Introducing the Discovery CT750 HD FREEdom Edition

By Scott Schubert, GM, Premium CT Product Marketing, GE Healthcare

The Discovery* CT750 HD is the world's first High Definition CT (HDCT), built on GE's exclusive Gemstone detector, the first new CT detector material in the past 20 years. With the Gemstone* detector, GE set new benchmarks for CT image quality, low dose, and spatial resolution. The smaller Gemstone detector elements and 100 times faster primary speed deliver spatial resolution of 0.23 mm for routine clinical applications. The Discovery CT750 HD was the first to introduce CT iterative reconstruction with ASIR* (Adaptive Statistical Iterative Reconstruction), and subsequently with Veo*, the world's first model-based iterative reconstruction that opens the door to imaging at less than 1 mSv. And the Gemstone detector is the enabling technology behind Gemstone Spectral Imaging (GSI), a unique dual energy technique that uses rapid kV switching to acquire and generate quantitative material density data and derive monochromatic spectral images.

With the industry leading cardiac spatial resolution of 18.2 lp/cm, the Discovery CT750 HD provides greater cardiac spatial resolution than comparable systems.¹ Yet, even with all of the advancements in CT technology over the last 10 years, clinical challenges remain for cardiac CT studies including coronary motion and calcium blooming. One study reports that 15% of coronary segments were impaired because of calcifications and 9.8% of segments had limited image quality where motion artifacts affected the diagnostic evaluation.¹

The HD FREEdom Edition is designed to address these challenges. The Discovery CT750 HD is the world’s first CT based on GE exclusive FREEdom Technologies (Fast Registered Energies & ECG), which includes:

- Motion FREEdom: intelligent motion correction to “freeze” coronary motion with SnapShot* Freeze;
- Calcium FREEdom: enhanced coronary visualization with GSI Cardiac;

¹Based upon internal test data comparing Discovery CT750 HD cardiac half scan spatial resolution to data from Advanced CT Scanners for Coronary Angiography, ImPACT Report CEP10043, March 2010, available at http://www.impactscan.org.
• Horizon FREE: providing clinicians with additional information on plaque material composition and accurate perfusion calculations; and

• "Dose-neutral" GSi: bringing together two of GE's key innovations, GSi and ASiR, enables virtually dose neutral spectral imaging across a wide range of applications.

**Motion FREEdom with SnapShot Freeze**

Coronary CTA exams at 65 bpm or lower have a single optimal reconstruction phase. As heart rate increases beyond 75 bpm, so does the minimum velocity of the coronaries. At higher heart rates, the lowest coronary motion for the three major vessels no longer has a common phase location, and the magnitude of vessel velocity is substantial. At 75 bpm, a coronary vessel traveling at 40 mm/s can travel 3 mm when captured with a 75 ms temporal resolution (40 mm/sec * 0.075 sec = 3 mm). For a 3 mm diameter RCA, that degree of motion is equal to the size of the coronary vessel itself. From this we must conclude that CT gantry speed alone may be insufficient to overcome this degree of coronary motion. Because of this, GE has developed an intelligent motion correction algorithm, SnapShot Freeze, that addresses the challenge of coronary motion. SnapShot Freeze utilizes the motion path and velocity of the coronary arteries, and on a vessel-by-vessel and segment-by-segment basis, corrects for the elastic beating motion of the heart. Phantom studies show that motion blurring with SnapShot Freeze is reduced by a factor of six, corresponding to an equivalent gantry rotation speed of 0.058 sec (58 msec).2

Error free cardiac exams can be challenging. Setup, scanning, and reconstruction vary with patient condition. SnapShot* Assist is a tool in HD FREEdom Edition designed to help optimize scanning and enable the creation of advanced vessel-path reconstructions based on individual patient parameters. SnapShot Assist is designed to help achieve consistent application of advanced cardiac features and reduce the complexity of creating optimal, SnapShot Freeze diagnostic images.
Calcium FREEdom with GSI Cardiac

GSI Cardiac introduces the first cardiac spectral imaging scanning that merges GE’s pioneering prospective gated SnapShot technology with fast kV switching of 80 kVp and 140 kVp. Switching at less than 0.252 msec ensures a spatially registered dual energy dataset that is then decomposed into material density images and synthesized into monochromatic energies.

The registered dual energy datasets are important for assessing coronary vessels using material separation of calcium and iodine. Monochromatic spectral energies can also be used to display beam hardening reduced extents of calcification, enabling enhanced coronary visualization in the presence of calcium.

GSI Cardiac may allow for enhanced visual assessment of coronary vessels due to its ability to separate materials like iodine and calcium. Interactively changing the spectral energies allows physicians to enhance vessel visualization. Material separated images provide physicians with a new level of capability to visualize the vessel and aid in their assessment of patency. Users also have the ability to insert their own material with data provided in the NIST data base (e.g. Hydroxyapatite-HaP).

Horizon FREE with GSI Cardiac

It has long been a goal of cardiac CT clinicians to go beyond the coronary arteries into new horizons, and provide a comprehensive exam of the myocardium and the wall of the coronary arteries. GSI Cardiac is designed to enable exploration into these capabilities by providing clinicians with additional information on plaque material composition and accurate perfusion calculations.

A key challenge associated with CT myocardial perfusion is the presence of beam hardening artifacts stemming from contrast-filled chambers and vessels. GSI Cardiac is designed to reduce beam hardening in these regions, enabling reliable CT numbers for perfusion measurements.

Dose-neutral spectral imaging with GSI ASiR

The HD FREEdom Edition has also been developed with new GSI dose presets and merges GSI technology with ASiR. GSI ASiR has improved contrast-to-noise ratio (CNR) when compared with 120 kVp scans at matched dose. CNR improvements are robust across dose levels and patient sizes. Phantom testing has validated this performance.

HD FREEdom Edition: designed to take cardiac CT and spectral imaging to a new level

The Discovery CT750 HD FREEdom Edition is built on GE’s exclusive technologies: the Gemstone detector, GSI, ASiR, and Veo.

On the following pages, you’ll learn more about the HD FREEdom Edition and how it was designed to address the key clinical challenges of today and tomorrow.

References


Scott Schubert, GM, Premium CT Product Marketing, GE Healthcare
Addressing the Challenges of Coronary Artery Motion Blurring and Heart Rate Variability

By Vincent Norlock, Global Product Manager and Alyssa Nowak, CT Product Development Specialist, GE Healthcare

Coronary artery motion, especially at increased heart rates, is a leading cause of non-diagnostic cardiac CTA exams. As heart rates rise over 75 bpm, the lack of a single optimal phase and high residual motion can result in sub-optimal image quality. A 3 mm vessel moving at 33 mm/sec can travel 2.5 mm during an acquisition on even the fastest rotating gantry. CT hardware solutions alone cannot overcome coronary motion.

SnapShot* Freeze from GE Healthcare is an intelligent motion correction algorithm that overcomes the limitations of a hardware-only approach to the challenge of coronary artery motion blurring. To do this, SnapShot Freeze characterizes the vessel motion path and velocity from adjacent cardiac phases and uses this information to calculate an optimal estimate of the vessel position at the target phase.

Using a mechanical heart phantom, the motion blurring correction of SnapShot Freeze was measured to be equivalent to that of a gantry rotation speed of 58 msec. That translates to an effective cardiac temporal resolution of 29 ms.

Another feature of the HD FREEdom Edition is SnapShot* Assist. It is designed to work with SnapShot Freeze, and can provide CT operators with recommended scan settings based on the individual patient heart rate and heart rate variations.

SnapShot Assist combines information about patient heart rate variability and BMI to guide the CT operator to optimal cardiac scan settings. These displayed settings are based on over a decade of GE experience in cardiac CT and can be updated as desired to match a department’s best practices scan protocols.

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**Figure 1.** At <65 bpm there is a single optimal recon phase for all vessels; residual motion ~10 mm/sec causes loss of resolution (A). Over 75 bpm, recon shifts to systole and there is no single optimal phase even at 75 msec. Residual motion is 25 to 40 mm/sec (B).
SnapShot Freeze evaluation

Jonathon Leipsic, MD, Vice Chairman of Radiology at University of British Columbia (Vancouver, BC), was involved in early investigations of the SnapShot Freeze technique. He explains that if you can't evaluate a coronary artery segment due to motion, you can't evaluate that vessel and as a result the default must be that it is narrowed. “This means a reduction in non-evaluable segments. Motion correction is designed to address this issue.

“Essentially, SnapShot Freeze is designed to assist in the diagnostic interpretability of coronary CT angiography by reducing the burden of non-diagnostic segments,” he says.

Reliable, robust, high-quality coronary CTA imaging in higher heart rate exams have shown hardware approaches to be unsatisfactory in freezing coronary motion. Fortunately, there is SnapShot Freeze intelligent motion correction.

Figure 2. Images of the right coronary artery (RCA). Images on left are blurred due to coronary motion and heart rate variability (A). Motion corrected images using SnapShot Freeze (B).

Figure 3. Phantom results showing extent of motion blurring correction.

Figure 4. Cardiac cycle phases in 10% increments, from 10 to 90%. Top row: Uncorrected motion blurring. Bottom row: SnapShot Freeze motion corrected coronary artery images.

Vincent Norlock is Global Product Manager at GE Healthcare.

Alyssa Nowak is CT Product Development Specialist at GE Healthcare.
Motion-corrected Cardiac CTA

By David Dowe, MD, FACR, Medical Director, Cardiac CT Program, Atlantic Medical Imaging
Galloway, NJ USA

Chest pain and equivocal stress test

Introduction

Our clinical practice has benefited from ASiR** dose-reduction technology and the increased spatial resolution of the Discovery* CT750 HD scanner when evaluating the coronary arteries. Recently we took part in a clinical review of Cardiac CTA images created using the SnapShot* Freeze option on the Discovery CT750 HD.

Evidence has shown that as heart rates rise, the motion present in the coronary artery can leave images from even the fastest CT scanners with motion-blurring artifacts. Above 75 bpm, coronary motion can be as much as 40 mm/sec; equivalent to 3 mm of travel in a 75 ms acquisition.

SnapShot Freeze corrected images

Any patient with an increased heart rate, like emergency cases, may benefit from the fast, non-invasive results of Cardiac CT. Gaining optimal heart rate control prior to these exams is not always possible. SnapShot Freeze intelligent motion correction can help.

There was no dose increase as a result of using SnapShot Freeze for this patient, as adequate padding was already prescribed due to higher patient heart rate and variability.

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**In clinical practice, the use of ASiR may reduce CT patient dose depending on the clinical task, patient size, anatomical location, and clinical practice. A consultation with a radiologist and a physicist should be made to determine the appropriate dose to obtain diagnostic image quality for the particular clinical task.

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Patient history

54-year-old white male; no family history of CAD; high blood pressure and high cholesterol; unexplained, sub-sternal chest pain for one year; with equivocal stress test results; anxiety is likely cause of elevated heart rate.

Results

The scan showed mild coronary artery disease in the RCA with no stenosis. No other disease was found.

Discussion

I was able to clear the RCA in the original image. However, viewing the same image with the motion correction from SnapShot Freeze gave me greater confidence that the RCA was indeed normal.

In this case, SnapShot Freeze greatly improved the RCA, and the visualization of smaller vessels such as the small obtuse marginal shown in these attached images. I believe SnapShot Freeze is going to have great utility in similar high-heart-rate setting cases.

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**Figure 2.** Original image (A). With SnapShot Freeze (B).

**Figure 3.** Original image (A). With SnapShot Freeze (B).

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**David A. Dowe, MD,** is Medical Director and Coronary CTA Program Director, Atlantic Medical Imaging (Galloway, New Jersey). He received his medical degree and completed his residency at SUNY Health Science Center (Syracuse, New York). Dr. Dowe is board-certified in diagnostic radiology by the American Board of Radiology; special interests include coronary CTA, and nuclear medicine. Dr. Dowe lectures nationally and internationally, has written several articles related to coronary CTA, and collaborates on coronary research and development.

**Atlantic Medical Imaging (AMI)** Atlantic Medical Imaging (AMI) is a full service, outpatient imaging practice operating seven offices throughout New Jersey and providing professional services to three area hospitals. Since 1964, AMI’s goal has been to provide the most advanced diagnostic imaging services to our patients and referring physicians. With 32 board-certified, sub-specialty trained radiologists and a staff of 350 technical, clerical, and administrative personnel, AMI is committed to providing patients with unsurpassed service and care and will ensure that their visit is comfortable and relaxing. AMI offers a full spectrum of diagnostic imaging services including CT, Coronary CTA, MRI, Nuclear Medicine, PET/CT, Digital Mammography, Ultrasound, DEXA, General Radiology and Fluoroscopy, and Interventional Radiology. Since 2001, Atlantic Medical Imaging has been performing Coronary CTA.
GSi Cardiac: A New Horizon in Cardiac CT Imaging

An interview with Saad Sirohey, PhD, Global Product Manager CT Advanced Applications, GE Healthcare

Q: What is GSI Cardiac?

Dr. Sirohey: GSI Cardiac is GE Healthcare’s dual-energy acquisition using fast kVp switching between low and high energies (80 and 140 kVp) to acquire data less than 0.25 ms apart in time. This allows the use of projection-based reconstruction to decompose the dual energy data into material basis pairs. From these material basis pairs, GSI Cardiac uses known material attenuation coefficients to synthesize monochromatic spectral images between 40 and 140 keV.

Because of simultaneous acquisition between the two different energies, GSI can acquire dual energy data at a high enough frequency so any data misregistration due to motion (in an organ that it is imaging) is imperceptible—essentially freezing the motion of the heart between two energies. This is particularly critical for the visualization of coronary vessels.

What does GSI Cardiac provide?

Dr. Sirohey: GSI Cardiac produces material separated and monochromatic spectral energy images. These images provide clinicians with the ability to separate materials such as iodine and calcium, as well as changing the energy level (keV) for better delineation of the borders of objects such as calcium. Furthermore, due to the inherent beam hardening reduction based on the principles of the acquisition and the raw data space reconstruction, GSI Cardiac provides clinicians with an accurate myocardial perfusion assessment.

Figure 1A-C. Beam hardening artifacts may mimic myocardial perfusion defects.1 Beam hardening artifact resulting in an apparent perfusion defect in patient without coronary artery disease (A, B). Is this an artifact or defect (C)?

Figure 1D-E. 120 kVp conventional scan (D) and GSI scan (E). GSI image demonstrates a reduction in the beam hardening artifact.

What do you mean by material separation?

**Dr. Sirohey:** Material separation means we can decompose the data into an iodine-suppressed or calcium-suppressed image. The ability to separate iodine and calcium provides tools for the user to view vessel patency in the presence of calcification. As a result, we can interrogate the data to help determine the boundaries of the lumen and calcification in the vessel.

How does GSI Cardiac address motion?

**Dr. Sirohey:** In dual-energy acquisition techniques, the ability to manage physiological motion is essential for true quantitative images. This capability is directly linked to acquiring low kVp and high kVp scan data simultaneously.

Coronary vessels have a very high frequency of motion, much larger than 75 msec, due to the pulsing of the heart. With ultrafast kVp switching, GSI Cardiac allows imaging of the coronaries in motion and is able to produce registered dual energy data.

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**Figure 2.** GSI monochromatic image at 70 keV shows calcium in the LAD (left); material separated (HAP suppressed) image showing vessel lumen view (right).

**Figure 3.** GSI Cardiac with fast switched kVp delivers near perfect energy registration to minimize motion artifacts.

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**GSI Cardiac – Fast Dual Energy Comparison**

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<th>Sub msec kVp switching</th>
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**Increased susceptibility to motion**

Simulated pulsatile motion and 75 mSec of temporal resolution
What other imaging capabilities does GSI Cardiac make possible?

Dr. Sirohey: The challenges of cardiac imaging go beyond anatomically imaging the coronaries to identify the presence of stenosis but to also explore whether the stenosis has an impact on the function of the heart tissue. Beam hardening presents a tremendous challenge when assessing the myocardium with traditional CT imaging as it can be difficult to determine whether a region of low density is a true deficit or a beam hardening artifact. The physics of GSi Cardiac using projection space reconstruction inherently allows beam hardening reduction, which can be visibly seen as the monochromatic energies change, resulting in images with a reduction in these artifacts. This capability enables precise imaging of the functional assessment of the heart for a more confident diagnosis of myocardial ischemia.

Where else in cardiac imaging could this technique be useful?

Dr. Sirohey: GSi Cardiac will enable the user to interrogate different types of composition of plaque using material separation and Spectral HU curves. Spectral curves may provide information on the composition of the material being assessed based on the physics of attenuation.

According to James P. Earls, MD, "We can look at the heart and coronary arteries with all these different monochromatic energies and different material pairs. What I find most useful so far is the ability to minimize the artifacts that result from coronary calcium by using the higher-energy monochromatic images.

"There are limitations associated with using only Hounsfield units and anatomy when interpreting cardiac CT images," Dr. Earls explains. "GSI Cardiac is designed to allow us to look at the level of myocardial perfusion with fewer beam hardening artifacts and the drawbacks associated with them."

He further notes that there is already a preponderance of clinical evidence that cardiac CT is an important diagnostic tool. "GSI Cardiac will enhance this useful and widely accepted tool."
Beam-hardening Correction in Resting Myocardial Perfusion

By James P. Earls, MD, Medical Director and Director of the Cardiac CT Program at Fairfax Radiological Consultants, P.C., Fairfax, VA and Co-Director Cardiac CT Lab at the INOVA Heart and Vascular Institute of Falls Church, VA.

Introduction

The Discovery* CT750 HD, combined with the AW or AW Server, offers Gemstone* Spectral Imaging (GSi), which uses ultra-fast kVp switching to generate material decomposed images that provide additional information of the anatomy being scanned. As GSi retains the full spectral content in the review environment, it gives the clinician access to a range of the displayed energies, and even the ability to interrogate the density of the material, like IV contrast, displayed within the image.

The new GSi Cardiac application takes advantage of Discovery CT750 HD’s high-speed X-ray switching (0.25 ms) to deliver accurate, registered dual-energy image reconstruction of moving anatomy.

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**Acquisition Protocol**

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<tr>
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**Figure 1.** Iodine overlay myocardium (A). Myocardium at 70 keV (B). 70 keV perfusion color overlay (C).
Large amounts of contrast in the heart, which hardens the beam; leaving an image artifact which resembles a hypo-perfused region on the muscle. GSI Cardiac provides images with reduced beam-hardening artifacts, which is important for accurate perfusion calculations.

Dr. Earls recently used GSI Cardiac with CT MPI to evaluate a patient with likely coronary artery disease.

**Patient history**

58-year-old male with chest pain after exercise and a family history of coronary artery disease. No prior cardiac exams.

**Case description**

GSI Cardiac Coronary CT angiography with resting assessment of blood perfusion in the myocardium.

**Results**

The study helped identify:

- Multiple significant stenoses in the LAD and first and second diagonal;
- Stenoses in the first obtuse marginal branch, and posteriolateral branch; and
- Perfusion defects corresponding to the stenoses in the anterior wall, apex, inferior wall. These defects are consistent with ischemia.

**Discussion**

In this case, using GSI I was able to see under-perfused myocardium that correlated with the anatomical stenosis. Generating the quantitative iodine maps of the myocardium increased my confidence that the exam depicted hypo perfused myocardium allowing me to render a diagnosis of coronary stenosis with accompanying myocardial ischemia.

The conventional angiography confirmed the multiple coronary stenoses which were treated with surgical intervention.

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**James P. Earls, MD**, is Medical Director and Director of the Cardiac CT Program at Fairfax Radiological Consultants, P.C., Fairfax, VA and Co-Director Cardiac CT Lab at the INOVA Heart and Vascular Institute of Falls Church, VA. Dr. Earls received his medical degree from New York University School of Medicine and completed his residency in diagnostic radiology at Walter Reed Army Medical Center in Washington, DC. He is a member of the board of directors of the Society for Cardiac Computed Tomography, and a member of the Radiological Society of North America and Roentgen Ray Society.

**Fairfax Radiological Consultants, PC (FRC)** was established in 1963. It is currently the largest radiology organization in the Washington Metropolitan Area as well as in the Commonwealth of Virginia. FRC provides services to Inova Fairfax Hospital, which is the only Level 1 trauma center in Northern Virginia. FRC also provides services to Inova Loudoun Hospital, Inova Fair Oaks Hospital, as well as fourteen outpatient facilities conveniently located throughout the Northern Virginia area.

FRC currently employs 70 radiologists, all of whom are board certified by the American Board of Radiology and are specialized in the subsection of radiology such as mammography, ultrasound, interventional radiology, neuro-interventional radiology, CT scanning, MRI, nuclear medicine, pediatrics and other radiological services. FRC employs over 500 professionals, registered technologists and support personnel, to provide a full service organization.
Advanced post-processing of CT images has become an important—if not necessary—step in the diagnostic workflow/interpretation process. Today’s advanced workstations, such as the AW from GE Healthcare, enable radiologists to 3D render, pinpoint, and segment anatomic features for a confident diagnosis (Figure 1).

Now with the HD FREEdom Edition, the GSI Viewer 3D is designed to enable clinicians to post-process GSI data on any AW workstation and to access and process spectral imaging data within the entire suite of AW post-processing capabilities. This includes generating GSI volumes—interactive dynamic monochromatic volumes, material density volumes, such as iodine with water suppressed, and effective Z volumes—and extended capabilities for vessel and lesion analysis.

*Trademark of General Electric Company.
The integration of GSI capabilities with VessellQ Xpress and CardiQ* Xpress Reveal provides the tools to segment vessels, visualize the lumen, examine anatomy with different spectral energy levels, separate materials, and view Spectral Hounsfield Unit curves across all vessels—peripheral, neuro, and cardiovascular. Problem-solving tools enhance vessel visualization at different keV levels and separate materials, such as iodine and calcium (Figure 2).

GSI Viewer 3D is also designed to assist in the quantitative assessments of spectral data using familiar visualization/processing tools. Automated segmentation tools are available for volumetric lesion characterization using Spectral Hounsfield Unit curves (Figure 3). Users can selectively threshold materials to enable bone segmentation allowing for reduced bone interference in visualization of vasculature.

Custom protocols can be created in GSI Viewer 3D to suit the clinician’s layout preferences. Users are able to save preferred settings and apply them to a future exam to selectively segment a volume of interest, which can then be merged with the 3D anatomic volume rendering—allowing visualization with anatomic reference (Figure 4).

By bringing together the post-processing capabilities of the Volume Viewer+ with GSI, clinicians can access segmentation, tracking, and threshold capabilities for spectral imaging data.