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White Paper

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Considerations in cardiac CT: Understanding temporal resolution and rotation speed for improved cardiac imaging

White Paper
Philips CT Clinical Science • Philips Healthcare • USA

Introduction

Historically, Computed tomography (CT) was primarily concerned with only two resolutions - spatial and contrast. However, now with Cardiac CT imaging, another resolution - temporal - enters the picture.

Cardiac CT imaging has emerged as one of the most promising methods of detection of coronary artery disease (CAD). Rapid, noninvasive, and accurate, this imaging technology enables clinicians to arrive at a quick cardiac diagnosis, as well as to assist in treatment planning and follow up. Recent advances in CT equipment and image processing have resulted in significant improvements temporal resolution. Correspondingly, there is a need to understand temporal resolution for Cardiac CT imaging. This paper takes a closer look at the temporal resolution as it relates to Cardiac CT imaging.

A fuller view of CT temporal resolution

The efficacy of any cardiac imaging technology relates to its ability to deliver image detail (as expressed in spatial resolution) in the smallest "window" of time - expressed as temporal resolution, often by a number of milliseconds (ms).

Among most cardiac CT manufacturers, many clinicians and the lay press have translated cardiac temporal resolution into a race to design scanners with significantly more detectors and/or faster rotation times, so the X-ray beam can capture the maximum amount of data "slices" in the shortest amount of time, thus reducing patient breath hold. A glance at the top four vendors with 64-slice scanners clearly shows this design trend.

However, temporal resolution of a particular scanner is not synonymous with the number of detectors, nor is it related to rotation speed alone, but is impacted by a number of factors. In CT imaging, an image can be reconstructed with a minimum 180° of acquired data. For a scanner exhibiting 0.5 second (500 ms) rotation speed, the temporal resolution would be stated as 250 ms (one half of the rotation speed/360°). This simple form of Cardiac CT data reconstruction is defined as "Single Segment Reconstruction."

On the contrary, exclusively defining temporal resolution by expression of rotation speed alone is as limiting as evaluating automobile performance based on engine displacement.

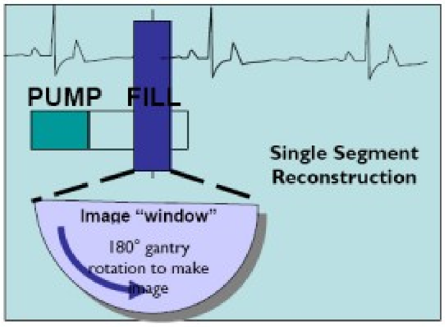
Another analogy would be two bicyclists racing without considering the gears they use:

Question: If two bicyclists pedal at the same rate on identical bikes, who wins?

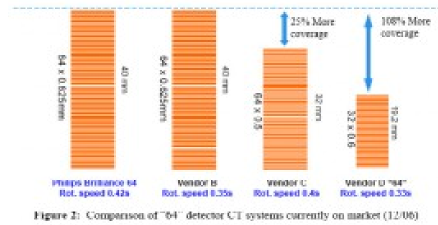
Answer: They will tie if both bikes are in the same "gear". However, a bicyclist may win the race yet pedal slower by better use of gears on her bike.

Analogy: Multi-cycle reconstruction is like using "gears" for cardiac CT imaging.

In reality, excellent temporal resolution can be achieved through a number of patient-centric techniques. These techniques rely on sophisticated acquisition and image reconstruction software and not solely on the mechanics of the scanner itself.



Single cycle reconstruction relies exclusively on the speed of gantry design.

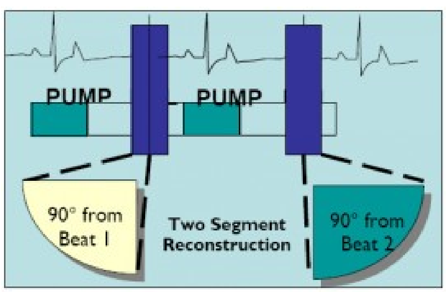


Comparison of "64" detector CT systems currently on market (12/06).

Software vs. Hardware-focused temporal resolution

One patient-adaptive technique, for example, captures images in two or more cycles rather than acquiring 100 percent of the cardiovascular data in a single cardiac cycle. Multi-cycle, gated reconstruction techniques are utilized in other types of cardiac imaging as well, such as Nuclear SPECT, Cardiac MRI, and 3D Cardiac Ultrasound. A multicycle approach reduces the rotational arc of the gantry required to produce an image.

Unlike single cycle approaches that use data from a single cardiac cycle in reconstructing an image, adaptive multicycle algorithms can produce a whole image from as many as five cycles of the cardiac cycle[i,ii,iii]. Philips' employs advanced acquisition software to automatically adjust to a patient's heart rate - called Rate Responsive technologies. It delivers the best temporal resolution possible all of the time for stable, clear cardiac imaging. This adaptive multi-segment reconstruction technique makes it ideal for applications where patients present with irregular heart beats or elevated heart rates up to 120 bpm, or for patients contraindicated for beta-blockers to reduce heart rates[ix].



2-cycle reconstruction improves temporal resolution by 50% versus single-cycle.

Clinical proof of patient-adaptive advancements

Patient-focused advancements have resulted in improvements in the detection of cardiovascular disease in a significant number of clinical studies.

A study conducted at the University of Ulm, Germany in 2004 concluded that motion-free coronary angiograms could be obtained consistently in patients with heart rates up to 80 beats per minute (bpm) with a Philip's 16-detector row CT scanners utilizing Rate Responsive adaptive multicycle reconstruction algorithms[iv].

A comparison of the diagnostic accuracy and image quality of two reconstruction algorithms (multi-segment and single segment half scan) for CT coronary angiography in Figure 4: 2-cycle reconstruction improves temporal resolution by 50% versus single-cycle patients without beta-blocker medication was conducted at Medical School of the Freie Universitat and Humboldt-Universitat in Berlin, Germany. As revealed in the April 2004 Investigative Radiology, statistically significant better image quality was achieved using the multi-segment reconstruction versus single cycle reconstruction to determine vessel continuity as well as visibility of side branche (v).

In back-to-back oral presentations at the 2005 Radiological Society of North America, Phillips Brilliance CT 40-channel scanner showed significantly better visualization of coronary artery stenosis than did a single cycle reconstruction vendor. Using multi-segment reconstruction, the Philips system rotating at 0.42 seconds was able to achieve a better average temporal resolution of 95 ms (range 1.5 to 3.1 multi-cycles) versus the single cycle reconstruction employed on the competitive system rotating at 0.33 seconds for a temporal resolution of 165 ms[vi, vii].

Furthermore, the temporal resolution capability and benefits of the Brilliance 40-channel CT scanner has been further reinforced in a recent publication by clinicians from Singapore[viii].

Finally, a paper published in the Journal of the American College of Cardiology by researchers from the Cleveland Clinic Foundation determined the feasibility of detecting occlusive coronary disease in heart transplant recipients with average heart rate of 90 bpm using a Philip's 16-slice scanner with multi-segment reconstruction. In fact, the authors summarize, "[normally] elevated heart rates would be considered a limitation to MDCT imaging, but in this patient population [i.e. high heart rates and contraindicated for beta blockers] it seemed to facilitate multi-segment imaging with improved temporal resolution"[ix].

	Pts	Heart Rate (bpm)	Breath hold (s)	Detector coverage/ rotation	Non-Evaluable Segments	Sensitivity	Temporal Resolution (ms)
Philips Brilliance 40	100	71 (53-109)	11.4	25.0mm (40 x 0.625mm)	5.3%	93%	95ms (1.5-3.1 cycles)
Siemens Sensation 64	50	n/a	13.6	19.2mm (32 x 0.60mm)	13%	83%	165 (1 cycle)
Table 1: Cardiac CT abstracts presented at RSNA 2005: Cluzel[vi]; Nikolaou[vii]					p < 0.05	p < 0.05	

Conclusion

Cardiac CT is emerging as one of the most promising noninvasive cardiac imaging technologies, exhibiting relatively high levels of precision in identifying and diagnosing cardiovascular disease. Cardiac CT works by taking traditional x-ray images of cross sectional views of the cardiac anatomy. In order to improve temporal resolution, many scanner vendors have focused exclusively on gantry rotation speed, capturing all of the data necessary to reconstruct a volume image of the heart in a single cardiac cycle. Thus for some vendors, gantry speed is synonymous with temporal resolution. However, a more extensive investigation of temporal resolution reveals that other factors - such as more sophisticated reconstruction techniques, can - and do - deliver exceptional temporal resolution, thus good, clinical cardiac CT image quality. This technology may be especially helpful for patients with elevated heart rates and contra-indicated for beta-blockers.

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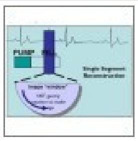

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This white paper provides information on how temporal resolution and rotation speeds improve cardiac imaging.

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