Banding and Step-Stair Artifacts on the Cardiac-CT Caused By Pseudo-Ectopic Beats

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ABSTRACT

Step-stair and banding artifacts may result from irregular ventricular rhythm caused by atrial fibrillation or premature ectopic ventricular contractions. In the case reported here, severe banding and misalignment artifacts occurred due to electrocardiographic noise mimicking ectopic beats. Severe EKG noise or pseudo-ectopic beats may cause rare but serious artifacts during cardiac-CT acquisition. Vendor-provided software for correcting ectopic beats can be used to remove pseudo-ectopic beats and eliminate artifacts caused by the EKG noise. All efforts should be made to prevent this kind of problem from happening in the first place.

CASE REPORT

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Introduction:

Recent advances in multi-detector computed tomography (MDCT) have led to diminished number of artifacts on the cardiac-CT (CCT) images. Dual-Source CT (DSCT) can provide motion-free images of coronary arteries even at higher heart rates as long as a stable cardiac rhythm is maintained. However, irregular ventricular rhythm caused by atrial fibrillation or premature ectopic ventricular contractions continues to be a problem. In the case reported here, severe banding and misalignment artifacts were produced by the electrocardiographic noise mimicking ectopic beats.

Case History:

A 47-year-old obese (BMI 34.5) patient with atypical chest pain and history of cardiac arrhythmia underwent cardiac-CT to exclude coronary artery disease (CAD). Risk factors included a strong family history of premature CAD and hyperlipidemia. A coronary calcium scoring study revealed Agatston score of 40 with mild calcification of left anterior descending artery (LAD). After appropriate patient preparation that included oral hydration and 200 mg of oral metoprolol, a cardiac-CT angiography (CTA) was performed using Siemens Dual-Source CT Scanner (Definition). An 18-gauge intravenous catheter was inserted in the right antecubital fossa to facilitate infusion rate selected. An iodinated contrast (Omnipaque-350) was infused at a rate of 5ml/sec for timing bolus (20 ml) and subsequent coronary angiogram (80 ml). Saline chaser (50 ml) was administered at the same rate immediately after each administration of contrast for this biphasic protocol. Patient received 0.8 mg of sublingual nitroglycerin before contrast injection. A min-dose, EKG dose-modulation protocol was selected for retrospective gating. The data was acquired at 70-80% phase and the tube current was reduced to 4% for the remainder of the cardiac cycle. The patient was scanned at a standard voltage of 120 KeV and tube current (effective mAs) was automatically determined by the CT-scanner. The region of interest extended from tracheal bifurcation to the bottom of the heart. The detector collimation and slice thickness were 0.6 mm and 0.75 mm, respectively. Medium Kernel of B26f was used and pitch was automatically determined by the scanner based on the heart rate. The data was reconstructed using a TeraRecon workstation at -300 msec (300 msec before the R wave). The reconstructed images included: volume rendered images (VR), transaxial images, maximum intensity projections (MIP) and multiplanar reconstruction (MPR) images.

Baseline EKG revealed ventricular arrhythmia with premature ectopic beats (Figure-1A). An oral dose of metoprolol administered during patient preparation restored normal sinus rhythm. At the time of contrast administration, the patient's heart rate was regular with normal sinus rhythm at 60 beats per minute. Unfortunately, electrocardiographic (EKG) noise simulating ectopic beats (pseudo-ectopic beats) developed during data acquisition with scanner firing inappropriately. Figure-1B demonstrates the patient's rhythm strip and EKG noise that was erroneously interpreted as cardiac beats by the scanner. The computer calculated the heart rate at 53-300 beats per minute with an average of 75 beats per minute during acquisition. The reconstructed CCT images revealed large banding artifacts and misalignment artifacts as shown in Figure 2. This illustration exhibits VR and several MIP images with the aforementioned artifacts. The LAD was unaffected by these artifacts. A non-occlusive calcified plaque was present in the mid-LAD (not shown). The right coronary artery (RCA) and posterior descending artery (PDA) could not be evaluated due to the presence of artifacts until the pseudo-ectopic beats were deleted and replaced with better data from other parts of the cardiac cycle. Figure 3 exhibits the corresponding VR and multiple MIP images after successful correction of banding artifacts. The RCA was found to be normal. Some step-stair artifacts could not be corrected. Perhaps inclusion of systolic phase selection during acquisition may have helped, but this was felt to be unnecessary as the heart rate at the time of acquisition was low and regular. Nevertheless, residual step-stair artifacts were recognized and images were not misinterpreted.

DISCUSSION

Cardiac-CT angiography is one the powerful new technique for evaluating patients with possible coronary artery disease. This is one the most sensitive non-invasive technique for detecting clinical or subclinical coronary artery disease. Moreover this evaluation comes with little or no risk to the patient apart from rare potential adverse reactions to radiographic contrast and low/moderate radiation from CT scanning. However, some limitations exist in patients with marked coronary calcification, morbid obesity and in patients with irregular cardiac rhythm regardless of its etiology. Motion-related artifacts on cardiac-CT may occur due to patient motion, respiratory breathing, tachycardia, and premature ventricular contractions (1-2). Premature beats may lead to step-stair artifacts or banding artifacts. The banding artifacts are somewhat different from step-stair artifacts in appearance as contrast intensity varies in different stacks. In the case reported here, the banding artifacts, unlike step-stair artifacts, resulted in an inability to evaluate RCA until appropriate correction was made. Residual step-stair artifacts were recognized and were not misinterpreted.

The cardiac motion-related artifacts seen with 64-slice CT-scanning in patients with high heart rates are decreasing with introduction of DSCT which has higher temporal resolution of 83 msec. In a prospective study, Oncel et al performed DSCT and conventional coronary angiography in 15 patients with atrial fibrillation and suspected CAD (3). No significant difference between DSCT and conventional angiography was observed in detecting significant coronary stenosis. A normal CTA excluded CAD with a high negative predictive value approaching 99%.

In a recent study in an experimental model, no motion artifacts were observed when evaluating coronary stents for stenosis with high heart rates up to 120 beats per minute (4). In a clinical study by Ancel et al, 48 stents in 35 patients were examined prospectively without administering beta blockers. All stents were evaluable with DSCT. Good image quality was present in 85% (41/48) of the stents evaluated. When compared to coronary angiography, the negative predictive value of DSCT images was 100% and accuracy was 96% in evaluating in-stent stenosis or re-stenosis (5).

Recent development of large (16 cm) field of view (LFOV) CT-scanner with 320 detectors can image entire heart volume with one rotation and in a prospective, non-helical mode (6). This could help eliminate step-stair artifacts or mis-registration artifacts observed with 64-slice CT-scanners when stacks of data from multiple heart beats are used for reconstructing images. Since LFOV CT-scanners are better suited for prospective gating; optimal coronary artery imaging with least radiation exposure and least mis-registration artifacts is possible. The blurring of coronary arteries on CTA images due to cardiac or coronary motion may be better prevented with CT-scanners with higher temporal resolution. Compared to traditional retrospective gating, prospective gating can help reduce patient radiation exposure by 75% (7).

Several vendors supply ectopic beat correction software which allows deletion of bad data associated with ectopic beats. Using software supplied by the vendor the pseudo-ectopic beats were deleted and substituted by good data from other parts of the cardiac cycle in our patient. The large banding artifacts were eliminated in the resultant images. Except for a small portion of RCA that could not be evaluated due to motion-related misalignment artifact, the remaining RCA and PDA were evaluated and were found to be free from atherosclerotic disease.

Pseudo-ectopic beats or EKG noise in this case not only resulted in image artifacts but also in increased radiation exposure to the patient as the CT-scanner fired in-appropriately. The calculated radiation exposure was 19 mSv which was about twice what would have been observed with our min-dose protocol. The case reported here emphasizes the importance of optimizing EKG gating. Failure of attention to relatively small things such as lead placement can cause serious difficulties even with the most advanced CT-scanners. Steps to prevent this sort of problem from happening in our patients include shaving all male patients' skin prior to the lead placement, ensuring proper contact using gel, and taping of the lead wires a short distance from lead placed to prevent inadvertent pulling and disconnection.

TEACHING POINT

EKG noise may cause rare but serious artifacts during cardiac-CT acquisition and all efforts should be made to prevent this in the first place. Vendor provided software for correcting ectopic beats can be used to remove pseudo-ectopic beats and eliminate artifacts caused by the EKG noise.

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FIGURES

Figure 1: 47-year-old male underwent cardiac CT which shows step-stair and banding artifacts. Figure 1A exhibits baseline EKG with ventricular arrhythmia. The premature ectopic beats resolved with oral metoprolol prior to scanning. Figure 1B shows electrocardiographic strip as viewed by the scanner during acquisition of CCT. The patient's rhythm is regular. EKG noise simulating ectopic beats was erroneously interpreted as cardiac beats by the scanner. The computer calculated the heart rate to be 53-300 beats per minute with an average of 75 beats per minute during acquisition.

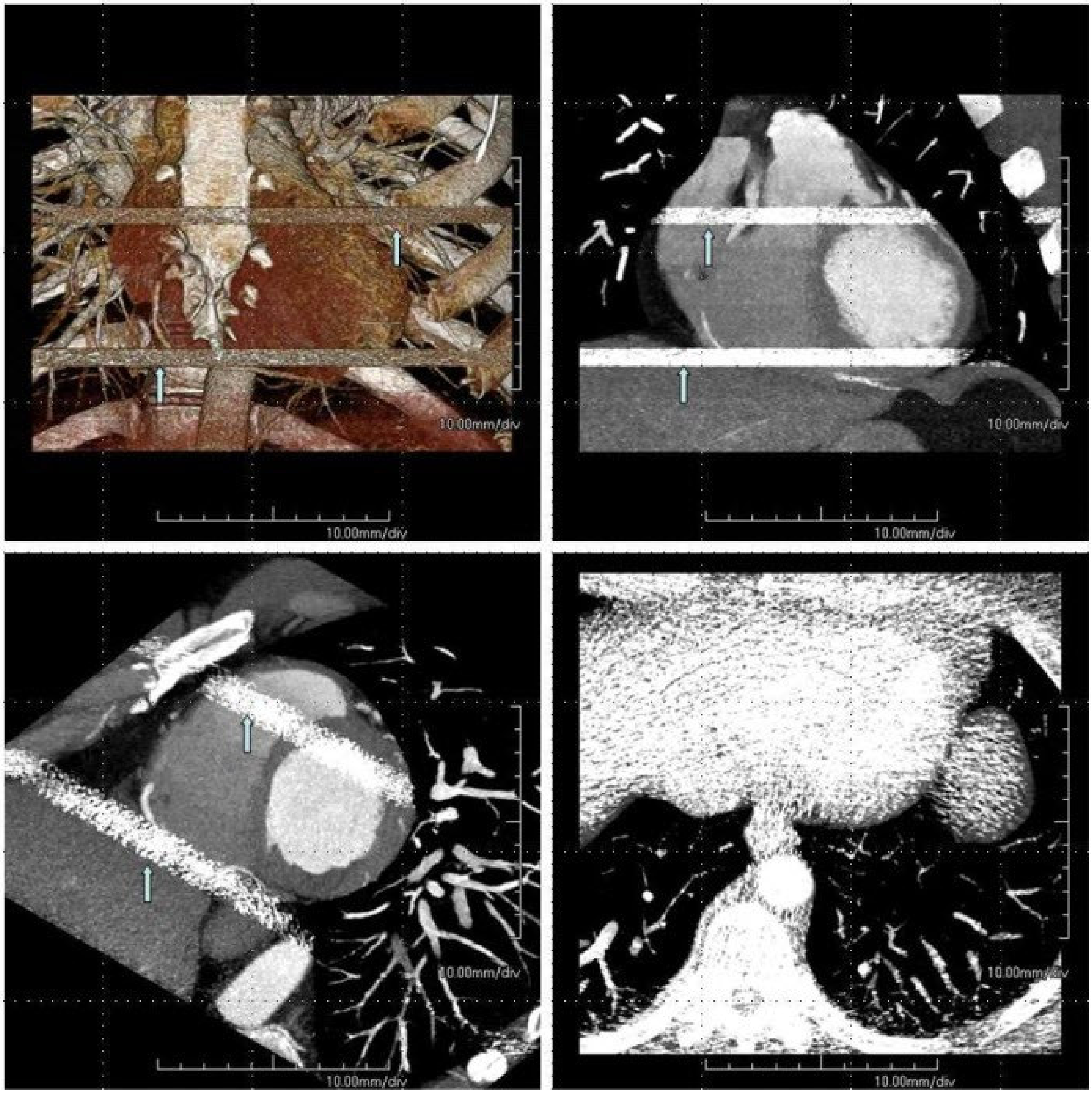

Figure 2: 47-year-old male underwent cardiac CT which shows step-stair and banding artifacts. This illustration exhibits VR and three MIP images with several banding artifacts indicated by the vertical grey arrows. Note a complete loss of data for interpretation in the bottom right image. The right coronary artery (RCA) and posterior descending artery (PDA) could not be evaluated due to the presence of artifacts shown.

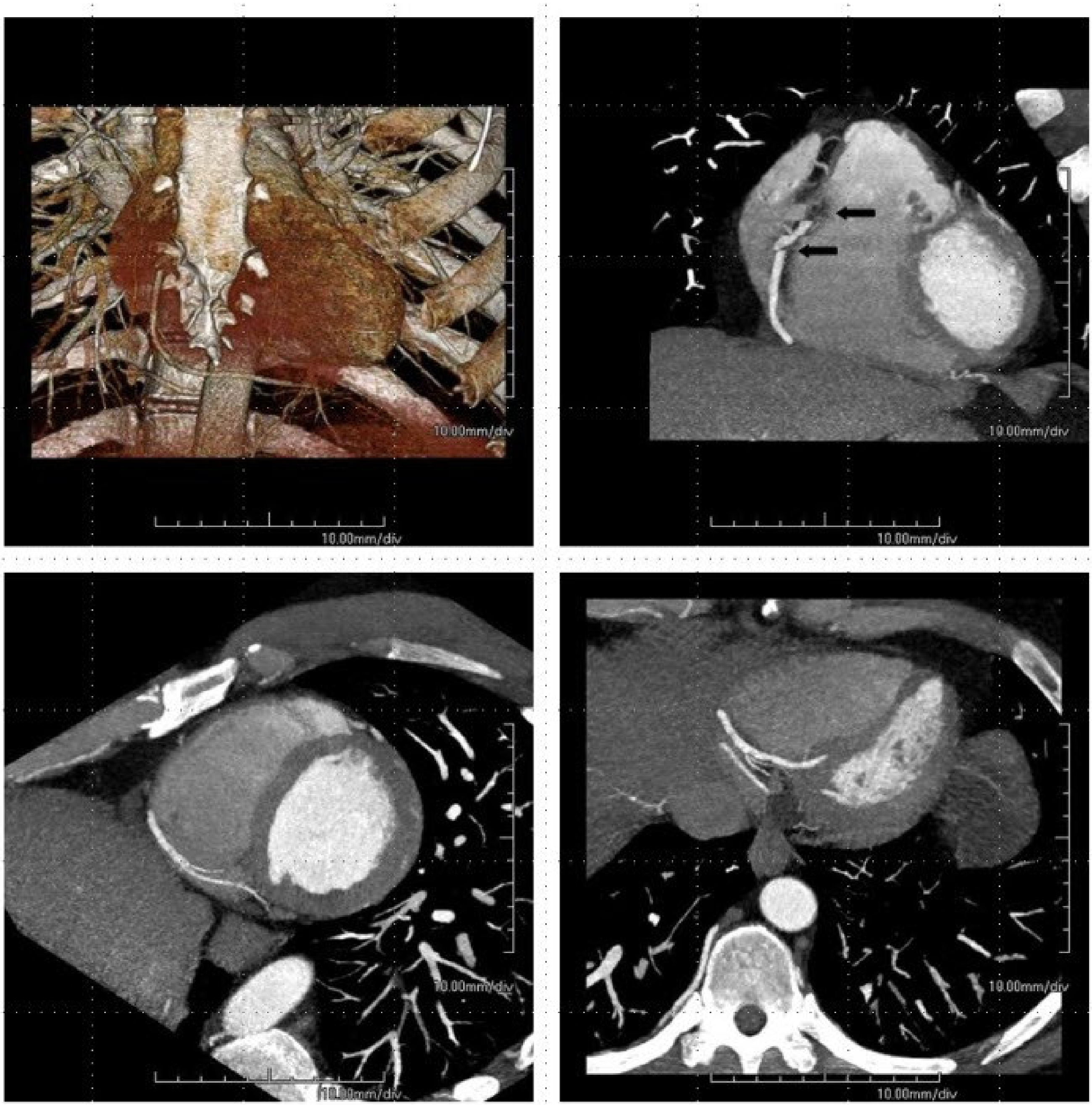

Figure 3: 47-year-old male underwent cardiac CT which shows step-stair and banding artifacts. This figure shows VR and three MIP projections similar to Figure 2 after correction of data which involved deleting pseudo-ectopic beats and inserting good data from other parts of the cardiac cycle. Banding artifacts are completely eliminated. Residual step-stair artifacts indicated by black horizontal arrows are seen in proximal RCA regions.

ABBREVIATIONS

CAD = coronary artery disease
CCT = cardiac-CT
CTA = coronary CT angiography
DSCT = dual source computed tomography
EKG = electrocardiographic
LAD = left anterior descending artery
LFOV = large field of view
MIP = maximum intensity projections
MPR = multiplanar reconstruction images
PDA = posterior descending artery
RCA = right coronary artery
VR = volume rendered images

KEYWORDS

Cardiac-ct, banding artifacts, coronary artery disease

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