# Living in a volume world: Applications for 320-detector row CT in a community-based hospital

Mark Palacio

At community-based St. Elizabeth Medical Center, part of St. Elizabeth Healthcare in Edgewood, KY, physicians are turning to the Aquilion® ONE dynamic volume computed tomography (CT) scanner for all of their imaging needs. The system is allowing radiologists to dramatically shorten scanning times, reduce X-ray dose, and it is making new clinical capabilities an everyday reality. It has turned into the CT of choice for visualizing neurology, trauma, general body, lung, cardiac, vascular and pediatric studies. With its unique volume imaging capabilities and unmatched 16 cm per gantry rotation detector coverage, the system is making a difference in many more indications.

"The Aquilion ONE is a turning point in our diagnostic and treatment protocols," said Jeffrey Dardinger, MD, MBA, Director of Imaging at the Vascular Institute of St. Elizabeth Healthcare. "Since installing the system in August 2008, we have improved our clinical workflow, our clinical workups and our outcomes."

As of June 2009, St. Elizabeth Healthcare has performed more than 10,000 CT procedures on the Aquilion ONE. The system operates in both helical and the new volume scanning modes, but since installation, 95% of all exams have been done with volume acquisition. Physicians at St. Elizabeth Healthcare are using the scanner for conventional CT procedures and for many new applications.

## Unique features of the Aquilion ONE

The Aquilion ONE incorporates 320, 0.5 mm high-efficiency detector elements. It also utilizes an industry-leading 16 cm Z-axis field of view. Each rotation yields 16 cm of clinically relevant volume. Additionally, the system tilts +/- 22 degrees, which is an important feature for neurology workups, so the scanner can line up parallel to the posterior fossa to minimize artifacts. Gantry tilt is not available on many advanced CT scanners today.

"To justify the investment, we needed a CT like the Aquilion ONE that not only could perform advanced applications like whole-brain perfusion, cardiac CTA and detailed orthopedic scans, but also could perform bread-and-butter imaging procedures better and faster," said Dr. Dardinger.

The system is extremely flexible in imaging patients. It has a patient table that moves 8.4 cm laterally for more accurate isocentering and interventional access. Lateral movement also helps when scanning trauma patients or patients with disabilities that limit their

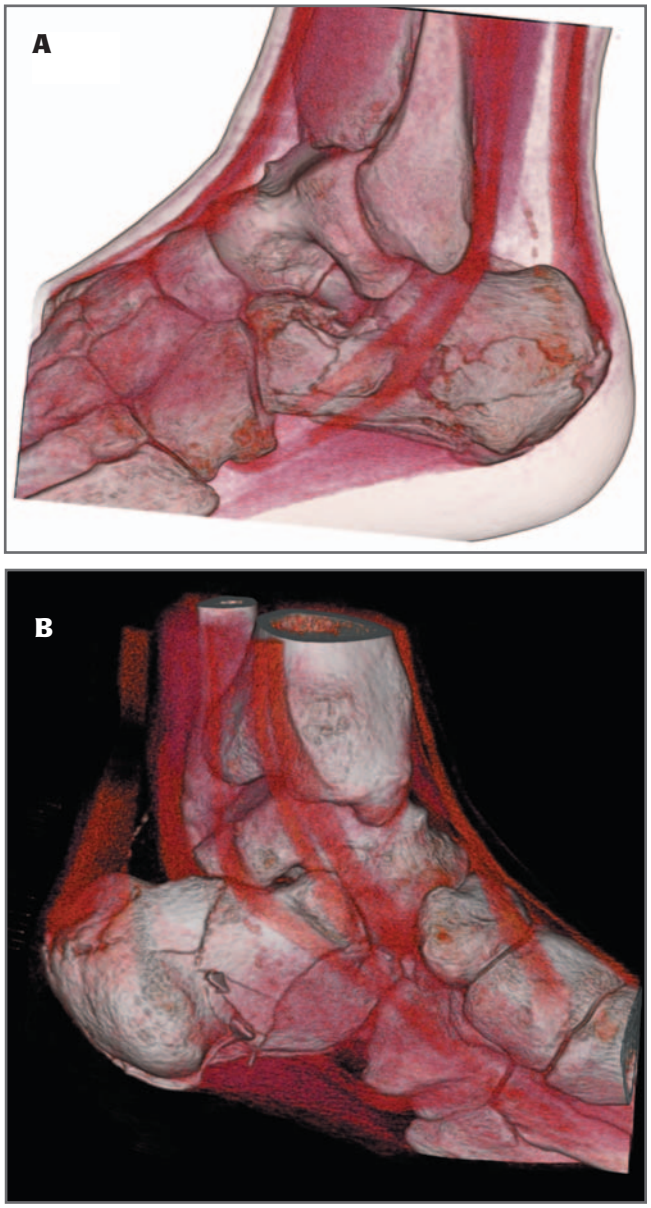


***Figure 1.*** *(A and B) 40-year-old male with fractured calcaneous. Images acquired in volume scan mode using one 0.5 second rotation.*

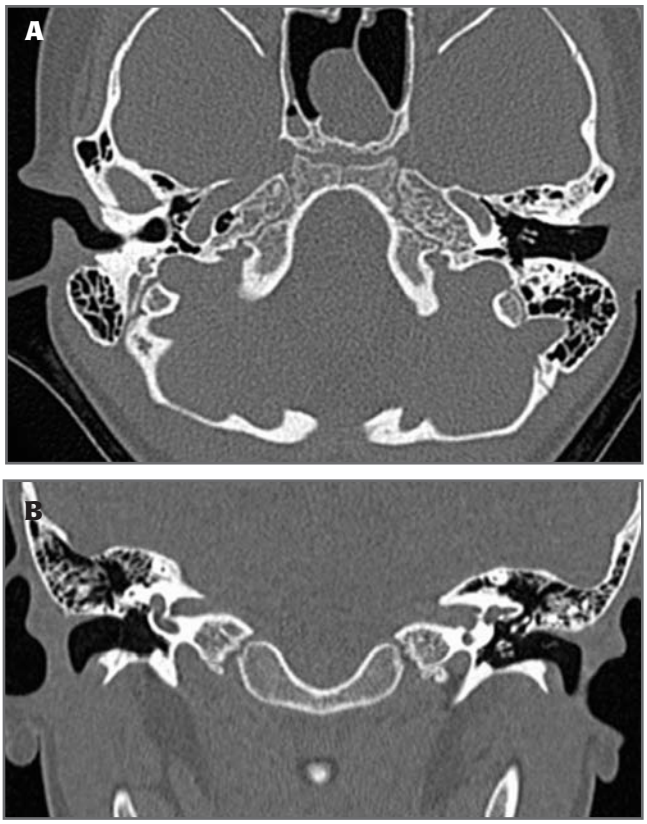


***Figure 2*** *(A and B). Pediatric temporal bone with tympanostomy tube. Volume scan acquired in one 0.35 sec. rotation. This scan mode is ideal for pediatric imaging due to its lower radiation and faster scan time.*

proper positioning. St. Elizabeth Healthcare routinely sees patients who weigh around 600 lbs, and a table that supports that weight (standard couch 660 lbs) means that they can image patients who may have been turned away from other facilities.

The Aquilion ONE has three new innovative acquisition methods in addition to those available on conventional multidetector row CT. These modes are due to the 16 cm per rotation detector coverage. It can acquire either single volume, wide volume or dynamic volume. Dr. Dardinger and colleagues are acquiring clinical information in all three modes in routine clinical practice.

## Single volume imaging

In single volume acquisition, one gantry rotation acquires up to 16 cm of coverage. This means an entire organ can be imaged as fast as 0.35 seconds. There are many advantages to fast whole-organ imaging times, including decreased radiation and contrast dose. Additionally there is no helical overscan, and no helical overlapping, which can reduce radiation by as much as 80%.

Dr. Dardinger recently scanned a 40-year-old male roofer who fell off a roof and broke his calcaneus (Figure 1). The image was acquired in a single gantry rotation. One rotation resulted in a scan of the whole calcaneus, and it was acquired in less than 1 second.

In neurological imaging applications with single volume scanning, the scanner's speed is a benefit when imaging patients who are not able to hold still, e.g. pediatric patients, the elderly and intoxicated patients presenting in the ED. A routine head CT, formerly obtained

***Figure 3.*** *Prospectively gated wide volume scan for chest pain triage in the ED. This 3-volume scan can be used to evaluate pulmonary arteries, thoracic aorta and coronary arteries simultaneously.*

in a 6 second helical scan, can now be obtained in less than 1 second on a volume scan.

The paradigm of 16 cm volume coverage has tremendous implications for CT imaging. The acquired 16 cm volume now has perfect temporal uniformity throughout the entire volume.

In cardiac CT, they can perform one-rotation prospective cardiac gating. The gantry starts to rotate with the tube off and gets to the proper site of the R-R interval then it acquires an image of the whole heart in one rotation, within a single heartbeat.

"This gives you physiologic uniformity," said Dr. Dardinger. "Every voxel is acquired at exactly the same moment in time. We can see the entire right coronary in exactly the same phase as the left anterior descending. We see it with no motion artifact, with no unreadable segments. These are beautiful, low-dose diagnostic images."

The Aquilion ONE has unique pediatric applications that benefit from single volume acquisition. Dr. Dardinger recently saw a child for temporal bone analysis and completed the entire exam in a single gantry rotation in less than 1 second (Figure 2).

"The Aquilion ONE gives us rapid, easy-to-acquire, high-quality, repeatable imaging," Dr. Dardinger said.

## Wide volume imaging

Building on the methodology of single volume acquisition, the Aquilion ONE is capable of wide volume imaging whereby the system acquires multiple single volumes to generate wide volume coverage—allowing users to cover any length of Z-axis. The technique works by acquiring one volume, turning the beam off, moving the table, acquiring another volume, turning the beam off and moving the table, and acquiring a third volume. The table moves only between volumes, it does not move during image acquisition.

"With wide volume acquisition, our routine chest CT has become the comprehensive exam," said Dr. Dardinger. "Almost every chest

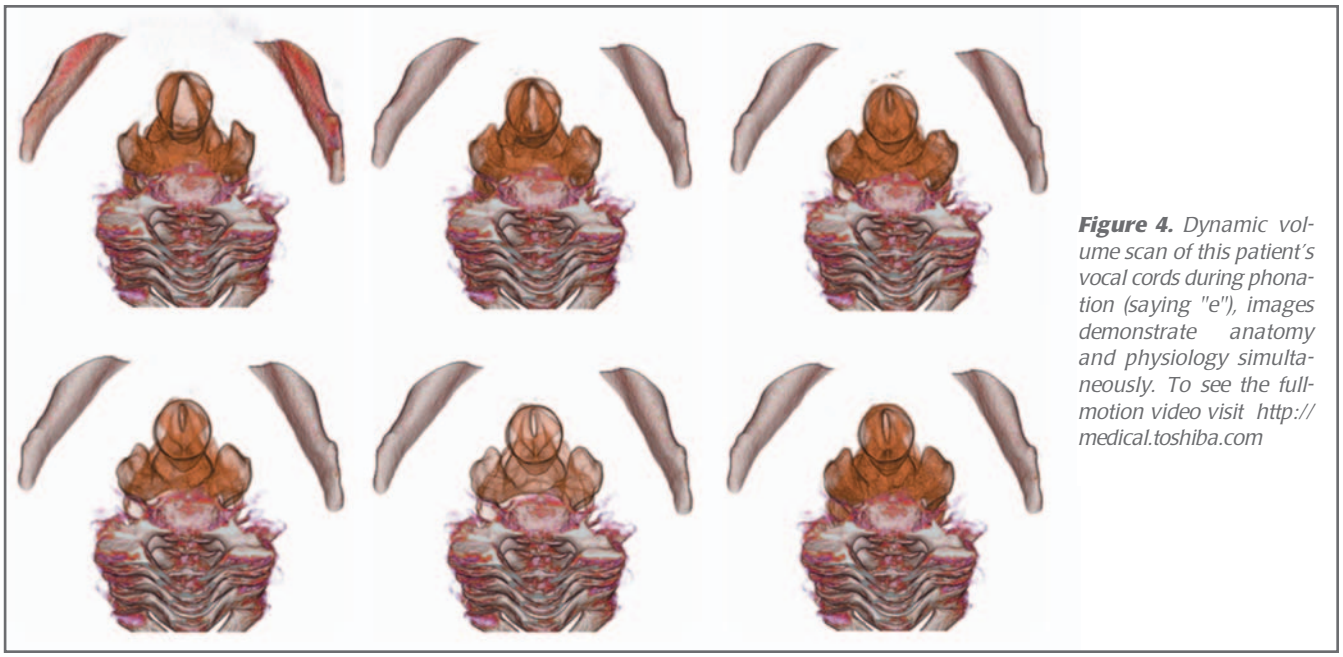

***Figure 4.*** *Dynamic volume scan of this patient's vocal cords during phonation (saying "e"), images demonstrate anatomy and physiology simultaneously. To see the full-motion video visit http://medical.toshiba.com*

CT study done is acquired in three volumes and all of them are acquired at maximum gantry rotation with half reconstruction. It's the same principle we use for cardiac CT. So now with a chest CT there is no motion artifact at the aortic root. There is no motion artifact in the lower pulmonary branches and no motion artifact at the lower pulmonary artery branches."

Figure 3 shows a motion-free coronary artery image acquired in a routine chest CT. The beam is on for less than a second in total, so the radiation dose to the patient is less than that of helical imaging.

"We find the dose in wide volume chest coverage to be 1/3 of what would be delivered with gated helical chest CT," said Dr. Dardinger.

## Dynamic volume imaging

The most exciting advancement on the Aquilion ONE is its ability to perform dynamic volume imaging.

"It gives us opportunities to do things we couldn't do before," said Dr. Dardinger. "It is acquiring the same volume of tissue over time, and it can acquire the images with the beam on continuously or in an intermittent fashion."

While the images are acquired in either continuous or intermittent acquisition, the table remains motionless. The system does not need to jog or shuttle the table so only the gantry rotates around the imaging target. This allows possibilities for kinematic studies of the joint, true digital subtraction angiography and organ perfusion.

## Continuous dynamic imaging

Continuous dynamic imaging confers the ability to use CT to capture motion images. They recently performed a vocal chord analysis with CT where they could visualize soft tissue of the neck. The resulting images were similar to what is seen on X-ray fluoroscopy of the vocal chords. The Aquilion ONE was able to capture images of the patient phonating (saying "e"). The resulting images were acquired in 5 seconds at a very low dose and then rendered with a surface-shaded display (Figure 4).

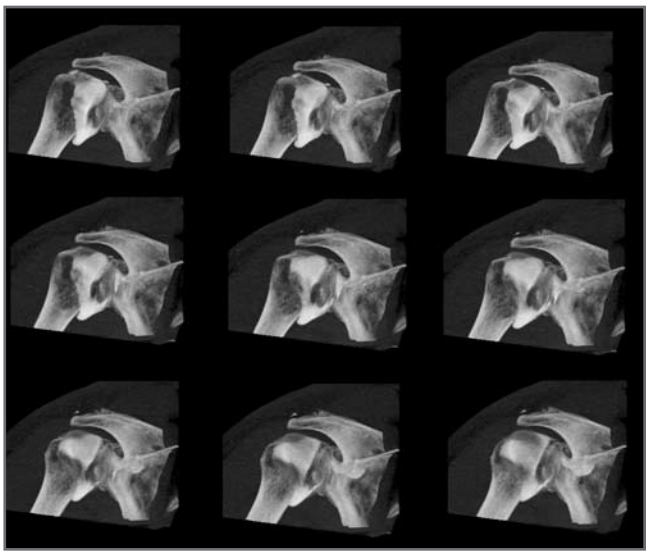

***Figure 5.*** *Shoulder arthrogram acquired in a 5 second acquisition while the patient rotated the humeral head. Images were acquired at 80 mA, 80 kV and less than 5 mSv for the whole study. Internal and external rotation of this shoulder arthrogram can be viewed in realtime with Aquilion ONE and a dynamic volume scan acquisition.*

In another exciting application, Dr. Dardinger was able to acquire a shoulder arthrogram on a patient who could not receive an MRI because of an implanted pacemaker (Figure 5).

"We did a shoulder study with motion in a 5 second acquisition and we asked the patient to externally rotate the humeral head," he said. "We could watch the contrast flow through the bursa. And we acquired these images at a very low dose of 80 mA, 80 kV and less than 5 mSv for the whole study."

The Aquilion ONE with continuous dynamic imaging also has applications in temporomandibular joint imaging where a patient can open and close the jaw during a 5 second continuous acquisition on the CT scanner.

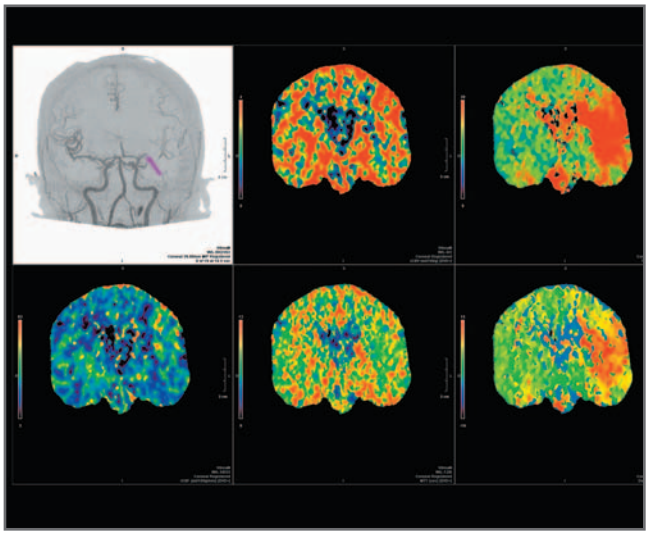

***Figure 6.*** *Whole-brain perfusion with dynamic CTA with a single injection of 50 cc of contrast. Images are acquired in 1 minute at less than 5 mSv for the whole exam. Acute occlusion of the left middle cerebral artery is demonstrated on the CT DSA image and the corresponding whole-brain perfusion maps.*

"We could watch the mandibular condyles as they translocated normally and fell back," said Dr. Dardinger. "We got physiologic, dynamic information that we could not get any other way. And since it is a volume acquisition, we can look at it any way we like: as a MIP image of bone or as soft tissue."

## Intermittent dynamic imaging

Intermittent dynamic imaging opens exciting new avenues in CT.

"This is true digital subtraction angiography brought to CT," said Dr. Dardinger. In intermittent dynamic imaging procedures, the scanner first acquires a non-contrast mask, which is like what is used in the catheterization lab. Then the system acquires additional 16 cm volumes of tissue. Putting the images together renders an angiographic view that can be used anywhere in the body, such as the renal arteries, the carotids, the pelvis or extremities.

"This gives you rapid, low-dose imaging with no physician input to the post processing," he said.

St. Elizabeth Healthcare performs whole-brain perfusion with dynamic CTA (Figure 6). It is a simple protocol for the CT technologists since it is operationally identical to any other CT protocol. It requires a single injection of 50 cc of contrast and the images are acquired in 1 minute at less than 5 mSv for the whole exam.

Over the course of 1 minute the system acquires an entire head CT with no contrast, a head CT with contrast, an arterial-phase CT, a venous-phase CT and a whole-brain perfusion data set. These images are all acquired simultaneously in 1 minute of acquisition with 2 minutes of post processing. To further speed workflow, it eliminates bone segmentation with automatic bone subtraction.

"In the past we had a 3D lab that dropped center lines down the Circle of Willis and they sculpted out bone — now it is automatic," Dr. Dardinger said. "As a private practice radiologist it is important that this is automated. I don't have to do it at the workstation and we do not need to use a 3D technologist."

The Aquilion ONE can also perform pure arterial CT angiography, allowing users to move backward and forward in time through the images. With current CTA procedures, contrast is injected and then after a certain amount of time, a CT scan from top to bottom is performed. In that time, contrast flows and physiologic functions are occurring, but there is no uniformity in the resulting images. On the Aquilion ONE there is temporal uniformity throughout the volume, as well as contrast uniformity and physiologic uniformity.

"You can evaluate in time and find the true arterial phase you need," said Dr. Dardinger. "Another advantage is you can go back and find the true venous phase with no arterial contamination. You get this data with less dose and contrast and as part of the whole-brain perfusion study."

At St. Elizabeth Healthcare, Dr. Dardinger uses intermittent dynamic imaging to visualize flow in the vasculature, solid organs and extremities. For instance, he can perform a dynamic renal artery CTA that acquires information over time. It is more than a non-contrast arterial nephrogram and delayed phase. With intermittent dynamic volume imaging he has the ability to track contrast over time and generate a time-density curve. This is similar to what occurs in breast MRI procedures that show signal-intensity curves after contrast.

"Before we only saw that the contrast enhanced, now we also know the slope and peak of enhancement and the washout to better characterize lesions," he said. "This gives us powerful, simple imaging tools that we can put into clinical practice."

## Future applications

The Aquilion ONE has many applications that are truly groundbreaking for a CT scanner: It has the ability to look at anatomy and physiology and visualize the body in motion. Dr. Dardinger is currently evaluating a body perfusion application where the system color codes the aforementioned renal contrast curves the same way that a brain perfusion study is color coded. This allows radiologists to watch a relative enhancement of any organ they choose. There are exciting oncology applications for these color-coded maps. For instance, radiologists could acquire a prechemotherapy perfusion study and then repeat the imaging after chemotherapy. If the treatment is working, the amount of angiogenic activity goes down and the enhancement pattern changes. If there is no change in the enhancement pattern, oncologists could consider a different therapeutic regimen.

"It is not just anatomic information, it is a true anatomic and physiologic evaluation," said Dr. Dardinger. "This is a dynamic time to be a radiologist."

For the first time, the Aquilion ONE gives facilities the flexibility to perform routine exams, while also enabling them to conduct cutting edge exams. It is a unique tool that maximizes the value of radiology and helps to reduce the cost of healthcare by providing faster, more efficient imaging. With additional applications on the horizon, the system will continue to improve the paradigms of healthcare imaging.

*Mark Palacio is the Executive Editor of* Applied Radiology.