracking require minimal user interaction. For example, with the Siemens Leonardo (Siemens Medical Solutions, Malvern, PA) workstation program called Circulation, the computer tracks the vessel by calculating a centerline after the user selects start and end points on either 2D or 3D reconstructions (**Fig. 3**). Similar programs run on the GE Advantage workstation (GE Healthcare, Milwaukee, WI) and other vendors. These generate curved planar images with the artery elongated for display in a single plane that can be rotated to view from any perspective. Viewing options include classic CT windows or as an MIP. One pearl is that in cases with a gap or high-grade stenosis in the vessel, dropping additional seed points can be useful to accurately track the artery.

POSTPROCESSING TECHNIQUES FOR DISPLAY

Knowledge of the algorithm behind each postprocessing tool, their strengths and weaknesses is mandatory. Regardless of technique, to perform the best dataset analysis, it is essential that the radiologist interactively evaluates the volume. This belief is based on our experience and the literature. Interactive review of the dataset ensures that the length and branches of each coronary artery are adequately visualized from all necessary orientations and enables the radiologist to use each available technique to greatest advantage. Review of preset 2D MPRs, 3D MIPs or VRs is prone to errors in interpretation. This relates to the skill of the radiologist or technologist who performs the postprocessing, and the potential for misinterpretation of static images that may not accurately demonstrate the anatomy or depict narrowed segments.

The most comprehensive article on postprocessing, which included all types of postprocessing tools,[11] supported interactive evaluation of the dataset; the results revealed that interactive