ORIGINAL ARTICLE

Advantages of retrospective ECG-gating in cardio-thoracic imaging with 16-row multislice computed tomography

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Abstract. Purpose: to test the added information of a retrospective ECG-gating to the 16-row Multislice Computed Tomography (MSCT) scan of intrathoracic vessels. Materials and methods: ninety-six patients (61 males, aged 59±20 years) underwent MSCT with a 16-row scanner (Sensation 16, Siemens, Germany) for the study of the thoracic vessels. In group 1 (66 patients) a retrospectively ECG-gated protocol was applied; in the control-group 2 (30 patients) a conventional MSCT protocol for thoracic imaging was applied. Images were scored regarding 1) presence or absence of artifacts determined by breath-hold, beam hardening and mis-triggering; 2) visualization (optimal, mild and poor) of great intrathoracic vessels (aorta, pulmonary arteries and veins); 3) visualization (presence or absence) of proximal, mid and distal coronary arteries (left main - LM, left anterior descending - LAD, circumflex - CX, and right coronary artery - RCA). Results: ascending aorta showed motion artifacts in 7 (24%) cases in group 2 and 2 (4%) in group 1. In group 1, proximal LAD, CX, and RCA were assessable in 89%, 91%, and 89%, respectively. Left main coronary artery was assessable in 61 (92%) and 18 (60%) cases for group 1 and 2, respectively. Conclusions: the retrospectively ECG-gated 16-row MSCT provides information regarding ascending aorta and coronary arteries not available in the conventional scan.

Key words: multislice spiral computed tomography, thoracic vessels, coronary arteries, non-invasive angiography

Introduction

Non-invasive cardio-vascular imaging represents one of the cutting-edge fields where radiologic technology has been challenged in the past. In particular spiral computed tomography (CT) and magnetic resonance (MR) showed significant improvements in the last decade, at the point that, for several applications such as the study of aortic aneurysms and pulmonary arteries, non-invasive techniques have become the modality of choice for diagnosis and follow-up.

The thoracic vascular structures are variably influenced and affected by heart-beat motion. In particular, the coronary arteries and the great vessels in the area directly connected to the heart suffer from heavy motion artifacts that severely impair the proper motion-less visualization (e.g. aortic root). Therefore, to image vascular structures in the mediastinic region, a high acquisition speed paired with a synchronization of the image reconstruction with the heart cycle should be applied in order to reduce, or eventually minimize, motion artifacts.

Four-row multislice CT (MSCT) was able to reduce heart motion by retrospective synchronization of image reconstruction and ECG signal (1). A new generation of MSCT scanners has been introduced with increased number of detector rows and rotation speed (2). Early reports showed promising results in the detection of coronary arteries stenosis (2). Based on these technical improvements a protocol has been developed for the study of the thorax with retrospective ECG-gating within one breath-hold, allowing to minimize artifacts related to heart-beat motion on other vascular structures of the thorax. The protocol allows also visualizing the coronary arteries, which could add important information in the differential diagnosis of patients with acute chest pain. The aim of this study is to assess the feasibility of a protocol with retrospective ECG gating and the added value compared to the conventional spiral scanning in non-invasive thoracic CT angiography.

Methods

A population of 96 patients (61 males, aged 59±20 years) with clinical indication for non-invasive angiographic study of the thorax with a spiral multislice CT scanner (Sensation 16, Siemens, Germany) was enrolled in our study. The protocol was approved by the Ethics Committee and patients gave written informed consent.

Sixty-six patients (19 aortic dissections, 11 aortic coarctations, 21 study of the pulmonary veins prior to ablation intervention, 6 aortic aneurysms, 9 ascending aorta dilatation) underwent contrast enhanced ECG gated 16-row MSCT (group 1), while thirty patients undergoing 16-row MSCT angiography of the thorax without ECG gating were used as a control group (group 2). A bolus of hundred millilitres of contrast medium (Iodixanol 320 mgI/ml, Visipaque, Amersham Health, UK) was administered with an 18 gauge cannula through an antecubital vein at a rate of 4 ml/s. The scan was automatically triggered by the arrival of contrast medium inside the ascending aorta with a threshold of +100 HU above the baseline attenuation (CARE bolus, Siemens, Germany).

Patients in group 1 underwent 16-row MSCT with the following parameters: detectors 16, collimation 1.5 mm, feed/rotation 6 mm, rotation time 420 ms, effective slice width 2 mm, increment 1 mm, kV 120, mAs 400-550, scan time 18s.

Patients in group 2 underwent 16-row MSCT with the following parameters: detectors 16, collimation 1.5 mm, feed/rotation 24 mm, rotation time 500 ms, effective slice width 2 mm, increment 1 mm, kV 120, mAs 120, scan time 6s.

Reconstructed images were sent to a stand-alone workstation equipped with post-processing software (Leonardo, Siemens, Germany). Image evaluation was performed in consensus by two radiologists.

The presence of artifacts from breath-holding, beam hardening and mis-triggering (absent, mild and evident) was evaluated.

The assessibility of cardiovascular structures of the thorax has been graded as poor (not assessable), mild (structures visualized with sub-optimal confidence), and optimal (structures visualized with high confidence). The main vessels (Ascending aorta, Aortic arch, Descending aorta, Pulmonary veins, Pulmonary arteries), heart valves (Aortic valve, Pulmonary valve, Mitral valve, and Tricuspid valve), and coronary arteries (Left main, Left anterior descending, Circumflex, and Right coronary artery, divided into proximal, middle and distal segments) were evaluated using this technique.

The feasibility of left ventricular (LV) function has been evaluated (not feasible, feasible, and optimal) creating the dataset in end-diastolic and end-systolic phase and loading them into a dedicated software to calculate the ejection fraction and wall motion abnormalities (ARGUS, Siemens, Germany).

Results (Table 1)

All scans in both groups were successfully completed. Mean heart rate during the scan was 67 (range 41-95) in group 1. Twelve patients in group one, studied prior to intra-catheter ablation therapy, had atrial fibrillation but only in 8 (12%) cases this determined significant mis-triggering artifacts. Mild breath-hold artifacts were present in 5 (8%) patients in group 1 and in none in group 2 due to the significantly shorter scan time (5-7s vs. 18-20s).

The assessibility of thoracic vessels was optimal in both groups, except for ascending aorta. In 7 (24%) cases the visualization of ascending aorta was poor or sub-optimal in group 2 because of motion artifacts, while only in 2 (4%) cases it was compromised in

Table 1. Results

	Group 1			Group 2		
	Absent	*Mild*	*Evident*	*Absent*	*Mild*	*Evident*
Artifacts						
Breath-hold	92% (61)	8% (5)	0	100% (30)	0	0
Beam hardening	70% (46)	14% (9)	17% (11)	83% (25)	10% (3)	7% (2)
Mis-triggering[1]	88% (58)	0	12% (8)	-	-	-
			Assessibility			
	Poor	*Mild*	*Optimal*	*Poor*	*Mild*	*Optimal*
Thoracic vessels						
Ascending aorta	2% (1)	2% (1)	97% (64)	7% (2)	17% (5)	77% (23)
Aortic arch	0	0	100% (66)	0	0	100% (30)
Descending aorta	0	0	100% (66)	0	0	100% (30)
Pulmonary veins	0	0	100% (66)	0	0	100% (30)
Pulmonary arteries[2]	0	0	100% (66)	0	0	100% (30)
Heart valves						
Aortic valve	0	0	100% (66)	100% (30)	0	0
Pulmonary valve	73% (48)	21% (14)	6% (4)	100% (30)	0	0
Mitral valve	0	8% (5)	92% (61)	100% (30)	0	0
Tricuspid valve	17% (11)	23% (15)	60% (40)	100% (30)	0	0
		Segments			*Segments*	
	prox	*mid*	*Distal*	*Prox*	*mid*	*distal*
Coronary arteries[3]						
Left main	92% (61)	60% (18)				
Left anterior descending	91% (60)	76% (50)	41% (27)	10% (3)	0	0
Circumflex	89% (59)	64% (42)	39% (26)	0	0	0
Right coronary artery	91% (60)	47% (31)	48% (32)	17% (5)	0	0
			Feasibility			
	NF	*F*	*Optimal*	*NF*	*F*	*Optimal*
Functional evaluation[4]						
LV function	0	12% (8)	88% (58)	100% (30)	0	0

[1]In group 2 the artifacts from mis-triggering are not present for technical reasons.
[2]Pulmonary arteries were scored until 3rd generation (segmental branches).
[3]Coronary arteries are graded as assessable or not assessable and the assessable fraction is displayed in the table.
[4]Functional evaluation has been considered as feasible if in dyastolic and systolic phase the margins are detected with no or mild motion artifacts.
NF= not feasible; F= feasible; LV function= left ventricular function.

group 1, due to irregular heart rate. In group 1, aortic and mitral valve were assessable, tricuspid valve was mildly assessable, and pulmonary valve was poorly displayed. Heart valves were not assessable in group 2. The left main coronary artery was assessable in 61 (92%) and 18 (60%) cases for group 1 and 2, respectively. In group 2, proximal segments of left anterior descending (LAD), circumflex (CX), and right coronary artery (RCA), were almost always not assessable. In group 1, LAD, CX, and RCA were assessable in 89%, 91%, and 89% proximally, and progressively decreasing in the mid and distal segments. Left ventricular function was feasible in 8 (12%) cases and optimal in 58 (88%) cases for group 1, while in group 2 was always not feasible for technical reasons related to the geometry of acquisition.

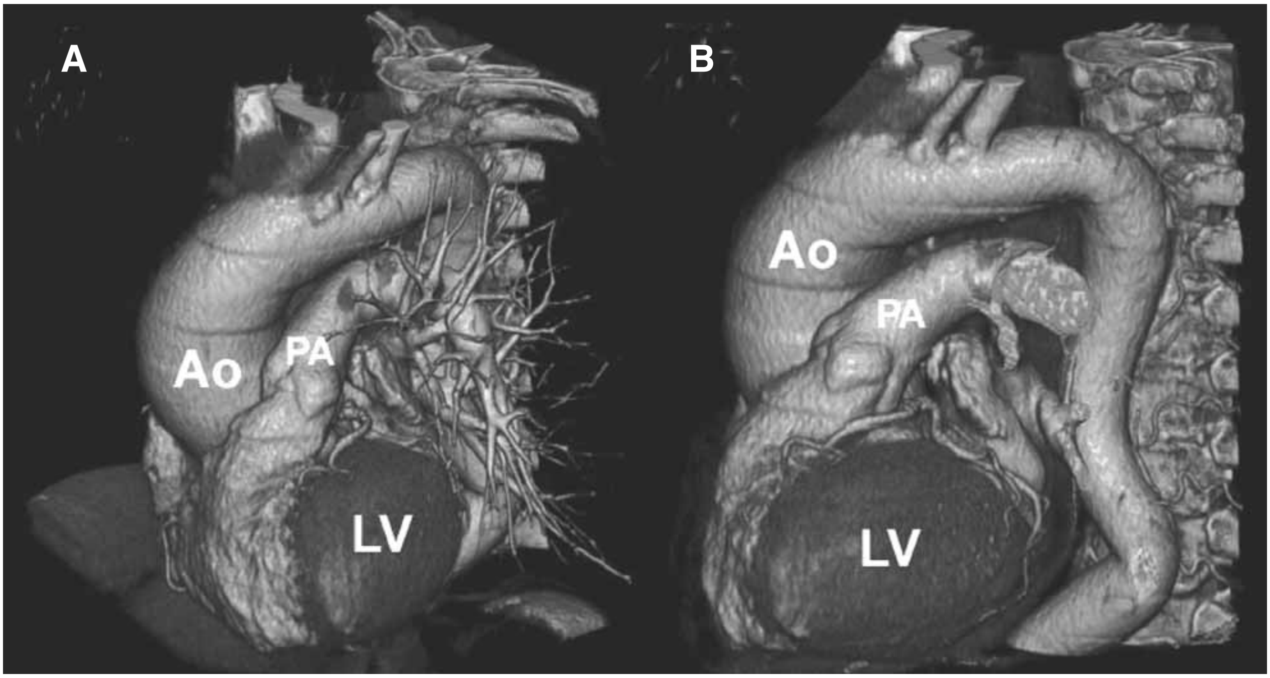

Figure 1. Example of ECG gated 16-row MSCT scan with three-dimensional volume rendering reconstruction.
A patient with dilated ascending aorta underwent the scan. The dilatation of the ascending aorta (Ao) is pronounced without signs of dissection or atherosclerosis. All the vascular structures of the thorax (A and B) appear absolutely motion free (PA= pulmonary artery; LV= left ventricle).

Discussion

Non-invasive cardio-vascular imaging can be considered one of the biggest improvements in diagnostic medicine in recent years. The non-invasive visualization of large diameter vessels (e.g. aorta) is nowadays an accepted standard, while for smaller vessels (e.g. cerebral and coronary arteries), still technology and validation efforts are needed. The introduction of a generation of MSCT scanners with more rows of detectors (16) and improved spatial (0.75 mm minimum collimation) and temporal (420 ms rotation time) resolution allows to perform reliable non invasive coronary angiography (2). This capability has been extended into a new protocol (group 1) for the study of vascular diseases of the thorax (2, 3). In group 1 we observed more beam hardening and mistriggering artifacts, even though this represents a trade-off for the added information given by this technique. In fact, in group 1, the visualization of the ascending aorta was more reliable compared to group 2. This improvement can be of great relevance in patients with dissection or aneurysms involving ascending aorta. The aortic and mitral valves were well appreciated in group 1 because of their thickness while in group 2 the motion did not allow to assess valves. For almost the same reason, in group 2 no information about coronary arteries was obtained, while ECG-gated protocol (group 1) allowed the visualization of all four vessels with decreasing accuracy towards distal segments. The reasons for this decreased accuracy are: the smaller size of distal segments of coronary arteries, the plane orientation of mid and distal branches (mid RCA and mid-distal CX) that is less favorable for coronary arteries visualization, and the collimation of 1.5 mm used for this protocol in order to allow a breath-hold of 18-20s. Left ventricular function was always feasible in group 1, while it was not possible in group 2. The estimated radiation dose delivered to the patient was also significantly larger with gated protocol (average three-to four times more with ECG-gated protocol). This dose can be significantly reduced using ECG-gated tube current modulation (4).

This protocol could be potentially applied to patients with acute chest pain with differential diagnosis between vascular diseases of the great vessels (e.g. dissection/ruptured aneurysms) vs. acute myocardial infarction. The possibility to perform an early diagnosis between those two groups of diseases could significantly increase the potential success of surgical/interventional treatment in the first case and pharmacological/interventional treatment with recovery of functional myocardium in the second case.

Beside this application, the routine study of vascular diseases affecting the ascending aorta can be greatly improved by the use of an ECG-gated protocol, improving the confidence of the observer to rule-out dissections and aortic intramural haematoma.

Further extensive studies comparing different clinical population will be needed to explore those aspects of this new technology. Moreover the implementation of more detector rows and faster rotation time could allow scanning the entire thorax within the same 18-20s breath-hold but with sub-millimetric spatial resolution. This will be reflected in a greater diagnostic accuracy for coronary arteries.

In conclusion, the use of MSCT ECG-gated technique to thoracic cardio-vascular imaging provides added information compared to the conventional MSCT protocol. Main advantages are in the improved visualization of the ascending aorta, heart valves, coronary arteries, and left ventricular function.

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