Aims and objectives

Coronary CT angiography (CCTA) was rated as appropriate by the American College of Cardiology Foundation in patients with low or intermediate risk or pretest probability (1).

CCTA has not been advised for patients with cardiac devices as pacemakers, implanted cardioverter-defibrillator (ICD) and cardiac resynchronization therapy devices (CRT). Image quality is impaired according to the position of endocardial leads (2-5).

Iterative reconstruction is a new reconstruction technique that is able to reduce image noise (6;7). Moreover a moderate reduction of metal artifacts is expected (8;9).

To determine the feasibility of coronary CT angiography with iterative reconstruction in patients with endocardial leads we evaluated the image quality using a 320 slice MSCT and iterative reconstruction technique.
Methods and materials

This retrospective study was approved by our institutional clinical study review board, and written informed consent had been obtained from all participants.

Coronary CT angiography (CCTA)

From 04/2012 until 01/2015 in 1641 consecutive patients a CCTA was performed with a 320-row CT-scanner for clinical indications.

All CCTA studies were performed with prospective ECG-triggering. Patient with a heart rate of more than 65/min received 100 mg atenolol peroral or 5 -15 mg metoprolol succinate intravenous in advance.

Contrast material (60-80 ml; 400 mg/ml iodine; flow rate 3.5-4.5 ml/sec) was injected via an 18-gauge antecubital intravenous access using flow rates followed by a normal saline flush of 40 ml injected at a rate of 3 ml/sec.

Tube potential was 100-135 kVp dependent on the patients BMI; rotation time was 350 msec.

The phase window was set according to the heart rate between 70% and 80% of the R-R-intervall in patients with a heart rate less than 65/min, and was increased in patients with a heart rate of more than 65/min.

Reconstruction parameters were as follows: medium-smooth kernel (FC43), matrix size 512 x 512, slice thickness 0.5 mm. Images were reconstructed with adaptive-iterative-dose-reduction in 3D (AIDR 3D) using the vendor-recommended standard presetting. Image data were transferred to a workstation (Vitrea, Vital Images) for reconstructing curved maximal intensity projections of each vessel with a diameter of more than 1.5 mm. AIDR 3D works in the raw data and in the image domain (10).

Matched pairs of patients

CCTA was performed in 1641 patients overall, from these 55 patients had endocardial leads, the remaining were considered as a control group. Retrospectively we built matched pairs of patients from each group with identical sex, age ± 6 years and BMI±2 points. In 4 patients no matching partner was available, so 51 matched pairs could be evaluated. Of these 42 patients had pacemakers, 7 ICD and 2 CRT.

Image quality
For evaluation of noise and signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR), regions of interest (ROI) were positioned in the ascending aorta (Ao) and the left ventricle (LV) as large as possible avoiding the vessel wall or plaques. The mean standard deviation of the Hounsfield units of both values was defined as image noise. SNR was determined by dividing the averaged CT number HU by the pixel noise [HU] resulting in two different values SNR-Ao and SNR-LV. SNR and CNR were evaluated for the left (LCA) and for the right coronary artery (RCA). The ROI were positioned in the proximal vessel lumen and in the surrounding epicardial fat. In the LCA the position of the ROI was located in the left main artery or in the left anterior descending artery (LAD) according to the anatomic conditions. The difference of the CT number HU in the vessel lumen and the surrounding epicardial fat was determined for the contrast of the vessel lumen, the difference of the CT number HU in the ventricle lumen and in the myocardium for the LV.

The SNR and CNR of the vessel lumen were determined with respect to the noise in the Ao and the noise in the LV separately; this resulted in two different values for each of the LCA, RCA and LV (SNR LCA/Ao; SNR LCA/LV; SNR RCA/Ao; SNR RCA/LV), (CNRLCA/Ao; CNRLCA/LV; CNR-RCA/Ao; CNR-RCA/LV)

Subjective image quality was rated separately for the 15 segments of the coronary arteries by 2 radiologists with >15 years experience in reading CT examinations. Segments with a diameter of more than 1,5 mm were considered. All images were displayed in our picture-archiving-and-communications-system with available functions of windowing and zooming. A scale from 1 (non diagnostic with marked artifacts by endocardial leads) to 5 (excellent without any artifacts) was applied independently by each rater. In case of different ratings consensus was reached. Rating 1 and 2 were deemed to be non diagnostic. Criteria for evaluation were beam hardening artifacts and discrimination of the vessels. The presence of artifacts was assigned to the atrial lead, to the ventricular lead or to the coronary sinus lead.

**Data analysis**

Statistical analysis was done using the statistical software SAS (SAS Institute Inc., Cary, NC, USA). The data of the matched pairs were assumed to be dependent.

Values are given as mean ± standard deviation (SD) or as median with the interquartile range (IQR), as appropriate. The Shapiro-Wilk test was used to identify normal distribution of the differences. The student’s t-test for paired samples was used for normally distributed data, the Wilcoxon-test was used for not normally distributed data. A p-value of 0.05 or less was deemed statistically significant.

The test of marginal homogeneity was used to compare the ratings of the images.
Results

Patient characteristics

In 51 matched pairs 4 were female (27%) and 37 male (73%). Patients with endocardial leads were younger than patients without devices, however, the median of the difference was one year. BMI was comparable with a mean of 26.19 in both groups. Heart rate during the scan was higher in patients with endocardial leads than in the control group with a median of 64 versus 61, p < 0.001. The median of the difference was 2 bpm.

Image quality - objective parameters

SNR-Ao was reduced in the study group compared to the control group (median 15.04 versus 16.6; p = 0.004), SNR-LV was only slightly reduced (median 13.62 versus 14.24; p= 0.055).

CNR in the LCA and the RCA was reduced in the study group compared to the control group related to noise in Ao and LV.

Median CNR-LCA/Ao 17.40 versus 19.26; p = 0.002
Median CNR-LCA/LV 17.75 versus 20.12; p = 0.001
Median CNR-RCA/Ao 16.46 versus 19.24; p < 0,001
Median CNR-RCA/LV 16.42 versus 19.00; p < 0,001

Image quality - subjective parameters

Atrial leads resulted in artifacts predominantly in segment 1 (proximal right coronary artery RCA; 45%) and 2 (mid RCA; 37%) and slightly in segment 7 (mid LAD; 4%), non-diagnostic ratings were assigned only in two cases in segment 1 (4%). As motion artifacts were found in both groups the test of marginal homogeneity did not show a significant unequal distribution between study group and control group.

Artifacts by ventricular leads in segment 8 (distal LAD) were found in 72% of all patients in the study group and led to a significant shift (p=0.01) in subjective image quality rating, non-diagnostic rating was assigned in 9 cases in segment 8 (18%).

Segment 7 (mid-LAD) also showed an unequal distribution using the test of marginal homogeneity (p=0.008), but image quality was affected by motion (8%) and stents
(6%) more than by atrial (4%) or ventricular (4%) leads; non-diagnostic rating was only assigned to motion and to a stent in one case each.

Artifacts by coronary sinus leads were found in segment 4 (right posterolateral branch; 2%), segment 12 (first marginal branch; 5%) and segment 13 (distal left circumflex CX; 4%) with non-diagnostic rating in segment 12 and 13 in one case each.
**Table 1:** Patient characteristics; 1) p-value of the Wilcoxon test

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<th>SD</th>
<th>min</th>
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<th>median</th>
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Fig. 1: Patient with CRT: left circumflex artery with artifacts by coronary sinus lead (left ventricle); RCA without artifacts by atrial leads but artifacts by stent material

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Fig. 2: Patient with ICD: strong artifacts in the left ventricle affecting the LAD distal

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Conclusion

Our results suggest that there are limited problems in cardiac MSCT in patients with endocardial leads.

There are only two studies in the literature that focus on image quality in these patients. In PET/CT (11) there are problems predominantly by ICD leads in about half of the patients. In 64 slice MSCT using retrospective ECG gating Sosnowski et al. reported impossible evaluation of the left main artery in 5%, LAD in 11% and RCA in 51% (4).

This is the first study evaluating cardiac 320 slice MSCT in patients with endocardial leads using prospective ECG-gating and iterative reconstruction.

Objective image quality is impaired compared to a control group. SNR is reduced in the Aorta but not significantly in the LV suggesting more artifacts in the position of the aorta. CNR are reduced for the RCA and LCA.

Nevertheless, the subjective image quality in patients with endocardial leads was rated significantly inferior only in segment 8 (distal LAD) (p=0.001), this segment seems to be of limited clinical relevance, Sosnowski et al. did not report at all problems caused by left ventricular leads in the LAD.

The RCA is influenced by some artifacts but non-diagnostic rating was only assigned in 4%, the test of marginal homogeneity did not show a significant unequal distribution between study group and control group.

There are only two CRT devices in our study population with one non-diagnostic segment each in the LCX; this could be more challenging in the future with increasing number of these devices.

With slight restrictions 320 slice cardiac MSCT with iterative reconstruction can be advised for patients with pacemakers and endocardial leads.

Limitations

This is a retrospective study with limited number of patients.

Stents, valve protheses and sternum cerclage material were not excluded, this may have contributed to worse effects.
Patients with endocardial leads had a higher heart rate than the control group, devices were not reprogrammed on the time of examination, problems with ECG gating were not considered in this study.

Bipolar pacing was shown to be beneficial for optimal image quality as ventricle spikes could be misinterpreted as R spike in image reconstruction (12).

However, our results suggest that cardiac MSCT with prospective gating in pacemaker patients is possible. Optimal triggering and radiation exposure could be interesting for further evaluation.
Personal information

Marietta Garmer, MD
Diagnostik Zentrum Ruhr, Bochum
Grönemeyer Institute for Microtherapy
Witten/Herdecke University, Clinical Radiology Wuppertal/Cologne-Merheim
Universitätsstr. 142, 44799 Bochum, Germany
garmer@groenemeyer.com

Marc Bonsels, MD
Witten/Herdecke University, Grönemeyer Institute for Microtherapy

Frauke Metz, MD
Grönemeyer Institute for Microtherapy

Oliver Klein-Wiele, MD
Witten/Herdecke University, Grönemeyer Institute for Microtherapy

Bodo Brandts, MD,
Witten/Herdecke University, Dept. of Cardiology, Augusta-Kranken-Anstalt Bochum

Dietrich Grönemeyer
Witten/Herdecke University, Grönemeyer Institute for Microtherapy