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Diagnostic performance of prospectively ECG triggered versus retrospectively ECG gated 64-slice computed tomography coronary angiography in a heterogeneous patient population

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ABSTRACT

Objective: To compare diagnostic performance and applicability of prospectively versus retrospectively gated 64-slice computed tomography coronary angiography (pro-CTCA vs. retro-CTCA) in a heterogeneous patient population compared to invasive coronary angiography.
Methods: 77 patients referred to an ECG-gated-CT of the chest were retrospectively included. Pro-CTCA was applied, whenever possible, alternatively retro-CTCA was performed. All coronary artery segments ≥1.5 mm were analysed and image quality was assessed.
Results: In 39 patients retro-CTCA and in 38 patients pro-CTCA was applied, mean heart rate (HR) was $69.5 \pm 9.1\ min^{-1}$ and 62.8 ± 5.9, respectively. For a stenosis ≥50% segment-based (patient-based) analysis revealed a sensitivity, specificity, positive (PPV) and negative predictive value (NPV) of 97%, 98%, 71%, 100% (91%, 82%, 67%, 96%) using retro-CTCA and 94%, 97%, 75%, 99% (93%, 96%, 93%, 96%) using pro-CTCA. Sensitivity and NPV increased in the pro-CTCA group in patients with a HR < 65. Vessel-based analysis showed lower diagnostic performance for the right coronary artery (RCA) using pro-CTCA, which increased when HR < 65. Image quality did not differ significantly in both groups.
Conclusions: Prospectively triggered CTCA in a heterogeneous patient group has a very high diagnostic accuracy and image quality, when used in HR ≤ 65. A low HR is of special importance for the evaluation of the RCA.

1. Background

Coronary heart disease (CHD) is one of the most common causes of death in Western industrialized nations [1]. Invasive coronary angiography (ICA) as the standard of reference enables diagnosis and treatment in one session, but approximately half of all ICA usually remain purely diagnostic without any coronary intervention [2]. Since complications of this invasive procedure can occur, although very rare, but potentially serious, a non-invasive diagnostic method such as computed tomography coronary angiography (CTCA) is desirable. The technological development of CTCA in the last few years has increased the importance of this procedure regarding the assessment of CHD in comparison to cardiac catheterization and led to a more frequent application of CTCA. Recent studies, carried out on 64-slice and dual source scanners, attest CTCA a sensitivity of up to 85–99% and a specificity of up to 64–98% for the detection of haemodynamically relevant stenosis (≥50%) over all coronary segments (Table 1) [3–12]. Due to a high negative predictive value of 83–100%, the procedure can be applied for non-invasive CHD exclusion. Limitations with regard to the diagnostic reliability depend on the patient group, the used equipment, heart rates and body weight of the examined patients.

One of the main remaining disadvantages of CTCA is the high radiation exposure compared to diagnostic ICA. But with the introduction of prospectively triggered CTCA, it is possible to reduce radiation exposure by a factor of 4 compared to the previously applied retrospectively gated technique [13–15] and therefore, also below the radiation exposure of diagnostic ICA [16–18].

1.1. Study purpose

The aim of this study was to determine accuracy, image quality and applicability of the prospectively triggered CTCA in comparison

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Table 1
Summary of all CTCA studies with ICA as standard of reference listed in Medline since the introduction of 64-slice CT.

Author	Study design/CT technique	Patients *n*, max. HR, pre-test probability/% with CHD	Gating	All segments		Evaluable segments		Per patient		Per vessel	
				Sens. %	Spec. %	Sens. %	Spec. %	Sens. %	Spec. %	Sens. %	Spec. %
Leschka et al. [5]	Prospective, unicenter/64 slice	*n* = 67, 90, "suspected CAD"/70%	r	n.s.	n.s.	94	97	99	98	n.s.	n.s.
Raff et al. [10]	Prospective, unicenter/64 slice	*n* = 70, 70, "suspected CAD"/54%	r	n.s.	n.s.	86	95	95	90	91	92
Mollet et al. [9]	Prospective, unicenter/64 slice	*n* = 52, 70, intermediate and high/73%	r	99	95	99	95	99	92	99	95
Pugliese et al. [23]	Prospective, unicenter/64 slice	*n* = 35, 70, high/n.s.%	r	99	96	99	96	98	90	n.s.	n.s.
Ropers et al. [11]	Prospective, unicenter/64 slice	*n* = 84, rest n.s.	r	n.s.	n.s.	93	97	96	91	95	93
Leber et al. [21]	Prospective, unicenter/DSCT	*n* = 90, n.s. intermediate/85%	r	n.s.	n.s.	88	99	92	94	n.s.	n.s.
Miller et al. [8]	Prospective, multicenter/64 slice	*n* = 291, 80, "suspected symptomat. CAD"/56%	r	n.s.	n.s.	n.s.	n.s.	85	90	75	93
Maruyama et al. [20]	Prospective, unicenter/64 slice	*n* = 97, 65, "suspected CAD, stent follow up"/n.s.%	r	n.s.	n.s.	97	98	96	94	n.s.	n.s.
		n = 76, 65, "suspected CAD, stent follow up"/n.s.%	p	n.s.	n.s.	96	99	100	92	n.s	n.s
Budoff et al. [3]	Prospective, multicenter/64 slice	*n* = 230, 65, "chest pain"/38,7%	r	n.s.	n.s.	n.s.	n.s.	95	83	84	90
Meijboom et al. [7]	Prospective, multicenter, multivendor/64slice	*n* = 360, 65, high/68%	r	n.s.	n.s.	88	90	99	64	95	77
Leschka et al. [6]	Prospective, unicenter/HPDSCT	*n* = 35, 60, high/40%	p	94	96	n.s.	n.s.	100	91	96	92
Stolzmann et al. [12]	Retrospective, unicenter/DSCT	*n* = 100, 70, intermediate/49%	r	n.s.	n.s.	96	99	98	100	98	99
		n = 100, 70, intermediate/56%	p	n.s.	n.s.	98	98	100	93	99	97

n.s. = not specified; CAD = coronary artery disease; gating: r = retrospective, p = prospective; DSCT = dual source CT; HPDSCT = high pitch dual source CT.

to the retrospectively gated technique using an ICA as standard of reference in a heterogeneous patient population with various cardiovascular diseases referred for ECG gated CT of the chest.

2. Materials and methods

2.1. Study population and patient preparation

In total 77 patients (m/w = 39/38), who underwent ECG gated CT for clinical reasons in the period June–October 2009, were retrospectively included in this study. Inclusion criteria were an existing diagnostic ICA within 45 days before or after the CTCA without an interventional procedure in the meantime. Exclusion criteria were a change of symptoms in the interval between ICA and CTCA, a heart rate > 75 min^{-1}, a BMI > 35 and the presence of arrhythmias during the scan. Patients without an adequate arterial contrast enhancement in CTCA (<250 Hounsfield units [HU]) in the ascending aorta were also excluded. Prospectively triggered scan technique was applied, whenever possible depending on the clinical question. Among all patients, we included 39 retrospectively gated and 38 prospectively triggered scans. In patients with a heart rate > 75 min^{-1}, a beta-blocker was applied, unless contraindications existed.

2.2. CT protocols

All scans were performed on a 64-row CT (Brilliance 64, Philips Medical Systems, Cleveland, OH, USA). Two different scan protocols using retrospectively gated ("retro-CTCA") and prospectively triggered ("pro-CTCA") technique were used; scan parameters and resulting dose values are listed in Table 2. All patients were examined in supine position and breathhold technique. After creating localizer scans and intravenous injection of 100 ml nonionic iodinated contrast medium (Iopromide, 370 mg iodine per ml, Ultravist 370, BayerSchering, Berlin, Germany) with a flow rate of 5 ml/s, the scan was started by bolus tracking measurement in the left atrium at a threshold of 150 HU in caudocranial direction. Depending on the clinical question, the scan field included the entire heart and was extended to the aortic arch in some cases.

The retro-CTCA protocol corresponds to an overlapping helical image acquisition with retrospective ECG gating. A collimation of 64 mm × 0.625 mm at a rotation time of 0.4 s (Pitch 0.2) was used. Tube load and voltage were 800 mAs (effective) and 120 kV, respectively. Tube load settings were adapted to the patient's size by BMI and temporal dose modulation (ECG pulsing) was applied, if appropriate. Images were reconstructed at a slice thickness of 0.67 mm and an increment of 0.4 mm using a soft tissue reconstruction algorithm (CB) and a field-of-view of typically 25 mm.

The pro-CTCA protocol is a prospectively triggered CT of the heart with an incremental, slightly overlapping table shift. The

Table 2
Scan protocol parameters.

Parameter	retro-CTCA	pro-CTCA
Peak voltage (kVp)	120	120
Rotation time (s)	0.4	0.4
Exposure time per rotation (s)	0.4	0.4
Electric tube load (standard) (mAs)	160	150
Effective tube load (standard) (mAs)	800	192
Collimation (mm)	64 × 0.625	64 × 0.625
Table feed (mm)	8	31.2
Pitch factor	0.2	0.78
Net scan length (average) (mm)	192.4	175.3
CTDIvol (average) (mGy)	45.8	12.6
DLP (average) (mGy × cm)	1115	220
Effective dose (average) (mSv)[a]	15.6	3.1

[a] Estimated from DLP with conversion factor k = 0.014 mSv/mGy × cm.