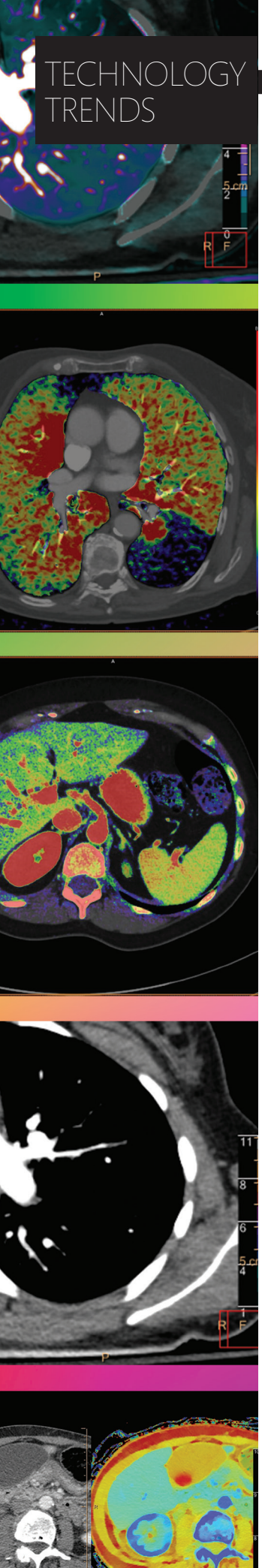

Spectral energy is redefining CT imaging

Mary Beth Massat

Computed tomography (CT) has undergone several transformations throughout its history of 40-plus years, from the introduction of the helical (spiral) CT to the development of the multi-detector row, to today's emerging dual energy, or spectral, CT.

While different manufacturers use different names—dual-energy, spectral CT and spectral imaging—and different underlying technologies, the latest iteration's purpose is inherently similar: simultaneously using two different energy settings to capture images that enable radiologists to differentiate tissues and pathologies based on their energy-related attenuation characteristics, or materials density. The data can be processed to create virtual unenhanced images and enhanced material density images, such as with iodinated contrast material. (For the purposes of this article, we will use spectral CT to describe all technologies.)

"You have to consider spectral energy as CT-plus," says Dushyant V. Sahani, MD, Director of CT at Massachusetts General Hospital (MGH) and Associate Professor of Radiology at Harvard University. "As the technology improved and we gained more experience, we could see the potential of spectral imaging to impact patient care and improve diagnostic performance of CT. We gradually increased our experience with both clinical exams and research. Currently we have several more (spectral) scanners, and it has become almost a standard of care."

MGH utilizes GSI Xtream on Revolution CT (GE Healthcare) where spectral imaging demonstrates clear clinical benefits: in oncology for tumor assessment and staging, in vascular imaging to optimize contrast and for tissue characterization. Tissue characterization utilizing CT is based on several features, including lesion enhancement, patterns of enhancement, lesion outline and/or the presence of calcium or fat within the lesion.

"The images from spectral CT can be interrogated to yield the desired tissue information more reliably from limited scan acquisition data," Dr. Sahani explains. "Therefore, for incidental findings, both detection and characterization can be concurrently performed with dual energy CT, often eliminating the need for a repeat exam. This benefit alone can efficiently facilitate patient care and also potentially reduce healthcare cost as well as patient anxiety and morbidity."

While Dr. Sahani believes conventional CT has performed exceedingly well in facilitating clinical decision-making, particularly in the ER, the image quality is often impacted by the scan acquisition protocol selected. Often,

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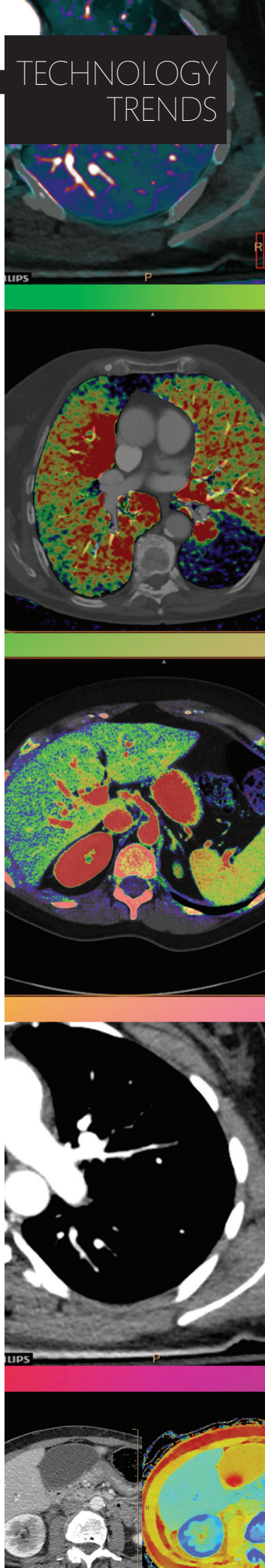


> ***"You have to consider spectral energy as CT-plus."***
>
> *Dushyant V. Sahani, MD, Director of CT, Massachusetts General Hospital, Boston, MA.*

CT protocols dictate multiple scan acquisition phases and more tailored contrast media use. Spectral CT can "overcome some of these barriers, as the images can be processed and interrogated to extract more information from a single scan acquisition phase. Basically, one can use the technology to fill those gaps in the image protocol and make it easier to diagnose problems," he says.

At Hennepin Healthcare in Minneapolis, Radiologist Gopal Punjabi, MD, who is also an Assistant Professor of Radiology at the University of Minnesota, routinely uses spectral CT for tissue characterization in emergency cases. The hospital installed its first IQon Spectral CT (Philips Healthcare) in 2016 in the emergency department (ED) and has recently installed its second IQon Spectral CT in the outpatient center. Dr. Punjabi finds it interesting that, in many instances, clinicians are specifically requesting spectral imaging in their orders.

"What I really like is that spectral energy saves me time in many ways," he says.

For example, in cases of suspected acute pulmonary embolism (PE), he first looks at the iodine map. If there is no perfusion defect, then the likelihood of the patient having a PE is extremely low. Similarly, he no longer measures kidney cysts or their attenuation value. He explains that with conventional CT in a typical practice, the radiologist would ensure the lesions were not more than 15 or 20 Hounsfield units (HU) and then they would measure the size of the lesions. Rather, with spectral CT, Dr. Punjabi will scroll through the linked iodine images and if there is no uptake he can confidently report the lesions are benign cysts.

Spectral CT can help decrease contrast load in patients with poor renal function. Dr. Punjabi will dilute 20 ml of contrast with normal saline for a CT angiogram and reconstruct the images at a lower kV energy level, which can salvage the angiography appearance and provide images that are adequate for interpretation. "On the lower keV images, iodine really stands out," he explains.

"Spectral CT allows you to see things you may not have expected to see. On conventional CT, we miss 30-40% of gallstones, which are isodense to bile," Dr. Punjabi says. "With spectral CT, we can see the gallstones because they have a different, effective anatomic number than bile—so they just pop out.

Other difficult-to-interpret areas include pancreatic necrosis and bowel ischemia. By utilizing spectral CT, Dr. Punjabi can clearly see if there is no perfusion in the bowel and alert the surgeon that the patient urgently needs surgery.

Adds Dr. Punjabi, "The technology is rapidly evolving; every day we discover new ways in which spectral CT can be used to help our colleagues and our patients. The technology is rapidly evolving; I am very excited about photon counting detectors in particular. With its vast troves of data, I predict spectral CT will be core to the exciting intersection of radiomics, AI, and personalized medicine."

Impact on workflow, protocols and dose

As with many disruptive technologies, the addition of spectral CT can impact workflow. According to Dr. Sahani, some of the key challenges include: the inclusion of protocols for both conventional (single) and spectral energy imaging; greater demands on processing power and speed with larger file sizes; and additional image series for radiologists to review for interpretation.

"These challenges can be overcome by tweaking your current workflow," says Dr.

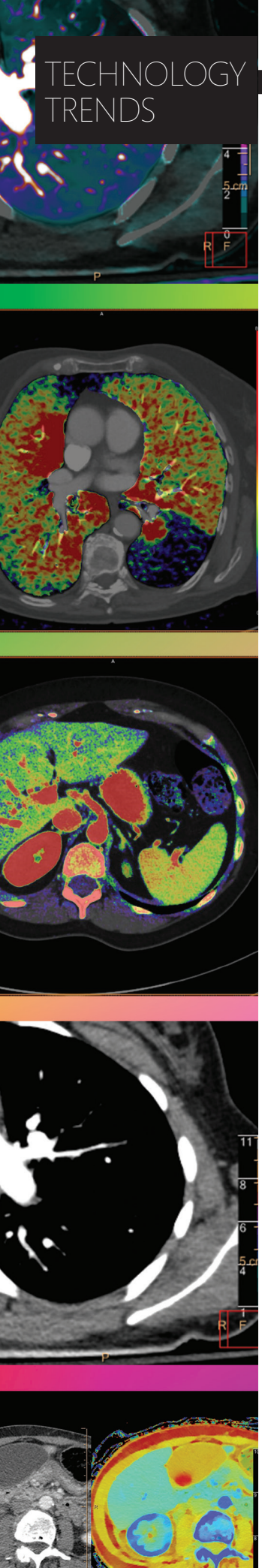


Table 1. List of systems that are spectral CT or dual energy capable, by manufacturer.

Canon Medical Systems USA
Aquilion ONE GENESIS 320
Aquilion ONE GENESIS 640
Aquilion ONE GENESIS Edition
Aquilion Prime SP
Aquilion PRIME
Aquilion Lightning
GE Healthcare
GSI Pro on Revolution Frontier
GSI Xtream on Revolution CT
GSI on Revolution HD
Philips
IQon Elite Spectral CT
IQon Spectral CT
iCT (dual energy, not spectral)
Ingenuity (dual energy, not spectral)
Siemens Healthineers
•SOMATOM Force
•SOMATOM Drive
•SOMATOM Edge Plus
•SOMATOM Definition Edge
•SOMATOM go.Top

Sahani. "There's definitely a learning curve, but things will get better."

He suggests appropriately protocoling exams so the technologist can prospectively prescribe a spectral energy acquisition. While continued advancements in computational power has helped address image processing needs for spectral CT, the data do take a few minutes longer to process than a single energy CT exam; therefore, Dr. Sahani suggests that departments consider scanner availability when scheduling patients for spectral CT exams.

For protocol development, Dr. Sahani also recommends starting with common exam types that will be impacted by spectral CT. At MGH, they started with protocols that had the "biggest bang for the buck, such as indications for tissue characterization, oncology-specific exams, and vascular imaging. We started slow and built our experience on those indications and gradually added more exam types. At the inception, our aim was to keep dual energy desirable but not mandatory," he explains.

As more spectral CT scanners were added in the department and imaging processing and workflow improved, MGH gradually added other protocols, such as ultra-low iodine dose CT angiography exams in patients with compromised renal function and pediatrics.

"One advantage of a dual-layer detector is that you can treat it like a conventional, single energy CT," Dr. Punjabi adds. "So, we were able to take our existing protocols and start doing spectral energy imaging from day one. Moreover, because the IQon's platform is detector based, we can also retrospectively process spectral images."

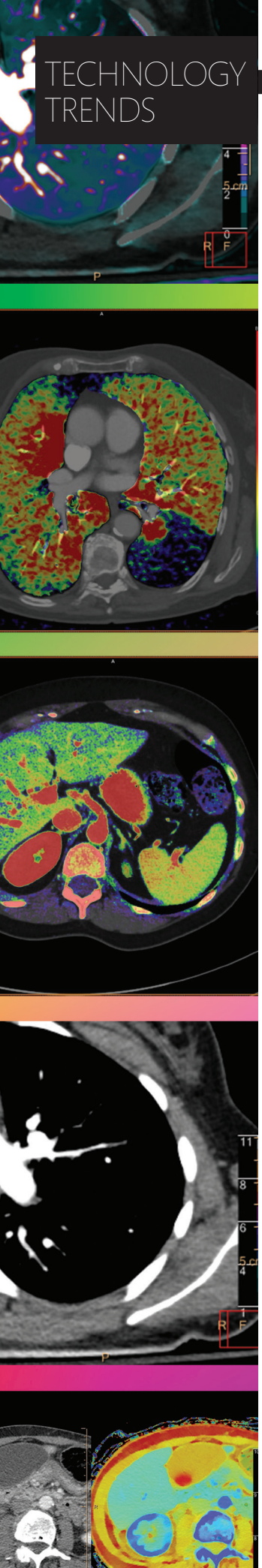
The clinical implementation team at Hennepin also focused on automating the protocols at the technologist's level and ensured that selected spectral reconstructions (virtual non-contrast, iodine map and low energy images) would be sent to PACS. This approach has enabled the majority of spectral CT interpretations to be conducted at a PACS workstation. Any image overlay or multi-planar reconstructions need to be processed at a dedicated thin-client workstation.

Dr. Punjabi says one advantage of utilizing existing CT protocols and adapting to spectral CT is that many already incorporate dose reductions. That was the case at Hennepin; as a result, spectral CT is a dose-neutral exam compared to conventional CT. The noncontrast phase of some protocols can be eliminated with spectral CT and the need for repeat exams is reduced.

"At Hennepin," says Dr. Punjabi, "we're focused on getting the right information the first time around, and so far, with spectral CT, that has been our experience."

Reducing repeat, or additional exams, is a key benefit of spectral CT, adds Dr. Sahani. "In general, the dose from a dual energy scan is lower than ACR guidelines. However, for more complex, multi-phase exam protocols, like oncology or vascular imaging, dual energy CT has the potential to eliminate a few exam acquisition phases, therefore, lowering radiation dose and offering more information."

Acquiring more information is particularly important in oncology cases, he says. Dual energy can help deliver a more reliable, efficient diagnosis and staging of cancer—providing patient benefits that outweigh concerns of radiation dose. Additionally, most dual energy scanners are premium scanners, and therefore have the capability to significantly reduce dose.



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> *Gopal Punjabi, MD, radiologist, Hennepin Healthcare, Minneapolis, MN*

Strong demand for automation and workflow enhancements

Market demand for spectral imaging remains strong at academic centers, with additional growth projected at the community hospital level. According to Maarten Leertouwer, Head of Customer Service, Computed Tomography and Nuclear Medicine, Philips, nearly half of the company's installed base are at academic medical centers, with the majority of the remaining installed at community hospitals.

Siemens Healthineers' Matthew Dedman, Marketing Director of the Computed Tomography Business, has witnessed tremendous growth in ED and trauma departments over the last two years. "In academic and large hospitals, there is typically a dedicated CT system in the ED and trauma departments. In that segment, we see dual energy becoming a standard of care right now, with nearly 100% adoption by our customers."

Most buyers in the premium CT segment are asking for spectral CT capabilities, says Tim Nicholson, Senior Manager of Marketing Development for CT at Canon Medical Systems USA. "These premium CT customers want to do everything today and be ready for future applications."

Nicholson also explains that in the buying cycle, many C-suite and IDN executives are asking Canon to consult on which technology best fits a certain type of facility—such as tertiary or community hospitals and outpatient or cancer care centers.

According to Sonia Sahney, Premium Global CT Product Manager at GE Healthcare, approximately 30% of new CT scanners sold in the U.S. in 2017 were dual or spectral capable. "We see a growth in dual energy/spectral CT in community hospitals for oncology follow-up," she explains. "As sites think about their next CT, they want to stay on the cutting edge for the next 10-12 years—spectral CT is a growing trend that can keep them current."

There are three different commercially available approaches for spectral, or dual, energy CT systems: single-source with fast kV switching, dual-source dual-energy and layered detector technology.

"There are advantages and disadvantages for all, but the data and the information obtained from the different approaches is the same," says Nicholson.

Yet, Dedman says that with dual-source spectral CT systems, the two tubes essentially "double the power," making it possible to image bariatric patients weighing up to and possibly beyond 400 lbs.

Another benefit of spectral CT, Dedman adds, is the simultaneous acquisition of images at two different energy levels—one high and one low. "This allows for the greatest separation of the energy spectra between high and low. It is important to have as much differentiation as possible for contrasting views of the patient anatomy."

Workflow, however, has been the limiting factor for continued clinical adoption and is an area that all manufacturers are working to improve. Says Dedman, "With a workflow that enables more information to be sent to PACS automatically, we will see greater adoption of the technology."

Canon has also focused on automation in image processing. Recent software improvements, Nicholson says, enable the customer within an exam protocol to automatically process the images for review and send to PACS.

He adds that on the company's Aquilion ONE GENESIS platform, users can perform "volumetric dual energy with the kV switching and no table movement. If anatomy lies beyond that, they have an option for helical dual energy that scans beyond 16 cm, also with kV switching. So, it gives the customer, depending on the clinical task, the ability to select the protocol based on the patient and required coverage."

Philips provides what Leertouwer says is, "on-demand, real-time, and simultaneous analysis of multiple spectral results with Spectral Magic Glass. With the Spectral Detector-based IQon Spectral CT, every scan is spectral. Clinicians can interpret the conventional grey-scale anatomical images, and to improve their diagnostic confidence, can access the spectral information that was acquired during the same scan. The IQon Spectral CT system's retrospective on-demand data analysis allows clinicians to easily experience the benefits of spectral CT routinely within traditional radiology workflows."

With customers saying that a smooth and efficient workflow is the most important consideration, GE has focused on improvements all the way from requisition to report, says Sahney. "The most recent iteration of Gemstone Spectral Imaging features two-times faster reconstruction speed for routine spectral CT workflow."

Gemstone Spectral Imaging (GSI) is available on all GE CT scanners with a Gemstone detector. The company's single source spectral technology captures a full 50 cm FOV, which is important for imaging bariatric patients. Assistive tools help standardize and automate protocol selection and transfer images directly to PACS. "These improvements, combined with native GSI reconstruction, deliver spectral CT workflow that's twice as fast," says Sahney.

Nicholson says that all the manufacturers are really close to making significant progress in developing more efficient and automated workflows for spectral CT. And while workflow is key to future improvements and adoption, he adds, "There will be more advancements; today we are just acquiring dual energy. There is research being done on multi-energy systems, as well."

Please visit **https://www.ctspectral.com** for Dr. Gopal Punjabi's blog on Spectral CT, where he shares interesting cases and more information, including links to peer-reviewed articles.