Future of Nuclear Medicine: SPECT Versus PET

The development of nuclear medicine as a medical specialty has resulted in the large-scale application of effective routine imaging methods that have reached widely recognized clinical usefulness for the diagnosis and characterization of different disorders (*1*). The number of radionuclide investigations increased exponentially when the nuclear reactor in Oak Ridge, TN, was opened for radionuclide production in 1946 (*2*). Although important advances were initially made by relying on single-photon–emitting radiopharmaceuticals, the more recent introduction of positron-emitting tracers has represented another fundamental leap forward in the ability of nuclear medicine to exert a profound impact on patient management. The ability to produce radioisotopes of different elements initiated a variety of tracer studies in biology and medicine, facilitating enhanced interactions of nuclear medicine specialists and specialists in other disciplines.

Some authors have recently raised concerns about the future of single-photon emission imaging (including both SPECT and planar imaging). In particular, Alavi and Basu (*3*) speculated that, because of the shortcomings of planar and SPECT imaging when compared with PET (with respect to image quality and ability to assess regional function), "PET will become the standard of care in nuclear medicine and the use of SPECT will substantially decline over the next decade" (*3*). These authors also predicted that over the next decade cyclotrons will replace ^{99m}Tc generators and PET and PET/CT devices will gradually replace planar and SPECT imaging instruments. However, the debate on single-photon versus PET imaging is far from being concluded in total favor of PET, as shown by the lively discussion stimulated by such assertions (*4*).

Predicting the future is always a perilous enterprise and especially so if one considers unpredictable but significant variables such as the volatility of current economics, the resulting ability of medical institutions to acquire new equipment, the economic motivations of radiopharmaceutical companies to develop and distribute new SPECT or PET agents, and the future availability (or lack thereof) of positron emitters. Cost-related considerations are particularly important—not only because of the current economic crisis affecting developed countries in which improvement will eventually occur—but because of the chronically severe economic outlook and suboptimal health care services for the 80% of the world population who live in the 100 countries with what the United Nations classifies as "medium-to-low human development" parameters (see global data at http://hdr.undp.org/en/statistics). In these countries, nuclear medicine is almost invariably underfunded and underutilized with respect to other diagnostic modalities. Moreover, the combination of underdeveloped economic structure, poor management, and challenging local climate conditions hampers the ability of a nuclear medicine service to operate with adequate logistics to ensure either reliable supplies of radiopharmaceuticals or timely servicing and repair of imaging equipment (*4*).

We agree with Alavi and Basu that there is a need to look to the future to plan more targeted training for the coming generation of specialists in nuclear medicine and molecular imaging, as well as to allocate resources for projected transformations in the field. However, we believe that the following considerations should be kept in mind before reaching a final and irreversible conclusion about the future of nuclear medicine:

- Documented evidence available from developed countries such as Canada (where PET has been clinically used for more than a decade and covered by insurance plans) shows that the number of installed PET facilities and also the number of clinical PET procedures has continued to increase, thus confirming the increasing demand for PET imaging (*5,6*). At the same time, these increments in PET imaging have had no negative effect on the availability of and use rates for SPECT imaging. In fact, during the same period, the number of new γ cameras installed in Canada has remained stable, with a trend toward more dedicated SPECT facilities. In 2003, only 58% of Canadian γ cameras were dual- or triple-head devices, a figure that rose to 69% by 2007. Moreover, the average effective time of operation for γ cameras installed in Canada has remained stable at 40 h/wk between 2003/2004 and 2006/2007. Over a somewhat longer period (and despite the 113% increase in the use of competitive imaging modalities such as echocardiography, which entails no radiation burden and has lower cost), the number of cardiac nuclear wall motion studies performed annually in Ontario (Canada) increased by 19% between 1996/1997 and 2005/2006 (*5*). In the same period, the number of myocardial perfusion scans increased by 101%, and the number of bone scans increased by 24%.
- The market analysis firm Frost & Sullivan (Mountain View, CA) predicts a 16% annual growth rate for the SPECT/CT market between 2008 and 2014 (*7*). This

projection reflects the fact that the mean age of γ cameras has remained relatively stable, although PET has seen the mean age of instruments decrease.

- One informal report from Europe suggests that the overall number of single-photon diagnostic nuclear medicine procedures performed in France, Germany, Italy, Spain, and the United Kingdom fell by ~1% between 2005 and 2007, with a range of 1.5% growth in Italy and 4% decline in Germany (*8*). Nevertheless, between 2005 and 2006 the number of myocardial perfusion scintigraphies actually increased slightly in Germany, despite the emergence of competing methods (*9*). It should be noted, however, that the European picture is somewhat influenced by the relatively high proportion of radionuclide bone studies, which account for 44% of the nuclear medicine patient mix and show only small year-to-year changes (*8*). The same report indicates that radionuclide imaging procedures develop at different rates. On the other hand, an independent report shows that, although the UK and Germany are rapidly replacing lung scintigraphy with pulmonary CT angiography for the diagnosis of acute pulmonary embolism (with an average 15%–19% reduction in lung scans between 2005 and 2007), this trend is much slower in France and Spain (about 7% reduction over the same time period), with a stable level and in some cases an increase in the application of such radionuclide imaging procedures in Italy (*10*). Likewise, although sentinel lymph node mapping is among the fastest growing applications in nuclear medicine, the largest growth is seen in other diagnostic areas that were previously slow to adopt new nuclear medicine procedures (e.g., dopamine transport studies, primarily utilizing DATScan, show the highest yearly growth in Europe) (*8*). As a group, these statistics justify one study's observation that "To date there is little evidence that PET studies are cannibalising traditional nuclear medicine examinations" (*8*).
- As additional support to the opinion that single-photon imaging retains and presumably will retain in the short- and mid-terms an important role in diagnostic nuclear medicine, Mariani et al. (*4*) emphasize the concept that PET remains a rather complicated technique and that production of ^{18}F-labeled agents, either in-house or by central/regional radiopharmacies, requires a complex and technologically sophisticated infrastructure, not to mention sometimes challenging distribution logistics. Moreover, synthesis of PET tracers is a time-consuming process when compared with preparation of a ^{99m}Tc-agent using a simple kit formulation. In addition, it is not completely obvious on the basis of pure pathophysiology that true clinical advantages would accrue from development of some PET tracers. In the area of myocardial perfusion, for example, some authors have pointed out that, despite the immediately obvious advantage of PET in enabling quantitative measurement of myocardial blood flow, this parameter has only limited practical application in patient management. In fact, a true quantitative measurement would require the determination of other parameters, such as input function, that are difficult to acquire as part of routine procedures. Finally, Mariani et al. (*4*) assert that the true competition is not between SPECT and PET but, instead, between nuclear imaging and other imaging modalities that are easier to use in the clinical setting. If CT or MR imaging eventually prove to be capable of quantifying myocardial perfusion, it is difficult to believe that the existence of an optimal PET perfusion tracer will drive clinical preferences to PET over these other 2 imaging techniques. It can be concluded, then, that growth in the demand, usefulness, or availability of PET imaging devices and tracers will not inevitably impose a significant negative impact on existing (nor projected) single-photon imaging facilities and/or on the clinical applications of SPECT/planar procedures.
- Although some sources have predicted that the γ camera market will be constrained by competition with PET for budget and resources, most observers concede that the long-term outlook for the market is quite favorable. The γ camera's key competitive advantages over PET lie in a much larger worldwide installed base and the availability of longer half-life radioisotopes (*11*). The global γ camera market generated revenues of \$638 million in 2003 and is expected to grow at an annual rate of 3.1% to \$788.8 million in 2010 (*11*). Even what appear to be steep drops in the nuclear medicine markets should not be interpreted as SPECT declines. The 52% decrease in the domestic Japanese nuclear medicine market between 2006 and 2007 was mainly the result of a 79% drop in PET/CT installations, a figure that was actually tempered by a rise in new single-photon imaging equipment (*11*). A survey conducted in Beijing, China, between 2005 and 2006 revealed that over that single year only 1 new PET/CT installation was put in place, whereas 5 new γ cameras were installed (corresponding to a 12% growth in single-photon imaging equipment for that city) (*12*).
- It should also be emphasized that single-photon agents can provide more specific targeting abilities than PET agents in some applications (e.g., by enabling dual-tracer imaging, which is still unique to SPECT) (*13*). Other examples of areas in which diagnostic nuclear medicine relies heavily on single-photon imaging and and in which a handover to PET imaging is difficult to foresee include dynamic functional imaging in nephrology, evaluation of motor function in the gastrointestinal tract, gastrointestinal bleeding scintigraphy, Meckel's diverticulum scintigraphy, hepatobiliary scintigraphy, lymphoscintigraphy (either for peripheral disorders of lymph flow or for radioguided sentinel lymph node biopsy), and lung ventilation/perfusion scintigraphy.

- Finally, the recent diffusion of hybrid equipment for single-photon imaging, especially SPECT/CT, has markedly enhanced the diagnostic capability of traditional nuclear medicine, especially by increasing specificity through more precise definition of the location and extent of disease. In this regard, evidence is growing to support the advantages of SPECT/CT over either planar or SPECT imaging alone in a wide range of clinical conditions, including but not limited to differentiated thyroid carcinoma (including the medullary form), neuroendocrine tumors in general, medullary and cortical adrenal diseases, solitary pulmonary nodules, parathyroid adenomas, lymphoma, sentinel lymph node biopsy, infection/inflammation, and malignant and benign bone disease (*14*). We agree that for some of these applications PET imaging has definite advantages over single-photon imaging and is therefore gradually replacing conventional radionuclide imaging in the developed countries. Nevertheless, such transformation cannot be expected to occur at a comparable pace or extent in that vast portion of the world where even running the daily activities of a conventional nuclear medicine service constitutes a formidable challenge.

CONCLUSION

In conclusion, we believe that the debate currently surrounding the issue of single-photon imaging (SPECT or planar) versus PET or PET/CT may be considered somewhat similar to that which surrounds plain radiography and ultrasonography versus CT or MR imaging. In the latter debate, the increasing number of procedures and devices for CT and MR imaging has had no negative influence on plain film or ultrasound. According to the World Health Organization, "the assumption is that diagnostic imaging is needed in some 20% to 30% of medical cases worldwide" in which "clinical considerations alone are not sufficient to make a correct diagnosis" (*6*). When diagnostic imaging is required, some 80%−90% of diagnostic questions can generally be resolved using plain X-ray and/or ultrasound examinations (*6,15*). We believe that analogous assumptions can be true for nuclear medicine imaging techniques.

Based on all of these considerations, we firmly believe that, although single-photon nuclear medicine imaging faces competition from other methods (particularly PET), this traditional nuclear medicine imaging modality will continue to survive and to provide highly valuable clinical and investigational data to clinicians and to the entire medical community. This should be especially true in the global medical community, where questions of resources, technology availability, and growing need pose special challenges.

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