Normal Variations and Imaging Artifacts That May Mimic Disease at Coronary CT Angiography

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**Overview of Coronary CT Angiography**

- MDCT enables noninvasive imaging of coronary arteries as well as other cardiac structures
- Coronary CT Angiography (CCTA) - Patient Preparation
- Use of beta-blocker: For patients with a preexisting heart rate of 65 beats per minute or higher
- To decrease heart rate, heart rate variation during scanning
- Anti-arrhythmic drug: Propranolol 3 mg before the injection of contrast media, 0.5 mg of nitroglycerin is administered sublingually for vessel dilation
- CCTA - Potential Application
- Anatomic abnormalities - dominance / origin & course / fistula / stenosis
- Characterization of coronary plaques - calcified / noncalcified / soft rich / mixed
- Degree of Stenosis - cross sectional area / luminal diameter
- Septal hypertrophy

There have been stunning improvements in detectors and X-ray tube systems of MDCT, recently.

**Materials and Methods**

Over the past 10 years, we collected interesting cases from the CCTA database that show typical findings of normal variations and imaging artifacts.

**Anatomic Variations**

**Right Atrium - Prominent Crista Terminals**

The line of union between the right atrium and the right auricle is present on the interior of the atrium in the form of a vertical crest, known as the crista terminalis. Deposition of the crista terminalis is known to occur in variable degrees; thus, widely variable prominence exhibited by this structure is seen. A prominent crista terminalis can be maintained as a right atrial mass, especially when echocardiography is used as an isolated imaging technique for the heart. CCTA will generate misinterpretation of the presence of normal intracardiac structures by the accurate identification of the exact position and extension of thoracic prominent structures to distinguish the structures from a neoplasm or thrombus.

**Left Atrium - Accessory Appendages**

During CCTA using a 64-slice ECG-gated CT scanner, we have occasionally observed additional variations in the anatomy of the left atrium which have been reported before as case reports or in small studies, such as atrial diverticulum, atrial aneurysm, and small accessory veins or fistulas originating from the left atrium which might look like diverticulum.

The finding of accessory appendages of the left atrium is interesting and could have implications when evaluating patients with atrial fibrillation, or prior to radio frequency catheter ablation procedures, or when ventricular appendages for possible sources of emboli from cardiac chamber. Recent report shows left atrial accesssory appendages in 10% of the patients.

**Left Atrium - Slow Flow that May Mimic Thrombosis**

The mechanism of thrombogenesis is complex, including lack of effective atrial contractility and slow-flow states that may be visualized as smoke-like echoes within the left atrium or left atrial appendage (LAA) by echocardiography. Transesophageal echocardiography (TEE) is the criterion standard for evaluating the LAA and is routinely used for the assessment of atrial thrombus preprocedure in patients with atrial fibrillation and in the upkeeping of embolic stroke. However, contrast-enhanced MDCT also can demonstrate filling defects in the left atrium or LAA, which represent incomplete mixing of CT contrast and blood. These filling defects represent slow-flow states, or thrombi as visualized by TEE. Recent reports reveals two-phase 4-slice cardiac CT angiography is a noninvasive sensitive modality for detecting LAA thrombi and differentiating thrombus from circulatory stagnates in stroke patients.

**Left Atrium - Recess**

Septum Primum: In the developing heart, the cavity of the primitive atrium becomes subdivided into right and left chambers by a septum, the septum primum, which grows downward into the cavity. It eventually fuses with the endocardial cushion, and perforations appear in the superior part, forming the ostium primum. This will eventually form part of the fossa ovalis. Remnant of common pulmonary vein: Faulty incorporation of the common pulmonary vein leaves it as a distinct structure posteriorly, into which the pulmonary veins empty. This “channel” is separated from the anterior “false” left atrium (containing the left atrial appendages) only by a thin fibrous septum (the mural leaf) by a diaphragm, and is known as the foramen ovale (also known as or ovalis, one of the remnant of cardiac malformation. Less prominent, but still recognizable, is the remnant of common pulmonary vein, which may persist as a small accessory appendage (circle) seen in the left atrium.
Left ventricular end-diastolic wall thickness of 0.6 to 1.0 mm is generally considered normal. Focal thinning at the ventricular apex is a normal variation when associated with normal myocardial function.

And normal left ventricular myocardium is uniform in thickness. Deviations of the left ventricular wall thickness, especially in the apical region, may indicate myocardial infarction or regional contractile dysfunction. Segments with wall thinning may appear lower in density relative to normally enhancing myocardium.

Figure 10. A 62-year-old female. (A) CCTA shows hypointensification in the subendocardial zone of the left ventricular myocardium. (B) Curved planar reformats image reveals normal left anterior descending coronary artery. Figure 11. A 43-year-old female. (A) CCTA shows sequential wall thinning (arrows) in the interventricular septum. The patient has no symptom and past history of myocardial infarction. This regional wall motion and myocardial function is within normal limit (not shown here).

Left ventricular diverticulum is a rare congenital anomaly. In the adult population, the incidence was reported to be about 0.4% in a autopsy series of patients with cardiac death, and about 0.28% in non-invasive patients who underwent cardiac catheterization. With increased use of CT imaging, small diverticula are more commonly identified in the wall of the left ventricle.

Diverticula are usually localized near the apex and most often involve the inferior or lateral wall. The diagnosis of diverticulum, confirming that this is a benign process, unrelated to ischemic coronary disease. With increased use of CT imaging, small diverticula are more commonly identified in the wall of the left ventricle.

Interventricular Septum - Recess

A redundancy of the interventricular septum is often present at the level of the fossa ovalis, when this redundancy is large, the finding is called an interatrial septal aneurysm. The diagnosis of atrial septal aneurysm is based upon a continuous column of contrast material connecting the left and right atria, either on coronary angiography or on echocardiography. CT may successfully detect an atrial septal aneurysm as well as the fossa ovalis.

Figure 14. A 64-year-old female. (A, B) CCTA demonstrates enlargement of the left atrium with a saccular pouch at the level of the fossa ovale (arrows) secondary to the redundant tissue in the atrial septum.

In approximately 70% of the population, the primum and secundum septum of the interventricular septum fuse shortly after birth to form an intact barrier between the atria. However, in a significant proportion of the population, septal fusion fails or is incomplete. If the foramen ovale is covered but not sealed, the resulting condition is a patent foramen ovale. In this case, a potential channel exists between the atria that can be opened by a reversal of the interatrial pressure gradient.

Figure 15. A 52-year-old male. (A, B) CCTA shows characteristic findings of PFO with left atrial flap (arrow), continuous columnar contrast connecting the left and right atria, and jet of contrast material diffusing out into right atrium.

Figure 16. A 46-year-old male. (A, C) CCTA shows diverticulum in the interventricular septum. (B) Systolic view demonstrates normal contraction of the wall containing the diverticulum, confirming that this is a benign process, unrelated to ischemic coronary disease.

Although coronary angiographic images are obtained by using electrocardiographically gated reconstruction algorithm, image quality is affected by cardiac motion to some extent. Many factors can affect image quality like these, high heart rate greater than 70–75 beats per minute during imaging of the coronary arteries, variations in heart rate during image acquisition, arrhythmia, and inappropriate selection of pitch. Most of them has following features: stair step effects (Fig 17) or motion blurring (Fig 18). Blurring occurred when movement in the cardiac structures of interest exceeded the temporal resolution of scanning, either because of a fast heart rate or because of an inappropriate selection of the reconstruction window for the particular coronary artery.

Motion artifacts either than those from cardiac motion result either from respiratory motion (Fig 19) jet from voluntary motion (Fig 18). Images are routinely reconstructed from CT data acquired at 75% of the R–R interval with a retrospectively electrocardiographically gated algorithm. If the routine reconstructions of data acquired at 75% of the R–R interval are not sufficient to depict the coronary arteries, subsequent tailored reconstructions are performed with data acquired at 30%, 45%, 60%, and 80% of the R–R interval (Fig 15).

The most commonly encountered beam hardening are those produced by surgically implanted high attenuating materials, such as metallic objects such as clips, markers, and stents used in coronary artery bypass surgery or by coronary stents (Fig 20), but they may also be caused by naturally occurring coronary disease calcification (Fig 21). High attenuating objects generally appear larger than they are. Although the depiction of coronary calcifications provides useful information regarding atherosclerosis, the resultant artifacts may interfere with the evaluation of luminal stenosis, usually causes false positive result for the diagnosis of coronary artery stenosis. Low attenuating artifacts (Fig 22–23), which are caused by high density calcifications in coronary arteries.

Figure 26. A 52-year-old male. (A, B) CCTA shows characteristic findings of misregistration artifact which is due to inappropriate pitch for heart rate.

Conclusion

Awareness of the CCTA findings of normal variations and imaging artifacts will help to avoid misinterpretation.

References