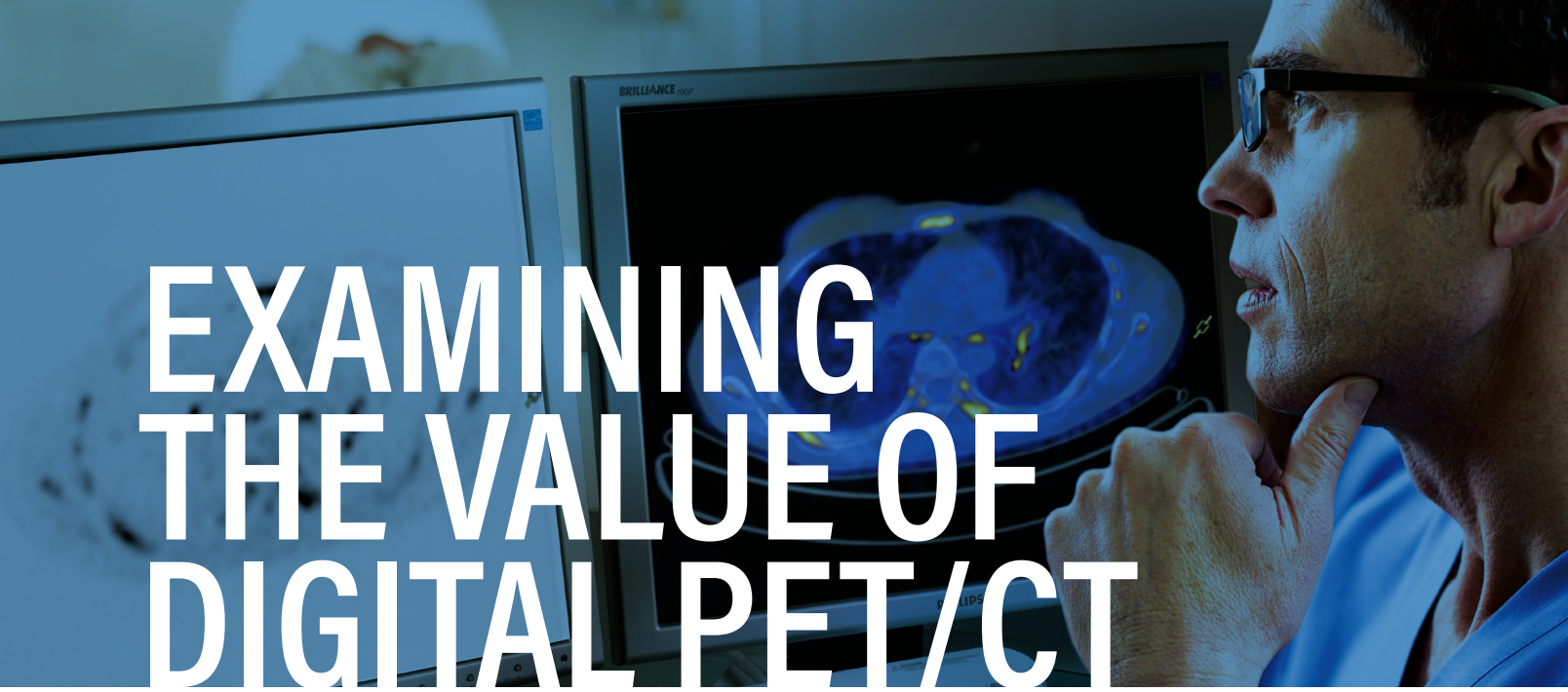


EXAMINING THE VALUE OF DIGITAL PET/CT

The Changing PET/CT Landscape

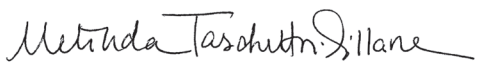
Melinda Taschetta-Millane
Editorial Director

Positron emission tomography/computed tomography (PET/CT) can be a valuable diagnostic and prognostic tool in the assessment of patient response to therapy and cancer recurrence. It can ultimately even impact the choice of therapy. The significance of this hybrid imaging modality has great potential to flourish in future years.

In 2017, the number of clinical PET and PET/CT scans performed in the U.S. was estimated at 1.9 million, a net increase of about 13 percent over 2015, according to the IMV 2018 PET Imaging Market Summary Report. These scans were performed at about 2,400 sites using fixed or mobile PET, PET/CT or PET/MR scanners. This device market accounted for $1.5 million in 2016, and is estimated to reach $2.1 million by 2023, growing at a CAGR of 5 percent during the analysis period of 2017-2023, according to Allied Market Research data.

Undoubtedly technological advancements including the time of flight (TOF) and rise in popularity of hybrid imaging systems play an important role in this market's growth. And, hybrid imaging, using combined scanners such as PET, offers a promising outlook for nuclear medicine. The advancements in various approaches for PET are expected to strengthen the personalized medicine industry, and continued growth is anticipated in the global market.

Efficiency and effectiveness go hand-in-hand in clinical medicine, and digital PET addresses them both. This supplement, written by industry consultant Greg Freiherr, will take a close look at the significance of this hybrid imaging modality and discuss how precision can have an enormous impact on patients. From diagnosis to patient monitoring (see "How Digital PET/CT Can Improve Clinical Care"), from the selection of therapy to its assessment (see "Digital PET Balances Scan Time and Resolution"), a digital detector built into PET/CT systems can help make positron imaging more precise (see "What Precision Means to PET"). And finally, Greg will discuss how the industry is working to push molecular imaging forward in "Digital Technology Pushes PET In New and Old Directions."



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Editorial Director

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How Digital PET/CT Can Improve Clinical Care

By Greg Freiherr

PET/CT can be indispensible as a diagnostic and prognostic tool; in the assessment of patient response to therapy and cancer recurrence; even in the choice of therapy. And the significance of this hybrid imaging modality could grow in future years.

Digitalization is increasing the medical value of PET/CT, according to Brian Gordon, M.D., who interprets the majority of digital PET/CTs performed at the WellStar Kennestone Cancer Center in Marietta, Ga.

"An improved patient experience is the major advantage of digital PET/CT," said Gordon, head of Nuclear Medicine for Quantum Radiology, a subspecialty radiology group that interprets images for the sprawling WellStar Health System.

The digital detector built into the Vereos PET/CT from Philips Healthcare improves sensitivity and, consequently, the detectability of small lesions. And it does so while reducing scan time.

"We have seen a significant decrease in scan time," he said. "About a third of the scan time has been removed."

PATIENT FIRST

The result is an enhanced patient experience, according to Gordon. The Vereos replaced an analog PET/CT at the WellStar Kennestone Cancer Center in November 2017. Since then, PET/CT scan volume has reached as high as 18 patients per day.

Despite the high throughput, which ranges from this peak to about a dozen scans per day, scan accuracy is excellent, he said.

The WellStar Kennestone Cancer Center is one of the busiest PET/CT providers in the state of Georgia, he said. The digital detector has dropped scan times for whole body exams from 50 to 30 minutes and ones from the base of the skull to mid-thigh from 30 to 20 minutes.

The vast majority of scans at the center are oncologic. Many are ordered to evaluate suspicious lesions that were spotted initially on CTs or MRIs, but Vereos is also used extensively to monitor patient response to cancer therapy and to look for cancer recurrence.

> **"AN IMPROVED PATIENT EXPERIENCE IS THE MAJOR ADVANTAGE OF DIGITAL PET/CT"**
>
> Brian Gordon, M.D.
> WellStar Kennestone Cancer Center
> Marietta, Ga.

Although shorter scan times have boosted throughput at the cancer center and improved the patient experience, accuracy is the top priority, Gordon said. The increased sensitivity of the digital detector improves image quality, while short scan times make the patient more comfortable and less prone to movement. This reduces the likelihood of motion artifacts that can degrade images.

The short scans do not reduce image quality, Gordon emphasized. On the contrary, compared with analog PET/CT that operated before Vereos, he said, "we are able to detect activity in smaller lesions."

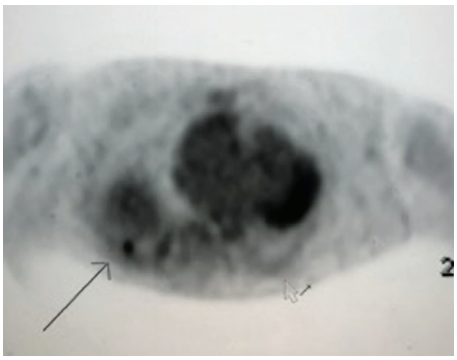
The ability to detect very small lesions is critically important when PET/CT is applied in staging or monitoring. This is where the digital detector excels, according to Philips' director of Clinical Science for Nuclear Medicine Piotr Maniawski.

"Digital technology allows us to improve small lesion detectability," said Maniawski, who has worked in nuclear medicine for more than three decades.

TRANSITION TO DIGITAL

The difference digitalization can make is apparent during tumor boards at the WellStar Kennestone Cancer Center. Vereos delivers digital PET images, which can be fused with ones from CT, Gordon said. These colorized, fused images "improve the discussion because the clinicians can see what I am talking about," he said.

Clear communication is especially important when planning patient management in tough cases, when therapy choices are not straightforward, he said, as exemplified when deciding whether a lesion may be resectable or if radiation or chemotherapy should be administered first. "If you can localize exactly where (the lesion) is, you can make better decisions," Gordon said.



Digital PET/CT, achieved using Vereos from Philips Healthcare, can spot even a small lesion (arrow). Image courtesy of Brian Gordon, M.D.

The clinical prospects of PET/CT are derived from the relative certainty possible with the digital detector, Maniawski said. But academic science advances cautiously.

Several collaborative projects between Philips and academic centers are underway using Vereos "to deliver clinical proof not only for competitive differentiation (digital versus analog) but also to push molecular imaging forward," he said.

*Disclaimer: Results from case studies are not predictive of results in other case studies. Results in other case studies may vary.

TO READ THE FULL ARTICLE, VISIT WWW.ITNONLINE.COM/DIGITALPETCT1

Digital PET Balances Scan Time and Resolution

By Greg Freiherr

Efficiency and effectiveness are inseparable in clinical medicine. Digital PET addresses them both. The key is the detector built into Philips Healthcare's digital Vereos PET/CT.

Because photons generated during a PET exam are counted individually, digital detectors can record more such events per second than analog ones.

The University of Vermont Medical Center (UVMC) often leverages this on its Vereos to produce images with very high quality. Alternatively, UVMC uses Vereos to shorten scan time while still producing diagnostic quality images.

"When there is a big leap in sensitivity like you see from analog to digital, you have to look at what you are going to do with it," said Jay Kikut, M.D., director of nuclear medicine and PET/CT at the UVMC. "For oncology patients, our decision is clear — we want to use it for improved image quality."

This is paramount when clinicians use Vereos to make diagnoses and stage cancer patients. "Vereos provides us very accurate staging of our patients," he said. "To have the best outcome, you have to match the treatments to the stage." Exactly staging patients leads to a more individualized choice of therapy.

Oncological applications account for about 80 percent of PET scans done at UVMC. (The remaining 20 percent of PET/CTs examine the heart or brain.)

When set to deliver maximum spatial resolution, the increased sensitivity achieved through digital PET is used to detect very small lesions. Alternatively, some patients at UVMC are best served by scans that minimize time spent inside the PET/CT bore. Such shorter exams might be chosen for children or patients who are uncomfortable in tight spaces to minimize the movement that can cause image artifacts.

Although the scans may be substantially shorter — five or even three minutes versus the 15 needed with an analog detector — Vereos' PET acquisitions can still deliver high diagnostic quality, he said.

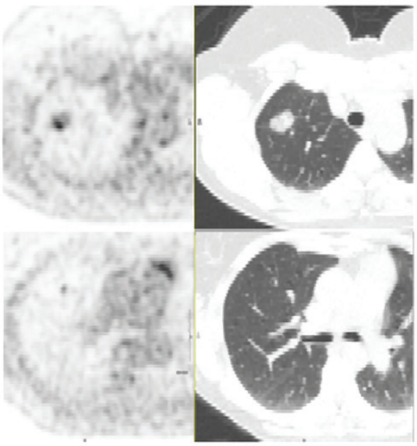
Development of the Digital Photon Counting (DPC) technology, which serves as Vereos' backbone, is the latest pivotal moment in the history of PET/CT, according to Dhruv Mehta, a senior product manager at Philips Healthcare. The first occurred some 20 years ago with the hybridization of PET with CT. The second was the development of time of flight (introduced first-to-market by Philips Healthcare), which helps localize lesions and improves signal-to-noise. Fully digital PET with DPC technology is the latest advancement affecting this hybrid, Mehta said.

"It is really the next generation of PET/CT," he said.

The difference between digital and analog PET is akin to the difference between projection and LCD televisions. The digital architecture of LCD TVs, he said, delivers a sharper image, higher efficiency and more dynamic range. Digital PET does much the same in molecular imaging. This linkage between image quality and dynamic range is important, Mehta said, when trying to go beyond the current FDG-based oncology applications into emerging applications in neurology and cardiology and emerging tracers.

"With a shorter acquisition, the patient is less likely to move," he said. "The clinical benefit is that you have a better study with less motion. As a result, you can visualize lesions better."

Mehta cautions that many factors beyond the scanner may affect throughput at a facility. Chief among them are ones related to patient management. Cutting scan time to under five minutes, however, "is a substantial improvement."



Staging F18FDG PET/CT images of adenocarcinoma in the RUL (right upper lobe) of the lung illustrates the value of Vereos. The primary lesion in the right upper lobe appears in the upper row (PET image is left, CT image is right). A 3 mm synchronous primary or metastatic lesion in the RUL is apparent in the lower row. The precision afforded by Vereos' images provided the basis for the patient to undergo RUL lobectomy instead of thermal ablation of the primary lesion. Image courtesy of Jay Kikut, M.D., and UVMC.

Very relevant when making purchasing decisions, he said, is the increased precision that digital PET offers and the hedge that Vereos provides against obsolescence. At present, PET is one of the few commercial modalities with high-end systems that are still analog, he said. That, however, could change.

"We envision a time in the future when all PET/CT is digital," Mehta said.

TO READ THE FULL ARTICLE, VISIT WWW.ITNONLINE.COM/DIGITALPETCT2

What Precision Means To PET

By Greg Freiherr

Precision can have an enormous impact on patients.

From diagnosis to patient monitoring, from the selection of therapy to its assessment, the digital detector built into Philips Vereos PET/CT makes positron imaging precise.

The digital detector, and the Vereos digital architecture, are a big part of the scanner's efficiency, said Tom Brennan, service leader of imaging for Nebraska Methodist Health Systems in Omaha. Staff at its Methodist Hospital in midtown Omaha use Vereos PET/CT to do seven PET scans a day — and about 20 CTs. Slots for PET patients are scheduled in pairs. In between, Vereos' 64-slice CT handles patients who can't be seen on the three CT scanners on the main campus or a fourth at a neighboring hospital in the network.

The need to do double duty on the hybrid scanner is why speed was a big factor in the choice of Vereos, said Brennan: "Because we share the system with CT, we have a lot of patients who want to get in, so we have to use (Vereos) efficiently."

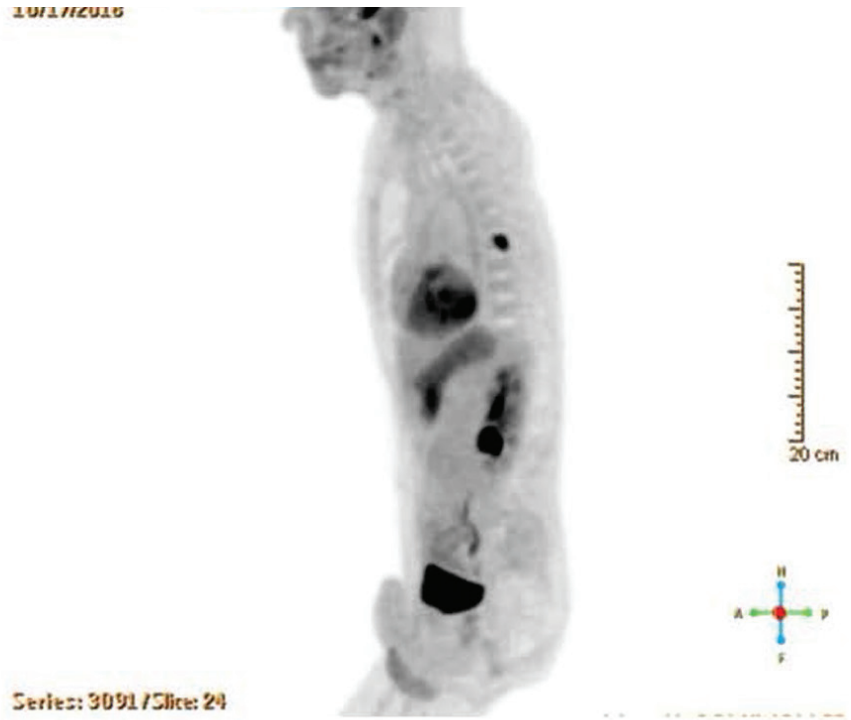
Because Vereos includes a 64-slice Ingenuity CT from Philips, "anything you can do with an Ingenuity CT you can do with the Vereos CT," said Karim Boussebaa, Philips' business leader for CT/Advanced Molecular Imaging.

EFFICIENCY

Vereos was chosen by Methodist Hospital to replace an aging analog system, one that also handled overflow CT scans "but didn't do nearly as well," Brennan said. The analog system "was much slower and less reliable."

Brennan credits the digital architecture of Vereos for making "it a more reliable system."

The vast majority of PET scans are oncologic,



PET images taken on Philips' Vereos PET/CT at Methodist Hospital in Omaha, Neb., show a lung lesion. **Caveat:** Because results may vary, "results from case studies are not predictive of results in other cases," Philips cautioned. Image courtesy of Omaha's Methodist Hospital, Nebraska.

> “THE SPEED OF VEREOS HAS HELPED US BECOME BETTER AT GETTING PATIENTS IN ON TIME”
>
> Tom Brennan, Nebraska Methodist Health Systems, Omaha

according to Brennan, who explains that the main campus hosts a major cancer center. Fluorine-18 deoxyglucose (FDG) is the radiotracer of choice, although gallium 68 is occasionally applied to visualize neuroendocrine tumors and yttrium-90 is used to treat and visualize liver metastases. The staff sometimes — but rarely — performs a myocardial viability study, Brennan noted.

Vereos' digital technology can be leveraged to reduce radiopharmaceutical dosing. At Methodist Hospital in Omaha, staff inject lower doses of PET radiopharmaceuticals than when they used Vereos' analog predecessor. Doses of FDG now are typically 30 percent lower than ones administered to patients before the hospital switched from an analog PET/CT to Vereos in early summer, according to Brennan. This has allowed the hospital to take advantage of the lower pricing tier of FDG that is available to Methodist Hospital.

"We went from a weight-based dosing system to one of standardized doses of just 12 mCi," Brennan said. "What that did for us is drop all of our doses into that lower price tier, which saves us about $25,000 per year."

High efficiency is possible with no compromise in image quality because of the one-to-one coupling between sensor and scintillation event. "Each of the 23,000 detectors has its own little counting chip, which I think leads to the amazing spatial resolution," Brennan said. "That goes back to the heart of why it is fast and why the image quality is so good."

At Omaha's Methodist Hospital, PET scan times have dropped from 24 to 12 minutes on the Vereos compared to the preceding analog system, according to Brennan. Patient slots have been reduced from 45 to 30 minutes. This has resulted in greater availability of PET and CT exams.

The increased efficiency achieved with Vereos means Methodist Hospital patients not only spend less time being scanned but less time waiting for appointments. This is important because "three out of our four patients are return patients. Vereos is the preferred tool to measure how treatments are going," Brennan said.

Staying on schedule is very important for these patients, he said, because they typically depend on having results from multiple tests available at the same time. "Access is important. The speed of Vereos has helped us become better at getting patients in on time," he said.

EXTENDING PATIENT COMFORT

Patient comfort depends on feeling good. And Philips' Ambient Experience directly addresses this in several modalities including CT and PET. "Ambient has shown some good results for reducing the level of stress," said Philips executive Boussebaa. "It can really make a difference with kids."

A mix of lighting and sound — movies projected on walls, for example — might combine to reduce stress, he said. These combinations can increase patient satisfaction, which has become a major survey item for hospitals.

Greater patient comfort can make patients easier to manage, which can make technologists' jobs easier. In this way, Philips' Ambient Experience improves working conditions for hospital staff.

"The question is how to make people happy," he said. "If you do that, patients will come back and staff will stay."

According to Boussebaa, health care administrators are coming to realize that patient comfort has a role in being efficient and effective.

With its emphasis on precision, Vereos addresses patient comfort, the components of value-based medicine — and the future.

TO READ THE FULL ARTICLE, VISIT WWW.ITNONLINE.COM/DIGITALPETCT3

Digital Technology Pushes PET In New and Old Directions

By Greg Freiherr

Digital technology is opening remarkable opportunities for clinical positron emission tomography (PET) about which research is only beginning to hint.

"Twenty years ago we were excited that we could see a lesion. Now we want to understand its underlying biologic heterogeneity," said Michael Knopp, M.D., a radiology professor at Ohio State University whose research with Philips' digital PET/CT, called Vereos, is exploring applications within and beyond traditional clinical areas.

The digital technology underlying Vereos can provide the details that may escape analog systems, said Piotr Maniawski, director of clinical science for nuclear medicine at Philips Healthcare. Visualization using 4 mm cubes, which are typically delivered by analog systems, makes small lesions look spherical, he said. The very small voxels in digital images better visualize shapes and texture.

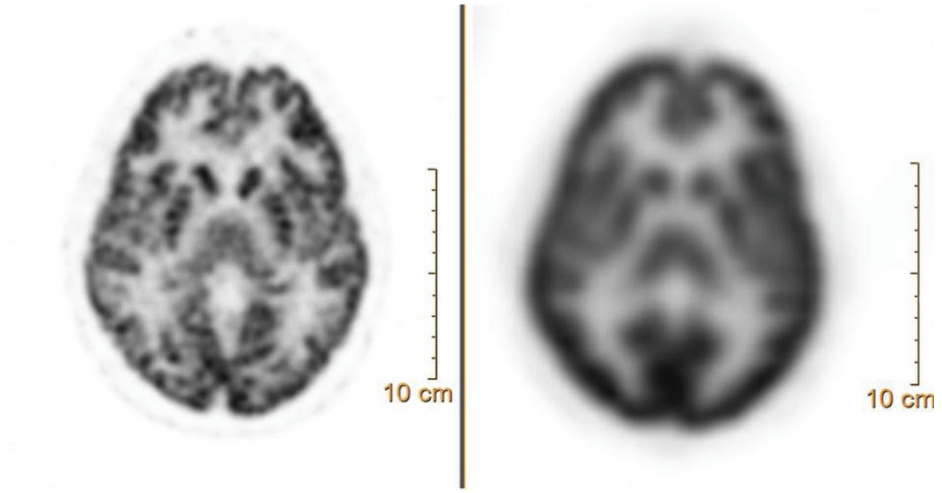
"Seeing if the texture is changing helps characterize the lesion," said Maniawski. The metabolism inside the lesion, he said, may be much different, depending on the location.

In a paper published May 2017 in the journal *Contrast Media and Molecular Imaging*, Knopp, who is the Novartis chair of Imaging Research at Ohio State University, and colleagues at Ohio State summarized how digital PET enables advanced functional tumor imaging.

A DIGITAL TWIST

Much like how radiography began, PET started as an analog modality. Instead of film, PET relied on photomultiplier tubes (PMTs). In analog systems, light generated by a single scintillating crystal is channeled to multiple PMTs. In Vereos, light generated by a single scintillating crystal is channeled to its own detector.

Vereos' digital detection is built on digital photon counting (DPC) technology, whereby crystals and sensors are coupled "one-to-



A 90-second brain acquisition with FDG radiotracer — comparison of digital (Vereos, left, 1 mm) and conventional (Gemini TF, 4 mm) images.

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one," said Maniawski, who has worked with Knopp and others to assess the clinical capabilities conferred by Vereos' digital technology. Light flashes produced by specific crystals are channeled directly to individual digital sensors. In stark contrast to analog technology, which accumulates signals from light flashes in analog detectors until reaching trigger points, "there is no light sharing," Maniawski said. "The moment the detector registers this light, we know precisely which crystal produced it."

Reconstruction algorithms onboard Vereos mathematically reconstruct digital PET into detailed images. These appear "more rich and precise" than those made using analog-based PET systems, Knopp said, due to the increased density of the data. The OSU researcher likened the benefit of data density to the improvement of smartphone images as those pictures gain more data density.

"When you pull up Google maps, the picture might look fuzzy at first and then as the data come in, it will look sharp and brilliant," Knopp said. "This happens because the data density changes."

Maniawski explained that voxels in Vereos images are densified with data collected by the 23,000 solid-state sensors from individual scintillation events. This added data density allows Vereos to package data into voxel volumes of 2 mm — or even 1 mm — cubes. This data density gives shape and texture to structures in the images.

BRINGING TOGETHER OLD AND NEW

The game-changing appearance of Vereos' images can be challenging, Knopp noted.

Because digital images show more detail, they may show lesions and features that might not be seen with analog technology. When comparing current digital images to past analog ones, the question arises: Were lesions now visible not seen previously because the technology could not see them? Or have they just recently occurred?

The answers to these questions can directly impact the management of patients being monitored for disease recurrence.

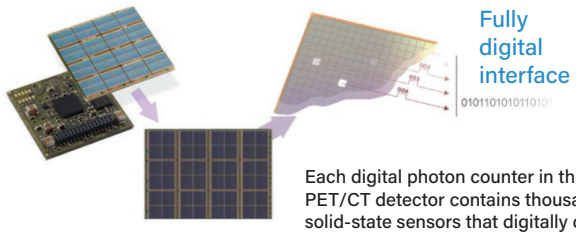
To deal with this incompatibility, Philips offers a feature in Vereos that reconstructs digital data as if they were acquired on an analog system. This is done with reconstruction algorithms, Maniawski said. These algorithms harmonize the digital data.

Vereos users who choose this option "end up with two images from the same data — a conventional looking image and a digital one," Maniawski said.

Vereos can create a still picture and visualize changes over time. In the mid- to late-1980s, early developers of PET often acquired data dynamically. Serial acquisitions came into vogue when PET/CT imaging entered the mainstream. But dynamic imaging, similar to short video clips, can provide clinical information not found in static images.

TO READ THE FULL ARTICLE, VISIT WWW.ITNONLINE.COM/DIGITALPETCT4

Why—And How—Digital PET Is Better Than Analog



Each digital photon counter in the Vereos PET/CT detector contains thousands of solid-state sensors that digitally count individual photons.

Analog is approximate. Digital is specific. Therein lies the fundamental difference between digital PET and its analog cousin.

We see this difference every day in clocks, one displaying numbers, the other telling time with big and little hands. Digital and analog versions of PET are like that, but much more sophisticated, according to Michael A. Miller, Ph.D., a physicist at Philips Healthcare.

The digital photon counting detector, which is the backbone of Philips' Vereos PET/CT, uses solid-state sensors to count the individual scintillation photons created during a PET scan. Analog PET detectors cannot count individual photons. Instead these detectors, which are built into the vast majority of installed PET/CTs, record flashes of light.

If lettuce farmers used similar technologies, their digital detectors would count the leaves of lettuce. Analog detectors would count the heads. When applied to clinical medicine, exactness translates into options, said Miller, who specializes in CT and advanced molecular imaging.

Vereos can be used to increase the quality of patient images compared to those obtained with analog PET/CT, making lesions easier to detect. Alternatively, the digital PET/CT might maintain image quality achieved over a substantially reduced scan time, as low as one-third or less of the typical 10 to 15 minutes. Or, physicians might choose a third option: to maintain image quality and scan time but reduce the dose of radiopharmaceutical injected into the patient.

"The detector allows us to get better data and do better corrections," Miller said. This, in turn, creates higher quality images.

HOW PET WORKS

Regardless of whether the detector is digital or analog, PET imaging operates on the same principles. Positrons released by a radiopharmaceutical injected into a patient create high-energy photons. When these photons crash into scintillation crystals in the detector, they are converted into optical ones. This is where the type of detector matters.

The digital detector in Vereos counts optical photons individually. "With one-to-one coupling between the scintillation crystals and the digital sensors, there are many channels, each with a relatively low count rate. So we end up with good count rate performance," Miller explained.

The resulting accuracy supports enhanced performance in time of flight (TOF) calculations, Miller said. These, as the name implies, reflect the millionths of a second in which the high-energy photons are in flight and provide the basis for determining the locations of the radiopharmaceutical in the patient's body. Consequently, Vereos excels at helping physicians detect cancer, which typically involves the radiotracer, fluorodeoxyglucose (F-18 FDG).

PET/CT HISTORY

PET itself goes back to the early 1970s, when photomultiplier tubes were used to record scintillation flashes. Today many installed PET/CTs rely on this inherently analog technology.

By contrast, Vereos uses digital technology. Data for its PET images are obtained from solid-state silicon tiles, which are arranged in a many-sided polygon that encircles the patient. Light sensors and data processing arrays are hardwired into these tiles. Putting them together makes photon counting fast, accurate and free from the electronic noise produced in analog systems.

"Vereos achieves high imaging performance, which supports clinical needs and is facilitated by (digital) technologies," said Miller, who puts Vereos at the apex of the PET/CT hierarchy. "It really gives people what they're looking for when they want it — without any questions."

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