

Salvage of diagnostic quality of image acquired by low-radiation-dose prospectively ECG-triggered coronary CTA during ventricular trigeminy: A case report of a novel image processing method



Harshna V. Vadvala, MD, Karl Sayegh, MD, Matthew Moy, MD, Pedro Vinícius Staziaki, MD, Brian B. Ghoshhajra, MD, MBA

From the Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts.

Introduction

Cardiac arrhythmias, whether ventricular or supraventricular, initially presented a challenge for coronary computed tomography angiography (CCTA) because they could result in motion artifact during image acquisition, increased acquisition times, and increased radiation dose.¹ Cardiac motion and misregistration artifacts in a scan performed during premature ventricular contractions can significantly compromise image quality and prevent diagnostic evaluation of the coronary arteries.^{2,3} Even the so-called “regularly irregular” rhythms, which are predictable, can trigger arrhythmia rejection algorithms^{4,5} during electrocardiogram (ECG)-gated imaging, delaying image acquisition to the next cardiac cycle and hence increasing the total radiation dose.⁶ We present an interesting CCTA case in a patient with ventricular trigeminy and introduce a novel postprocessing method used to derive diagnostic-quality images for coronary artery evaluation.

Case report

A 70-year-old man with long-standing cardiac arrhythmias including supraventricular tachycardia and, more recently, symptomatic premature ventricular contractions (PVCs) and atypical chest pain for the past week was referred for CCTA. The purpose was twofold: to investigate coronary causes of

atypical chest pain and to map pulmonary vein anatomy prior to possible radiofrequency ablation/isolation. The patient was overweight with body mass index 25 kg/m² and had history of hypertension and hyperlipidemia. During CCTA acquisition he developed ventricular trigeminy with an average heart rate of 58 (range 38–109) beats per minute. The scan was performed using 128-slice dual-source computed tomography (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany, with software update VA40) using a systolic-phase-targeted prospectively ECG-triggered axial-sequential method (using an absolute delay after the R-wave acquired from 200 to 450 ms with arrhythmia rejection algorithm [Adaptive Cardio Sequential, Siemens], automatic exposure control, and automatic tube potential selection [CAREdose 4D and CAREkV; Siemens] using 120 kilovoltage peak tube potential and 280 milliamperere-second reference [187 milliamperere-second total] tube current). Sublingual nitroglycerin (600 mcg), a vasodilator agent, was administered 5 minutes prior to the scan. No beta blocker was administered in the scanner suite.

Analysis of the dataset revealed failure of the arrhythmia rejection algorithm to reject acquisitions after the PVC depolarization. This led to a scan with motion artifacts in the proximal coronary artery segments at selected reconstruction intervals, but similar artifacts occurring in the distal coronary arteries at other reconstruction intervals.^{2,7} To reconstruct a single diagnostic CCTA dataset, we developed a novel image processing technique at the scanner console. From the single-acquisition dataset as shown in [Figure 1A](#), the disparate artifact-free phase intervals were reconstructed separately for proximal (240 ms time point) and distal (360 ms time point) coronary artery segments as shown in [Figure 1B](#) and [Figure 1C](#), respectively. Using otherwise identical parameters, these 2 datasets, each with a 0.75 mm image slice thickness and a 0.4 mm slice interval, were then combined in parallel range to reconstruct a unique dataset as illustrated in a flow chart in [Figure 2A](#). The resultant image had diagnostic quality

KEYWORDS Ventricular arrhythmia; Coronary computed tomography angiography; Image processing method

ABBREVIATIONS CCTA = coronary computed tomography angiography; ECG = electrocardiogram; ICA = invasive coronary angiography; LAD = left anterior descending artery; PVC = premature ventricular contractions; RCA = right coronary artery (Heart Rhythm Case Reports 2016;2:20–23)

Address reprint requests and correspondence: Brian B. Ghoshhajra, Assistant Professor of Radiology, Harvard Medical School, Service Chief, Cardiovascular Imaging, Cardiac MR PET CT Program, Department of Radiology, Massachusetts General Hospital, 55 Fruit St, Boston, MA 02114. E-mail address: bghoshhajra@mgh.harvard.edu.

KEY TEACHING POINTS

- Arrhythmia is no longer considered a relative contraindication for coronary computed tomography angiography when local expertise and equipment allow.
- Diagnostic-quality image sets can be achieved by postprocessing relatively arrhythmia-free acquisition slabs and combining them for separate coronary artery segments.
- Computed tomography radiation dose for scan acquisition during arrhythmia is lower for prospectively electrocardiogram-triggered scan as compared to retrospectively electrocardiogram-gated scan.

in all coronary segments, despite an easily recognizable slab-to-slab misalignment artifact, as shown in Figure 2B at the

merge plane (ie, the end position of the proximal dataset and beginning position of the distal dataset). The end result was an excellent-quality and a fully diagnostic scan with a contrast-to-noise ratio of 22 at the left main coronary artery and 20 at the proximal right coronary artery of 20.^{8,9}

CCTA demonstrated coronary atherosclerotic disease with multiple aneurysms and multisegment moderate stenosis in the right coronary artery and left anterior descending artery with excellent correlation with invasive coronary angiography, as shown in Figure 3. As mentioned earlier, the presence of slab-to-slab misalignment artifact was a limitation; however, the overall diagnostic interpretation was in concordance with the invasive coronary angiography results, which showed no stenosis $\geq 70\%$.

The scan was performed with a lower radiation exposure of 391 DLP mGy-cm, corresponding to an estimated effective dose of 5.5 mSv (using an adult weighting factor of $k = 0.014 \text{ mSv mGy}^{-1} \text{ cm}^{-1}$).⁹⁻¹¹

The patient felt better as his PVCs were controlled with mexiletine. The probable etiology of the coronary aneurysm was

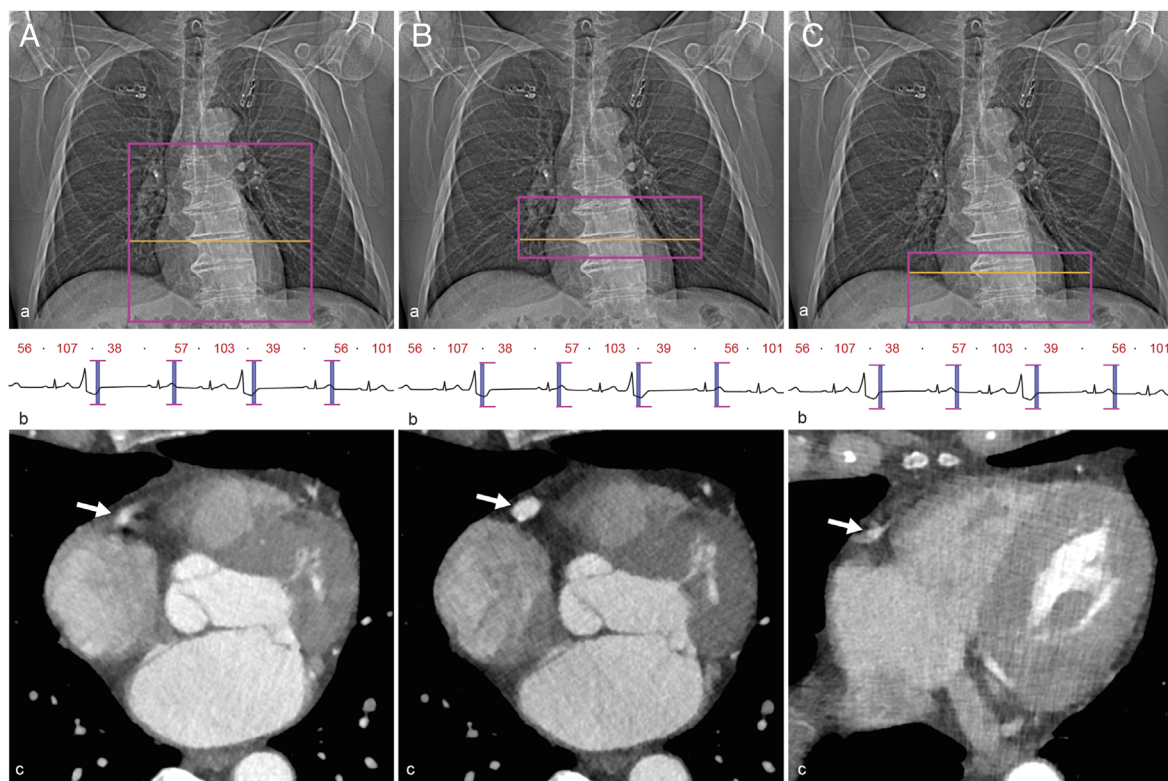


Figure 1 Overview of post-processing of cardiac computed tomography angiography (CTA) from the scanning console. **A:** Scanned range covering the entire heart, at 300 msec time-point at the level of the yellow line in the scout radiography, shows motion artifact in the proximal right coronary artery (arrow). **B:** Scanned range covering upper portion of the heart, at 240 msec time-point now demonstrates an aneurysmal right coronary artery without motion artifact (arrow). **C:** Scanned range covering the bottom half of the heart, at 360 msec time-point shows a partially calcified moderate stenosis in the mid right coronary artery (arrow). **a:** Scout radiographs showing the scanned range (pink box) with the yellow line representing the time-point of the scan. **b:** Rhythm strip demonstrates premature ventricular contractions (PVCs) every third beat of the cardiac cycle (trigeminy). Heart rate in beats per minute (bpm) was an average of 58, ranging from 68 to 109. Note the CTA is acquired as a systolic-targeted prospective ECG-triggered scan with a data acquisition window between 200 and 450 msec following each R peak (dark and light purple boxes on the rhythm strip). Despite application of an advanced arrhythmia rejection algorithm (“Adaptive Cardio Seq.”), the ectopic beats have not been excluded from acquisition (green arrows mark the post-PVC acquisitions). **c:** Resultant computed tomography image.

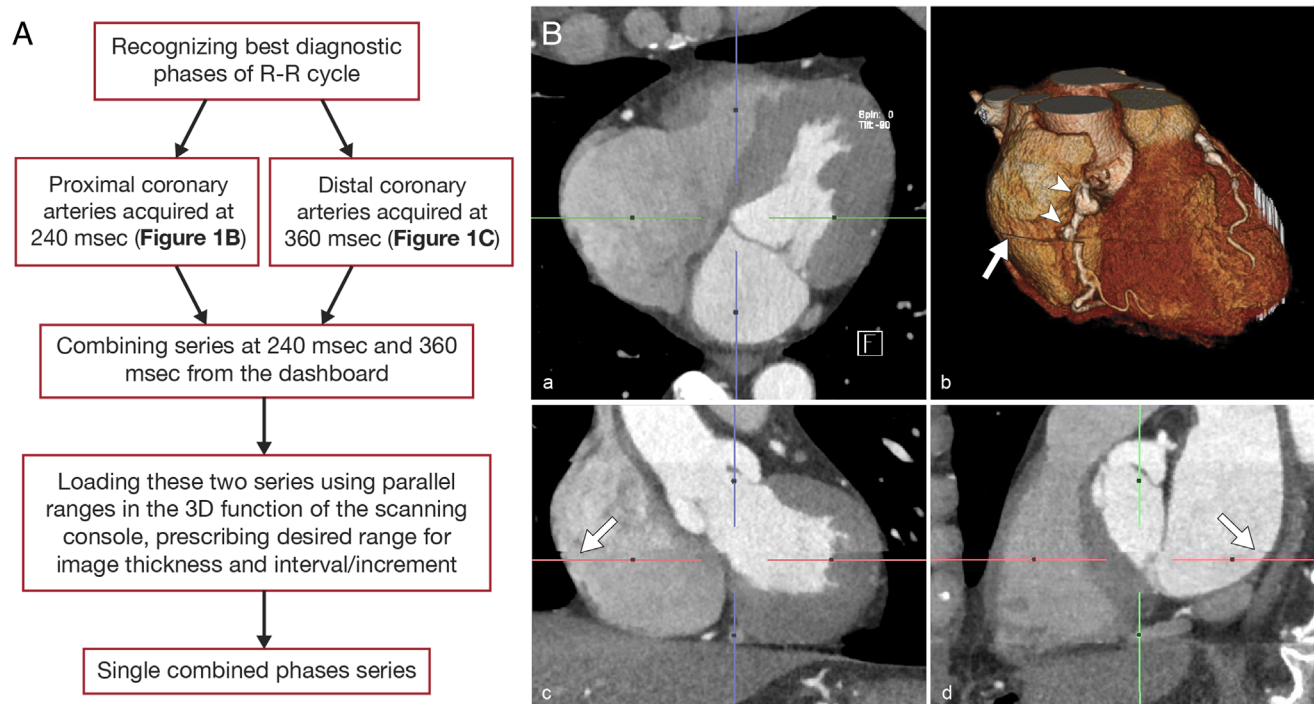


Figure 2 A: Outline of the definitive steps for image processing. B: Cardiac 3-dimensional (3-D) planes from the combined phase's series. a: Axial section; b: 3-D rendering. Notice the easily recognizable slab-to-slab misalignment artifact on the coronal (c) and sagittal (d) views of the heart (arrows) resulting from combining images from the 240 ms phase reconstruction (top half) and 360 ms phase reconstruction (bottom half). The 3-D volume-rendered reconstruction of the heart in the bottom right corner also shows easily recognizable slab-to-slab misalignment artifact and 2 serial aneurysms of the proximal right coronary artery (arrowheads).

thought to be Kawasaki disease and a repeat CCTA at a 6-month interval was suggested to ensure that there has been no interval increase in the size of the aneurysms.^{12,13} An antiplatelet agent was commenced to lower the consequent risk of thrombus formation and myocardial infarction, in addition to antihypertensive and antiarrhythmic medications.^{14,15} The patient was also advised to avoid high-contact or collision sport activities.

Discussion

Since the advent of prospective ECG triggering with arrhythmia rejection algorithms, CCTA can often be performed in patients with arrhythmias, yielding diagnostic-quality images at a reasonable radiation expense. In the setting of unavoidable arrhythmias, not only do the patient preparation (ie, beta-blocker administration), data acquisition, and data reconstruction (inclusive of field of view [FOV], slice thickness, and reconstruction filter) need modification, but also postprocessing techniques play a huge role. Arrhythmia

rejection algorithms allow prospective image acquisition only during desired portions of the cardiac cycle (and thus prevent data acquisitions during irregular beats) to obviate arrhythmia-induced artifacts and prevent the need for ECG editing; these algorithms are generally designed for simple arrhythmias whereby the occasional R-R cycle length falls outside a prespecified window. To our knowledge, this manual postprocessing method of combining (“stitching”) datasets from 2 different R-R interval phases at different z-axis positions in parallel ranges to obtain a unique combined dataset for coronary evaluation has not been reported previously. By using a single scan acquired by a systolic-targeted prospectively ECG-triggered axial dual source with arrhythmia rejection algorithm, and ECG-based widened data acquisition windows, we were able to salvage a diagnostic scan despite no single phase being adequate for evaluation in all the coronary artery segments. Prior studies have demonstrated diagnostic-quality images deemed interpretable at a lower radiation exposure as compared to retrospectively ECG-gated helical dual-source computed tomography.^{5,9,10}

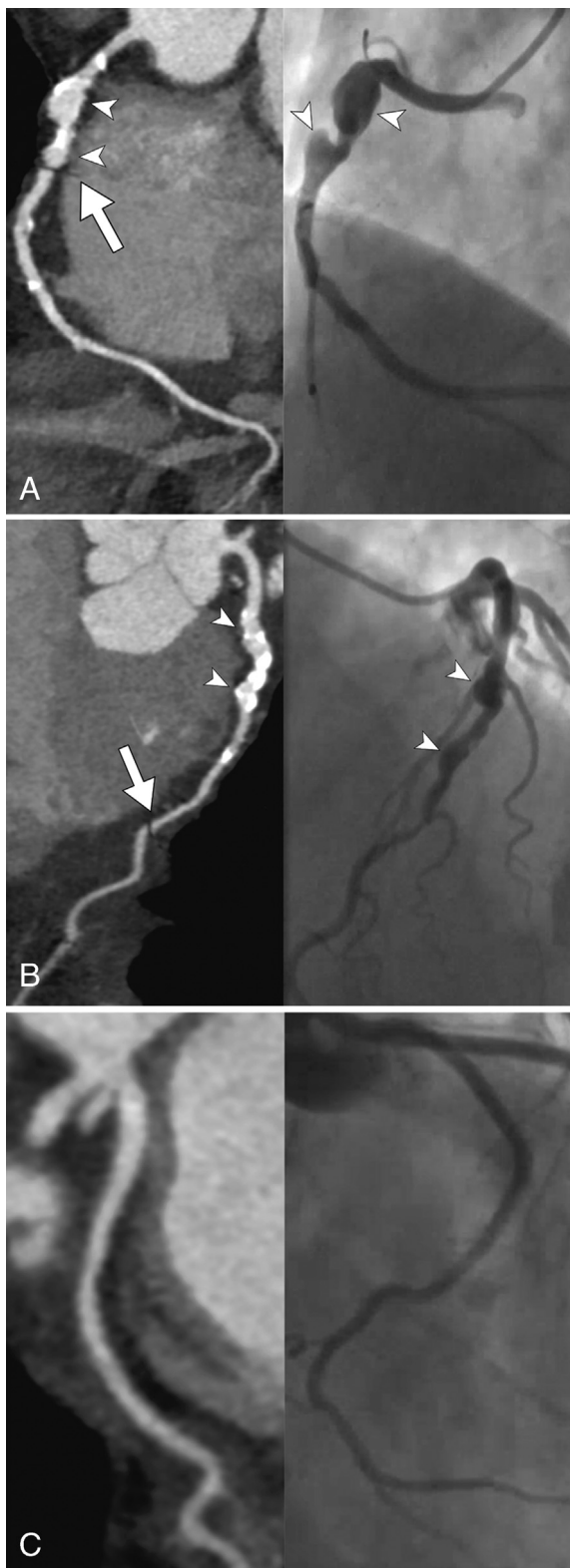


Figure 3 Representative images of the curved planar reformatted diagnostic cardiac computed tomography angiography (CTA) dataset derived from the combined phase series in concordance with invasive coronary angiography (ICA) findings. **A:** Right coronary artery (RCA); arrowheads show aneurysms. **B:** Left anterior descending artery (LAD). **C:** Left circumflex artery. Arrows denote slab-to-slab misalignment artifacts. Cardiac CTA findings completely correlated to that of ICA, demonstrating coronary atherosclerosis with multiple aneurysms and multisegment moderate stenosis in the RCA and LAD.

Conclusion

While the arrhythmia rejection algorithm is not designed to compensate for rare rhythms such as trigeminy, we were fortunate to salvage a diagnostic study that correlated well with the subsequent invasive coronary angiography. We believe that this method may be useful to others who encounter rare arrhythmias and who may elect to proceed with prospectively ECG-triggered CCTA while maintaining low radiation doses without resorting to retrospective ECG gating.

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