The Art of Imaging

The “art” of medical imaging is not in the image itself, but what it enables the physician to see.
Image quality has always been the common denominator of medical imaging. Since the first radiograph, more than a century ago, advancing technologies have raised the bar of what was acceptable, just as patient care has become increasingly dependent on what medical images reveal.

This technological evolution is evident in the hybridization of PET and CT, which catapulted positron imaging to the forefront of oncologic assessment, as well as SPECT/CT, which today is relied upon increasingly for oncologic, cardiac and orthopedic evaluation.

In these, the quality of images has increased, as well as that of quantitative data. Examples include the use of advanced crystals in PET detectors, such as Siemens’ pioneering use of LSO (lutetium oxyorthosilicate); continuous-bed-motion scanning, which allows for standardized disease-oriented protocols; the improved resolution and data registration obtained with xSPECT Bone®; and the use of IQ•SPECT to increase counts during cardiac scans.

Now, as healthcare transitions from volume-based to value-driven medicine, image quality empowers the broader “quality” of healthcare. In 2001, the Institute of Medicine broadened the definition of “quality” to include that which is safe, effective, patient-centered, timely, efficient and equitable.¹

The technologies that underlie the next-level of image quality have laid the groundwork for molecular imaging to achieve this more expansive standard. The dogged pursuit of ever better image quality has provided the means to be more effective in the use of imaging technologies and the reduction of radiation dose, which have increased patient health and safety. Similarly, technologies that make data acquisition more efficient have improved patient satisfaction and made healthcare more equitable by decreasing scan time and boosting throughput.

This article explores four key molecular imaging technologies and the value high-quality imaging brings to healthcare organizations and the health of the patients they serve. The true art of imaging.

I. High Image Quality, Faster Scan Times, Doubled Throughput Rooted in Crystal Type: LSO-based Detectors

II. Image Quality Supports Higher Standards of Care for All Patients: FlowMotion

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IV. Image Quality that Expands Clinical Capabilities and Increases Productivity: SPECT/CT and IQ•SPECT
I. High Image Quality, Faster Scan Times, Doubled Throughput Rooted in Crystal Type: LSO-based Detectors

By Greg Freiherr

In 1999, Nanfang Hospital, a 2,000-bed hospital affiliated with Southern Medical University, one of the premier medical universities in China, purchased its first PET. It was later upgraded to PET/CT, with both using detectors that utilized BGO crystals. In 2012, however, the Chinese hospital replaced its PET/CT with Siemens’ LSO-based Biograph™ mCT.

“We prefer our LSO-based scanner because of its high image quality,” said Wang Quan-Shi, MD, PhD, Director of Nuclear Medicine at Nanfang Hospital. “In general, with today’s technology, BGO- and LSO-based scanners can meet the entry level of clinical use. But for those tiny lesions, our LSO-based scanner adds diagnostic confidence.”

Nanfang Hospital is not the only one to take notice of the advantages of lutetium-based crystal (LSO or LYSO) scanners. Introduced commercially by Siemens more than a decade ago, LSO set the standard for image excellence and workflow efficiency, and continues to gain momentum. Since 2003, LSO and LYSO market share has increased an average of 22 percent per year, according to the independent IMV 2012 PET Summary Report. (BGO has likewise decreased 16 percent per year.)

The LSO Advantage

LSO has a number of properties that make it the ideal detector crystal of choice. Firstly, LSO is dense and has a high effective atomic number, which produces great stopping power and,
as a result, improves detection efficiency and sensitivity. This enables fast scans (about 5 to 10 minutes) and reduced injected dose.

Secondly, the LSO crystal can quickly convert the photons into detectable light. This helps to reduce image noise and enables the use of Time-of-Flight (ToF) calculations. BGO, has a slower light decay time and does not meet the standards to support ToF.

“The higher light output and shorter decay time of LSO enables faster scans and more patients per day,” Quan-Shi said. “In addition, LSO is better suited for 3D acquisition and is able to incorporate the ToF technique to improve image quality and lesion detectability.”

Time-of-Flight PET studies rely on coincidence events. In these, a positron, emitted by the PET radiotracer, collides with an electron, each annihilating the other and producing a pair of photons that travel in exactly opposite directions. Traveling at the speed of light, the two photons strike a detector ring at about the same time at points exactly opposite from each other.

Two counts made within each other’s “coincidence window”—about four nanoseconds with LSO-based Biograph mCTs (four billionths of a second)—indicate that the photons came from the same annihilation. Calculating the impacts of many different pairs of photons in three dimensional spaces provides an approximate location of the radiotracer.

High-resolution systems using ToF algorithms can precisely measure when the paired photons strike different sides of the detector ring. Because annihilation likely occurs nearer one side of the ring than the other, calculating the difference in the “time of flight” of each photon allows the ToF system to zero in on the radiotracer, pinpointing the origin of the positron-electron annihilation that gave birth to the two photons and, consequently, the location of the radiotracer.

ToF imaging is less affected by artifacts than conventional PET, as image reconstruction is less sensitive to mismatched attenuation correction, erroneous normalization and poorly estimated scatter correction—a robustness that stems from its improved time resolution achieved. This robustness and the ability to perform 3D acquisitions, accelerates workflow at Nanfang Hospital, according to Quan-Shi.

“We can obtain enough information in a relatively short period to improve the workflow, thus increase patient throughput,” he said. “Our LSO-based system can save almost half of the scan time and double our patient throughput.”

Of course, LSO is not the only technology that has advanced the clinical value of PET/CT. Over the past decade and a half, sophisticated electronics have been developed to measure coincidence events and reconstruction algorithms have been developed to assemble the ToF data efficiently and effectively. It is noteworthy, however, that already a year before PET/CT was commercially introduced, LSO was hailed as “promising to be the basis for the next generation of PET cameras,” a prediction that time—and Time-of-Flight—have proved correct.

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Continuous-bed-motion (CBM) scanning with Biograph mCT Flow™ translates into image quality and efficiency, shared two users, one in Lomme, France, the other in Chattanooga, Tennessee, USA. But there’s a lot more to this PET/CT scanner. And it relates to the bigger picture of quality of care.

Alban Bailliez, MD, and colleagues in the Nuclear Medicine Department of Saint Philibert Hospital, Lomme, France, are scanning patients faster and generating images with higher resolution than was possible before they began operating Biograph mCT Flow. “We do the exams in less time and at higher quality,” Bailliez said.

At a multi-hospital system with five campuses in Chattanooga, Tennessee, USA, Saima Muzahir, MD, leverages Biograph mCT Flow to provide patient-centric care by delivering exceptional data quality. “With respiratory gating, we don’t have motion artifacts, which means excellent imaging and quantitation makes a difference,” Muzahir said. “With the help of respiratory gating, I have improved my sensitivity and specificity in very small nodules.”

The improved quality of care that results is rooted in the ability of Biograph mCT Flow to perform a deceptively simple, yet critical task—to move the patient continuously through its gantry at programmable and variable speeds.

Standardized Protocols: The Game Changer in Patient Care
Working with medical staff in Lomme, France, and Chattanooga, Tennessee, Siemens clinical specialists helped to initially set up protocols with table speeds relevant to the pathologies these sites routinely encounter. In each protocol, the table slows to allow more counts from body areas of greater interest and speeds up when covering those of lesser interest.

Both sites routinely leverage CBM, made possible through Siemens’ FlowMotion™ technology, to assess
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Nuclear Medicine Physician
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patients with head and neck cancers. In these, the head and neck are scanned slowly to maximize the number of counts. Data are reconstructed into a high-resolution, 400x400 pixel matrix. Similarly scanned and reconstructed is the liver, where metastases often hide. Other body areas are scanned faster and reconstructed at lower resolution.

This approach delivers high-resolution images of the areas of greatest clinical interest, yet imposes no time penalty. The Biograph mCT Flow at Saint Philibert Hospital nets a savings of about five minutes per exam, compared to their previous PET/CT scanner.

“We now average between 15 and 20 minutes per patient,” Bailliez said, “compared to between 20 and 25 minutes (with conventional PET/CT).”

Reduced complexity and greater efficiency has added capacity that can be used to serve a growing patient population. “We could explore doing up to 30 patients per day without problem,” he said, noting that the current daily average is about 20.

At the Chattanooga, TN, facility, Muzahir is enthused about the respiratory gating that FlowMotion makes routinely possible for her lung cancer patients. Gating is now integrated into the base protocol, which is positively impacting the standard of care for every patient.

Its effect on standard uptake value (SUV) quantitation, Muzahir said, is remarkable. Muzahir and her colleagues recorded and then compared SUV_{max} in several patients with and without respiratory gating. “We found a more than 50 percent difference in the values,” Muzahir said. “That is a significant difference when you are trying to call something malignant versus non-malignant.”

Confidence Through Consistency
Muzahir credits the acquisition approach of Biograph mCT Flow for improving data quality when assessing lung cancer, as well as the
“The scans are so comfortable that some patients fall asleep during acquisitions. Those who do, tend to sleep through the exam.”

Alban Bailliez, MD
Nuclear Medicine Physician
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Lomme, France

many other types of cancers seen at the Chattanooga facility, including lymphomas, melanoma and cancers of the prostate and breast. Continuous bed motion diminishes the chance of artifacts that can occur during stop-and-go scans due to overlaps between bed positions.

“Eliminating the overlapping bed acquisitions and maintaining the uniform axial noise sensitivity across the entire scan decreases the actual noise variance,” she said. “This helps you better quantify the lesions based on SUV$_{\text{max}}$. And the reproducibility is maintained because of that.”

Bailliez noted the importance of reproducibility when using Biograph mCT Flow at Saint Philibert Hospital. In conventional stop-and-go scanning, he noted, data may be sampled anywhere in the field of view (FoV). If the sampling points are not the same before therapy as during or after, values may sometimes vary. Because FlowMotion protocols are built around organs rather than bed positions, the values are consistently acquired from the same locations regardless of when the exams are performed. This results in highly reproducible images and SUVs.

“We observe in our patients the same quality on the exams at different times,” Bailliez said. “Because we see the same quantification values in the normal organs at those times, we are very confident that we can compare the two exams—and that we can depend on the differences we see in the SUVs.”

Excellent Image Quality Without Compromise

Simplicity and dependability are key to the success of FlowMotion. Each protocol used by the French and American staff is triggered with a single click. So evident in the operation of Biograph mCT Flow, this simplicity is reflected also in the speed and ease with which staff are trained.

Other advantages accruing from FlowMotion address patient comfort and safety. One relates to what patients feel as they move through the PET/CT gantry.

“The scans are so comfortable that some patients fall asleep during acquisitions. Those who do, tend to sleep through the exam,” Bailliez said. “They do not wake up, because the bed doesn’t stop and start from one bed position to the next, as happens in conventional scanning.” The sudden movements from the previous PET/CT scanner not only kept patients awake, they sometimes startled them, he mentioned, causing motion artifacts.

Muzahir notes that the fast scans possible using Biograph mCT Flow further reduces the chance of patient motion. This improves image quality, she said, and contributes to a positive patient experience.

Another advantage obtained through FlowMotion is the reduction in CT radiation dose. Because FlowMotion protocols focus on specific organs and body areas, radiation exposure is restricted to just the parts of the body being examined. In conventional scans, the CT covers the entire bed position, regardless of whether data on the whole bed is needed. The clinic staff also routinely use Siemens CARE Dose4D™, which further minimizes CT exposure.

“We systematically apply the lowest CT dose possible,” Bailliez said. “We think that FlowMotion leads to optimal radiation exposure for the patient.”

“We have been able to use about 15 percent lower dose,” Muzahir said. “It is very important to minimize the radiation dose when you are imaging a ten-year-old who has another 50 or 60 years ahead.”

Those kinds of concerns go to the root of imaging, Muzahir said.

“The idea is to deliver patient-centric care,” Muzahir said. “That is our main focus.”
Symbia Intevo™ arrived in October 2014, at the general hospital “Ernst von Bergmann” in Potsdam, Germany, a University Teaching Hospital of the Charité Berlin. Ingo Brink, MD, who heads the nuclear medicine department at the University Teaching Hospital there, has been routinely using it ever since.

The new scanner, the latest SPECT/CT system in Siemens’ nuclear medicine portfolio, was installed with xSPECT Bone* and xSPECT Quant* features. Symbia Intevo, with xSPECT* technology, runs on a SPECT/CT platform, but the reconstruction algorithms are completely integrated, achieved by shifting the imaging viewpoint from the SPECT frame-of-reference and into the higher resolution CT frame-of-reference. As well, it is the first SPECT/CT scanner to offer automated quantification.

At the hospital “Ernst von Bergmann,” most scans done using xSPECT Bone are to assess bone cancer. What has most impressed Brink is the image quality. “Compared with the SPECT images, the image quality of xSPECT is outstanding,” Brink said.

Before obtaining Symbia Intevo, Brink and his team of two nuclear medicine physicians and two trainees assessed patients suspected of bone cancer with whole-body planar scintigraphy followed by a SPECT. If the images were indeterminate, they would recommend additional imaging with CT or MR, a process that could delay treatment and increase costs.

Now, with xSPECT Bone, the workflow has changed. The team still starts with whole-body planar scintigraphy, but if that is indeterminate, they have the option to proceed to SPECT, a SPECT/CT on Symbia Intevo, or use xSPECT Bone. Most of the time, the choice is Symbia Intevo with xSPECT Bone, according to Brink.

“A year ago, in many cases we did not obtain a final result,” Brink said. “Now, in most cases, we quickly have it.”

Brink estimates that since installing Symbia Intevo, the department’s ability to address disease has increased by about 30 percent. By merging the lower resolution SPECT data with the higher resolution CT dataset, xSPECT provides higher resolution images with a clear differentiation of bone and soft tissue. Hot spots on bone don’t overlap soft tissue, as they might in a scanner with lower resolution.

An added benefit of xSPECT Bone is an expanded referral base. Brink said he is definitely seeing more patients, as a result of the new scanner.

“Referring physicians like the images very much, and I serve more patients because of this,” he said. “They have more confidence in the results, much more than before because they can see it themselves. Acceptance is very high.”

**A Quantitative Future**

Brink’s use of xSPECT Quant is still in the early stages. But still, he expects that this feature, a result of xSPECT’s precise alignment of the CT and SPECT datasets, could become very valuable in the future.

“One year ago, I was telling my students quantitation was possible only with PET. Then I learned about xSPECT Quant,” Brink said. “I also told them that resolution is much better with PET than with SPECT. But my opinion on that has changed also.”

With the image quality improvement demonstrated by Symbia Intevo with xSPECT technology, Brink noted the greater opportunity to develop tracers for SPECT/CT. He is getting more excited for one opportunity in particular.

**177Lu**, a therapeutic radioisotope, emits gamma rays, which opens the door for imaging with SPECT. Several sites in Germany are already trying to use SPECT to keep track of **177Lu** when administered during therapy, he said. The quantification feature of xSPECT could become particularly valuable in monitoring the progress of therapy, according to Brink.

When asked if he would recommend these new approaches to other physicians, he said, “Yes, I would. I do so every day.”
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IV. Image Quality that Expands Clinical Capabilities and Increases Productivity: SPECT/CT and IQ•SPECT

By Greg Freiherr

When CT was first combined with SPECT a decade ago, there were two types of machines. Beijing Hospital, a 1,200-bed medical center in China’s capital city, installed the type that combined SPECT with a non-diagnostic CT over 14 years ago.

“The non-diagnostic CT images were not satisfying. Based on our years of experience, our nuclear medicine department needs high-quality CT images for better diagnostics,” said Zhi-Ming Yao, MD, PhD, Chief Physician and Director, Department of Nuclear Medicine, Beijing Hospital, Ministry of Health.

Administrators at the Chinese hospital have since purchased Siemens’ Symbia™ T16. Yao explained that the high profile of the hospital, and that of its patients, demanded excellence. “The image quality of both SPECT and CT [from Symbia T16] are excellent,” said Yao, who also serves as consultation expert for the Bureau of Health Care for Senior Officials, operated by the Ministry of Health.

Bone SPECT/CTs, parathyroid, myocardial perfusion, pulmonary ventilation and perfusion are among the most common nuclear medicine procedures performed by Symbia T16 at Beijing Hospital.

Making a Difference
Beijing Hospital requires excellence. Symbia T16 demonstrated that quality, when assessing a thyroid nodule initially found with ultrasound in a female patient. The initial biopsy indicated Hashimoto’s thyroiditis, an autoimmune disease that can lead to primary hypothyroidism. But drug therapy had no effect. Then new symptoms, including abdominal pain, thirst and nocturia appeared. The doctors ordered a SPECT/CT exam.

“Diagnostic fusion images clearly showed localized high-uptake,” Yao recalled. “Our diagnosis was moderately differentiated parathyroid carcinoma.” The diagnosis, confirmed by biopsy soon after the SPECT/CT, radically changed the management of the patient.

Symbia T16 offers the industry’s highest*** sensitivity, as measured using standards developed by the National Electrical Manufacturers Association (NEMA). This sensitivity is further amplified by Siemens’ IQ•SPECT.

This proprietary technology, designed specifically for cardiac imaging, is comprised of specially designed collimators, cardio-centric data acquisition and advanced reconstruction algorithms. Its SMARTZOOM collimators combine the best features of cone-beam and parallel-hole collimators, magnifying counts near the cen-
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