

Editorial

A Comprehensive Computed Tomography Protocol for Evaluating Left Ventricular Systolic Dysfunction

Un protocolo integral de tomografía computarizada para evaluar la disfunción sistólica ventricular izquierda

James C. Carr*

Department of Radiology and Medicine, Feinberg School of Medicine, Northwestern University and Bluhm Cardiovascular Institute, Northwestern Memorial Hospital, Chicago, Illinois, United States

Article history:

Available online 30 April 2012

The article by Estornell-Erill et al.¹ published in *Revista Española de Cardiología* investigates the ability of multidetector computed tomography (CT) to detect the causes of left ventricular systolic dysfunction (LVSD) in a single comprehensive assessment. In this study, the authors combine coronary artery calcium (CAC) scoring, anatomic luminal imaging of the coronary arteries by CT angiography, and CT myocardial tissue evaluation to assess the etiology of LVSD in one protocol using coronary angiography and cardiac magnetic resonance (CMR) imaging as the reference standard. Each of these imaging techniques has been studied independently using various reference standards; however, this is the first time that all have been evaluated together. The authors are to be commended for this approach particularly at a time when institutions are attempting to streamline medical care to reduce cost and provide optimal targeted investigation with the lowest number of studies. Traditional algorithms have combined invasive coronary angiography with at least one noninvasive modality such as nuclear medicine, echocardiography, and CMR. Each of these noninvasive tools has advantages and disadvantages that are described in the article. CMR has shown the greatest promise by being able to assess both perfusion and viability together; however, the success of coronary artery depiction with magnetic resonance imaging has proved elusive.² One approach has been to combine invasive coronary angiography with CMR to address both the anatomic and physiologic assessment; the authors use this as the reference standard in the current study. In fact, magnetic resonance imaging was originally postulated as a tool for comprehensive imaging of the heart, resulting in a coining of the phrase “one stop shop” imaging.³

CAC scoring has been well established in the literature as a useful tool for risk-stratifying patients undergoing assessment for cardiovascular disease. It is widely considered now that coronary calcium assessment should form part of the routine risk factor assessment in addition to other historical risk factors such as

hypertension and diabetes. The power of CAC assessment lies in its negative predictive value whereby coronary artery disease is effectively excluded if there is a score of zero. A CAC score higher than zero indicates that the individual has coronary artery disease; however, it does not reliably predict the presence of obstructive disease. Therefore the false positive rate is generally high for obstructive coronary disease and explains why CAC scoring has not commonly been used as a diagnostic tool in various disease states such as LVSD, as the authors acknowledge. In this study, CAC assessment had a sensitivity of 100% and specificity of 31%, which increases to 58% when the CAC level is increased to more than 100. This is confirmed by other studies evaluating the role of CAC scoring in LVSD. The main benefit for CAC measurement is that if the score is zero, then ischemic causes of LVSD can be excluded. From a practical standpoint therefore, coronary CT angiography (CCTA) can be avoided if an initial CAC score is zero. One caveat is that a small percentage of patients with zero calcium score may have soft atherosclerotic coronary plaque that remains undetected by CAC assessment; however, the risk of obstructive disease is extremely low.⁴ Since most of the information regarding coronary atherosclerosis, whether hard or soft, can be gleaned from the CCTA, it is difficult to see whether there is any point to carrying out the CAC score in this disease setting.

With the advent of multidetector CT technology, CCTA emerged as a useful and reproducible noninvasive tool for imaging the coronary artery anatomy. Multiple studies have demonstrated high sensitivity and specificity for detection of coronary artery disease when compared to invasive coronary angiography.^{5,6} Similar to CAC scoring, the principal advantages lies with its negative predictive value where, if the CCTA is normal, coronary artery disease is excluded. Therefore, CCTA has primarily been employed to exclude coronary disease in low- to intermediate-risk patients, such as in the setting of the emergency department; it has not been commonly employed to assess patients with LVSD. In this study, the detection rate for significant coronary disease according to Felker's criteria was high, with sensitivities and specificities of 100% and 96%, respectively. This compares remarkably well to the published literature. Based on the results in this study, one could argue that CCTA alone is sufficient to assess a potential ischemic etiology

SEE RELATED ARTICLE:

10.1016/j.rec.2011.07.011, *Rev Esp Cardiol.* 2012;517–24.

* Corresponding author: Department of Radiology, Northwestern University, 737 N Michigan Ave, Suite 1600, Chicago, IL 60611, United States.

E-mail address: jcarr@northwestern.edu

in LVSD patients, without adding in additional CT imaging techniques. One possible explanation for a relative lack of evidence and utility for CCTA in LVSD is the poorer image quality produced by CT angiography in patients with poor left ventricular function. This relates to poor enhancement of the coronary arteries due to wide dispersion of the contrast bolus as it transits through the poorly functioning left ventricle. In this study, 45% of patients had moderate or severe LVSD (New York Heart Association III and IV) and no patients were excluded from the evaluation due to poor image quality. It would be interesting to know how measures of image quality and diagnostic performance varied across the different ejection fractions. However, even with that considered it seems that CCTA performed well, even in the poorly functioning hearts.

Delayed enhanced imaging with CMR is increasingly recognized as the gold standard for assessing left ventricular myocardial scar. This technique relies on leakage of gadolinium contrast from the intravascular space into the interstitium in areas of myocardial fibrosis, resulting in high signal within the scarred region on T1 weighted imaging due to contrast retention within the abnormal area.⁷ CMR is particularly suited to imaging myocardial scar due to its inherent ability to demonstrate high contrast between different tissues due to their specific relaxation times. More recently, efforts have been made to simulate CMR mechanisms in order to demonstrate delayed enhancement with CT. Scar imaging with CT depends on leakage of iodine-based contrast into the extracellular space, analogous to gadolinium contrast with CMR; however, due to the inherently lower contrast with CT, depiction of myocardial fibrosis has been more challenging, requiring extensive post processing and windowing to reliably demonstrate myocardial enhancement. Initial results of delayed enhanced CT for detecting myocardial scar have been encouraging in human and animal studies.^{8–10} It has been shown that a combined approach using cine imaging, first-pass perfusion, and delayed contrast enhancement results in the highest diagnostic accuracy for infarct detection.¹⁰ In the current study, the sensitivity and specificity of late iodine enhancement in the setting of LVSD were 86% and 96%, respectively, using invasive coronary angiography as the reference standard. Groups 1 and group 3 showed nearly exact correlation when compared, although the individual imaging technique comparisons were not separated out. It would be informative to see the direct comparisons between late iodine enhancement by CT and late gadolinium enhancement by CMR, although all 6 patients with scar in group 2 were detected by CT and CMR. Delayed enhanced imaging by CT requires the addition of an extra CT acquisition, with the resultant increase in radiation exposure, as performed in this study. In this small study, myocardial scar was detected by an extra delayed CT acquisition and may justify the use of additional radiation exposure in this clinical setting. Further work with larger numbers of patients needs to be carried out.

Detection of hypoattenuation during first-pass contrast enhancement is analogous to first-pass perfusion imaging at CMR and is aimed at assessing myocardial necrosis or microvascular obstruction. Microvascular obstruction is usually seen in the setting of acute myocardial infarction where arteriolar thrombotic obstruction does not allow passage of any contrast material into the damaged muscle. This results in a perfusion defect on both CT and magnetic resonance imaging. CT, CMR and invasive coronary angiography were carried out on average 22 days after the initial clinical event in this study therefore it is less likely that microvascular obstruction would still be apparent. The results for hypoattenuation were mixed in this study having a low sensitivity of 57%. Since myocardial scar may not be apparent on first-pass imaging, this may explain its variable detection by hypoattenuating lesions.

A major consideration of multidetector cardiac CT is radiation exposure. Several techniques have been developed to reduce radiation dose including electrocardiogram pulse modulation, prospective electrocardiogram gating, and various postprocessing algorithms.^{11–13} All of these approaches have reduced radiation exposure from relatively high levels of 10 to 15 mSv to 4 to 5 mSv for a single acquisition. In this study, 3 different sequential CT acquisitions were carried out, resulting in an average dose of 25mSv per patient study. This would be considered high for a diagnostic study. The use of prospective electrocardiogram gating instead of retrospective gating, as used in this study, would result in at least a 50% reduction in radiation exposure thus mitigating the increased cumulative radiation due to multiple CT acquisitions.

This article¹ investigates the utility of a comprehensive CT approach for diagnosing ischemic cardiac disease and demonstrates that it has some utility in assessing the causes of LVSD. The most promising combination of techniques include CCTA and delayed enhanced imaging by CT, which allow combined assessment of obstructive coronary disease and myocardial scar, showing the highest rate of disease detection. Coronary calcium assessment did not add much diagnostic yield to the overall protocol, although it does add some value in potentially avoiding CCTA in low-risk patients with zero calcium score. A significant concern is the radiation exposure associated with the described multi-acquisition protocol. This can be obviated by using various dose reduction strategies that have the potential to reduce the overall radiation dose by at least half. Such a comprehensive CT protocol is highly promising for assessing acute cardiac disease, particularly when radiation dose is minimized.

CONFLICTS OF INTEREST

None declared.

REFERENCES

- Estornell-Erill J, Igual-Muñoz B, Monmeneu-Menadas JV, Soriano-Navarro C, Valle-Muñoz A, Vilar-Herrero JV, et al. Diagnóstico etiológico de la disfunción ventricular izquierda con tomografía computarizada: comparación con coronariografía y cardiorensonancia. *Rev Esp Cardiol.* 2012;517–24.
- Liu X, Bi X, Huang J, Jerecic R, Carr J, Li D. Contrast-enhanced whole-heart coronary magnetic resonance angiography at 3.0 T: comparison with steady-state free precession technique at 1.5 T. *Invest Radiol.* 2008;43:663–8.
- Kramer CM. Integrated approach to ischemic heart disease. The one-stop shop. *Cardiol Clin.* 1998;16:267–76.
- Nieman K, Galema TW, Neeffjes LA, Weustink AC, Musters P, Moelker AD, et al. Comparison of the value of coronary calcium detection to computed tomographic angiography and exercise testing in patients with chest pain. *Am J Cardiol.* 2009;104:1499–504.
- Schroeder S, Achenbach S, Bengel F, Burgstahler C, Cademartiri F, De Feyter P, et al. Cardiac computed tomography: indications, applications, limitations, and training requirements: report of a Writing Group deployed by the Working Group Nuclear Cardiology and Cardiac CT of the European Society of Cardiology and the European Council of Nuclear Cardiology. *Eur Heart J.* 2008;29:531–56.
- American College of Cardiology Foundation Task Force on Expert Consensus Documents, Mark DB, Berman DS, Budoff MJ, Carr JJ, Gerber TC, et al. ACCF/ACR/AHA/NASCI/SAIP/SCAI/SCCT 2010 expert consensus document on coronary computed tomographic angiography: a report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents. *Circulation.* 2010;121:2509–43.
- Simonetti OP, Kim RJ, Fieno DS, Hillenbrand HB, Wu E, Bundy JM, et al. An improved MR imaging technique for the visualization of myocardial infarction. *Radiology.* 2001;218:215–23.
- Lardo AC, Cordeiro MA, Silva C, Amado LC, George RT, Saliaris AP, et al. Contrast-enhanced multidetector computed tomography viability imaging after myocardial infarction: characterization of myocyte death, microvascular obstruction, and chronic scar. *Circulation.* 2006;113:394–404.
- Mendoza DD, Joshi SB, Weissman G, Taylor AJ, Weigold WG. Viability imaging by cardiac computed tomography. *J Cardiovasc Comput Tomogr.* 2010;4:83–91.

10. Ghoshhajra BB, Maurovich-Horvat P, Techasith T, Medina HM, Verdini D, Sidhu MS, et al. Infarct detection with a comprehensive cardiac CT protocol. *J Cardiovasc Comput Tomogr.* 2012;6:14–23.
11. Kim JS, Choo KS, Jeong DW, Chun KJ, Park YH, Song SG, et al. Step-and-shoot prospectively ECG-gated vs. retrospectively ECG-gated with tube current modulation coronary CT angiography using 128-slice MDCT patients with chest pain: diagnostic performance and radiation dose. *Acta Radiol.* 2011;52:860–5.
12. Farrelly C, Davarpanah A, Keeling AN, Sheehan J, Ragin A, Yaghmai V, et al. Low dose dual-source CT angiography of the thoracic aorta. *Int J Cardiovasc Imaging.* 2011;27:1025–34.
13. Park EA, Lee W, Kim KW, Kim KG, Thomas A, Chung JW, et al. Iterative reconstruction of dual-source coronary CT angiography: assessment of image quality and radiation dose. *Int J Cardiovasc Imaging.* 2011 Dec 21. [Epub ahead of print].