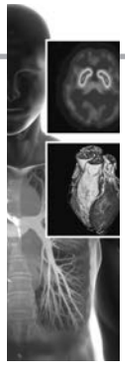

Myocardial perfusion imaging: achieving high image quality in half the time or in half the radiation dose

"*The routine use of myocardial perfusion imaging has some limitations; one is the prolonged imaging time compared with other modalities as CT angiography and a second is the exposure to ionizing radiation by the radiopharmaceutical used.*"

KEYWORDS: keyword ■ keyword ■ keyword ■ keyword

Nili Zafrir

Nuclear Cardiology Unit, Cardiology Department, Beilinson Hospital, Rabin Medical Center and Sackler Faculty of Medicine, Tel Aviv University, Israel
arielg@clalit.org.il

Myocardial perfusion imaging (MPI) using SPECT has been extensively utilized in the management of patients with suspected or known coronary artery disease for at least two decades [1,2]. Since then, slow progression has been made in updating γ-camera design and in advancing software to improve processing speed and to quantitatively assess imaging. However, during recent years, significant efforts have been made by the industry and academic research to develop novel technologies, the first new software that advanced image reconstruction techniques and the second in innovative technology of nuclear systems incorporating CZT crystals as detectors which result in a dramatic increase in counting statistics [3,4].

The routine use of MPI has some limitations; one is the prolonged imaging time compared with other modalities as CT angiography and a second is the exposure to ionizing radiation by the radiopharmaceutical used. This editorial will discuss the technological advances that have been developed recently to cope with these limitations, including the reduced imaging time and the reduction in radiation dose, both with preserved image quality.

Half-time acquisition

Time acquisition of MPI SPECT requires between 14 and 30 min in order to achieve good image quality, while keeping radiation dose at an acceptable level.

This prolonged acquisition causes uneasiness to the patient, frequent patient motions and respiratory variation during acquisition, that might interfere with image quality and require further motion correction. Moreover, it reduces camera productivity (fewer studies). There were attempts to reduce time acquisition by using low energy general purpose collimators in order to gain more counts, however, this was on account of reducing image spatial resolution.

Recently, MPI has been accomplished by advanced image reconstruction and resolution recovery techniques to cope with the prolonged acquisition imaging time. Incorporating these processing techniques, improves image contrast and reduces noise levels inherent in images with low counts. The first report on MPI SPECT reducing acquisition (imaging) time by half was performed using Wide Beam Reconstruction software developed by UltraSPECT, Ltd (Haifa, Israel).DePuey *et al.* showed that image quality using this 'half-time' software was equivalent to that achieved with a full time SPECT acquisition [5,6]. Later, another software developed for half-time acquisition named 'Evolution for Cardiac' was introduced (General Electric Medical Systems WI, USA). Philips and Siemens companies also incorporated fast SPECT processing software in their systems.

In our study presented in 2007 [7], reduced time algorithm was processed on 97 SPECT MPI studies, scanned twice and sequentially by full time acquisition for gated SPECT (17.17 min for low dose and 14.52 min for high dose) and by reduced time acquisition (8.4 and 7.10 min, respectively). The images were processed using an accepted method using ordered subset expectation maximization, and with evolution for cardiac algorithm for reduced time acquisition.

The results of this study showed that analysis of MPI in patients of sum rest score and sum stress score by Bland Altman plots showed that all patients score differences (except 2) were within two SDs. In sum stress score the differences in score were between +3.6 and -3.5

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and in sum rest score between +2.4 and -2.7. There were also highly significant correlation of rest and stress LVEF between full time and reduced time scans as demonstrated on plots. The clinical diagnosis of normal, ischemia or scar was identical in 47 from 50 patients and the comparison of catheterization results with full time and reduced time acquisition were similar in all but one case. We concluded that reduced time scan for gated SPECT is feasible while preserving image quality, and thus can replace the full time SPECT MPI .

Myocardial perfusion imaging with radiation dose reduction by half

Over the past quarter of a century, there has been a rapid growth in use of both CT and nuclear medicine as well as the higher radiation doses associated with these examinations. Several studies showed the accumulated radiation dose occurs especially in cardiac patients who are exposed to a number of invasive and non invasive procedures involving radiation [8–12]. Consequently the aim of medical interest has been to reduce the radiation exposure for each study patient as much as possible.

Recently, recommendations for reducing radiation in MPI was reported [13]. With the advent of software in nuclear cardiology to improve image quality, several studies showed that it is possible to shorten acquisition time by almost a half and even farther without reducing image quality (as detailed above). Our hypothesis was that reduction of radiation dose by half for each study, instead of reducing acquisition time using the novel iterative reconstruction software, might be feasible. Our preliminary results on this subject were reported as late breaking news at the International Conference on Nuclear Cardiology and cardiac CT (ICNC) 10 May 2011 [14].

A brief summary of the results of this study is given below. The accepted MPI stress rest study with technetium ^{99}m agents is limited by high radiation dose 10–25 mSv.

The study was performed randomly according to one of two protocols. Protocol one was the 'accepted protocol' stress rest or rest stress MPI study by accepted 'full dose' injections of Tc sestamibi (low dose 8-12 mCi, high dose 24–36 mCi) with time acquisition and image processing performed as accepted. Protocol 2 was the 'half-dose protocol' that was performed with injection of half doses of Tc sestamibi and processed by Evolution for Cardiac software. The radiation doses of technetium ^{99}m were adjusted for each patient weight, and recorded by mCi, MBq units and effective dose equivalent by mSv were calculated.

The study was conducted on 109 patients undergoing the half-dose protocol compared with 109 patients in the full dose protocol. The mean age, weight, BMI and percentage of men and women were similar in both groups. The mean radiation doses in patients with half-dose protocol were 5.75 ± 0.99 mCi and 17.34 ± 1.20 mCi compared with 12.68 ± 5.76 and 32.52 ± 3.02 the accepted full dose ($p < 0.001$). Total effective doses for the stress rest study were 7.19 ± 0.21 mSv in the half-dose protocol compared with 14.40 ± 0.61 in the accepted dose protocol ($p < 0.001$).

The image quality of SPECT MPI was good to excellent in 95% half dose by evolution for cardiac and in 96% of the full dose by ordered subset expectation maximization (p = NS). One third of the patients with half-dose protocol, underwent the stress only study and were exposed to 1.9 ± 0.19 mSv only.

The clinical results of MPI including the prevalence of normal, myocardial infarction and ischemia were similar in both in half-dose and in full-dose groups, as well as the prevalence of the amount of ischemia and myocardial infarction. It was concluded that MPI with radiation dose reduction by half is feasible with preserved image quality and with maintained diagnostic accuracy.

Strategy for reducing radiation dose

In addition to using half-dose strategies in order to minimize radiation, an effective protocol should be selected. The approach of starting each protocol with stress increases the probability of 'stress only' study, without need for rest high dose imaging, hence radiation activity dose and the effective dose, will be reduced even further. Secondly, stress imaging has to be followed by attenuation correction with CT or prone imaging if appropriate. This approach will increase the probability of stress-only imaging.

Saving radiation seems more applicable with the CZT camera as recently reported by Duvall *et al.* [15]. However, this camera is highly expensive and currently is limited in use because of limited source of CZT crystals needed for camera production. A comparison between the image quality of full-time myocardial perfusion SPECT and wide-beam reconstruction half-time and half-dose SPECT was reported recently by DePuey to have excellent results [16].

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Bibliography

1 Port SC, Berman DS, Garcia EV, Sinusas AJ, Wackers FJ. Imaging guidelines for nuclear cardiology procedures. ASNC. *J. Nucl. Cardiol.* 6, G47–G84 (1999).

2 Henzlova MJ, Cerqueira MD, Hansen CL, Taillefer R, Yao S. Imaging guidelines for nuclear cardiology procedures: stress protocols and tracers. *J. Nucl. Cardiol.* (2009).

3 Slomka PJ, Patton JA, Berman DS, Germano G. Advances in technical aspects of myocardial perfusion SPECT imaging. *J. Nucl. Cardiol.* 16, 255–276 (2009).

4 Sharir T, Ben-Haim S, Merzon K *et al.* Hugh speed myocardial perfusion imaging: initial clinical comparison with conventional dual detector anger camera imaging. *J. Am. Coll. Cardiol. Imaging* 1, 156–163 (2008).

5 Borges-Neto S, Pagnanelli RA, Shaw LK *et al.* Clinical results of a novel wide beam reconstruction method for shortening scan time of Tc-99m cardiac SPECT perfusion studies. *J. Nucl. Cardiol.* 14, 555–565 (2007).

6 DePuey EG, Gadiraju R, Clark J, Thompson L, Anstett F, Shwartz S. Ordered subset expectation maximization and wide beam reconstruction "half time" gated myocardial perfusion SPECT functional imaging: a comparison to "full time "filtered back projection. *J. Nucl. Cardiol.* 15, 547–563 (2008).

7 Zafrir N, Yuzefovich B, Mats Me, Solodky A, Blazar A, Battler A. A novel method to reduce the acquisition time of myocardial perfusion SPECT scan: a comparative study. ICNC 9 (2009) (Abstract).

8 Einstein JE, Moser KW, Thompson RC, Cerqueira MD, Henzlova MJ. Radiation dose to patients from cardiac diagnostic imaging. *Circulation* 116, 1290–1305 (2007).

9 Fazel R, Krumholz HM, Wang Y *et al.* Exposure to low-dose ionizing radiation from medical imaging procedures. *N. Eng. J. Med.* 361, 849–857 (2009).

10 Chen J, Einstein AJ, Fazel R *et al.* Cumulative exposure to ionizing radiation from diagnostic and therapeutic cardiac imaging: a population-based analysis. *J. Am. Coll. Cardiol.* 56, 702–711 (2010).

11 Berrington de Gonzalez A, Kim K-P, Smith-Bindman R, McAreavey D. Myocardial perfusion scans. Projected population cancer risk from current levels of use in the United States. *Circulation* 122, 2403–2410 (2010).

12 Beller GA. Importance of consideration of radiation doses from cardiac imaging procedures and risks of cancer. *J. Nucl. Cardiol.* 17, 1–3 (2010).

13 Cequeira MD, Allman KV, Ficaro EP *et al.* Recommendations for reducing radiation exposure in myocardial perfusion imaging. *J. Nucl. Cardiol.* 17, 709–718 (2010).

14 Zafrir N, Gutstein A, Ben Shlomo A *et al.* Feasibility of myocardial perfusion imaging with radiation dose reduction by half. *ICNC* 10 (2011).

15 Duvall WL, Croft LB, Godiwala T, Ginsberg T, Henzlova MJ. Reduced isotope dose with rapid SPECT MPI imaging: initial experience with a CZT SPECT. *J. Nucl. Cardiol.* 17, 1009–1014 (2010).

16 DePuey EG, Bommireddipalli S, Clark J, Leykekhman A, Thompson LB, Friedman M. A comparison of the image quality of full time myocardial perfusion SPECT vs. wide beam reconstruction half time and half dose SPECT. *J. Nucl. Cardiol.* 18, 273–280 (2011).