EDITORIAL

# Reducing radiation exposure from nuclear myocardial perfusion imaging: Time to act is now

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Over the past two decades there has been approximately 60% increase in the number of outpatient cardiac stress tests in the US.[1] In 2010, around 87% of these stress tests were done with concordant use of imaging. The bulk of growth in cardiac imaging has been due to a rising use of nuclear stress testing.[2] Increased emphasis on appropriate use criteria, may have led to a slight decline in nuclear myocardial perfusion imaging (MPI);[3] however, it still maintains its place as the workhorse for cardiac stress testing.

Significant growth in nuclear cardiac imaging along with serial testing, and testing in younger patients (<70 years), has led to intensification of international efforts to quantify and reduce the ionizing radiation exposure from MPI studies.[4–7] In 2010, American Society of Nuclear Cardiology, estimated that on average a total radiation exposure of ≤9 mSv can be achieved in 50% of the studies by 2014.[8] However, in a 2013 worldwide survey of nuclear cardiology practices in 65 countries conducted by the International Atomic Energy Agency (IAEA)—IAEA Nuclear Cardiology Protocols Cross-Sectional Study (INCAPS), median effective dose for MPI among 50 US laboratories was 11.6 mSv, which was well above the median goal of 9 mSv.[4] Only 30% of the laboratories surveyed worldwide had a median effective dose of ≤9 mSv (Figure 1). In a separate analysis from the INCAPS survey, a typical patient undergoing MPI in a US laboratory received a 20% higher radiation dose when compared with non-US laboratories.[5] Another study utilizing Intersocietal Accreditation Commission Data Repository from 2012 to 2013 found that only 1.5% of the participating 1,074 MPI US laboratories met current guidelines for an average laboratory radiation exposure of ≤9 mSv.[9] In this study, 10% of the submitted cases had effective doses >20 mSv, such a high dose should be rarely employed and should trigger a shared decision making with patients with formal discussion or written informed consent.[10] These findings of high radiation exposure for MPI in nuclear laboratories was in part due to a high rate of non-adherence to the best practices for reducing radiation exposure from MPI (Table 1). It has been estimated that the average effective dose from MPI can be reduced by nearly 21% if US laboratories were to adopt stress-only MPI protocols in 42% of the stress studies, a rate similar to the top 10% of laboratories in the INCAPS worldwide survey.[11]

In this issue of the *Journal*, Otsuka et al[12] published results from a nationwide survey from June to July 2016 investigating the current status of stress MPI and radiation exposure in Japan. Of the 431 nuclear facilities surveyed, they found a staggering high rate of Tl-201 MPI imaging in 65% of the Japanese nuclear laboratories. Forty-three percent of the surveyed laboratories used Tl-201 exclusively. The average effective dose in their study was 14 mSv with 1.8% of tests exceeding 20 mSv. The two main reasons for using Tl-201 instead of Tc-99m in their study was 'more familiarity with the use of Tl-201' and 'apprehension about increasing the burden of physicians performing tracer injection twice.'

Acknowledging the differences in survey methodologies, a comparison of the results from contemporary INCAPS worldwide survey[4] and country-specific

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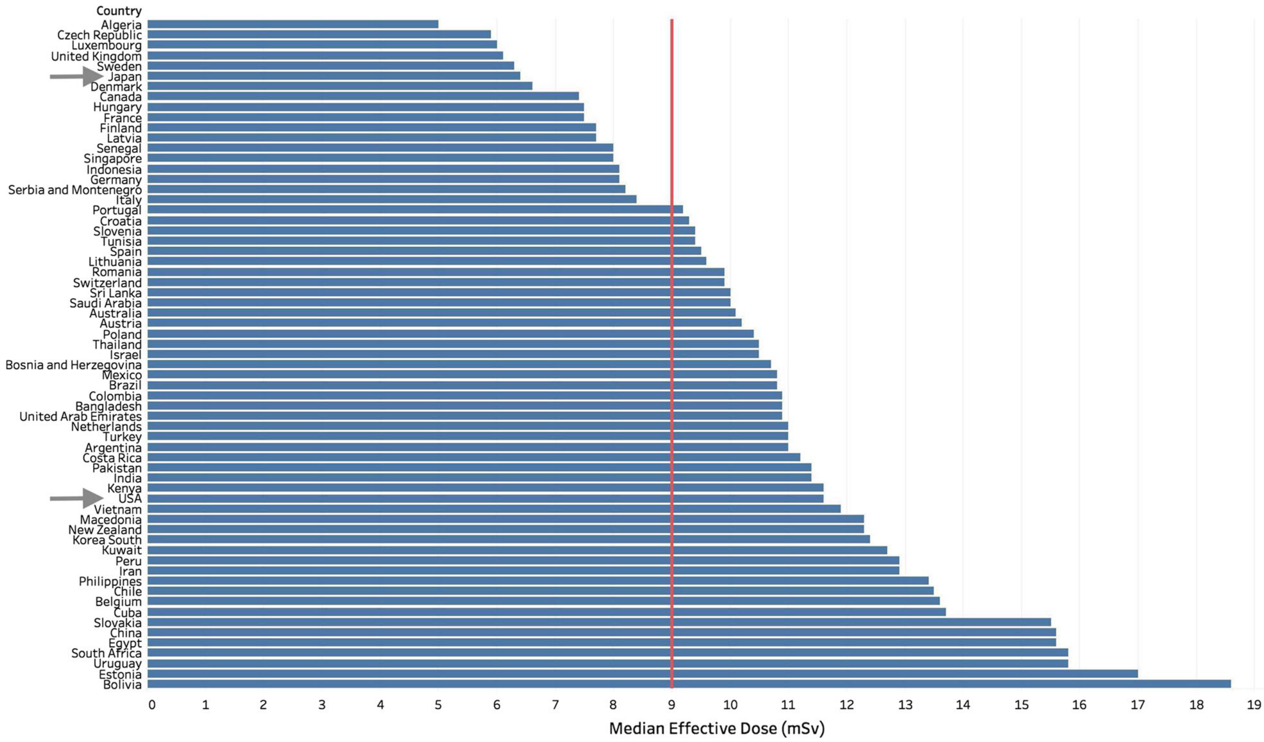


**Figure 1.** Median effective dose for myocardial perfusion imaging by country—INCAPS 2013 survey [Adapted from Einstein et al[4] under the terms of the creative commons attribution non-commercial license (http://creativecommons.org/licenses/by-nc/4.0/)]. From IAEA nuclear cardiol ogy protocols cross-sectional study (INCAPS) 2013 survey. A median effective dose of $\leq$9 mSv (*vertical red line*) is recommended. *Arrows* point to median effective doses from Japan and US.

surveys[6,9,12] highlights the magnitude of importance of country-specific surveys such as the one conducted by Otsuka et al:

1. *Country-specific surveys are more likely to accurately estimate the variation in radiation exposure from nuclear MPI* In the INCAPS survey, the mean effective dose for Japan was estimated to be 6.3 mSv. In the Otsuka et al[12] study, the mean effective dose was 14 mSv. This difference was mainly because the INCAPS estimate was derived from a survey of 9 patients from 1 laboratory in Japan whereas Otsuka et al surveyed 431 nuclear facilities. Similarly, for US, INCAPS estimated a mean effective dose of 10.9 mSv using data from 1,902 patients from 50 US laboratories. However, Jerome et al[9] estimated an average effective dose of 14.9 mSv from 5,216 cases in 1,074 US nuclear MPI laboratories. Therefore, an international survey such as INCAPS, although of high value in comparing different countries and monitoring worldwide trends over time, may markedly underestimate the radiation exposure from MPI in a given country due to survey of a limited number of laboratories in that country.
2. *Country-specific surveys can identify unique regional challenges in reducing radiation exposure* Otsuka et al[12] in their study identified that the high mean effective dose from MPI in Japan was in large part due to very frequent use of Tl-201. They also identified reasons for high Tl-201 usage and suggested unique policy challenges that are needed to be overcome. For example, in Japan, nuclear medicine technologists cannot inject radiopharmaceuticals intravenously. Therefore, in switching from Tl-201 to Tc-99m imaging, they found a high apprehension for increased burden on physicians for needing to inject tracers twice. Therefore, to lower MPI radiation exposure in Japan, the Japanese medical care law needs to be amended to allow nuclear medicine technologists to inject radiotracer intravenously. On the other hand, in the US Jerome et al[9] found that although Tc-99m was used in 83% of cases, the mean radiation exposure was still high and the reason was

**Table 1.** Eight best practices to reduce radiation exposure in nuclear cardiology laboratories

| Practice | Details |
|---|---|
| 1. Avoid thallium stress | No thallium stress tests in patients ≤70 years old |
| 2. Avoid dual isotope | No dual isotope (rest thallium and stress technetium) stress tests in patients ≤70 years old |
| 3. Avoid too much technetium | No study with administered activity >1332 MBq (36 mCi)<br>Mean total effective dose <15 mSv for all studies |
| 4. Avoid too much thallium | No study with administered activity >129.5 MBq (3.5 mCi) at stress |
| 5. Perform stress-only imaging | If stress images are completely normal, subsequent rest imaging can be avoided to reduce radiation dose by upto 80% |
| 6. Use camera-based dose reduction strategies | Attenuation correction (computed tomography or line source)<br>Imaging patients in multiple positions, e.g. both supine and prone<br>High-technology software (e.g., incorporating iterative reconstruction, resolution recovery, and noise reduction)<br>High-technology hardware (e.g., PET, a high-efficiency solid-state SPECT camera, or a cardiac-focused collimator) |
| 7. Weight-based dosing for technetium | Tailoring the administered activity to the patient size |
| 8. Avoid inappropriate dosing that can lead to 'shine through' artifact | No SPECT myocardial perfusion imaging studies with technetium rest and stress injections on the same day, in which activity of the second injection was <3 times that of the first injection. Shine through occurs in two injection, single-day technetium studies when residual radioactivity from the first injection interferes with interpretation of images for the second injection. |

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The eight best practices were developed by a committee of expert physicians and medical physicists convened by the International Atomic Energy Agency
*mBq*, megabecquerel; *mCi*, millicurie; *mSv*, millisievert; *PET*, positron emission tomography; *SPECT*, single-photon emission computed tomography

non-adherence to guidelines for patient-specific radiation exposure. Therefore, in the US we need to target development of performance measures for laboratory accreditation to increase adherence to guidelines for reducing radiation exposure.[9]

The country-specific surveys like the one by Otsuka et al are needed to better estimate the variation in radiation exposure from MPI and to identify unique challenges (and, hence, opportunities to target) in individual countries for reducing radiation exposure.

Our understanding of the relationship of radiation exposure at low levels (for example medical radiation exposure) and its biological effects is evolving.[13] A well-done study by Berrington et al estimated the lifetime risk of cancer from nuclear MPI.[14] It was based on the assumption of a linear relationship between radiation exposure even at low levels and cancer, as recommended by Biologic Effects of Ionizing Radiation VII report. They found that radiation-related cancer risk was almost double for Tl-201 stress/redistribution study at an average effective dose of 26 mSV when compared with Tc-99m rest/stress imaging at an average effective dose of 12 mSV (18 vs 10 radiation-related cancers per 10,000 tests at age 50). There are arguments in support of mitigating the concerns of biologic effects of radiation exposure from nuclear stress testing. Some of these are that the radiation-related cancer risk estimates are based on the assumption of linear relationship between radiation dose and cancer even at low levels of radiation exposure; that the life-expectancy of patients undergoing nuclear stress testing is likely lower than that of the general population which is not considered in these estimates; and, that there could be potential hormetic effects where low levels of radiation may also stimulate adaptive DNA protection.[13,14]

Even though these arguments may be somewhat reassuring, however, the uncertainty in the level of risk from radiation exposure should not hold us back in the adoption of the best practices to reduce radiation exposure from nuclear cardiac imaging (Table 1). We must follow the principle of 'As Low As Reasonably Achievable.' It is, therefore, now time that while we continue to research the biologic effects of radiation and how to weigh the risk and benefits of medical radiation exposure, we focus the efforts on identifying country-specific challenges and opportunities for reducing high radiation exposure from MPI and then lobby for targeted policies and procedures at national, state, local, and institutional levels that would lead to higher adoption rates of the best practices. It is not only feasible and tremendously important from a public health perspective but also a moral imperative upon us if we were to abide by *primum non nocere*.

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*Drs. Gupta and Bajaj have no relevant disclosures.*

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