cardiology is somewhat more challenging than in oncology. Often larger animal models and, therefore, larger research scanners are required.
- Current clinical imaging systems should be optimized to facilitate cardiovascular molecular imaging.
- And, as many individuals at the Molecular Imaging Summit have emphasized, standardization of imaging protocols and quantification schemes is needed to facilitate evidence-based, multicenter clinical studies.

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Utilizing Technological Advances to Grow Molecular Imaging Clinical Services: Industry Perspective

Technology has been a driving force behind the rapid growth of clinical molecular imaging. Advances in scanners, postprocessing, application software, and information technology (IT) integration have been key enablers of growth into broader clinical services and higher productivity in existing service lines. For example, today's PET/CT scanners have broad clinical utility in diagnostic oncology, radiation therapy planning, treatment monitoring, evaluation of myocardial perfusion and viability, and neurodegenerative diseases, as well as a complete diagnostic CT service including peripheral and coronary angiography, stroke, and interventional applications. Only a few years ago, many of these clinical applications were not possible on a single PET/CT system. Today, however, successful PET/CT centers are utilizing their scanners in many or all of these areas. Technology has also driven higher productivity for routine ^{18}F-FDG oncology, which comprises more than 90% of today's PET/CT procedures. Hybrid PET/CT imaging with CT attenuation correction has reduced exam times by half. Higher sensitivity scanners and 3D imaging can deliver shorter patient exam times. Physician productivity has improved through fused PET and CT displays with dedicated application software for faster interpretation and shorter report turnaround times.

The Molecular Imaging Value Stream

The perspective I bring to this session and to the Molecular Imaging Summit is that of industry. The makers of medical devices are as interested as the field's practitioners in determining how to grow clinical utilization and in identifying both drivers and bottlenecks in this process. The engine that drives innovation in medical imaging is powered by market forces: those that bring new devices to market and those that create sustainable markets for these new devices. One of the business improvement methodologies that GE uses to optimize different steps of a market or business process is Lean Six Sigma. Lean Six Sigma combines tools from the Lean Manufacturing and Six Sigma methodologies to focus on speed of development and on quality. A typical (simplified) application of Lean Six Sigma involves identifying the processes most important to delivering customer value, mapping these processes using value stream mapping, identifying the bottlenecks or constraints inherent in the value stream, and finally applying "variation reduction" techniques that can speed development and ensure consistent high quality. Lean Six Sigma allows us to create a framework for goal-directed discussion of growth, simplification, and quality in medical device manufacture and marketing.

The value stream for molecular imaging devices involves multiple viewpoints and elements that drive utilization. One way this value stream can be conceptualized is in a flow representing the stages at which a patient may be imaged, integrating industry, practice, and delivery into a framework for discussion. In the first stage, a patient comes in with a symptom or sign of a disease. The utilization drivers that can lead to imaging at this stage include disease prevalence, clinical indications for use, and cost effectiveness. The primary care physician or specialist then seeks diagnostic imaging based on patient management guidelines, the extent to which he or she as a physician is educated about the benefits of imaging in this specific disease setting, patient awareness of these benefits, and the quality of information the imaging report is likely to yield. If disease is confirmed, the patient then proceeds to treatment and/or monitoring, for which imaging choices are based on (and may be an active part of) clinical trial results and new drug development. Finally, imaging may be used in follow-up studies, where the decision to utilize imaging is driven by known survival and recurrence rates. Reimbursement is a prime utilization driver throughout the value stream.

At the center of this value stream, which includes key handoff points, is the imaging service provider. If we assume,

as the industry does, that market forces determine clinical adoption, we can get a better sense of the imaging service provider's point of view. Sustainability is an important concept, and the following basic business equation defines sustainability for the imaging provider across the value stream of molecular imaging:

$$\text{Profit (loss)} = \text{Revenue} - \text{variable costs} - \text{base costs},$$

where: revenue = number of exams × reimbursement per exam; variable costs = number of exams × cost per exam; and base costs = facilities + salary + equipment. Actions to address each of the elements in this equation can increase profits. These actions can include increasing the number of exams, decreasing costs per exams, and matching base costs to planned revenues.

Increasing the Number of Examinations

GE is particularly enthusiastic in its support of appropriateness criteria and well-delineated clinical pathways. We were the sponsors for the National Comprehensive Cancer Network (NCCN) *Clinical Practice Guidelines in Oncology*, published last year, which provide an excellent example of evidence-based information that can grow overall utilization. The NCCN is a not-for-profit alliance of 21 of the world's leading cancer centers, which develop resources that prepare valuable information for the numerous stakeholders in the health care delivery system. In 2007, an NCCN Task Force Report on PET/CT confirmed to these stakeholders that "The role of PET or PET/CT scans in oncology is rapidly evolving, with well-defined roles in the common malignancies of breast, lung, colorectal cancer, and lymphoma." The supplement in which this statement appeared (*J Nat Comp Cancer Net.* 2007;5[suppl]:1–32) contained specific guidelines and recommendations for PET/CT in each of these disease settings. The NCCN has also noted that the numbers of diagnostic and therapeutic pathways for PET/CT are growing.

Technological advances also continue to fuel growth in clinical utilization and, therefore, the numbers of examinations. Taking PET/CT alone as an example, current enabling technologies facilitate advances in clinical applications. Integrated lasers, flat tabletop modifications, and simulation software are enhancing radiation therapy planning. Software for quantitative comparison is improving treatment monitoring, new analysis software is advancing myocardial perfusion applications, the availability of normals databases is assisting in dementia evaluation, and fully integrated PET/CT is improving the accuracy of diagnostic CT. Emerging areas include fusion software in CT angiography plus perfusion (as a one-stop-shop cardiac approach), as well as respiratory monitors and correction algorithms in respiratory gating.

Decreasing Costs Per Exam

Enabling technologies are also driving efficiencies and enhancements that can result in decreasing costs per exam. Using PET/CT again as an example, these efficiencies are being realized across a spectrum of staff and physician time savings, as well as in better uses of existing technologies. Integrated CT is providing up to a 50% reduction in required attenuation correction times. Higher sensitivity scanners and iterative reconstruction are resulting in reduced scan times. Three-dimensional scanning is a factor in reduced dose. Physician interpretation is being enhanced and streamlined with fused PET and CT displays. A number of dedicated applications in radiation therapy planning, treatment monitoring, myocardial perfusion quantitation, and dementia diagnosis are providing efficiencies in advanced analysis. Emerging areas include IT integration that speeds report turnaround time and new types of structured reports that decrease reporting time while improving report quality.

Matching Base Costs to Planned Revenues

SNM performed a survey of nuclear medicine physicians and determined that 40% of respondents believed that PET/CT scanner costs constituted a major barrier to adoption. That is, they believed that the costs of the units, when contrasted with projected revenues, were challenging. In fact, if we look at typical 5-y expenses for a PET/CT operation, scanner and interest costs account for only 22% of the total. "Consumables," at 35%, account for a far larger slice of the operating budget pie. Another interesting fact points to the way in which state-of-the-art technology is valued by the molecular imaging community in planning future operations. Less than 15% of PET/CT purchasers buy refurbished systems, which are available at reduced prices. Because they are guided by long-term business models, most practices look at the latest and most advanced service. If cost were the most significant factor, more people would be buying refurbished systems.

Summary

Market forces will ultimately determine the rate of clinical adoption of molecular imaging. Understanding the complexities of the molecular imaging services value stream will allow us to address the inevitable bottlenecks and challenges along the way. Technology advancements will continue to drive expanded clinical applications and provide improved efficiency in examination throughput and physician interpretation.

Several priorities should be addressed in the near future. Industry, clinicians, and researchers have a stake in seeing that broader data, including outcomes studies, appear in the peer-reviewed literature. Evidence-based patient management guidelines should also be supported, with targeted publication in oncology, cardiology, and neurology specialty and subspecialty journals. We are also challenged to improve quantitation methodologies (including high-quality software for analyses) for reproducible comparison of longitudinal studies.

Educational outreach to referring physicians and patients, as others at this summit have emphasized, is crucially important to advancing molecular imaging utilization. At the same time that new technologies increase the interpreting physician's productivity and confidence, these same technologies can be applied to higher quality and faster reporting that can help to keep the referring physician satisfied. Industry, healthcare providers, and professional societies must partner to address these challenges.

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Individualizing Cancer Therapies Using "Anatomolecular" Imaging

Many of us remember the 1989 film *Field of Dreams*, starring Kevin Costner. In brief, the main character becomes convinced that a baseball field must be built on his failing farmland. Another character assures him that if he builds it, "they" will come. And come they did, not only within the storyline of the movie but, as a result of the movie's popularity, to the real field in Dyersville, IA. After some contention between the 2 adjacent landowners, the field created for the film was restored, attracting up to 50,000 visitors each year. Some came to hit a few balls, run the bases, and peer into the surrounding cornfields for the ghosts of past players. One question that guides the following discussion of our increasing ability to individualize cancer therapies using functional and anatomical imaging is: Is this the "field of dreams" for nuclear medicine?

Anatomolecular Imaging and Guided Therapy

Our field has been exponentially expanded by the ability to view molecular imaging results in an anatomic context, a capability that can be applied in PET, SPECT, MR imaging, MR spectroscopy, and a growing range of optical and fluorescent technologies. In fact, anatomic context is now requisite for most molecular imaging agents.

As we explore the possibilities of this expanded field, the number of stakeholders grows. These stakeholders include: patients and their families, payers (including the Centers for Medicare and Medicaid Services [CMS] and insurance companies), companies and shareholders (for pharmaceuticals, devices, molecular imaging agents, and molecular therapy agents), molecular imaging physicians and their staffs, referring physicians and their staffs, federal agencies (such as the National Institutes of Health [NIH], the Department of Energy, and the Food and Drug Administration [FDA]), professional organizations, and society in general.

Despite all these interested groups, a number of barriers stand in the way of rapid adoption and growing utilization. Among the areas in which these obstructions are most formidable are: securing FDA approval, ensuring ^{18}F-FDG availability, dealing with regulatory complexity and uncertainty, securing CMS acceptance and appropriate reimbursement, and reaching out for referring physician acceptance and routine utilization. Even when we meet these challenges, 2 critical questions are especially important for molecular imaging: (1) Are the economic models we are using viable? (2) How do we deal with the fairly rigid approval and reimbursement system when many of our new technologies are "disruptive" of the older models still in place?

As an example, we can look at ^{18}F-FDG and its uses as a tracer in glucose metabolism. Although some individuals talk about FDG as if it is not really a molecular imaging agent, it is a remarkably powerful tracer and a potent downstream marker of a variety of important upstream processes. It is extraordinarily useful as a response indicator for a variety of tumors and, therefore, useful in staging cancer. It provides extracellular and intracellular information about glucose metabolism, making it a truly molecular agent.

A number of oncology-specific PET indications for ^{18}F-FDG have been approved or partially approved by CMS. These include applications in solitary pulmonary nodules (SPNs), non–small cell lung cancer, colon cancer, Hodgkin's and non-Hodgkin's lymphomas (NHL), melanoma, head and neck cancer, esophageal cancer, thyroid cancer, and breast cancer.

Approval is only the first step in convincing our referring physician colleagues to accept and utilize these PET applications. Among the tools to increase physician acceptance that have been highlighted by others at this summit are: ensuring the regular publication of evidence-based literature supporting efficacy, attending tumor boards and conferences of other specialties, presenting high-quality images to these groups, making ourselves available to discuss cases with referring physicians, and providing prompt scheduling, consistent reads, and conscientious reporting and follow-up. I should add that outreach to referring physicians should also begin with making sure that medical students, as they