Cardiac CT Advancement – Evolution of SnapShot Freeze Technology

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Introduction

While the rapid adoption of Cardiac CT imaging and the underlying technical advances over the last decade have been impressive, coronary motion artifacts and calcium blooming have in general remained a challenge, potentially resulting in the clinicians having reduced confidence in reading Cardiac CT images. GE Healthcare’s Discovery CT750 FREEdom edition introduced SnapShot* Freeze, an intelligent motion correction algorithm, which was the first to truly characterize coronary motion and correct for the resulting artifacts. FREEdom edition also introduced GSI Cardiac acquisition mode that improved the assessment of coronary vessels in the presence of calcification, and myocardial perfusion with reduced beam hardening artifact. In this paper, we discuss the recent advances in SnapShot Freeze Technologies that takes Cardiac Imaging to the next level by expanding the breadth of intelligent motion correction applications, further enhancing clinical performance and introducing a significant dose reduction capability.

With the introduction of the Discovery CT750 HD FREEdom Edition and now the Revolution GSI, these advances equip users with new capabilities to further address known challenges in cardiac CT, including coronary motion, calcium blooming, accurate quantification, perfusion analysis, radiation-dose performance and faster acquisition. These will enable the system to deliver excellent image quality all the way from routine high-definition, low dose imaging to advanced spectral imaging.

This paper talks about the key technologies that are behind the advances in Cardiac CT: SnapShot Freeze and its extension to GSI Cardiac, Intelligent Boundary Registration (IBR), and Extended Cardiac Helical pitch.
SnapShot Freeze Technology: A primer

Because there is no truly quiescent phase for imaging the coronaries at higher heart rates, vessel motion remains a challenge to making high-quality and robust coronary CTA routine [1-5]. In 2012, GE introduced SnapShot Freeze (SSF) as a new approach to solving this challenge. This intelligent motion-correction technology employs a novel image reconstruction and processing technique that addresses the inherent limitations of a hardware-only solution (Fig. 1). It’s a technique that can significantly reduce coronary motion, as demonstrated in a number of clinical and phantom studies conducted at multiple institutions [6-11].

Unlike multi-sector reconstruction techniques, SSF directly targets coronary-specific motion, adaptively compressing the temporal window within those localized regions where it’s most needed. Because SnapShot Freeze characterizes motion within a single heart cycle, it is not susceptible to the beat-to-beat inconsistencies or heart-period/gantry-period resonance points that can plague multi-sector (i.e., multi-heart cycle) reconstruction.

Motion phantom experiments (Fig. 2) have shown that SnapShot Freeze significantly reduces blurring artifacts in 2- and 3-mm simulated coronary vessels. This was corroborated in additional studies with clinical coronary-vessel images [7-11], in which SSF demonstrated its ability to enhance both image quality and diagnostic accuracy. This technology’s potential for improving cardiac CT imaging has led to the initiation of a prospective global multi-center trial, where SSF’s contributions to the diagnostic accuracy of CTA are being evaluated [12].
SSF for GSI Cardiac Acquisitions

In the Discovery CT750 HD FREEdom Edition release, GSI Cardiac was introduced as a powerful imaging tool to further cardiac imaging’s potential for determining vessel patency and detecting myocardial perfusion defects. With its fast kV-switching and fast-sampling-scintillator detector, GSI Cardiac merged the prospective gating of SnapShot Pulse (SSP) with Adaptive Statistical Iterative Reconstruction (ASiR) technology to provide the benefit of cardiac spectral imaging at low dose.

Since then, a number of recent clinical studies have confirmed the potential of GSI’s Material Decomposition (MD) and monochromatic keV images for:

- Reducing beam-hardening artifacts[17]
- Improving contrast-to-noise ratio (CNR) over conventional single kV images obtained at similar dose levels[14,19]
- Improving low-iodinated-contrast visualization at lower keVs[15-16]
- Reducing calcium blooming at higher keVs[18]
- Conducting accurate material separation [20]
- Specifying material density in terms of mg/cm³[20]
- Equipping users to further decompose acquired data into alternate materials, including calcium, iodine, and bone

SnapShot Freeze processing is now available for GSI Cardiac monochromatic images, thus expanding the reach of the intelligent motion correction technology. This will allow motion correction to be applied to GSI images, providing the benefits of motion artifact reduction to an exam that already benefits from reduced calcification artifacts, enabling enhanced coronary vessel assessment [13]. GSI Cardiac already provides clinicians with the ability to reduce calcium blooming by assessing a range of keV images to address the beam-hardening effects [17]; by addressing the motion component of calcium blooming, SSF will provide further reductions in this common artifact.

SnapShot Freeze can be used with GSI SnapShot Pulse acquisition. This combination of capabilities requires only approximately 80 msec of padding, which fits well within nominal padding levels. Low-dose iterative reconstruction (ASiR) is also supported, and SSF can be applied to different monochromatic keV levels (Figs. 3-5).

SSF’s ability to improve coronary-vessel image quality has also been effectively demonstrated in a clinical study [21].

The combination of SnapShot Freeze technology with GSI acquisition may enable the development of interesting new applications in cardiac CT—the potential to realize functional and anatomical information from a single stress exam. We have already seen the benefits of GSI acquisition related to perfusion defects for higher heart-rate stress scans [22, 23]; adding SSF motion correction will allow the coronary vessels to be assessed with reduced motion artifacts from the same CT scan [21].
Intelligent Boundary Registration

Another significant enhancement to cardiac CT technology is Intelligent Boundary Registration (IBR) which further enhances the clinical performance of multi-beat cardiac CT images.

We developed IBR to address a well-known clinical problem of heart-rate variation and/or non-repeatable, beat-to-beat motion which frequently manifests itself as misalignment artifacts in cardiac images. Built on SSF technology, IBR is an intelligent, vessel-driven, non-rigid registration algorithm for automatic analysis of, and compensation for, inter-beat misalignment of data in the image volume.

IBR uses vessel centerlines to identify potential vessel misregistrations at heart-cycle slab boundaries along the full extent of the coronary vessels. Applied in conjunction with SSF intelligent motion correction for optimal performance, it employs local operations on axial planes, to minimize its impact on other structures (Fig. 6).

In addition, IBR’s effectiveness was demonstrated, in an experiment using a coronary-vessel phantom, by Prof. Yeon Hyeon Choe, MD, PhD and Prof. Sung Mok Kim, MD, PhD, both of Samsung Medical Center at Sungkyunkwan University School of Medicine, Seoul, Korea.

For this experiment, they simulated arrhythmia by scanning the vessels attached to a pulsating cardiac-motion phantom (Alpha1-VTPC, Fuyo Co., Japan). The heart rate for the phantom was changed by varying amounts during each scan and the resulting images were processed with SSF and IBR to produce the final images. The SSF images clearly showed reduced motion blurring in the phantom images, and IBR removed the vessel misregistrations in these image volumes (Fig. 9). Drs. Choe and Kim repeated the scans at various arrhythmia and heart-rate settings, and the IBR images were found to be effective in correcting various degrees of misregistration.

IBR processing can be initiated by the 3D technologist or reviewer in the CardiQ Xpress Reveal application on the Advantage Workstation, working from any protocol that includes coronary vessel tracking and has ~1 second processing time – allowing it to be easily toggled on and off for vessel assessment. IBR can be applied to any coronary CTA series, including GSI Cardiac acquisitions, and is also available for exams that do not require SSF motion correction. Whatever the application, the new image volume can be optionally saved as a new reformat series.
Extended Cardiac Helical Pitch

With our confidence in SnapShot Freeze technologies we have enabled an Extended Cardiac Helical Pitch scanning mode which provides a significant dose reduction for higher heart rate scans. This relies on the ability of SSF to reduce motion blurring at higher heart rates. The Revolution GSI now supports helical pitches up to 37.5% faster for cardiac SnapShot Segment acquisition protocols.

Until now, SnapShot Segment acquisition protocols have had a maximum pitch of 0.24 for higher heart rates. That cap was necessitated by SnapShot Burst (SSB), a multi-sector, reconstruction technique which was used to minimize motion artifacts if they were present in the SnapShot Segment images; this lower pitch was needed for covering the same anatomical location at multiple heart cycles, so that the data from different hearts cycles could be combined for the multi-sector images. Unfortunately, this capability came at the cost of longer acquisition times, which in turn meant higher radiation dose and increased patient breath-hold times.

Now, however, SnapShot Freeze has "Extended" this limitation, allowing helical pitches of 0.32 for cardiac acquisitions. This not only reduces acquisition times; SSF has also been shown to provide superior coronary image quality to multi-sector reconstruction, especially for very high or highly variable heart rates. Example clinical cases (Figs. 10, 11) demonstrate SSF high quality coronary imaging versus multi-sector reconstruction for high-heart-rate exams.

Thus, faster SnapShot Freeze-compatible helical pitches are now supported for higher heart rates (Fig. 12). While SnapShot Burst can still be explicitly prescribed if the user wants to utilize multi-sector reconstructions, new SnapShot Segment pitches can provide up to 37.5% dose savings compared to the SSB protocols for higher heart rates (Fig 13), as well as shorter breath-hold times for patients. It can also provide a significant benefit in non-coronary cardiovascular applications such as gated aorta, gated chest for PE, and TAVI/TAVR.

![SSF Compatible Helical Pitch Table](image)

<table>
<thead>
<tr>
<th>Heart Rate (BPM)</th>
<th>SSF Compatible Helical Pitch</th>
<th>Dose Reduction vs. SnapShot Segment Protocol</th>
<th>Dose Reduction vs. SnapShot Burst Protocol</th>
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<tr>
<td>65</td>
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![Evolution of SnapShot Freeze Technology](image)
Conclusion

We believe these advances in Cardiac CT technologies will open new clinical capabilities and diagnostic domains for Cardiac disease assessment and therapy planning. The availability of SSF with GSI Cardiac, its benefits with IBR and enablement of Extended Cardiac Helical Pitch further enhances the versatility of our cardiac CT offerings and provides the user with more advanced tools to perform high-quality cardiac CTA exams.

Revolution GSI capitalizes on these advances in cardiac CT – SnapShot Freeze integrated with GSI Cardiac may improve the clinician’s confidence in assessing coronary vessels at the higher heart rates stress exams. This can enable both functional and anatomical assessments from the same CTA examination.

The novel vessel-registration technique known as IBR can reduce the number and severity of misalignment artifacts in coronary CTA datasets acquired over multiple heart cycles. This may potentially improve the clinician’s diagnostic confidence while reducing exam read time.

Finally, for non-coronary cardiovascular acquisitions, higher helical pitches at higher heart rates can allow for lower radiation dose and improved throughput.
References


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