

Cardiac CT Angiography Findings In Paradoxical Coronary Artery Embolism

Michael K. Atalay, MD, PhD, and Athena Poppas, MD

AN ACTIVE 33-YEAR-OLD MALE WITH A history of hyperlipidemia, hypertension, and Wolff-Parkinson-White syndrome, presented to the emergency department with diaphoresis and acute onset 3/10 substernal chest pain triggered during heavy lifting. The pain was relieved with nitroglycerin and morphine. EKG showed sinus bradycardia (58 bpm) and less than one mm ST elevation in an inferior lead. The first troponin value was normal, but acute coronary syndrome remained a concern and the patient was started on enoxaparin, clopidogrel, aspirin, a statin, and nitrates—the latter for possible vasospasm. A **cardiac CT angiogram (CCTA)** showed no evidence of coronary artery disease or pulmonary embolism. (Figure 1a) However, a small hypoperfusion defect was present in the distal inferior left ventricular wall. (Figure 1b) Moreover, because retrospective ECG-gating was employed, segmental wall motion analysis could be assessed. This demonstrated focal hypokinesis of the underperfused segment. (Figures 1c & 1d)

The second troponin value was elevated (3.0 ng/ml), and the patient underwent cardiac catheterization for definitive coronary artery assessment. While atherosclerotic stenosis was again excluded, angiography did reveal an abrupt cut-off of the 1 mm-diameter terminus of a long, apical **left anterior descending coronary artery (LAD)**, suggestive of embolism. (Figure 2) Due to the small vessel size no intervention was performed. However, based on these findings, a bubble echocardiogram was performed. This confirmed right to left blood flow across a **patent foramen ovale (PFO)** during Valsalva maneuver. Hypercoagulable work-up and toxicology screen were normal. Paradoxical embolus remained the presumptive diagnosis, and percutaneous closure of the PFO was subsequently performed. (Figure 3)

DISCUSSION

The foramen ovale is formed by the overlap of the primum and secundum membranes that constitute the interatrial

septum. During fetal life, the opening permits shunting of oxygenated umbilical venous blood from the **right atrium (RA)** to the **left atrium (LA)**, bypassing the non-inflated lungs. In most individuals, the membranes fuse after birth. However, in 25-30% of adults the foramen ovale remains patent¹ and can serve as a potential right-to-left shunt and a source of paradoxical emboli (described below).

LA pressure usually slightly exceeds RA pressure and ensures that the PFO—when present—remains closed. Transient increases in RA pressure can occur in normal individuals (e.g. Valsalva maneuver, coughing), opening the PFO and briefly shunting blood to the LA. This provides

a short-lived opportunity for a small embolus traveling in venous circulation—and otherwise destined for the lungs—to crossover into the arterial circulation where it will eventually lodge in a small, peripheral vessel and cause end-organ ischemia. This is the paradoxical embolus. While PFO has been associated with cryptogenic embolic stroke, transient ischemic attacks, and migraine headaches,² causation has not been proven. Its association with other systemic embolic events such as myocardial infarction is rare. In a series of 416 patients referred for evaluation of PFO related conditions, only eight (3.6%) had acute MI without evidence of obstructive CAD on angiography.³

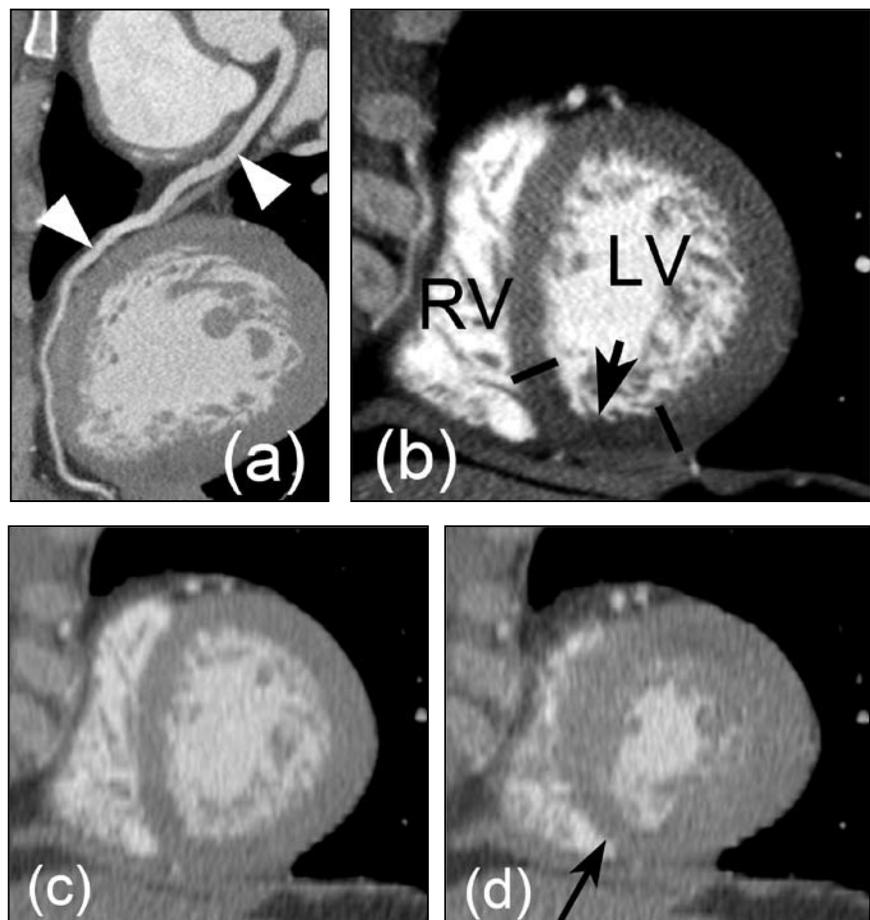


Figure 1. (a) Curved reconstructed image from the CCTA shows a normal LAD (arrowhead). (b) Short axis (SA) CT image shows a small focus of low density (relative darkness, arrow) in the inferior LV due to hypoperfusion. Small black bars delineate this segment. (c-d) End-diastolic and end-systolic phase SA CT images show lack of normal thickening of the underperfused segment (arrow).

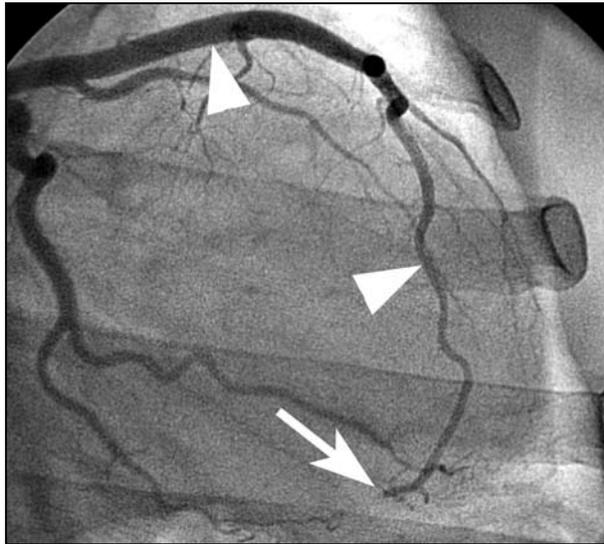


Figure 2. Single view from the conventional angiogram shows LAD (arrowheads) with an abrupt distal cut-off (arrow) suggestive of embolus.



Figure 3. Transesophageal echocardiogram shows the echogenic (bright) closure device (arrow) along the interatrial septum occluding the PFO. Asterisk: aortic valve.

Paradoxical embolism is a diagnosis of exclusion, invoked when other explanations for the observed systemic events are disproved. Such is our case where a young, healthy man with no CAD had a myocardial infarction, a PFO, and no other explanation. Three imaging modalities were employed to render this diagnosis and ultimately manage his treatment.

Echocardiography and conventional angiography remain the gold standard of anatomical and functional cardiac assessment. However, recent advances in computed tomography technology now permit non-invasive, highly detailed, stop-action imaging of the heart. With a spatial resolution of ~ 0.5 mm, CCTA now provides accurate imaging of the proximal coronary arteries. CCTA has a high negative predictive value for the detection of significant coronary artery disease in selected populations ($\sim 99\%$) and has emerged as a useful tool in the assessment of low to intermediate risk patients with chest pain or equivocal stress tests. Its use in the setting of coronary embolism is not established. In our case, the angiographic portion of the CTA examination was falsely negative owing to the small, distal nature of the affected segment, but the secondary signs of myocardial injury were evident on the perfusion and wall motion portions of the same examination.

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Michael K. Atalay, MD, PhD, is an Assistant Professor Department of Diagnostic imaging at the Warren Alpert School of Medicine of Brown University.

Athena Poppas, MD, is an Associate Professor Department of Medicine at the Warren Alpert School of Medicine of Brown University.

Disclosure of Financial Interests

The authors and/or their spouses/significant others have no financial interests to disclose.

CORRESPONDENCE

Michael K. Atalay, MD, PhD, FSCCT
 phone: (401) 444 - 5184
 fax: (401) 444 - 5017
 e-mail: atalay_99@yahoo.com