



Iterative Reconstruction in CT Evolves for Lower Dose, Increased Clarity

By Deborah Abrams Kaplan | October 12, 2011

Radiologists have been struggling to balance image noise with radiation dose in computed tomography (CT) scans for decades. But the competition just went up a notch (or perhaps many notches) with the recent FDA approval of GE Healthcare's Model Based Image Reconstruction (MBIR) technology, Veo. Although it takes this software longer to compute, physicians are using ultra-low radiation doses and getting images with increased clarity.

While MBIR is the most recent of the iterative reconstruction technologies, top manufacturers offer their own software answers to the noise versus dose argument. Here's a closer look at the offerings.

Iterative Reconstruction Background

First, a little background. Filtered Back Projection (FBP) technology has been around since the beginning of CT in the 70s, said Wendy Kreider, customer development manager for computed tomography at Siemens Healthcare. "It's based on back projection of attenuation line integrals from the radial views that converge on the patient." While it's robust and has a fast reconstruction speed, filters accentuate the noise in the image. "This becomes pronounced in really large patients that are dose-starved or when you're trying to intentionally lower dose, which is what we've been trying to do over the years," she said.

Filters have another problem, according to Eric Stahre, general manager of premium CT for GE Healthcare. "You're effectively losing information," he said. "You're compromising the diagnostic information." FBP takes only a single pass through the raw data, which accounts for its fast speed.

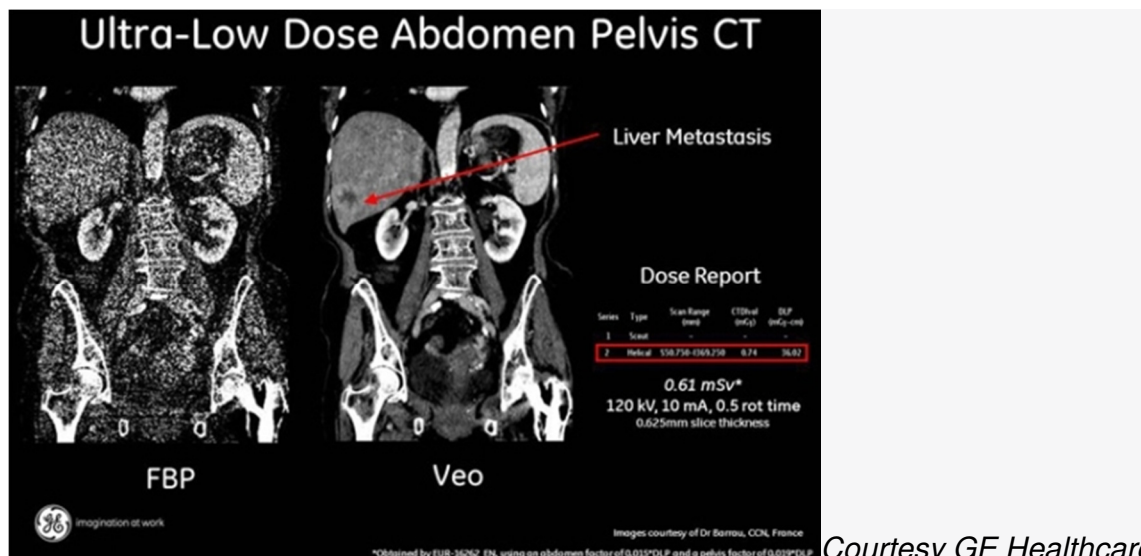
Along came iterative reconstruction algorithms, which reduce the noise and dose, while increasing the image quality. This is one form of dose reduction, but the companies all offer additional and complementary programs that further reduce radiation exposure.

With each new technology, the image has a different appearance, and some clinicians comment that iterative reconstructive images have a waxy or plastic look. “With each change, when you go from filtered back projection to iterative reconstruction, it has a different looking appearance,” said Stahre. “And to the radiologist who is trained to look at the pathology and image, it takes time to understand the different look. After a few weeks of working with the cases, they become accustomed to the new look and they don’t want to go back.”

GE: ASiR and Veo

GE introduced its Adaptive Statistical Iterative Reconstruction (ASiR) program in 2008, but Veo is the first MBIR technology, and it just received FDA clearance in September.

“Veo is a real disruptive breakthrough, first of its kind, the biggest image clarity improvement in the last 20 years in CT. It fundamentally changes how the images are produced,” said Scott Schubert, general manager for premium CT marketing for GE Healthcare. “With the Veo technology we’re introducing something that takes dose reduction technology to a higher level.”



Courtesy GE Healthcare

Schubert said the Veo is an extension of ASiR. “Veo creates an initial image and compares that back to the measure of raw data of the system,” he said. “It uses a model of the entire CT scanner: the tube, the detector, the focal spot of the tube, and the slice thickness, and iterates to create an optimized image of that patient. Through the model based iterations, it can produce the most optimum image in terms of dose and image clarity. It’s the first time it’s been able to do this at the same time, together.” He said that FBP technology has to trade off dose versus image clarity.

As for dose reduction, Stahre said that in Europe, they’re reporting body imaging doses of less than one mSv, and lung cases at the same dose levels of a chest X-ray.

Due to the Veo's longer processing time, Schubert expects ASiR to continue as their routine mainstream dose reduction technology, since it handles five to 10 cases per hour. "The computational power is significantly more demanding with Veo," he said, though it has dropped dramatically. He said that two years ago, a study would take 24 hours of mainframe-type computing power, but now it can do about two cases an hour. The technology is currently used for women of child-bearing age, pediatrics, and those scanned most frequently (e.g. cancer follow-ups), according to Stahre.

In addition to noise and dose reduction, William Shuman, MD, professor of body imaging and director of clinical radiology at University of Washington, said that there are unanticipated fringe benefits: better artifact reduction and spatial resolution. "It has a nice 3D sagittal and coronal reconstruction," he said.

Shuman said that the reconstruction time is becoming less of an issue. He said he can get pelvic and abdominal reconstructions done on the Veo in about 15 minutes, with 0.6 mSv. For ASiR and FBP, he said the dose would be 3-8 mSv. He anticipated the Veo reconstruction time dropping to around 12 minutes in the near future, making it manageable to use the program on a regular basis for his workflow. At 12 minutes, "we're in the timeframe where it won't significantly impact on our workflow, and it can potentially become a routine exam," he said.

That timeframe would be closer to keeping up with the workflow, especially if he could intermingle shorter exams on the head, with longer chest and abdominal exams. Currently CT exam turnover times are eight to 10 minutes, scanning six to eight patients an hour. He said it takes around 12 minutes to move patients in and out of the scanner, send the exam to PACS, have it show up on the work list and get the radiologist to open and start reading the images.

Currently, he bases his Veo scan decisions on dose considerations. "But with faster reconstruction, we're at the stage where we can do them all that way, and capture that low radiation dose for everybody. That's the conceptual breakthrough that occurred recently," said Shuman.

Siemens Healthcare: IRIS

Iterative Reconstruction in Image Space (IRIS) is Siemens' approach to reconstruction, approved by the FDA in 2009. "IRIS translates the iterative loop into image domain, thus avoiding the long reconstruction time," said Kreider. "The starting point of IRIS is a master volume reconstruction that optimally utilizes all measured data and provides all available detail, but at the expense of significant noise in the image." The master reconstruction cleans up the image in step-by-step iterations in the image domain, to increase speed.

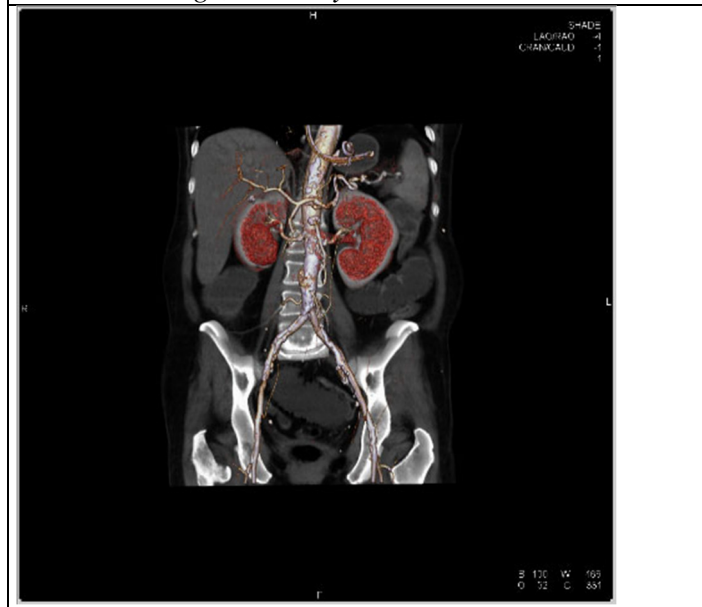
Kreider said that for iterative reconstruction technology to be clinically beneficial, it should have three qualities: noise reduction (which gives the potential for dose reduction), reconstruction time short enough for clinical routine, and preservation or

improvement of image quality. "For spatial resolution and texture appearance, you want it to be close to FBP, but lower dose. That's what the radiologists are used to," she said. She said that the IRIS quality is closer to FBP. "IRIS doesn't have that plastic look because the recon image has more detail than the statistical image," she said.

As for IRIS's image reconstruction time, Kreider said that new systems shipping today reconstruct at 20 images per second. She noted that their systems reconstruct FBP at 40 to 50 images per second.



IRIS axial image, courtesy Siemens



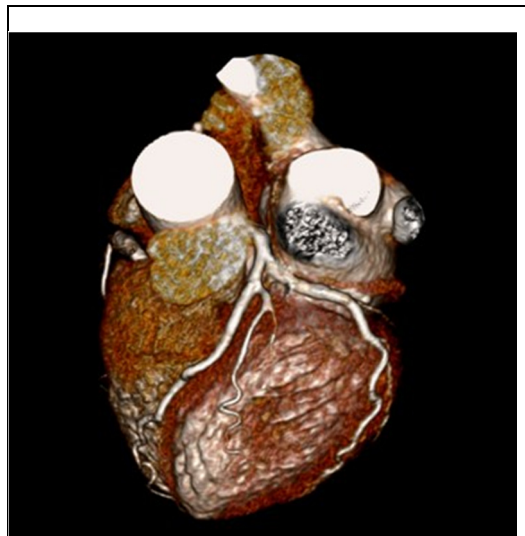
IRIS VRT (volume rendering technique)/MPR (multiplanar reformation) coronal image, courtesy Siemens

Toshiba: AIDR and AIDR 3D

Toshiba's Adaptive Iterative Dose Reduction (AIDR) software was introduced in the U.S. in 2010, and its AIDR 3D is a works-in-progress (WIP). The newer AIDR 3D has improved noise reduction, improved image quality, and is integrated (the current version is not). The 3D name might be misleading, since the current AIDR program offers 3D images as well.

Erin Angel, manager of clinical sciences for CT at Toshiba, said that her company was the first to market with nonlinear noise reduction algorithms in 2004, with its QDS technology. She said that Toshiba used this experience to optimize their reconstruction algorithm to maintain spatial resolution, low-contrast resolution and image texture so that it looks similar to FBP, avoiding the plastic look of some non-FBP images.

Angel said that because AIDR is adaptive, it doesn't require the user to set levels, and the system optimizes for the diagnostic task depending on the type of scan. "The parameters for the algorithm are set automatically," she said. What's new in AIDR 3D, is that it will be integrated, speaking to the two current modulation systems. "If AIDR is turned on in the protocol, the dose will automatically be brought down to account for the noise reduction," Angel said. AIDR 3D will work in both image space and raw data space.



Volume rendered 3D cardiac CTA acquired on Aquilion ONE using AIDR software. This exam was acquired in a single heartbeat with 0.9mSv of radiation dose. Courtesy Toshiba.

Philips: iDose⁴

While there are different algorithmic approaches and names given to low-dose and image reconstruction techniques, the image quality is one of the main areas in which a technology should be assessed, according to Mark Olszewski, senior product manager, computed tomography at Philips Healthcare.

Philips' iDose⁴, introduced at RSNA in 2009 with shipments beginning early 2011, does several things according to Jamie Valliant, senior director and head of global computed tomography marketing. "We prevent the introduction of artifacts into the image, preserve the look and feel of the image, what people are used to, provide flexibility to adjust the iDose image quality target, and optimize the speed of the algorithm." And Olszewski added one more: "We implemented the iDose⁴ in a way such that the clinical workflow doesn't differ (from what they were used to from FBP)."

Olszewski said that pure FBP suffers from one flaw in particular: It treats every projection from the scan equally, no matter if it's corrupted by noise as a result of a reduced signal, or data with variations from system model approximations. Either could lead to the magnification of noise in the images, limiting diagnostic acceptability.

The iDose⁴ reconstructs in both raw data space and image space. "We've found that optimizes what we're trying to accomplish -- reducing the artifacts in the projection domain and the quantum mottle noise across all frequencies in the image domain," said Valliant.

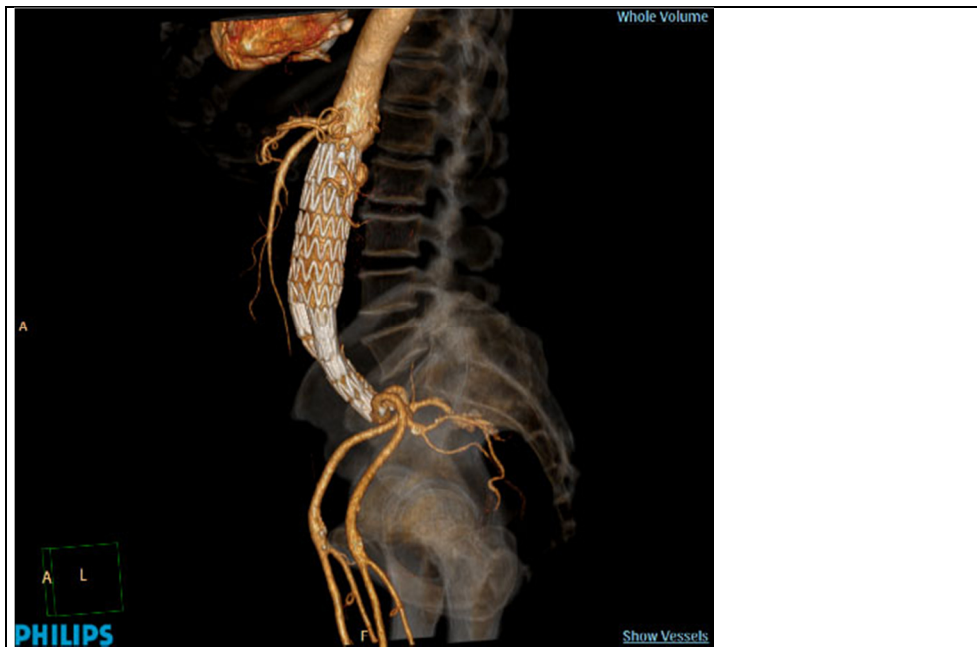
Olszewski added that the iDose⁴ also has statistical models to accurately identify the corrupt signal and minimize it in the iterative process, leading to more natural looking images. The results are that the basic characteristics look similar to FBP. "(It has) the same noise characteristics as they were used to seeing before, but just less noise," said Valliant.

"As a radiologist, they're trained to look at images. If you reduce the amount they have to relearn, the easier it is to adopt the technology," said Olszewski. "We remove noise in a way that doesn't get in the way of reading the image." The technology also prevents the artifacts from being presented.

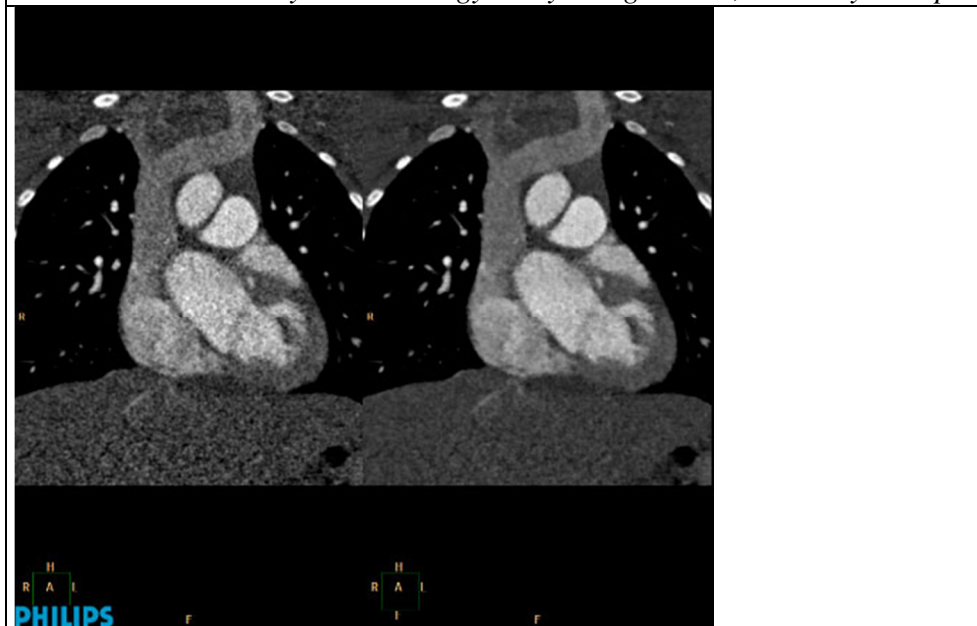
As for reconstruction speed, Valliant said that the speed is what radiologists are currently used to. The iDose currently reconstructs up to 24 images per second. Olszewski said that a better way to quantify this, though, is to note that 72 percent of their protocols are reconstructed in under a minute.

It's safe to say clinicians want the highest image quality at the lowest dose, with an efficient workflow. If Schubert of GE is right, the role of CT may expand with technology like Veo. "If you can do 3D technology, but with the dose comparable of a projection X-ray, it potentially opens up CT as a routine exam for more applications, and new

applications you wouldn't historically think of," he said. And those who are using the latest technologies and offering high quality images at a lowest dose, regardless of the reconstruction method, will have a competitive advantage.



Advanced Vessel Analysis low energy study using iDose⁴, Courtesy Philips



Pediatric cardiac scan comparison. Left image is Standard Reconstruction without iDose⁴, right image is Standard Reconstruction with iDose⁴ Courtesy Philips