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Maximizing the clinical benefit of high-pitch, single-heartbeat CT coronary angiography in clinical practice

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AIM: To prospectively analyse the occurrence of right coronary artery (RCA) artefact and assess its relationship with patient heart rate (HR) and HR variability (HRV) in order to determine the most appropriate parameters for high-pitch cardiovascular computed tomography (CT) acquisition, minimize the likelihood of artefact, and maximize the clinical benefit in consecutive clinical high-pitch CT coronary angiography (CA) examinations.

MATERIALS AND METHODS: One hundred and seventy-three patients undergoing high-pitch CTCA were prospectively assessed for the presence of RCA artefact. Median and maximum HR and the difference in predicted and actual acquisition HR (HR difference, HRD) were correlated from the electrocardiograms recorded at the time of acquisition.

RESULTS: Sixty-six percent of the cohort was male, with a median age of 54 (range 16–84 years). There were 53 cases of RCA artefact (30.6%); 26 (49.1%) of these required further imaging to fully delineate the RCA. Of the 53 cases with artefact, 81.1% affected the distal RCA and 18.9% were more proximal. Gender was not associated with an increased likelihood of the artefact ($p = 0.14$). RCA artefact decreased by 2% with each year of increasing age ($p = 0.04$). When compared with a reference HR of >70 beats/min, univariate analysis demonstrated RCA artefact significantly increased with both increasing median and maximum HR, whilst the incidence of RCA artefact increased for all HRD >1, with a greater likelihood of artefact with increasing HRD.

CONCLUSION: The present results highlight the importance of optimizing patient HR in order to reduce the likelihood of RCA artefact. In addition to aggressive HR control to a median HR of ≤60 beats/min, the present results suggest limiting high-pitch acquisition to patients with HR variability of <3 beats/min. Therefore, use of beta-blockers is of crucial importance to both reduce HR and HR variability to optimize use of high-pitch single-heartbeat CTCA.

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Introduction

Dual-source computed tomography (DSCT) halves temporal resolution when compared to single-source CT, allowing the requisite data for image generation to be acquired in just over a quarter gantry rotation. When used in

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conjunction with a very high pitch this allows the entire coronary circulation to be imaged in a single heart beat (0.27 s for 12 cm coverage), theoretically making image quality less dependent on heart rate (HR), and the phase of the cardiac cycle.[1] Overlapping radiation exposure is also minimized in high-pitch DSCT, significantly reducing radiation dose, often to <1 mSv.[2]

Although lower-pitch DSCT has been demonstrated to deliver diagnostic quality with HRs of ≥100 beats/min[3,4]; when using a high-pitch acquisition, enough time is required to capture complete coronary stasis in a single heartbeat and even small errors in timing during high-pitch acquisition may give rise to artefact due to cardiac and coronary motion. Right coronary artery (RCA) artefact was noted by the present authors with particular frequency when using a single-heartbeat protocol [this particularly affected the distal RCA as it turned under the inferior surface of the heart (Fig 1a)]. This was despite HRs of <65 beats/min and analysis of the electrocardiogram (ECG) in patients with this artefact appeared to suggest this was due to the latter part of the acquisition running into systole, due to a shorter R–R interval than anticipated by the scanner in its pre-acquisition analysis (Fig 1b).

Therefore, the aim of the present study was to prospectively analyse the occurrence of RCA artefact and assess its relationship with patient HR and HR variability (HRV) in order to determine the most appropriate parameters for high-pitch cardiovascular CT acquisition, minimize the likelihood of artefact, and maximize the clinical benefit in consecutive clinical high-pitch CT coronary angiography (CTCA) examinations.

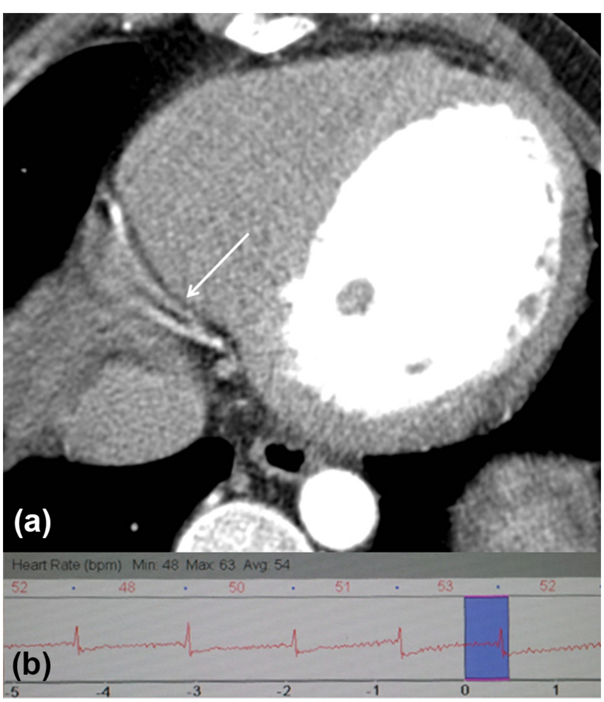

Figure 1 (a) Axial image showing distal RCA artefact (white arrow) due to the more inferior aspect of heart being imaged in systole. (b) ECG trace in the same patient shows predicted HRV of 50. The images were acquired at an HR of 53 beats/min; therefore, at a more delayed phase of the cardiac cycle, running into systole.

Materials and methods

One hundred and seventy-three consecutive clinical patients undergoing high-pitch CTCA were prospectively analysed. Patients aged <10 years old were excluded from the study. Following discussion with the local research and development office, the requirement for ethics was waived as all examinations were performed purely based on clinical indication alone.

All examinations were performed for clinical reasons on a Siemens SOMATOM Definition Flash (Erlangen, Germany). Patients were scanned at 100 kV unless their weight exceeded 90 kg, when a 120 kV protocol was used. All examinations were tube current dose modulated, had a standard rotation time of 0.28 s with a pitch of 3.2, and a dual-phase contrast medium injection. Intravenous beta-blockers were administered (if not contraindicated) to obtain a HR of <60 beats/min. In cases of RCA artefact where images were deemed clinically non-diagnostic, a repeat prospective examination of the inferior 4–8 cm of the heart was performed to fully delineate the RCA if the clinician felt this was required to fully exclude significant coronary artery disease (CAD).

As the CT machine predicts the HR for acquisition based on the median of the differences in the three previous heartbeats, (excluding the one directly before acquisition, where this is not analysed as the table feed has already started; Fig 2), the median and maximum HRs and the difference in predicted and actual acquisition HR (HR difference, HRD) were calculated from the ECGs recorded at the time of the acquisition.

Axial and multiplanar reformat (MPR) images were assessed independently by two cardiac radiologists, experienced in coronary CT (level 3 SCCT/BSCI), for the presence of artefact that might suggest poor-quality acquisition (excluding the typical high-pitch RCA artefact), and to determine whether any additional confounding factors may be affecting image quality. Overall image quality (specifically ignoring RCA artefact) was evaluated using a four-point scale (4 = optimal, 3 = minor artefact only, 2 = moderate artefact but diagnostic, 1 = non-evaluable), incorporating factors such as signal-to-noise ratio, breathing, and motion and streak artefacts.

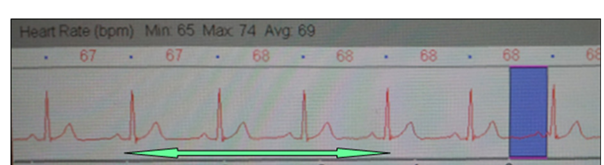

Figure 2 Example ECG to show predicted HRV as calculated by the scanner (67 + 68+68)/3 (green arrow). Image acquisition corresponds to the blue box. The beat prior to the acquisition is not assessed as table feed has commenced.

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