Since the mid-1970s, stress radionuclide myocardial perfusion imaging (MPI) has been an integral part of clinical cardiology and has become the most frequently used non-invasive stress imaging test of the heart.

This is all the more remarkable because stress nuclear imaging has some practical disadvantages; image acquisition time is long and involves ionizing radiation. However, for many years, these drawbacks seemed to be offset by the amply proven clinical value of stress MPI.

Recently, important technical innovations in hardware and software have emerged that may transform radically the practice of nuclear cardiology and substantially lessen the importance of these drawbacks.

**Limitations and problems of conventional gamma camera imaging.** It may be useful to discuss some of the problems and limitations that have beset conventional single-photon emission computed tomography (SPECT) imaging. The basic components of the Anger scintillation camera have not changed for more than 50 years (i.e., lead collimation, sodium iodide scintillation crystal, and photomultipliers).

Conventional SPECT imaging consists of the acquisition of 32 to 64 planar projection images, 3° to 6° apart, in an arc around the patient. To obtain planar projection images that consist predominantly of “good” photons, that is, photons that travel perpendicularly to the detector crystal, the traditional Anger camera uses parallel-hole lead collimation. Photons moving at shallower angles are absorbed in the lead septa of the collimator and do not contribute to image formation. Of the photons that passed through the collimator, only a minority generates detectable scintillations within the crystal. Thus, a substantial portion of available gamma ray information emanating from the heart is not used. Typical Anger gamma camera images often have relatively low count density (Table 1). From the multiple 2-dimensional projection images, 3-dimensional information is created indirectly by reconstruction software that uses filtered back-projection. In addition to the noted inefficiencies in acquisition, the filtered back-projection further degrades image quality and spatial resolution.

The suboptimal efficiency in detecting photons by conventional gamma cameras has had important and adverse consequences for practical stress-rest MPI protocols. Optimal diagnostic quality of an image is determined not only by adequate count density, but also by spatial resolution and energy resolution. The longer imaging time can be extended, the more counts are acquired and the better the image. However, radionuclide imaging protocols have been by necessity a compromise between adequate image acquisition time and patient comfort. In practice, a patient cannot lie still for much longer than 20 to 25 min. Thus, when acquiring numerous planar projection images, the acquisition time per image usually is only 40 s for 32 projections and 25 s for 64 projections. These very short acquisition times are responsible for the typical low-count SPECT images.

Image quality can be improved by injecting greater doses of radiotracer. However, the amount of allowable radiotracer is limited by radiation burden. A further complicating factor is that using Tc-99m–labeled MPI agents, 2 radiotracer injections are necessary, 1 at rest and 1 during stress. The first of 2 doses must be a smaller one, which in turn further jeopardizes adequate count density of these images. Thus, radionuclide imaging has always been a tug of war between optimal image count density on one side and decreasing imaging time and radiation exposure on the other side.

Despite technical progress over the years from planar imaging to tomographic SPECT MPI, from single-head to multihed detectors, from thallium-201 to Tc-99m–labeled agents, and recently the implementation of attenuation correction, radionuclide SPECT MPI always has been marred by relatively low count density, suboptimal spatial image resolution, and long imaging times.

Considering these shortcomings, it may be surprising that SPECT MPI has nevertheless been proven unequivocally in numerous clinical studies that it has important clinical diagnostic and prognostic value.

**New imaging hardware and software designs.** The recognized shortcomings of SPECT MPI have stimulated in recent years the development of novel imaging devices that are a radical departure from the traditional design of Anger cameras. For a technical review, I refer to recent excellent and comprehensive discussions of various new devices (1–3). The most important innovation of these new devices is that they acquire 3-dimensional data directly using an array of...
multiple dedicated and highly sensitive detectors and collimators. Because image acquisition is focused on the heart of an individual patient by region of interest–centric scanning, the process is highly efficient. Rather than using large scintillation crystals, the new devices use small pixilated solid-state detectors. These new designs combined with innovative reconstruction software result in high count sensitivity, high spatial resolution, improved energy resolution (Table 1), and potentially more accurate and better quality images.

At the same time, less costly but equally important advances have been made with new tomographic reconstruction software. It should be noted that the filtered back-projection software, as used for many years for conventional SPECT, was never designed or optimized for scintigraphic images. The new iterative reconstruction algorithms, based on ordered subsets expectation maximization, produce markedly improved images from data acquired with conventional hardware by modeling detector spatial response and implementing noise reduction. Using these novel reconstruction algorithms, the same image quality can be obtained with fewer acquired counts and thus presents another option to reduce imaging time significantly. Attenuation correction, an important innovation of the 1990s, can be integrated with the new algorithms (4).

In this issue of the Journal, Sharir et al. (5) present the results of a multicenter study that compared SPECT MPI using a new high-speed imaging device with conventional SPECT imaging. The comparative results confirm the feasibility of performing very fast SPECT imaging without jeopardizing the quality of images. It is appropriate to emphasize that the authors used only quantitative imaging data to circumvent the problem of interobserver/ intraobserver variability that is intrinsic to visual analysis. In their analysis, objective measures of myocardial perfusion and function were statistically not different using both approaches. However, looking closely at the Bland–Altman analyses of the data, it is apparent that the measures in individual patients are not identical or comparable. The limits of agreement are relatively large in both directions, particularly for small defects and ejection fractions in the normal range. As the authors suggested, this may be in part due to imaging with 2 different cameras. Because the majority of patients (71%) had normal MPI, the study does not have the power to analyze in detail measurements in patients with abnormal MPI. Kappa statistics that correct for the predominance of normal findings calculated a kappa value of 0.65, indicating “fair agreement beyond chance.” It is notable, for instance, that of 162 patients with normal MPI by conventional SPECT, 13 (8%) had abnormal MPI by high-speed SPECT, whereas 20 patients (11%) with mild–moderate defects on conventional MPI were normal by high-speed MPI. However, most of the severe defects were categorized as such with both imaging systems. Nevertheless it is unclear, because of lack of an independent benchmark, whether overall sensitivity and specificity were affected. As such, this study cannot be considered definitive proof of the clinical value of the new imaging system. The basic problem of this comparison is that the new device is potentially superior, different, and more accurate than the conventional device. Without an independent comparator, such as coronary angiography or (preferably) cardiac outcome, no judgment can be made about accuracy and prognostic value of images obtained with the new high-speed device. If a picture says more than a thousand words and if Figure 5 of Sharir et al. (5) is a representative one, it very eloquently illustrates the high quality of images that may be obtained with the new imaging device.

The data reported by Sharir et al. (5) are promising and concur with a number of other recent studies on either high-speed acquisition or new reconstruction algorithms (4,6–9). That acquisition time can be reduced to one-fifth and yet yield better image quality is simply astounding, and practical implications of this have been discussed in recent editorials (10,11).

These technical advances can be expected to have a substantial impact on the practice of clinical nuclear imaging. A number of aspects of radionuclide MPI that may change with the implementation of these innovations are addressed in the following paragraphs.

FASTER IMAGING. As reported by Sharir et al. (5), total imaging time can be markedly reduced from the conventional 15- to 20-min imaging time to 2 to 4 min. Such short imaging times will be much better tolerated by patients. This alone has the potential of improving image quality by reducing the chance of patient motion artifacts.

The number of patients who can be imaged on the same day with the same equipment can be increased substantially, resulting in more efficient utilization of costly imaging devices. This may be an important issue in busy high-volume laboratories.

HIGHER RESOLUTION AND MORE ACCURATE IMAGES. The technical characteristics of the new devices (Table 1) and the direct acquisition in 3-dimensional image data promise higher resolution and potentially more accurate images. However, greater accuracy is still to be proven in clinical studies with angiographic correlation or outcome data. Optimism also may be tempered because increased sensitivity is often traded for decreased specificity.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Anger Scintillation Camera</th>
<th>Solid-State Camera</th>
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<tbody>
<tr>
<td>Count sensitivity (kcps)</td>
<td>0.5–0.7</td>
<td>2.2–2.7</td>
</tr>
<tr>
<td>Energy resolution (%)</td>
<td>9–10</td>
<td>5–6</td>
</tr>
<tr>
<td>Spatial resolution (mm)</td>
<td>9–11</td>
<td>4.3–4.9</td>
</tr>
<tr>
<td>Total SPECT acquisition (min)</td>
<td>15–20</td>
<td>2–4</td>
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Modified from Garcia and Faber (3). kcps = kilo counts per second; SPECT = single-photon emission computed tomography.
LESS RADIATION EXPOSURE. In laboratories where high-volume patient throughput is not an important issue or for patients who tolerate well prolonged imaging time, one may consider reducing the amount of radiotracer injected and acquiring images for the conventional time, thus exposing the patient to less radiation. Unnecessary radiation exposure is a particular concern in relatively young patients and in patients with a low to intermediate likelihood of coronary artery disease. These patients, who have a high probability of having normal stress imaging and in whom a second dose for rest imaging may not be needed, stress-only imaging with a reduced radiotracer dose would limit radiation exposure markedly. The latter group may constitute a substantial portion of patients referred to many laboratories.

FASTER IMAGING AND LESS RADIATION. In some selected patients, for instance, those with a body mass index \( \leq 25 \) kg/m\(^2\), it may be feasible to reduce both the amount of radiotracer and the imaging time and yet obtain optimal quality images.

OPTIMIZED IMAGE QUALITY AND DEFECT DETECTION. Despite the long imaging time and the administration of the maximum allowable dose of radiotracer with conventional SPECT, image quality may be suboptimal in a significant number of patients. The increasing obesity of patients presents a serious challenge in many laboratories. In addition, patients with markedly abnormal stress-rest MPI and low myocardial radiotracer uptake are often not easy to interpret. The new gamma camera devices and new reconstruction algorithms hold the promise of improved image quality and interpretation with conventional imaging times and radiotracer doses, particularly in these patients.

IMPROVED QUALITY OF ELECTROCARDIOGRAPHY-GATED SPECT. One may also expect that the quality of electrocardiography-gated SPECT images and cine display will improve. With conventional SPECT MPI, each gated frame is count-poor and contains only one-eighth or one-sixteenth of the counts of the summed image. With the new high-speed imaging systems, each gated frame contains substantially more counts, and less filtering is required for cine display. Such high-count density gated slices also may be used for novel image processing and remove blur caused by cardiac contraction. For instance, each individual systolic slice can be “morphed” and expanded to the shape of the end-diastolic slice. By summing all morphed slices into 1 static slice, conceivably a more accurate myocardial perfusion image without blur can be created and defect detection may be improved (12).

SIMULTANEOUS DUAL-ISOTOPE IMAGING. With the improved energy resolution and higher image contrast of the new imaging systems, it may become practically feasible to acquire simultaneous rest thallium-201 and stress Tc-99m images. This will further reduce the time required for rest-stress imaging. Alternatively, the high-count sensitivity may offer new potential for thallium-201 stress SPECT MPI. Berman et al. (13) recently described the feasibility of a high-speed stress thallium-201/rest Tc-99m SPECT MPI protocol.

DYNAMIC ACQUISITION. Finally, a utopic dream, high-count sensitivity and short acquisition times may make it feasible to acquire dynamic data in list mode and analyze first-pass kinetics of regional myocardial radiotracer uptake. This may ultimately allow quantitative assessment of myocardial blood flow, the holy grail of MPI.

The recent innovations of hardware design and reconstruction software for cardiac SPECT MPI, their impact on clinical protocols as well as the first results of clinical trials are very promising and may have major implications for the way in which nuclear cardiology will be practiced. It seems that SPECT MPI is coming up to speed and more patient accommodating. Faster imaging time, lower radiopharmaceutical doses, and more efficient utilization of equipment also may result in overall cost savings. However, because these innovations may not simply involve shorter imaging time but also improved accuracy, further clinical studies that incorporate clinical follow-up and cardiac outcomes will have the final word.

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