Coronary artery calcium quantification with retrospectively gated helical CT: Protocols and techniques

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Abstract

Current generation Helical Computed Tomography, when coupled with cardiac gating can be used to measure coronary vascular calcium. In this article we review the development of retrospectively gated helical computed tomography on a single slice HCT system and its relation to electron beam CT. The impact of heart rate on selection of helical pitch for the creation of a diastolic image set is detailed, as well as, scanning and post-processing techniques are discussed. The development and initial experience of cardiac gating with multidetector CT systems is presented.

Introduction

The heart has always held a central part in computed tomography (CT) imaging of the chest. Recent advances in helical CT technology, however, have made cardiac imaging, including form and function, feasible with helical CT scanners. In this article we will review our initial research with retrospectively gated cardiac CT with a single-detector helical CT system, how this compared with electron beam CT, and our initial experience with cardiac gating with a multidetector CT scanner. Woodhouse et al. [1]. Since their original article, further improvements in the temporal resolution of helical scanners has occurred. To acquire the cardiac images a single-detector helical CT scanner (CTi, General Electric Medical Systems, Milwau-kee, WI) equipped with a high heat unit tube that allows subsecond scanning was used. By combining a partial (or segmented) scan reconstruction algorithm and a gantry rotation speed of 0.8 s, the temporal resolution of 500 ms per image is achieved. A detailed explanation of retrospective cardiac gating with helical CT, along with informative diagrams, is provided in the article by Woodhouse et al. [1].

The scan technique consists of obtaining a helical volume of information through the heart during a single breathhold. The partial or segmented scan reconstruction algorithm is used. This results in images with a 500 ms temporal resolution. The reconstruction is prescribed in such a way that 3 mm slices are reconstructed at 0.3 mm intervals. This reconstruction results in a series of
350–400 images with a 90% spatial overlap along the Z-axis and time increments of 100 ms. The result is a series of images from the aortic root through the heart with approximately 10 images per cardiac cycle.

For quantifying the amount of coronary calcium the goal, as with electron beam CT, is to obtain a contiguous set of cardiac images during diastole so as to minimize coronary artery motion. To achieve this, a digital ECG is recorded during the scan acquisition. This digital ECG is then synchronized with the CT image data such that the appropriate diastolic images can be selected for scoring coronary calcium. Practically speaking, the individual receiving the cardiac CT scan is connected to a standard ECG monitor that has been modified to record the ECG waveform when the CT scanner is activated. The waveform is checked on the ECG monitor to ensure appropriate lead position and tracing amplitude. Upon the acquisition of the helical volume through the heart, a signal from the scanner is passed to the ECG, at which point the tracing is recorded, the R-waves are detected, and a file is written with the relevant information to a floppy disk. Following the scan acquisition both the 350–400 reconstructed CT image data and digital ECG data are transferred to a postprocessing workstation (Advantage Windows 3.1, General Electric Medical Systems).

Creating a diastolic image set for calcium scoring

Measuring coronary calcium by means of retrospective cardiac gating requires two steps following scan completion and image reconstruction. The first process is selection of a contiguous set of diastolic-phase images; this step is followed by identifying, selecting, and labeling coronary calcium. As mentioned previously, the image data are transferred over a local area network to the postprocessing computer workstation. This workstation has a software program designed to accept both the image and ECG data and to perform diastolic image selection, as well as calcium scoring (SmartScore, GE Medical Systems). Creating the diastolic-phase image set requires that one image per cardiac cycle be selected based on an offset in time from the R-wave. The program reads the digital ECG, which was recorded during image acquisition. An automated algorithm then selects the image that occurs in late diastole based on either a preset time from the R-wave or a percent of the R-to-R interval. The selected diastolic images can then be reviewed for appropriateness by the individual scoring the coronary calcium and can be either accepted or modified.

It may be useful to summarize the process with a hypothetical example. For instance, the initial scan prescription might have required 35 3-mm slices to cover the entire heart. These initial 35 slices in a typical scan would be reconstructed without respect to the cardiac cycle. To perform retrospective cardiac-gated CT, the scanner operator would perform a reconstruction using the raw scan data and create a new series with approximately 10 times the number of images. This is achieved by prescribing a series with 90% overlap along the