JACC Vol. 62, No. 4, 2013
July 23, 2013:351–6

examinations *before* or at least 4 hours *after* MPI are needed. Other services in which medical staff have prolonged close patient contact should occur outside of this window. If rescheduling cannot occur, the use of lead aprons by staff working closely with patients should be considered during the first 4 h following MPI.

Experts have suggested that it is difficult to generate definitive conclusions about the health risks attributable to radiation doses <50 mSv in 1 year or <100 mSv over a lifetime (5). Although it is unlikely that repeated exposure to post-MPI patients will exceed these limits in adults, our data suggest that close and repeated contact should be avoided in populations that are more radiosensitive, such as pregnant women and children.

An estimation of the total effective dose equivalent was not the subject of our study and would be exceedingly challenging given the variability in the time of exposure, distance, and body position. Our measures of radiation exposure are routinely performed by radiation safety departments.

MPI is an important tool in the evaluation of patients for coronary artery disease, providing valuable diagnostic and prognostic information. Current recommendations for the appropriate use of MPI generally limit its use to those patients with at least intermediate risk, inability to exercise, an abnormal baseline electrocardiogram, or other situations in which the risk–benefit ratio is favorable. Our data confirm that radiation exposure to hospital personnel and the public can be minimized by maintaining adequate distance from the patient. Instituting appropriate changes in scheduling, the use of lead shielding, and patient education can further aid in reducing radiation exposure in others.

Connie W. Tsao, MD
Lauren E. Frost, MD
Kim Fanning, RDCS
Warren J. Manning, MD
***Thomas H. Hauser, MD, MMSc, MPH**

*Cardiovascular Division
Beth Israel Deaconess Medical Center
330 Brookline Avenue (RW-453)
Boston, Massachusetts 02215
E-mail: thauser@bidmc.harvard.edu

http://dx.doi.org/10.1016/j.jacc.2013.04.032

From the Cardiovascular Division, Beth Israel Deaconess Medical Center, Boston, Massachusetts.

Note: supported in part by an unrestricted grant from the family of Edward Modest.

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APPENDIX

For more details on the methods, as well as supplemental figures, please see online version of this article.

Letters to the Editor

Multidetector Computed Tomography Stress-Rest Perfusion Imaging for Detection of Coronary Artery Disease

Dr. Bettencourt and colleagues compare the diagnostic performance of multidetector computed tomography (MDCT) stress-rest perfusion imaging (using significantly lower dose radiation) with cardiac magnetic resonance myocardial perfusion imaging (CMR-Perf) for detection of functionally significant coronary artery disease with fractional flow reserve (FFR) as reference standard (1).

It would be interesting to know the following. First, did the authors make an attempt to compare performance of computed tomography perfusion (CTP) and CMR-Perf among patients with multivessel disease or those with >70% stenosis? Second, did the authors make an attempt to investigate the lesions labeled "false positive" on CTP, which could be incorrectly labeled as "false positive" in setting of nonobstructive coronaries (due to thrombus recannalization or post-percutaneous coronary intervention)? The authors measured FFR in vessels with >40% stenosis; however, abnormal FFR can be found in vessels with lesser degree of stenosis (2). This is more important in setting of microvascular disease, which has worse prognosis. CTP could be particularly helpful in such scenario due to its high resolution and ability to evaluate parameters of endothelial function and microvascular circulation (3).

Though use of 17-segment model to compare CTP and CMR-Perf is itself not perfect, due to overlap of segments between various coronary territories, the current report is a welcome step in the ongoing search for "1-stop" cardiac imaging modality.

However, an important practical limitation of CTP at this time is need for designated software for image analyses and substantial expertise to interpret images and make accurate diagnoses. Further, as patient population in current study was very selective, it would be interesting to see in future studies how MDCT-integrated protocol performs in "real world."

***Abhishek Sharma, MD**

*Maimonides Medical Center, New York
1016 50th Street, Apartment 2C
Brooklyn, New York 11219
E-mail: abhisheksharma4mamc@gmail.com

http://dx.doi.org/10.1016/j.jacc.2013.03.077

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Reply

We thank Dr. Sharma for the interest in our paper (1) and the recognition of our work as "a welcome step in the ongoing search for one-stop cardiac imaging modality." Dr. Sharma highlights some of the advantages and limitations of our approach and focuses on several points that merit discussion.

How did computed tomography perfusion (CTP) and cardiac magnetic resonance myocardial perfusion imaging (CMR-Perf) perform among patients with multivessel disease (MVD) or high-grade stenosis? A significant proportion of our patients ($n = 20$) had MVD as assessed by fractional flow reserve (FFR). In this subgroup, CMR-Perf and integrative multidetector computed tomography integrated protocol (MDCT-IP) had similar sensitivity (95%) and performed better than isolated CTP (65%). In patients with MVD as assessed by quantitative coronary angiography (QCA) ($n = 23$), CMR-Perf achieved a per-vessel accuracy of 80% (sensitivity = 77%; specificity = 86%) performing better than CTP (accuracy = 58%; sensitivity = 44%; specificity = 90%). In patients with stenoses $\geq$70% on QCA ($n = 44$), CMR-Perf was also superior, with a per-vessel accuracy of 87%, sensitivity of 81%, and specificity of 94% (vs. 71%, 55%, and 89% for CTP, respectively). Nevertheless, CTP specificity was very important for MDCT-IP per-vessel performance in these subgroups (accuracies of 68% and 75%, respectively) as computed tomography angiography classified almost all these vessels as either "significant disease" or "unevaluable."

Could the false positive CTP be rather misclassifications in the setting of nonobstructive coronaries due to thrombus recanalization or post-percutaneous coronary intervention (PCI)? Following the study protocol, patients with known coronary artery disease, including previous infarction and PCI, were excluded and only the areas with reversible hypoperfusion were classified as positive. While perfusion defects at rest and stress were found in 16 patients, all of these corresponded to scar (confirmed by late gadolinium enhancement) and were not considered as a marker for functionally significant coronary artery disease to avoid "an incorrect label of false positive" in comparison with a functional standard.

While we acknowledge that FFR was only determined in stenosis >40% and that occasionally abnormal FFR can be found in vessels with lesser degree of narrowing, this is rare. Similarly, no FFR was performed in patients with subocclusive stenoses or with tortuous/calcified/complex lesions, which may induce some remaining level of inaccuracy. The use of a functional reference is an important improvement compared to the vast majority of published studies. However, FFR is not an optimal reference standard, as it does not account for the amount of ischemic burden. We also recognize overlap of segments between coronary territories when a segment-based analysis is used. Having this in consideration, per-vessel analysis was performed assigning the perfusion segments to the corresponding vascular territory, as assessed by invasive coronary angiography.

Finally, we support Dr. Sharma's statement emphasizing the need for designated CTP software and substantial expertise for image interpretation, which is still time consuming and observer dependent. Radiation exposure and the need for medication for computed tomography angiography are other important limitations for a generalized use of MDCT-IP. Nevertheless, simultaneous morphologic and functional analysis is already possible, as we have shown using a single-source 64-slice generation scanner.

***Nuno Bettencourt, MD**
Eike Nagel, MD, PhD

*Cardiology Department
Centro Hospitalar de Vila Nova de Gaia/Espinho EPE
Rua Conceição Fernandes
4434-502 Vila Nova de Gaia
Portugal
E-mail: bettencourt.n@gmail.com

http://dx.doi.org/10.1016/j.jacc.2013.04.048

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Comparison of Cardiac Magnetic Resonance and Computed Tomography Stress-Rest Perfusion Imaging for Detection of Coronary Artery Disease

In their recent paper, Dr. Bettencourt and colleagues (1) report similar accuracy for the detection of coronary artery disease (CAD) between cardiac magnetic resonance (CMR) perfusion and an integrated computed tomography (CT) perfusion/angiography protocol.

Unfortunately, the authors did not interpret their CMR images in the standard way (2,3), which may limit the applicability of their findings. They state that only areas with ischemia on CMR perfusion imaging were regarded as positive for CAD and that patients with late gadolinium enhancement (LGE) scar but no additional ischemia were classified as negative for CAD. Thus, patients with infarction and an occluded or severely stenotic supplying vessel would be incorrectly classified as having no CAD by their CMR protocol. For this reason, areas of LGE in an infarct pattern are typically interpreted as demonstrating the presence of CAD (2,3). Because ~16% of the patients in this study had LGE in an infarct pattern, it would be useful to know the diagnostic performance of CMR if standard interpretation of LGE were used.