

REVIEW ARTICLE

Optimal Protocol of Myocardial Perfusion Imaging for Reduction of Radiation Exposure

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Abstract

The Japanese Circulation Society (JCS) 2021 guideline on radiation safety in cardiology was updated based on the eight best practices for myocardial perfusion single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI), which was determined by panels of international atomic energy agency (IAEA) nuclear cardiology protocols cross-sectional study (INCAPS). Although the guideline recommends to avoid too much ^{201}Tl or $^{201}\text{Tl}/^{99\text{m}}\text{Tc}$ dual-isotope protocol, the utilization rate of ^{201}Tl for SPECT-MPI in Japan is considerably high compared to other countries. In Japan, protocols using $^{99\text{m}}\text{Tc}$ should be appropriately promoted based on the guideline to reduce radiation exposure in SPECT-MPI. Among the eight practices, stress-only imaging is considered to be a useful strategy that contributes to a significant reduction in radiation exposure, and hybrid assessment in combination with rest computed tomography (CT)-MPI is one of the practical application methods.

Keywords: Computed tomography, Hybrid assessment, Myocardial perfusion imaging, Radiation exposure, Single-photon emission computed tomography, Stress-only imaging

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Single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) requires ^{201}Tl or $^{99\text{m}}\text{Tc}$ labeled radiopharmaceuticals. Otsuka et al. reported that the utilization rate of ^{201}Tl and $^{99\text{m}}\text{Tc}$ for SPECT-MPI in Japan in 2016 were almost the same, about 50% (1). Previous study reported that the rates of ^{201}Tl protocol for SPECT-MPI in Germany and the USA were less than 10% (2–4). The rates of ^{201}Tl for SPECT-MPI in Japan is considerably higher than that in other countries, and it seems to affect the increase of radiation exposure. International atomic energy agency (IAEA) nuclear cardiology protocols cross-sectional study (INCAPS) described the definition of eight best practices for reduction of the patients' radiation exposure (5). In the Japanese Circulation Society (JCS) 2021 guideline on Radiation safety in Cardiology, optimization methods for SPECT-MPI were proposed based on the eight best practices. In this paper, the eight best practices are explained, and additional explanations are given on the stress only protocol as part of hybrid assessment in clinical scenario of sequential

assessment (6, 7), which can significantly reduce radiation exposure even with conventional SPECT scanner, and camera-based dose-reduction strategies using semiconductor scanner.

The eight best practices

The following criteria were determined by a committee of expert physicians and medical physicists convened by IAEA. The core elements identified by the panel based on previous guidelines (8, 9) included practices such as avoiding administering too much isotope, avoiding higher dose isotopes, and using newer technologies that can lower radiation doses.

1. Avoid ^{201}Tl

The JCS 2021 guideline on radiation safety in cardiology recommended to avoid ^{201}Tl stress tests in patients ≤ 70 years old. The INCAPS reported that 92% of participating institutions had met this standard (5). Previous study from Einstein et al. reported that SPECT-MPI performed with ^{201}Tl is associated with a

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considerably higher radiation dose to patients than when it is performed with ^{99m}Tc (10). Note that this excludes ^{201}Tl rest-redistribution viability studies and stress-redistribution-reinjection stress-and-viability studies.

2. Avoid dual-isotope

Dual-isotope (rest ^{201}Tl and stress ^{99m}Tc) stress tests recommended to be avoided in patients ≤ 70 years old. Dual-isotope SPECT-MPI is associated with the highest radiation dose of any protocols (10). The INCAPS reported that 97% of participating institute had met this standard (5).

3. Avoid too much ^{99m}Tc

It is recommended to avoid ^{99m}Tc injection with administered activity $> 1,332$ MBq (36 mCi), and mean total effective dose ≥ 15 mSv for all studies using ^{99m}Tc injections. 1,332 MBq is the highest recommended activity in guidelines (9), and 15 mSv is a high radiation dose for a study using ^{99m}Tc . This standard is achieved in Japan by complying with the diagnostic reference level (DRL; 1,220 MBq) in Japan.

4. Avoid too much ^{201}Tl

For each nuclear stress test involving ^{201}Tl , no more than 129.5 MBq (3.5 mCi) should be administered at stress. The expert committee maintained that no more than this activity is needed for patients who are good candidates to receive ^{201}Tl SPECT-MPI. This standard was achieved in 99% of INCAPS participating institutions (5).

5. Perform stress-only imaging

If stress images are completely normal, subsequent rest imaging can be avoided in order to reduce radiation dose up to 80% (5). In previous reports on stress-only imaging, rest testing was omitted in 2/3 of all examinations, which is considered to greatly contribute to the reduction of radiation exposure (11). The global average rate of stress-only imaging was 30%, indicating a particularly low trend (5). In stress-only imaging, the need for additional resting imaging must be determined reliably. In the clinical scenario of sequential imaging in which coronary computed tomography (CT) is performed prior to SPECT-MPI, stress-only imaging should be considered more actively to enable hybrid assessment, which will be discussed later.

6. Use camera-based dose reduction strategies

Following dose reduction strategies are recommended: (a) attenuation correction (CT or line source), (b) imaging patients in multiple positions (e.g. both supine and prone), (c) high-technology software (e.g. incorporating iterative reconstruction, resolution recovery, and noise reduction), and (d) high-technology hardware (e.g. a high-efficiency solid state SPECT camera or cardiac-

focused collimator). The JCS 2021 guideline recommended longer scan time to reduce radiation dose instead of CT attenuation collection. Each of the approaches reduces the radiation dose and image noise, thereby facilitating stress-only imaging.

7. Weight-based dosing for ^{99m}Tc

In Japan, most of the study site use syringe kit as a type of radiopharmaceuticals which is difficult to adjust weight-based dosing. The JCS guideline recommended to reduce the applied dose in patients < 50 kg.

8. Avoid inappropriate dosing that can lead to ‘shine through’ artifact

Shine through occurs in ^{99m}Tc one-day protocol. To avoid shine through, it is recommended that the radioactivity imaged for the second injection be at least three to four times that of the first injection. Relatively short half-life ^{99m}Tc agent contributes to the reduction of radiation exposure in the second injection of ^{99m}Tc agent. It should be noted that INCAPS described that avoiding ‘shine through’ does not directly resulted in radiation dose reduction. According to the hierarchical regression model, avoiding ‘shine-through’ resulted in 1.03 mSv “increase” of effective dose (5).

Hybrid assessment using stress-only imaging

Stress-only imaging requires reliable assessment of the need for additional resting images for all stress images, which may be a barrier to implementation. If stress-only imaging was normal, no more resting images are required. Conversely, stress-only imaging with perfusion defect needs to have resting images for eliminating myocardial infarction or artifacts. Sequential assessment with SPECT-MPI after anatomical assessment of the coronary arteries using coronary CT with judgement of intermediate coronary stenosis or insufficient image quality is considered an appropriate clinical choice (7). The image dataset from coronary CT can be used not only for anatomical assessment of the coronary arteries, but also for resting myocardial perfusion, including myocardial scar or infarction detection. Gerber et al. reported that CT perfusion imaging (CT-MPI) showed good enough correlation with delayed enhancement on magnetic resonance imaging for assessment of the size of the myocardial infarction (12). Therefore, in the clinical scenario of sequential assessment, image dataset of CT-MPI can be substituted for rest SPECT-MPI in addition to stress-only imaging. Suzuki et al. proposed hybrid assessment, which combines stress SPECT-MPI and rest CT-MPI, in sequential assessment as a practical application of stress-only imaging (6). Graphical explanation of hybrid assessment using stress-only SPECT-MPI and rest CT-MPI is shown in Figure 1. Suzuki et al. reported that total effective radiation dose of hybrid assessment with coronary

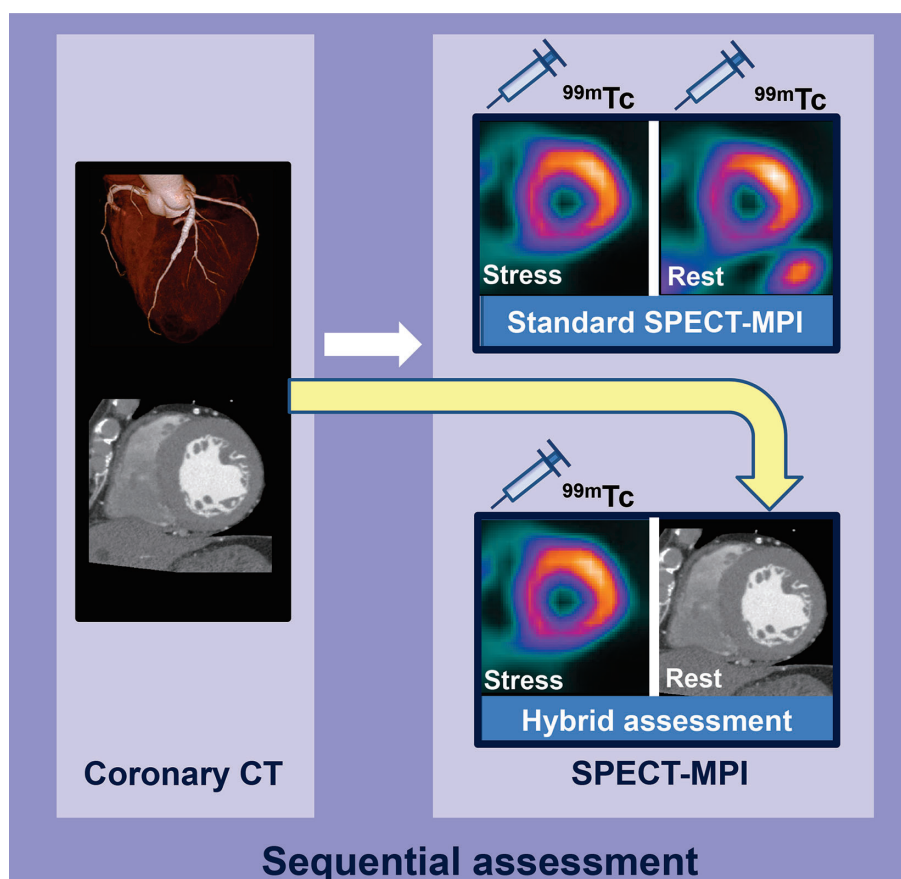


Figure 1 Graphical explanation of hybrid assessment using stress-only imaging as part of sequential imaging. (Right upper) Standard assessment of stress/rest SPECT-MPI, (Right lower) hybrid assessment using stress-only SPECT-MPI and CT-MPI.

SPECT-MPI: single-photon emission computed tomography myocardial perfusion imaging, CT-MPI: computed tomography myocardial perfusion imaging.

CT was 4.6 mSv when administering 296 MBq of ^{99m}Tc -tetrofosmin, which was less than half of that using standard stress/rest SPECT-MPI with coronary CT (9.7 mSv), whereas diagnostic performance of hybrid assessment was not significantly different (conversion factor for ^{99m}Tc -tetrofosmin at stress (0.0069 mSv/MBq) and conversion factor of dose length product for the calculation of radiation dose of coronary CT (0.014 mSv/[mGy/cm]) were applied based on the previous recommendation) (6, 13). It should be noted that conversion factor for ^{99m}Tc -sestamibi at stress is slightly higher (0.0079 mSv/MBq) than that of ^{99m}Tc -tetrofosmin.

Hybrid assessment using stress-only imaging can be applied combination of other dose reduction strategies including weight-based and camera-based methods. Even when using a conventional gamma camera, stress-only imaging with a smaller amount of ^{99m}Tc can be achieved under some conditions. Stress-only imaging with 296 MBq of ^{99m}Tc can be performed with a conventional gamma camera in a patient with body mass index ≤ 25 (kg/m²) (14). Previous study from Zafrir et al. reported half-dose (185 MBq) ^{99m}Tc protocol for stress SPECT-MPI using a conventional gamma camera and dedicated image processing (15). Hybrid assessment with

camera-based dose reduction strategies may lead lower level of radiation exposure than previously reported. The imaging guideline of the American Society of Nuclear Cardiology in 2016 recommended 148–222 MBq of ^{99m}Tc tracer for stress-only imaging if newer technology, including semiconductor scanners, is available (14). In addition, previous studies reported the potential of semiconductor scanners to achieve an extremely lower dose protocol using < 148 MBq of ^{99m}Tc without sacrificing image quality or diagnostic performance (16, 17).

Conclusions

New guideline on radiation safety in cardiology in Japan was updated based on the eight best practices, which is important elements for reduction of patients' radiation exposure. In Japan, protocols using ^{99m}Tc should be appropriately promoted based on the guideline to reduce radiation exposure in SPECT-MPI. In addition, among the eight best practices, stress-only imaging is considered to be a useful strategy that contributes to a significant reduction in radiation exposure, and hybrid assessment in combination with rest CT-MPI is one of the practical application methods.

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Conflicts of interest

None.

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