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Incidental myocardial perfusion defect detected on ECG-gated CT aortogram

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ABSTRACT

We report the case of a 49-year-old man with a history of diabetes and hypertension who presented to the emergency room with intermittent chest pain radiating to the back for one day. An electrocardiogram-gated CT aortogram excluded the emergency department's primary consideration of aortic dissection, but incidentally revealed a myocardial perfusion defect and corresponding coronary artery stenosis. Cardiac catheterization performed the following day confirmed the CT findings and the patient underwent angioplasty and stent placement. We show that despite a different protocol than coronary CTA or myocardial perfusion CT, a gated CTA for dissection (CT aortogram) is capable of detecting resting perfusion abnormalities in patients presenting to the emergency room with chest pain.

1. Introduction

It is estimated that chest pain accounts for over 8 million emergency room visits per year in the United States [1]. Etiologies of chest pain range from costochondritis to potentially life threatening diagnoses, such as acute aortic syndrome, pulmonary embolism, or myocardial infarction. On presentation, certain symptoms may prompt the clinician to prioritize their differential diagnosis and request an imaging study that is most appropriate accordingly. For example, signs and symptoms of deep vein thrombosis, history of immobilization, or elevated D-dimer in the setting of pleuritic chest pain, might prompt the clinician to order a CT pulmonary angiogram (CTPA) to evaluate for pulmonary embolism. In the setting of hypertension, patients presenting with chest pain may be referred for a CT angiogram (CTA) to evaluate for aortic dissection. Exertional chest pain or chest pain radiating down the left arm with elevated serum troponin levels may trigger a workup for acute coronary syndrome (ACS), usually in the form of a stress test. More recently, advanced cardiac imaging techniques such as coronary CTA have demonstrated the ability to rule out ACS and allow the safe discharge of patients with chest pain from the emergency department [2]. CT guided fractional flow reserve (CT-FFR), and CT perfusion (CTP) have also recently been used to detect coronary artery stenosis and to perform concurrent hemodynamic evaluation, but the former requires significant computational skills and the latter requires administration of adenosine or Regadenoson for simulating stress perfusion conditions, thus limiting their use in the emergency setting. In the current case, we show that despite being performed using different protocol than coronary CTA or myocardial perfusion CT, a gated CTA for dissection (CT aortogram) is capable of detecting resting perfusion abnormalities in patients presenting to the emergency room with nonspecific chest pain.

2. Methods

Our institution's CTA dissection protocol uses electrocardiogram (ECG)-gating along with a standard tube voltage of 120 kV, current of 150 mAs, tube rotation time of 0.6 s, and pitch factor of 0.813. A precontrast phase is acquired from the aortic arch through the diaphragm, followed by a gated arterial phase acquired from the lung apices to the bottom of the heart. The study is then continued in a non-gated fashion to the pubic symphysis. Arterial phase imaging is triggered by bolus tracking in the aorta at the level of L1, with a trigger threshold of 150 Hounsfield Units, following a 90 cc injection of contrast at a rate of 4.0 cc/s.

3. Case report

A 49-year-old man with a history of diabetes mellitus and hypertension presented to our institution's emergency department with

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complaints of shortness of breath for the past two weeks and intermittent chest pain beginning on the day prior to presentation. The patient described his chest pain as a stabbing pressure and chest heaviness radiating to the left shoulder and back. The pain was temporarily alleviated with aspirin and naproxen, but subsequently returned. Associated symptoms included diaphoresis and trouble breathing. The patient's family history was notable for a myocardial infarction in his grandfather at age 75. He denied any history of smoking or drug use. At the time of his presentation, he was taking no medications, having discontinued his own anti-diabetic medication one week earlier. Upon presentation to the emergency department, the patient was found to be tachycardiac to 105 beats per minute and hypertensive to 152/95 mm Hg. Physical exam was otherwise unremarkable, including a normal cardiac and respiratory exam. An ECG demonstrated tachycardia as described, a slightly prolonged corrected QT interval (QTc) of 464 ms, and T-wave inversions in the lateral and anteroseptal leads (leads I, aVL, and V1-V5). Laboratory results were notable for leukocytosis to 13.7 K/μl, hyperglycemia to 356 mg/dL, and elevated serum pro-brain natriuretic peptide (pro-BNP) to 1018 pg/mL. D-dimer was negative. The first two sets of troponins remained stable at 37 ng/L and 35 ng/L, respectively, levels that are considered indeterminate at our institution (< 6–14 ng/L is normal; 15–51 ng/L is indeterminate, > 51 ng/L is elevated).

The patient's blood pressure subsequently climbed as high as 184/118 mm Hg in the emergency department. Given the patient's presenting symptom of chest pain radiating to his back, profound hypertension, negative D-dimer, and indeterminate troponins, a CT aortogram was requested to evaluate for aortic dissection.

4. Results

The ECG-gated CT aortogram demonstrated no evidence of aortic dissection or intramural hematoma but was notable for low attenuation within the left ventricular subendocardium along the anterior wall, septum, and apex (Fig. 1) and moderate to severe narrowing of the mid-left anterior descending (LAD) coronary artery as well as the first diagonal branch (Fig. 2). Given these CT findings, a presumed diagnosis of angina was made. Cardiology was consulted, and the patient was admitted to the telemetry unit with a plan for a cardiac catheterization. The patient was started on aspirin, metoprolol, atorvastatin, insulin, and a heparin drip.

Cardiac catheterization the next morning confirmed the findings seen on CT and the patient was treated with angioplasty and stenting of the LAD and angioplasty of the first diagonal branch (Fig. 3). The patient recovered well following the procedure, denying further episodes of chest pain or shortness of breath, and was discharged with plans for outpatient cardiology follow up.

5. Discussion

For patients presenting with chest pain, emergency department physicians can narrow their differential diagnosis using tests ranging from a 12-lead ECG and stress test to more advanced CT studies depending on the level of suspicion for particular diagnoses. The standard of care for patients with suspected angina and negative troponins is provocative testing [3]. Recently, coronary CTA (CCTA) has emerged as a new and adjunct test for coronary artery evaluation in patients with low-to-intermediate risk chest pain [2,4,5], but requires administration of beta-blockers and sublingual nitroglycerine. CT-perfusion (CTP) imaging has also emerged as a means to assess coronary blood flow, but requires administration of a stress agent and is time consuming and thus not practical in the emergency department setting. In patients in whom an aortic dissection is suspected, a gated or non-gated CT aortogram can be requested and is considered appropriate [6]. At select, highly specialized centers, triple rule out (TRO) CTA has a role in evaluating patients with nonspecific chest pain, in whom acute coronary syndrome, pulmonary embolism, and aortic dissection can be evaluated with one scan protocol.

In the current case, a myocardial perfusion abnormality and associated coronary artery stenoses were incidentally detected on a CT aortogram, requested to evaluate for aortic dissection, despite the protocol not requiring the administration nitroglycerine or a stress agent. Our institution's dissection protocol is performed with ECG-gating, which, in addition to minimizing motion of the aortic root that can sometimes mimic a dissection flap, also facilitates evaluation of the coronary arteries without adversely affecting emergency department workflow [7–9]. Even though sublingual nitroglycerin and beta-blockers are not administered, in contradistinction to CCTA done for ruling out coronary artery disease, an ECG-gated CT aortogram still allows for evaluation of coronary artery stenosis if performed properly. Of note, diagnostic accuracy for coronary artery stenosis of 50% or greater has been shown to be higher in all coronary artery segments following the administration of sublingual nitroglycerin, and significantly higher in the proximal coronary artery segments [10]. Given that elevated heart rates are associated with motion artifacts that could degrade the image quality and decrease the sensitivity of the exam, beta-blockers are believed to improve diagnostic accuracy of CCTA through their ability to lower the heart rate [11–17]. It is for these reasons that nitroglycerin and a beta-blocker are routinely administered prior to a dedicated CCTA, provided no contraindication exists.

Inevitably, a subset of patients presenting with chest pain presumed to have one clinical diagnosis will turn out to have a different diagnosis. In the current case, the cause of chest pain was presumed to be an aortic dissection, but was subsequently proven to represent the sequelae of myocardial ischemia. Mano et al. reported retrospectively detecting myocardial perfusion abnormalities in 28% of 154 consecutive patients undergoing non-ECG-gated CT aortograms that were read as negative for pulmonary embolism and aortic dissection [18]. If a myocardial perfusion abnormality is detected at CTA, it suggests severe coronary artery stenosis, likely to demonstrate > 90% stenosis at angiography. In fact, in a study of emergency department patients undergoing non-ECG-gated CT aortograms, Huang et al. found that cardiac perfusion abnormalities had a specificity of 95% in identifying individuals with acute myocardial infarctions [19]. Likewise, in nuclear medicine imaging, a resting myocardial perfusion defect is expected to demonstrate a correlate of > 90% stenosis at angiography [20]. However, perfusion abnormalities may also represent ischemia rather than infarction, as in the current case.

As ECG-gated CTAs become more widely available [21], it is important for even non-cardiothoracic imagers to include the myocardium and coronary arteries in their search patterns, just as they should analyze the aorta on a CTPA and the pulmonary arteries on a dissection study. Specifically, it is important to describe the presence of coronary artery plaque, the degree of coronary artery narrowing, and the presence and distribution of myocardial perfusion abnormalities [22]. Imagers should also be aware that myocardial hypoattenuation could sometimes be artifactual, rather than secondary to a perfusion abnormality [23,24]. Choi et al. classified several types of artifacts that could potentially interfere with CCTA interpretation: Beam-hardening artifact/structural artifact due to adjacent high-attenuation material (calcification, surgical material, or contrast within an adjacent structure), motion artifact, and artifacts related to technical errors (suboptimal scan parameters, poor contrast enhancement, or incomplete anatomic coverage) [25]. Specifically, beam hardening has been implicated as a frequent cause of artifactual myocardial hypoattenuation, most commonly affecting the posterobasal wall of the left ventricle but also seen in the inferior and anteroapical left ventricular segments (Fig. 4) [26]. Beam hardening artifact characteristically produces a triangular area of transmural hypoattenuation radiating from a hyperattenuating structure. In contrast, cardiac motion also produces focal hypoattenuation, but with alternating areas of hyperattenuation [27]. ECG-gating, as well as the speed with which modern multidetector CT

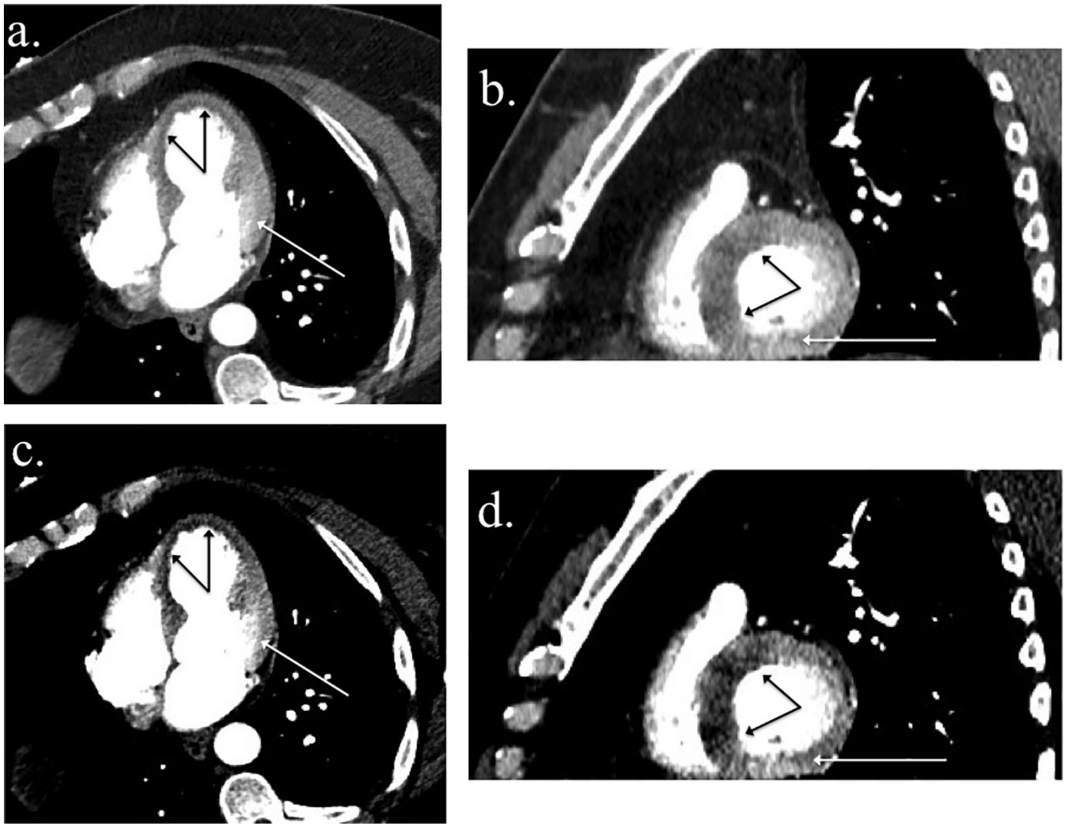

Fig. 1. Reformatted 4-chamber (a) and short axis (b) ECG-gated CT aortogram images of the heart at window width 400 HU and window level 50 HU demonstrating a hypoperfusion defect of the anterior, septal, and apical myocardium (solid black arrows). Compare to normally perfused myocardium on the same images (solid white arrows). The hypoperfusion defect is seen to even greater advantage on the same reformatted 4-chamber (c) and short axis (d) ECG-gated CT aortogram images of the heart with window width set to 200 HU level and window level to 100 HU.

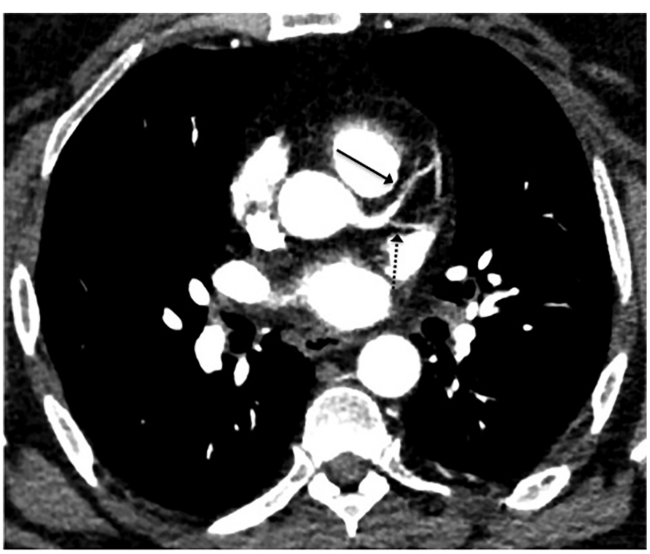

Fig. 2. Axial ECG-gated CT aortogram image demonstrating stenosis of the left anterior descending (LAD) coronary artery (solid black arrow) and the first diagonal branch (dashed black arrow).

scanners acquire data, are said to reduce cardiac motion-related artifact. A true myocardial perfusion abnormality must be seen in a subendocardial location and in a vascular distribution, whereas artifact may be focal but not usually subendocardial or global. The presence of a possible perfusion abnormality should prompt the radiologist to evaluate the coronary artery supplying the affected myocardial distribution. Furthermore, given the likelihood of artifacts associated with cardiac motion, respiratory motion, and beam hardening, all cases with a suspected perfusion abnormality should be reviewed in multiple planes and, if available, in multiple phases, with an awareness of the myocardial segments supplied by each coronary artery to determine if the apparent abnormality is perfusion related.

6. Summary

In summary, a cardiac perfusion abnormality detected at CT represents a resting perfusion defect, and may represent high-grade coronary artery stenosis. Such a finding is likely to be more apparent on ECG-gated imaging than on non-ECG-gated modalities. Therefore, vigilance in evaluating the heart is a necessity for all radiologists reading ECG-gated CT aortograms, and, in the setting of a cardiac perfusion abnormality, may result in timely triage of patients to cardiac catheterization. Despite a different protocol than coronary CTA or myocardial perfusion CT, gated CT aortogram is capable of detecting resting perfusion abnormalities in patients presenting to the emergency room with chest pain. Radiologists should familiarize themselves with findings related to myocardial perfusion abnormalities (vascular distribution and subendocardial low attenuation) so that they can recognize these findings and alert referring clinicians.

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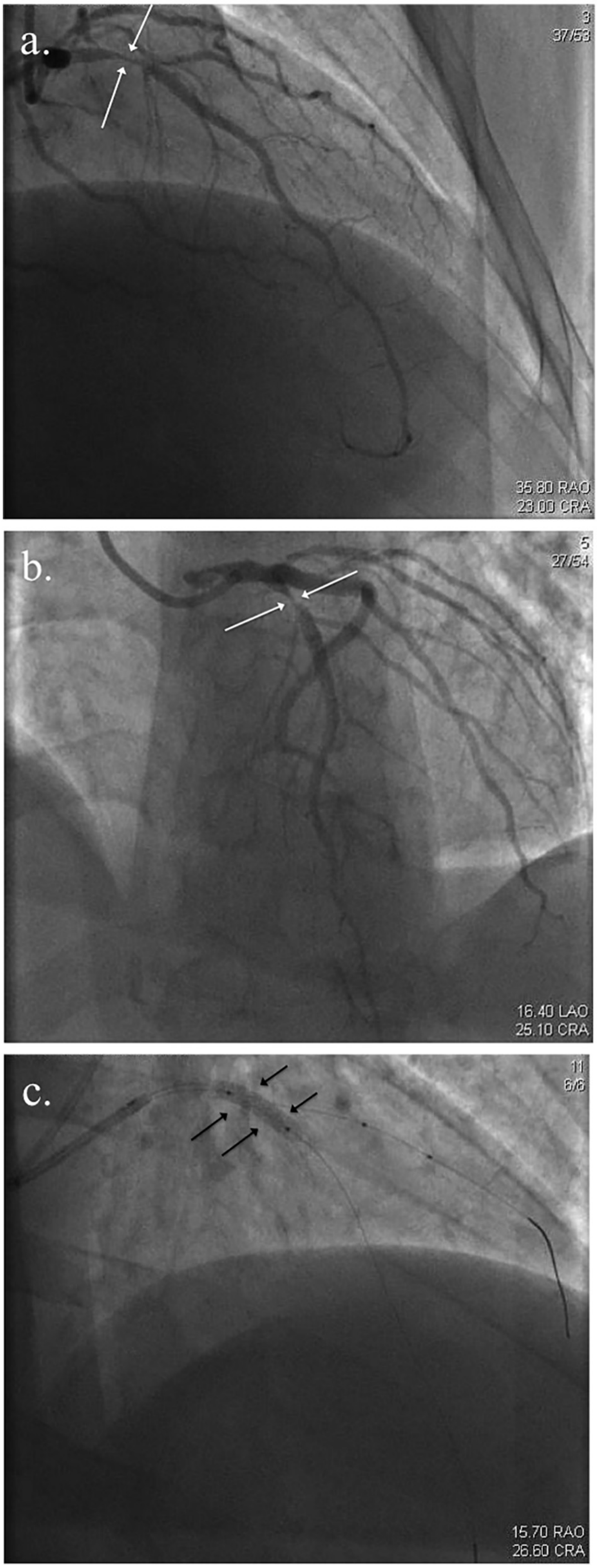

Fig. 3. Subsequent conventional coronary angiography confirmed severe stenosis (solid white arrows) of the mid LAD shown on RAO view (a) and the proximal first diagonal branch shown on LAO view (b). Angioplasty and stent placement (solid black arrows) were performed at the site of LAD stenosis (c).

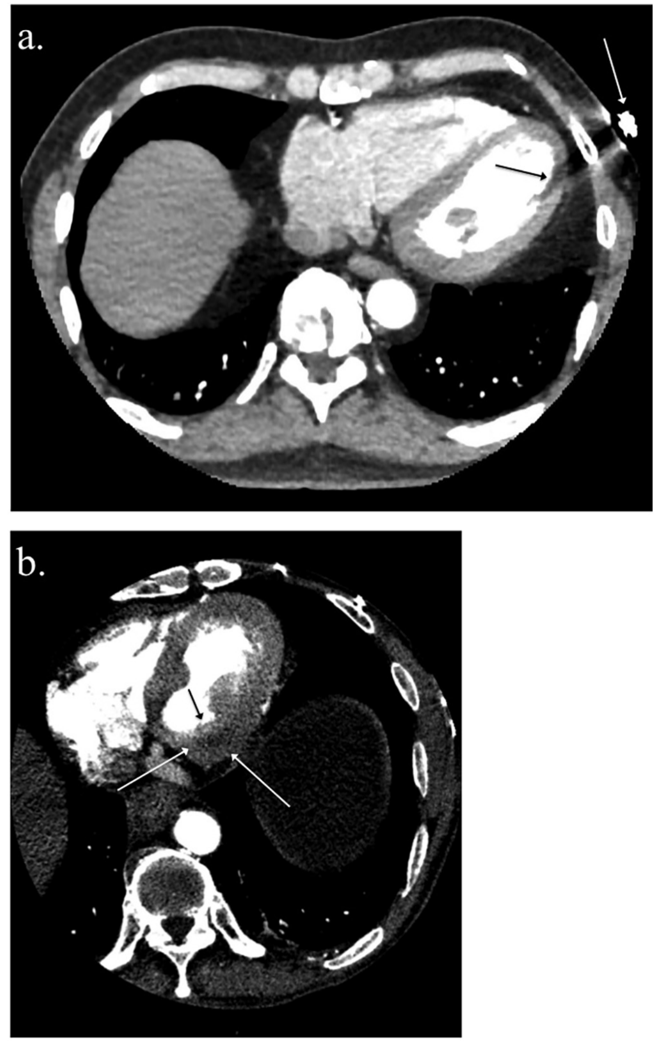

Fig. 4. (a) Axial image from an ECG-gated CT aortogram performed on a 57-year-old male with chest pain demonstrating artifactual hypoattenuation of the apical lateral left ventricular myocardium (solid black arrow) secondary to beam hardening artifact caused by a metallic button external to the patient (solid white arrow). (b) Axial image from an ECG-gated CT aortogram performed on a 67-year-old male with chest pain demonstrating artifactual hypoattenuation within the basal inferolateral left ventricular mid-myocardium (solid white arrows). Note that the subendocardium is normally perfused (solid black arrow) and that the area of hypoattenuation does not correspond to a vascular distribution.

References

[1] Hsia RY, Hale Z, Tabas JA. A national study of the prevalence of life-threatening diagnoses in patients with chest pain. JAMA Intern Med 2016;176(7):1029–32. Epub 2016/06/14 https://doi.org/10.1001/jamainternmed.2016.2498. PubMed PMID 27295579.

[2] Litt HI, Gatsonis C, Snyder B, Singh H, Miller CD, Entrikin DW, et al. CT angiography for safe discharge of patients with possible acute coronary syndromes. N Engl J Med 2012;366(15):1393–403. Epub 2012/03/28 https://doi.org/10.1056/NEJMoa1201163. PubMed PMID 22449295.

[3] Kirk JD, Diercks DB, Turnipseed SD, Amsterdam EA. Evaluation of chest pain suspicious for acute coronary syndrome: use of an accelerated diagnostic protocol in a chest pain evaluation unit. Am J Cardiol 2000;85(5a). 40B-8B; discussion 9B. Epub 2000/11/15. PubMed PMID 11076130.

[4] Goldstein JA, Chinnaiyan KM, Abidov A, Achenbach S, Berman DS, Hayes SW, et al. The CT-STAT (coronary computed tomographic angiography for systematic triage of acute chest pain patients to treatment) trial. J Am Coll Cardiol 2011;58(14):1414–22. Epub 2011/09/24 https://doi.org/10.1016/j.jacc.2011.03.068. PubMed PMID 21939822.

[5] Hoffmann U, Truong QA, Schoenfeld DA, Chou ET, Woodard PK, Nagurney JT, et al. Coronary CT angiography versus standard evaluation in acute chest pain. N Engl J Med 2012;367(4):299–308. Epub 2012/07/27 https://doi.org/10.1056/

NEJMoa1201161. [PubMed PMID: 22830462; PubMed Central PMCID: PMCPMC3662217].
[6] Jacobs JE, Latson LA, Abbara S, Akers SR, Araoz PA, Cummings KW, et al. Acute chest pain – suspected aortic dissection. American College of Radiology; 1995 [updated 2014; cited 8/15/2018]. Available from. https://acsearch.acr.org/docs/69402/Narrative/.
[7] Fleischmann D, Mitchell RS, Miller DC. Acute aortic syndromes: new insights from electrocardiographically gated computed tomography. Semin Thorac Cardiovasc Surg 2008;20(4):340–7. Epub 2008/01/01 https://doi.org/10.1053/j.semtcvs.2008.11.011. PubMed PMID 19251175.
[8] Schertler T, Glucker T, Wildermuth S, Jungius KP, Marincek B, Boehm T. Comparison of retrospectively ECG-gated and nongated MDCT of the chest in an emergency setting regarding workflow, image quality, and diagnostic certainty. Emerg Radiol 2005;12(1–2):19–29. Epub 2005/11/12 https://doi.org/10.1007/s10140-005-0435-y. PubMed PMID 16283221.
[9] Wu W, Budovec J, Foley WD. Prospective and retrospective ECG gating for thoracic CT angiography: a comparative study. AJR Am J Roentgenol 2009;193(4):955–63. Epub 2009/09/23 https://doi.org/10.2214/ajr.08.2158. PubMed PMID 19770316.
[10] Chun EJ, Lee W, Choi YH, Koo BK, Choi SI, Jae HJ, et al. Effects of nitroglycerin on the diagnostic accuracy of electrocardiogram-gated coronary computed tomography angiography. J Comput Assist Tomogr 2008;32(1):86–92. Epub 2008/02/28 https://doi.org/10.1097/rct.0b013e318059befa. PubMed PMID 18303294.
[11] Bamberg F, Abbara S, Schlett CL, Cury RC, Truong QA, Rogers IS, et al. Predictors of image quality of coronary computed tomography in the acute care setting of patients with chest pain. Eur J Radiol 2010;74(1):182–8. Epub 2009/04/07 https://doi.org/10.1016/j.ejrad.2009.03.001. [PubMed PMID: 19346094; PubMed Central PMCID: PMCPMC3719970].
[12] Giesler T, Baum U, Ropers D, Ulzheimer S, Wenkel E, Mennicke M, et al. Noninvasive visualization of coronary arteries using contrast-enhanced multidetector CT: influence of heart rate on image quality and stenosis detection. AJR Am J Roentgenol 2002;179(4):911–6. Epub 2002/09/20 https://doi.org/10.2214/ajr.179.4.1790911. PubMed PMID 12239036.
[13] Herzog C, Arning-Erb M, Zangos S, Eichler K, Hammerstingl R, Dogan S, et al. Multidetector row CT coronary angiography: influence of reconstruction technique and heart rate on image quality. Radiology 2006;238(1):75–86. Epub 2005/12/24 https://doi.org/10.1148/radiol.2381041595. PubMed PMID 16373760.
[14] Hoffmann MH, Shi H, Manzke R, Schmid FT, De Vries L, Grass M, et al. Noninvasive coronary angiography with 16-detector row CT: effect of heart rate. Radiology 2005;234(1):86–97. Epub 2004/11/20 https://doi.org/10.1148/radiol.2341031408. PubMed PMID 15550373.
[15] Leschka S, Wildermuth S, Boehm T, Desbiolles L, Husmann L, Plass A, et al. Noninvasive coronary angiography with 64-section CT: effect of average heart rate and heart rate variability on image quality. Radiology 2006;241(2):378–85. Epub 2006/09/13 https://doi.org/10.1148/radiol.2412051384. PubMed PMID 16966483.
[16] Mahabadi AA, Achenbach S, Burgstahler C, Dill T, Fischbach R, Knez A, et al. Safety, efficacy, and indications of beta-adrenergic receptor blockade to reduce heart rate prior to coronary CT angiography. Radiology 2010;257(3):614–23. Epub 2010/11/19 https://doi.org/10.1148/radiol.10100140. PubMed PMID 21084413.
[17] Shim SS, Kim Y, Lim SM. Improvement of image quality with beta-blocker premedication on ECG-gated 16-MDCT coronary angiography. AJR Am J Roentgenol 2005;184(2):649–54. Epub 2005/01/27 https://doi.org/10.2214/ajr.184.2.01840649. PubMed PMID 15671392.
[18] Mano Y, Anzai T, Yoshizawa A, Itabashi Y, Ohki T. Role of non-electrocardiogram-gated contrast-enhanced computed tomography in the diagnosis of acute coronary syndrome. Heart Vessel 2015;30(1):1–8. Epub 2013/11/14 https://doi.org/10.1007/s00380-013-0437-8. PubMed PMID 24221182.
[19] Huang LT, Chan SH, Chuang CC, Tsai YS. Non-gated high-pitch computed tomography aortic angiography: myocardial perfusion defects in patients with suspected aortic dissection. J Cardiovasc Comput Tomogr 2017;11(3):208–12. Epub 2017/04/19 https://doi.org/10.1016/j.jcct.2017.04.003. PubMed PMID 28416358.
[20] Ziessman HA, O'Malley JP, Thrall JH. Nuclear medicine: The requisites in radiology. 3rd ed. Philadelphia: Mosby Elsevier; 2006.
[21] Marano R, Pirro F, Silvestri V, Merlino B, Savino G, Rutigliano C, et al. Comprehensive CT cardiothoracic imaging: a new challenge for chest imaging. Chest 2015;147(2):538–51. Epub 2015/02/04 https://doi.org/10.1378/chest.14-1403. PubMed PMID 25644907.
[22] Chu LC, Johnson PT, Fishman EK. Cardiac CT angiography beyond the coronary arteries: what radiologists need to know and why they need to know it. AJR Am J Roentgenol 2014;203(6):W583–95. Epub 2014/11/22 https://doi.org/10.2214/ajr.13.12400. PubMed PMID 25415723.
[23] Machida H, Tanaka I, Fukui R, Shen Y, Ishikawa T, Tate E, et al. Current and novel imaging techniques in coronary CT. Radiographics: A Review Publication of the Radiological Society of North America, Inc 2015;35(4):991–1010. Epub 2015/06/06 https://doi.org/10.1148/rg.2015140181. PubMed PMID 26046942.
[24] Varga-Szemes A, Meinel FG, De Cecco CN, Fuller SR, Bayer 2nd RR, Schoepf UJ. CT myocardial perfusion imaging. AJR Am J Roentgenol 2015;204(3):487–97. Epub 2015/02/26 https://doi.org/10.2214/ajr.14.13546. PubMed PMID 25714277.
[25] Choi HS, Choi BW, Choe KO, Choi D, Yoo KJ, Kim MI, et al. Pitfalls, artifacts, and remedies in multi-detector row CT coronary angiography. Radiographics: A Review Publication of the Radiological Society of North America, Inc 2004;24(3):787–800. Epub 2004/05/15 https://doi.org/10.1148/rg.243035502. PubMed PMID 15143228.
[26] Rodriguez-Granillo GA, Rosales MA, Degrossi E, Rodriguez AE. Signal density of left ventricular myocardial segments and impact of beam hardening artifact: implications for myocardial perfusion assessment by multidetector CT coronary angiography. Int J Card Imaging 2010;26(3):345–54. Epub 2009/11/13 https://doi.org/10.1007/s10554-009-9531-5. PubMed PMID 19908161.
[27] Mehra VC, Valdiviezo C, Arbab-Zadeh A, Ko BS, Seneviratne SK, Cerci R, et al. A stepwise approach to the visual interpretation of CT-based myocardial perfusion. J Cardiovasc Comput Tomogr 2011;5(6):357–69. Epub 2011/12/08 https://doi.org/10.1016/j.jcct.2011.10.010. PubMed PMID 22146495.