Timing on 16-Slice Scanner and Implications for 64-Slice Cardiac CT: Do You Start Scanning Immediately After Breath Hold?[1]

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Rationale and Objectives. Slow heart rate and small changes in heart rate are factors for improving image quality on spiral cardiac computed tomography (CT). The purpose of this study is to investigate whether it is possible to improve nonenhanced cardiac CT quality by delaying the data-acquisition window after breath hold.

Materials and Methods. Electrocardiograph files (n = 240) for 16-slice nonenhanced cardiac CT scans were analyzed. Mean heart rates and maximal changes in heart rates between adjacent cardiac cycles were compared between phase 1 (defined as cardiac cycles 1–5), phase 2 (cardiac cycles 2–6), . . . , and phase 6 (cardiac cycles 6–10).

Results. Heart rates gradually increased by phases, but were limited to a range of 66.8–68.0 beats/min. Maximal changes in heart rates were 2.5 beats/min (phase 1) at the highest and 1.3 beats/min (phases 5 and 6) at the lowest (*t*-test; $P < .01$). Maximal changes in heart rates for more than five beats/min occurred in 24, eight, and eight patients on phases 1, 5, and 6, respectively (chi-square test; $P < .01$).

Conclusion. The delayed scan (four or five cardiac cycles after breath hold) has the potential to improve the quality of nonenhanced cardiac CT.

Key Words. Cardiac; computed tomography (CT); heart rate.

For reducing or minimizing motion artifacts of the heart, high temporal-resolution levels of 19 (1), 41.8 (2), and 30–50 milliseconds (3) are considered to be required. However, because of the mechanical limitation of gantry rotation speed, the temporal resolution of spiral computed tomography (CT) is approximately 100 milliseconds, even at best. Therefore, optimization of the data-acquisition window on the electrocardiograph (ECG) is vital for cardiac spiral CT. Slow heart rate is considered an important factor on both coronary CT angiography (4) and coronary artery calcium scoring (5). Stability of heart rate also is a key requirement because changes alter the data-acquisition window of the cardiac cycle, which may result in the inclusion of systole or atrial contraction (5,6).

Cardiovascular rhythms are modulated by central mechanisms and afferent input from arterial baroreceptors, chemoreceptors, cardiac receptors, and pulmonary and thoracic stretch receptors (7). During inspiration and suspension of respiration at the cardiac CT scan, heart rate is influenced by pulmonary and thoracic stretch receptors. Increased venous return with the negative in-

Acad Radiol 2006; 13:173–176

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doi:10.1016/j.acra.2005.10.006

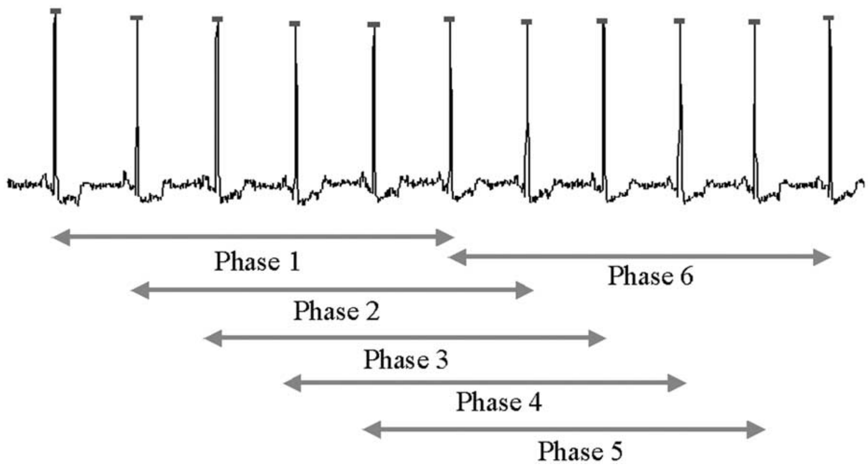

Figure 1. Data acquisition phase. In ECGs obtained during a coronary calcium score study using 16-slice CT, phases 1, 2, 3, 4, 5, and 6 were assigned to cardiac cycles 1–5, 2–6, 3–7, 4–8, 5–9, and 6–10, respectively.

trathoracic pressure of a deep inspiration also acts as a factor that speeds up heart beat. However, to date, there has not been much focus in cardiac CT examination on when we should start scanning after the breath hold. This probably is because of a longer scanning time on 16-slice or fewer-slice CT.

With the advent of the 64-slice spiral CT scanner, scanning time is reduced remarkably to approximately eight cardiac beats when using the retrospective ECG-gating technique. The purpose of this study is to test whether it is better to start scanning immediately after breath hold.

MATERIALS AND METHODS

Two hundred forty patients (198 men, 42 women; age, 66 ± 9 years: range, 37–85 years) undergoing coronary artery calcium scoring by using 16-slice CT with retrospective ECG gating were involved in this study. Informed consent was received from all patients. The deep-inspiration and breath-hold–triggered ECG files obtained by using three-lead ECG during CT scans were used. ECG files recorded were diagnostic in cardiac cycles of 10 beats/min or greater in all cases.

Data acquisition phase including five cardiac cycles is defined as shown in Figure 1. First, means of heart rates in five cardiac cycles were calculated and compared between phases. Next, changes in heart rates between adjacent cardiac cycles were calculated, and the mean and maximum were obtained. An example of phase 1 is as follows:

$$Mean = (abs[HR1 - HR2] + abs[HR2 - HR3] + abs[HR3 - HR4] + abs[HR4 - HR5])/4$$

$$Maximum = maximal\ value\ between\ abs(HR1 - HR2),\ abs(HR2 - HR3),\ abs(HR3 - HR4),\ and\ abs(HR4 - HR5)$$

where HR1 is the heart rate of the first cardiac cycle. Thus, means and maximums of heart rate changes were compared between phases.

Last, maximal changes in heart rate of more than 5 and 10 beats/min were obtained, and numbers of cases were compared between phases.

For statistical analysis, *t*-tests and chi-square tests were used. $P < .05$ is considered to identify significant differences.

RESULTS

Heart rate results are listed in Table 1. Heart rate gradually increased by phases; however, the difference was only 1.2 beats/min at its greatest, observed between phases 1 and 6. The relationship between phase beats per minute in mean heart rate was as follows:

$$Mean\ heart\ rate = 66.5 + 0.24 \times phase\ (R = 0.98)$$

Heart rate changes are listed in Table 2. The change was 2.5 beats/min at its greatest in phase 1. Change de-