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iREVIEWS

STATE-OF-THE-ART PAPER

Stress Myocardial CT Perfusion

An Update and Future Perspective

Tust Techasith, BS,*† Ricardo C. Cury, MD‡
Boston, Massachusetts; and Miami, Florida

Coronary computed tomography angiography (CTA) has been shown by several multicenter trials to have excellent diagnostic accuracy in the detection and exclusion of significant coronary stenosis. However, a major limitation of coronary CTA is that the physiological significance of stenotic lesions identified is often unknown. Stress myocardial computed tomography perfusion (CTP) is a novel examination that provides both anatomic and physiological information (i.e., myocardial perfusion). Multiple single-center studies have established the feasibility of stress myocardial CTP. Furthermore, it has been illustrated that a combined CTA/CTP protocol improves the diagnostic accuracy to detect hemodynamic significant stenosis as compared with CTA alone; this combined protocol can also be accomplished at a radiation dose comparable to nuclear myocardial perfusion imaging exams. Although initial results hold some promise, stress myocardial CTP is a modality in its infancy. Further research is required to define, validate, and optimize this new technique. However, it is a modality with significant potential, particularly in the evaluation of chest pain patients, given the advantages of short exam time and comprehensive data acquisition. This review highlights how to perform and interpret stress myocardial CTP, summarizes the current literature, and discusses some future directions. (J Am Coll Cardiol Img 2011;4:905–16) © 2011 by the American College of Cardiology Foundation

Recent advances in computed tomography (CT) technology and the rapid evolution of multidetector row CT (1), have allowed cardiac imaging to flourish on this platform. Cardiac CT has been proven to have numerous clinically relevant applications, including coronary artery calcium scoring, coronary computed tomography angiography (CTA), global and regional left ventricular function assessment, and most recently, the assessment of myocardial CT perfusion (CTP) (2–6).

The majority of cardiac CT exams performed today are coronary CTAs, aiming to elucidate the patient's coronary anatomy noninvasively. Coronary CTA has been shown by several multicenter trials to have excellent diagnostic accuracy in the detection and exclusion of significant coronary stenosis (CAD) as compared with invasive coronary angiography (6–8).

Despite its successes, coronary CTA has several inherent limitations restricting its use to a specific population. First and foremost, coronary CTA only provides anatomic information. Many studies have established that functional information is essential in both guiding clinical management and long-term prognosis

From the *Harvard Medical School, Boston, Massachusetts; †Cardiac MR PET CT Program, Massachusetts General Hospital, Boston, Massachusetts; and the ‡Baptist Cardiac and Vascular Institute and Baptist Hospital of Miami, Miami, Florida. Mr. Techasith has reported that he has no relationships relevant to the contents of this paper to disclose. Dr. Cury receives research grants from Astellas Pharma, and GE Healthcare.

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(9–11). The presence of anatomic lesions does not necessarily correlate with functional abnormality—that is, decreased myocardial perfusion (12). Another shortcoming of coronary CTA is its tendency to overestimate the extent of CAD in high-risk patients due to the presence of calcified plaques and stents (13–14).

Given these shortcomings, many attempts have been made to combine coronary CTA with functional studies such as positron emission tomography or single-photon emission computed tomography (SPECT), illustrating complementarity between the techniques (15,16). However, in such scenarios, the patient is required to undergo at least 2 diagnostic studies in order to arrive at the final result, which not only is inconvenient but also subjects the patient to increased radiation exposure. As such, it is evident that a CT-based exam that combines the information provided by anatomy and perfusion, namely stress myocardial computed tomography perfusion (CTP) imaging, can have many potential benefits.

ABBREVIATIONS AND ACRONYMS

CAD = coronary artery disease

CTA = computed tomography angiography

CTP = computed tomography perfusion

DECT = dual energy computed tomography

ECG = electrocardiogram

MBF = myocardial blood flow

MDCT = multidetector computed tomography

MPI = myocardial perfusion imaging

NPV = negative predictive value

PPV = positive predictive value

QCA = quantitative coronary angiography

SPECT = single-photon emission computed tomography

Recently, several single-center studies have illustrated the feasibility of stress myocardial CTP and have shown that stress myocardial CTP adds incremental value to traditional coronary CTA in the detection of significant coronary stenosis, potentially overcoming the limitations of coronary CTA alone (17–20). Although initial results hold some promise, stress myocardial CTP is a modality in its infancy, with only a small number of subjects evaluated overall, with no clear optimized protocol as of yet. Further research is required to define, validate, and optimize this technique. However, it is a modality with significant potential, particularly in the evaluation of chest pain patients, given the advantages of short exam time and comprehensive data acquisition. This review will address protocol setup and interpretation of stress myocardial CTP, current literature, and future directions.

Protocol Setup and Interpretation of Stress Myocardial CTP

Overview. Myocardial CTP protocol is composed of a stress phase acquisition and a rest phase acquisition, similar to a nuclear myocardial perfusion imaging (MPI) exam. These acquisitions are evaluated for myocardial perfusion information but also coronary anatomy as well, generally using the rest acquisition. Iodinated contrast is administered both in the stress and rest acquisition (60 to 75 ml for each acquisition), for a total contrast dose of approximately 130 to 150 ml. Stress phase imaging is performed under pharmacological administration of stress agents, such as adenosine, dipyridamole, or regadenoson, similar to nuclear medicine MPI. Additionally, a third optional delayed-phase acquisition can be performed in cases where late contrast enhancement evaluation for myocardial scar is desired.

Patient preparation. In addition to the standard setup of a coronary CTA, myocardial CTP protocol requires a few additional components: namely, 1 additional intravenous catheter if adenosine/dipyridamole infusion is being used, a 12-lead electrocardiogram (ECG) machine, and a blood pressure monitor. Two 18- to 20-gauge intravenous catheters are inserted into the patient's antecubital veins: 1 for the delivery of iodinated contrast material and the other for infusion of the pharmacological stress agent. Actual gauge and site of insertion may vary depending upon the patient's anatomy. Contrast is prepared in a dual-syringe contrast injection system. The pharmacological stress agent is prepared in an infusion pump. Note is made that newer stress agents, such as regadenoson, may require only 1 intravenous site for delivery of the stress agent in a single bolus of 10 s followed by a saline flush. The contrast administration can be given after 1 to 2 min of regadenoson infusion. ECG and blood pressure measurements are performed prior to scan acquisition to establish a baseline for patient monitoring, during and after the procedure is completed.

Choice of stress agents. Although it has been shown in many studies that pharmacological and exercise stress testing have comparable diagnostic characteristics, exercise is the preferred method of stress in myocardial perfusion imaging when possible (21–25). This is due to its physiological mechanism and some reports of greater extent, severity, and reversibility of defects with exercise compared with pharmacological stress (26,27). The main significant limitation of exercise is that many patients, especially in a specific population that would benefit from a stress test, are not able to exercise adequately. Additionally, all published literature on stress myocardial CTP to date has employed pharmacological stress. As such, this review will focus on pharmacological stress agents; however, using exercise stress in myocardial CTP is an area that should be explored in future studies.

Pharmacological stress agents that have been validated via feasibility trials include adenosine and dipyridamole (17–19). Both agents are coronary