Which SPECT for today, which SPECT for tomorrow?

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For over 50 years, the choice of equipment for cardiac SPECT imaging was simple: the Na-I Anger camera was the only game in town. You had many more manufactures to choose from, you could choose a single, dual, or even triple head SPECT camera. More recently, you could add one of the attenuation correction technologies: either scanning line sources or CT. Since there was and there is no reimbursement for attenuation correction, only larger or hospital-based laboratories opted for the additional costs associated with this valuable new technology, and as a result, there has not been meaningful market penetration of attenuation correction despite its clear advantages.

Starting with the second decade of the 21st century, the purchase decisions are less straightforward than they have been for several decades. New high-efficiency cadmium-zinc-telluride (CZT) solid-state cameras are now commercially available and provide a new fundamental question for a potential buyer: Should we embrace the new technology (CZT) or opt for improved and time-tested (Na-I) technology?

And while it may seem that finances are again the driving force behind not adopting new and improved technology like they were with attenuation correction, there are other facts to be considered. In this issue of the *Journal*, Drs. Gaemperli, Buechel, and DePuey summarized exhaustively the pluses and minuses of both technologies.[1,2]

High-efficiency CZT cameras were designed specifically for cardiac imaging and have a number of advantages. Their solid-state detectors and novel cardiocentric collimation first and foremost results in higher count sensitivity which dramatically shortens acquisition time and/or markedly lowers radiation dose (both to the patients and employees).[3–5] They are also less bulky, offer better image quality, and provide improved spatial. Additionally, the new technology opens up the possibility of new ''disruptive'' advances in SPECT as well. On the horizon is possible simultaneous dual isotope acquisition (e.g., Tl-201-Tc-99m, I-123-Tc-99m),[6,7] and most excitingly availability of dynamic acquisition which may allow calculation of absolute coronary flow or at least determination of coronary flow reserve.[8] First results of gated blood pool SPECT imaging using CZT cameras with low tracer doses and short imaging times were recently published.[9–11]

''Traditionalists'' point to a number of real advantages of Na-I SPECT along with incremental technological improvements. Newer processing software applied to conventional SPECT cameras allows for routine use of ½ time or ½ dose acquisition, thus diminishing the time and dose gap with the solid-state cameras. Na-I-based cameras better accommodate large patients and have superior versatility (CZT cameras are organ-specific, only the myocardium can be imaged, and therefore cannot be used for general nuclear medicine procedures). The most glaring omissions of the new CZT cameras are inferior detection of motion and the lack of built-in attenuation correction. And perhaps the most daunting in the current medical economic climate is the perception of higher purchase prices of CZT technology.

TIME AND DOSE

As admitted by both sides of the debate, there are a number of competing noninvasive modalities chasing the same ''holy grail'': the accurate, rapid, noninvasive, available, affordable, and safe diagnosis of the presence or absence of epicardial CAD and of its progression. Traditional Na-I SPECT MPI fulfills most of the criteria with exception of the length of the test and of the use of radiation. New CZT SPECT MPI's biggest advantage

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comes from its ability to dramatically reduce administered activity and acquisition time.

Competing technologies (stress echocardiography, CT Angiography, and PET) arrive at a diagnosis on average in less than 1 hour. Traditional SPECT MPI takes half a day. With the combined adoption of ''stress-first'' imaging, decreased time from tracer injection to imaging and with short image acquisition times, the 1 hour mark is within reach for CZT SPECT MPI.[12] Test time can be shortened even more using a very low Tl-201 stress dose (preferentially in older patients, >70 years of age), with immediate stress imaging and very short imaging time. This approach was proven with CZT cameras.[13] Shorter time to diagnosis has not only economic consequences, as seen from cost analysis of trials comparing MPI and CTA in patients with acute chest pain referred from the ED,[14–16] but also practical and ethical consequences for patients who more and more often are of advanced age, have significant co-morbidities, and are subjected to multiple back-to-back tests and procedures. The rapidity of image acquisition can be traded (e.g., in younger patients) for reduced administered activity; 1 mSv studies are achievable and faster than ''normal'' imaging.[5,12] Full rest-stress studies are possible with 4.2-6.3 mSv and rapid imaging.[17] In reality, it is not only the administered activity from a single test which is of importance, but also the cumulative dose from multiple, repeat studies performed over decades to follow a chronic, noncurable disease.

Can we achieve the same time and dose reduction with traditional SPECT utilizing ½ time, ½ dose software? New processing software can improve upon the old lengthy and high-dose protocols, but has its own pitfalls of cost and applicability. With the average age of the newest cardiac SPECT camera in a US laboratory in 2012 being 8.9 ± 5.3 years old,[18] many of the older SPECT cameras may not be able to be upgraded to the newer software due to incompatibility issues. So in many laboratories, the only way to acquire ½ time, ½ dose software is by purchasing new hardware. Considering that the mean effective dose of a SPECT study done in the United States is 14.9 ± 5.8 mSv,[19] the use of this software is likely very limited. These financial hurdles as well as the financial disincentive to using ''stress-first'' imaging limit attempts to reduce radiation exposure to the patient only to ineffective periodic appeals to do so.

COST

The cost of CZT cameras has decreased, since the time of their introduction. However, currently a refurbished Na-I general purpose SPECT or a dedicated cardiac SPECT camera without CT attenuation costs $100,000 to $200,000 less than a new CZT camera (Table 1, Depuey[1]). An important consideration at the time of purchase of new equipment is not only the equipment cost but also the savings made possible by a more efficient workflow and increased laboratory productivity. Increased patient throughput due to markedly shortened imaging time allows either for a higher daily patient volume, for shorter working days (less overtime or fewer technologists) or less equipment (one instead of two cameras). Quality control is also minimized and markedly shortened due to the lack of rotating parts on a CZT camera. This reality, if accounted for and taken advantage of, can quickly offset the higher initial cost.

Unfortunately, there is no systemic incentive to modernize SPECT hardware or software for the purpose of lowering radiation exposure and providing better patient care. In fact, the up-front costs in the current area of shrinking reimbursement are strong financial disincentives. These financial disincentives are present for both CZT and Na-I cameras. CZT technology has the obvious increased purchase cost, but obtaining ½ time, ½ dose software either requires tens of thousands of dollars if the software can be added to current hardware, or a completely new SPECT platform if the current hardware is too old.

MOTION DETECTION AND ATTENUATION CORRECTION

In practice, excessively short imaging times with high-efficiency cameras prevent most of the motion artifacts. If imaging time is only 3-5 minutes as opposed to 15-25 minutes, there is little time for the patient to move. The short imaging time increases imager alertness and improves detection of patient motion (it is hard to make a phone call, read a novel, surf the net, or text in such a brief time span). While CZT camera software is suboptimal for detecting motion, one can often spot patient motion after image processing as the short axes slices become distorted. All the while re-imaging, if needed, is better accepted by most patients, as only a few minutes are needed to accomplish the task.

Lack of true attenuation correction with CZT is a drawback, with no easy remedy in sight. Prone imaging is a suboptimal substitute, possible in most patients but not all. The addition of prone imaging also adds time to the procedure, cutting down the efficiency advantage of the technology. CT attenuation would add additional cost to an already high purchase price. It could be done on a close-by free standing CT,[20] but this is not widely practiced and logistically difficult.

Large or Immobile Patients

Very large patients are challenging for all imaging technologies. CZT cameras with a smaller field of view are less suitable for imaging obese patients compared to Na-I cameras with a larger field of view. The image quality is highly unpredictable, depending not only on patient weight, but also on BMI and distribution of the excessive soft tissue (breast vs. abdominal obesity). It is questionable, if morbidly obese patients should be injected with a radioactive tracer, if only CZT technology is available. The smaller footprint high-efficiency cameras also come with smaller tables often making it difficult to safely transfer and image immobile or infirm patients.

Versatility

The lack of versatility of available CZT cameras (designed for cardiac imaging only) is a deterrent for laboratories with a low daily volume of cardiac studies as the camera cannot be employed for general nuclear medicine purposes. If fewer than 6-10 cardiac studies are done every day, there would be prohibitive downtime for the expensive equipment.

Future Applications

New technologies also have the potential for as yet unknown advances and new applications. The potential already exists for simultaneous dual isotope imaging, for dynamic flow imaging and for gated blood pool SPECT imaging, although none are yet ready for prime time. The innovations may come to pass, they may not. Purchases of nuclear cameras are mostly made for at least a decade of use. If a wrong choice is made today, the potential for participating in disruptive future innovation may be missed.

Traditional SPECT or CZT SPECT

The advantages and disadvantages of CZT technology after its introduction less than 10 years ago are now clear. The decision to embrace the older or the newer technology is not as straightforward, however. The final decision on camera choice depends on the specifics of an individual laboratory and local needs. It is important for the decision makers and their advisers to be well informed, visionary, and realistic when making the selection.

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