'Cardiac motion correction' software: a method of improving coronary artery visualisation on contrast enhanced CT chest

Poster No.: C-1368
Congress: ECR 2014
Type: Scientific Exhibit
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Keywords: Cardiac, CT, Computer Applications-Detection, diagnosis, Arteriosclerosis, Outcomes
DOI: 10.1594/ecr2014/C-1368

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**Aims and objectives**

Imaging the coronary arteries is challenging because of their small dimensions and 'non-stoppable' cardiac motion. CT coronary angiography (CTCA) has benefited from faster CT gantry rotation speeds, CT tube configurations and detector slice number, and also the use of beta-blocking medication. Despite these, a slow heart rate, generally less than 60 beats/minute (BPM), is generally the key to a good quality CTCA.

Recent software advancement allows correction of motion of vessels within a single heart cycle by mapping vessel movement and velocity [1], and therefore, has a computing 'heart motion frozen' effect and the effective temporal resolution can be down to 29msec [1]. This may help to produce interpretable CTCA without the need of beta-blocking, even though the heart rate is high. The aim of this prospective study was to determine the efficacy of 'cardiac motion correction' software in the assessment of coronary arteries on patient's attending for a contrast enhanced CT chest for lung nodule follow up seen on cardiac CT.
Methods and materials

Subjects:

Consecutive adult patients who had lung nodules identified on cardiac CT and returned for follow up lung nodule CT chest at 3 months were included. Patients, who had severe renal impairment, were excluded.

CT Coronary angiography:

The initial cardiac CT was performed as a volumetric acquisition on the 320-slice multidetector CT (320-CT) (Aquilion One, Toshiba Medicals, Tokyo, Japan). Heart rates in these patients were generally below 65 BPM. The scanning parameters were: 120 kVp, 150 mAs, 0.5 mm collimation, and 350 milli-second rotation.

When the patients returned for CT chest follow up for lung nodules found on initial CTCA, an ECG-gated CT chest was performed at any heart rate on these patients with the GE Discovery CT750HD Vision multidetector CT (GE Medical, Milwaukee, USA), which utilised 'cardiac motion correction' (CMC) software. No Beta-blockers or GTN spray were administered. Intravenous contrast (Omnipaque 350) volumes varied between 65-100mls at 5mls/second. The scanning parameters were 120 kVp, 140-260mAs, 0.625mm collimation and 350 milli-second rotation. The dose length product (DLP) did not exceed the Australian National Diagnostic Reference Level (NDRL) for a chest of an average sized patient (450 mGy.cm) [2]. Routine CT images of lung nodules and additional software corrected coronary artery images were produced.

Image Analysis:

The coronary artery images from both 320-CT and ECG-gated CT chest with CMC were individually and randomly read by 2 blinded radiologists for the number of stenoses, motion artefact and vessel clarity. The number of stenoses were recorded in the segments which they were located, and the quality of vessels were graded on a five point scale for the proximal, mid and distal segments (1: Non-diagnostic, 2: Bad, 3: Fair, 4: Good and 5: Excellent). These results from the 2 groups were compared.
Results

Kappa score between 2 blinded readers were 0.85.

Twenty patients (12 males and 8 females, age range of 44-77 years with a mean age of 63, and BMIs of 22 to 36) were recruited. The heart rates were below 65 beats/min at the initial CTCA with 320-CT, and were between 43-92 BPM at the follow up ECG-gated CT chest with CMC.

In total, 480 coronary artery segments from these 20 patients's CTCA were assessed.

There were 32 stenoses identified on the 320-CT, but only 28 stenoses on the ECG-gated CT chest with CMC (Figure 1). There was significant motion degradation leading to non-visualization of these stenoses on the ECG-gated CT chest. These 'missed' stenoses were in the distal LAD and mid RCA, which were the likely coronary arterial segments prone to motion artefacts [3]. This is not surprising as the heart rates for the initial cardiac CT acquisition ranged between 46-65 BPM, significantly lower and more stable compared with the follow up ECG-gated CT chest due to the administration of oral beta-blockers [3]. The 'cardiac motion correction' software was not able to correct these significant artefacts.

Regarding the quality of the coronary arterial segments, the 320-CT and the ECG-gated CT chest had gradings of Good-Excellent in 84.2% and 54.2% of cases respectively (Table 1 & Fig 2). The distal vessels tended to have lower image quality in the ECG-gated CT chest, probably due to the following factors (Fig 3). The patients undergoing the ECG-gated CT chest required the full chest to be scanned which increased the length of the breathhold and scan time. As a result, hypoxia may have increased the heart rate for some patients therefore causing more vessel motion which could not be optimally corrected by the software. In addition, the contrast volumes were only between 65-100mls with a standard injection protocol used, not a cardiac CTA injection protocol which utilizes a faster injection rate, greater volumes of contrast, saline bolus and also a significantly smaller z-axis coverage. A targeted CTCA injection protocol with subsequent saline push would ensure optimal filling of the full length of the coronary arteries (Fig 4).

Interestingly, heart rate was not a true and only indicator of a lower quality scan for the ECG-gated chest with 'cardiac motion correction' software. In some instances, patients with higher heart rates had better quality images suggesting that the motion and velocity of the vessel were properly mapped by the software, which was not entirely dependent on the heart rate (Fig 5). The orientation to which the vessels move can adversely impact the success of motion correction.
Limitation of this study was the small number of patients that could be recruited due to the low incidence of lung nodules found in CTCA.
Fig. 1: Number of stenoses detected per vessel segment

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### Table 1: Breakdown of image quality gradings in all segments assessed

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Fig. 2: Comparison of overall image quality gradings

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Fig. 3: Percentage of cases demonstrating image quality grading per vessel segment

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Fig. 4: Same patient with optimal contrast enhancement of the coronary vessels for the dedicated CTCA (right) versus sub-optimal contrast enhancement on the ECG-gated chest with motion correction (left)

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Fig. 5: Motion corrected scans of high heart rate versus lower heart rate

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Conclusion

Motion correction software is capable of producing adequate coronary artery images to detect the majority of significant stenoses on a routine CT chest without the need to beta-block. To increase image quality, greater contrast amounts with subsequent saline bolus should be considered and in the cases of unstable heart rates, greater padding would ensure a more optimal phase to apply the motion correction software. This 'cardiac motion software' could be of value in excluding major proximal coronary artery stenosis in patients who were referred for indications, such as pulmonary embolism or pre-operative assessment of chest lesions, in whom detection of significant coronary artery stenosis may alter management.
References

