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Research paper

High pitch third generation dual-source CT: Coronary and cardiac visualization on routine chest CT

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Background: Chest CT scans are frequently performed in radiology departments but have not previously contained detailed depiction of cardiac structures.
Objectives: To evaluate myocardial and coronary visualization on high-pitch non-gated CT of the chest using 3rd generation dual-source computed tomography (CT).
Methods: Cardiac anatomy of patients who had 3rd generation, non-gated high pitch contrast enhanced chest CT and who also had prior conventional (low pitch) chest CT as part of a chest abdomen pelvis exam was evaluated. Cardiac image features were scored by reviewers blinded to diagnosis and pitch. Paired analysis was performed.
Results: 3862 coronary segments and 2220 cardiac structures were evaluated by two readers in 222 CT scans. Most patients (97.2%) had chest CT for oncologic evaluation. The median pitch was 2.34 (IQR 2.05, 2.65) in high pitch and 0.8 (IQR 0.8, 0.8) in low pitch scans ($p < 0.001$). High pitch CT showed higher image visualization scores for all cardiovascular structures compared with conventional pitch scans ($p < 0.0001$). Coronary arteries were visualized in 9 coronary segments per exam in high pitch scans versus 2 segments for conventional pitch ($p < 0.0001$). Radiation exposure was lower in the high pitch group compared with the conventional pitch group (median CTDIvol 10.83 vs. 12.36 mGy and DLP 790 vs. 827 mGycm respectively, $p < 0.01$ for both) with comparable image noise ($p = 0.43$).
Conclusion: Myocardial structure and coronary arteries are frequently visualized on non-gated 3rd generation chest CT. These results raise the question of whether the heart and coronary arteries should be routinely interpreted on routine chest CT that is otherwise obtained for non-cardiac indications.

1. Introduction

Chest computed tomography (CT) protocols are one of the most commonly performed CT examinations in radiology departments. For oncologic disease, chest CT is performed without ECG gating and with iodinated contrast injected at moderate flow rates. In comparison, cardiac CT protocols typically include a) pharmacologic control of heart rate, b) coronary vasodilation, c) electrocardiogram gating and d) optimization of high flow iodine injection rates and e) diastolic phase imaging. These specialized cardiac CT protocols result in very high sensitivity and specificity of greater than 90% for significant coronary artery disease.[1]

However, even using older generation CT scans, coronary artery calcification scores can be obtained from routine non-contrast chest CT (i.e., CT performed for non-cardiac indications).[2] These calcium score findings may be “incidental” to the primary indication for the chest CT, but may be important to patient care.[3] Despite the wide availability of treatment for coronary artery disease, there is no consensus in the radiology community as to whether patients and physicians should be made aware of incidental calcium score findings. In contradistinction, pulmonary nodules are common incidental findings on dedicated calcium score CT (23–48% incidence[4]). Pulmonary nodules are routinely reported by radiologists despite much less compelling data for follow-up and treatment.[4]

New, third generation dual source CT scanners can now image

Abbreviations: IQR, interquartile range; CAD, coronary artery disease; DLP, dose length product; CTDIvol, ct dose index (volume); CI, confidence interval; HU, hounsfield units; IRB, institutional review board.

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the entire chest in less than 1 second with isotropic 3-dimensional spatial resolution of approximately 0.5 mm.[5] With this rapid scan speed, the superior to inferior extent of the heart is imaged in only a few hundred milliseconds. Technical issues including a reduced field of view in high-pitch dual source CT and a potential for increased artifacts have been largely mitigated using a wider second detector and improved reconstruction algorithms. Rapid scanning can "freeze" cardiac motion, providing heart and coronary detail that has not previously been visualized on chest CT[6] and that may require interpretation by the imaging physician. Thus, the purpose of this study was to evaluate visualization of coronary and cardiovascular features on routine chest CT using 3rd generation dual source CT. For comparison, we identified patients who also had undergone 2nd generation dual source CT of the chest.

2. Methods

2.1. Study design and patient selection

Our institution's Office of Human Research Services reviewed the study design; institutional requirements for IRB review and patient consent were waived. All patient related information (including CT scan date) was anonymized by an independent third party who was not involved in review of CT scan data. We used the hospital information system to identify consecutive patients who had both 3rd generation high pitch (pitch > 1) contrast enhanced chest, abdomen and pelvis scans between 11/5/2014 and 1/5/2015 as well as prior conventional pitch CT (pitch ≤ 1, referred to as "low pitch"), performed within 12 months of the high pitch CT scan. No further selection of studies was applied (i.e., consecutive patient studies were reviewed without further exclusions).

2.2. Image acquisition

The "pitch" of a CT scan is commonly defined as the ratio of table feed per 360° gantry rotation and collimated beam width.[7] High pitch scans were performed using a 3rd generation dual-source CT scanner as a standard procedure for chest abdomen pelvis exams (Somatom Force, Siemens Medical Systems, Forchheim, Germany). A key feature of 3rd generation dual source CT is a high capacity x-ray tube capable of very high photon flux to allow approximate doubling of scan pitch. Iterative reconstruction methods were also reported by the manufacturer to be improved in order to reduce radiation exposure. For chest CT, scan parameters included peak kilovoltage (kVp) of 120; tube current was set according to manufacturer recommendations to maintain image quality. ECG gating was not used, since ECG gating is not the standard of care for chest CT scans. "High pitch" CT was at a maximum pitch of 3.0 for a field of view of 35.4 cm or smaller (in accordance with manufacturer recommendations). The field of view was chosen by the operator based on clinical indication and independent of pitch considerations. If a FOV >35.4 cm was selected by the operator, the pitch was automatically reduced by the scanner software to enable the specified FOV (this limitation is due to different detector sizes of the dual source system). Intravenous contrast injection without bolus tracking was used (Iopamidol 300 mg/ml [Isovue, Bracco Diagnostics, Melville, NY], 120–130 ml, 2 ml/sec, 70 sec scan delay).

2.3. Image reconstruction

Images were reconstructed for 2 mm axial thickness and 512 × 512 in-plane resolution. In addition, thin slices at 0.5 mm were reconstructed for high pitch examinations in order to specifically address coronary artery visualization. Reconstruction kernel was B43f (body kernel) for studies on the Somatom Flash, Br40 (body kernel) for the Somatom Force 2 mm slices and Bv36 (vessel kernel) for 0.5 mm slices. A slice overlap of 50% was used for all reconstructions. For iterative reconstruction, Safire level 2 was used in the Somatom Force and in the Somatom Flash. The maximum field of view available was reconstructed.

2.4. Image analysis

All scans were fully anonymized using commercially available software (DICOMAnonymizer Pro, Neologica, Italy). Readers were blinded to clinical indication and scan parameters. Datasets were presented in random order. For the mediastinum and heart, two radiologist readers (M.A. and E.J., 8 and > 15 years of experience in CT imaging) assessed CT image quality using a 5 point rating scale (5 = excellent and 1 = non-evaluable) as displayed on a DICOM viewer (Radiant, Medixant, Poland). For each structure of interest, readers where given samples of image quality (data supplement, Fig. 1) in order to standardize image quality readings. For coronary artery images, two cardiologist readers (V.S. and M.C with 5 and 11 years of experience in cardiac CT imaging) scored images using a 4 point scale described previously[8] (4 = excellent and 1 = non-evaluable) using a cardiac CT workstation (Vitrea Software, Vital imaging, MN). Assessment of the coronary segment involvement score (SIS) was performed on blinded axial 2 mm slices by a cardiologist reader (V.S) using the SCCT segment model.[9] Image noise was measured as the standard deviation of CT Hounsfield units as previously described[10] using ImageJ software (NIH, Bethesda).[11] Image noise was measured in regions of interest approximately 1 cm^2 size in the trachea and left lung (avoiding branch vessels) at a level just above the aortic arch and on the level of the left ventricle in the anterior/posterior subcutaneous fat tissue and descending aorta.

2.5. Statistical methods

Median and IQR were calculated for quality scales. Cohen's kappa and reader agreement was calculated to assess reproducibility of quality assessments. A paired Wilcoxon signed rank test was used for comparison of two groups. A Kruskal-Wallis test was performed for multiple group comparisons, followed by a pairwise Dunn test if applicable. Logistic regression was used to determine the relationship of quality score to patient and CT acquisition factors. All statistical analysis was performed using R Version 3.2.2.[12]

3. Results

3.1. Study population and scan parameters

A total of 333 datasets from 111 patients were evaluated (111 low pitch scans and 111 paired high pitch scans at 2 mm slice thickness in addition to 111 high resolution (0.5 mm) reconstructions using high pitch mode). The median time interval between low pitch and high pitch CT was 70 days (IQR 49, 144.5). The majority of patients underwent chest CT for evaluation of oncologic disease (97.3%, 108/111, Table 1). The median body mass index was 26.64 kg/m^2 (IQR 23.67, 31.02) and 57% (63/111) of the patients were male. The median age was 56 years (IQR 46, 63).

CT scan parameters are shown in Table 2. The median pitch in the high pitch exams was 2.3. There was no significant difference in heart rate between the high and low pitch groups (79.5 vs. 78.5 beats per min). The contrast enhancement in the ascending aorta was higher in the high pitch group (229 vs. 205 HU, $p = 0.0036$).