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ORIGINAL PAPER

Prevalence of noncardiac findings on low dose 64-slice computed tomography used for attenuation correction in myocardial perfusion imaging with SPECT

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Abstract Electrocardiogram (ECG)-triggered, low dose computed tomography (CT) is increasingly used for attenuation correction in myocardial perfusion imaging (MPI) with SPECT. The purpose of the study was to assess the prevalence of relevant noncardiac findings in the field-of-view of such attenuation correction CT scans. Five hundred and eighty-two consecutive patients (211 female, 371 male; mean age: 64 ± 11 years; BMI: 27.7 ± 5.3 kg/m²) underwent 64-slice, ECG-triggered CT scanning for attenuation correction of MPI with SPECT. Relevant findings were defined as abnormalities that required clinical or radiological follow-up. Noncardiac findings were detected in 400 patients (68.7%). In 196 patients (33.7%) 226 relevant findings were detected. Findings included noncalcified pulmonary nodules

($n = 156$), interstitial lung disease ($n = 6$), pleural effusion ($n = 20$), pneumonia ($n = 1$), aortic aneurysm ($n = 5$), aortic dissection ($n = 4$), enlarged mediastinal lymph nodes ($n = 5$), mediastinal tumor ($n = 3$), breast abnormalities ($n = 3$), liver cirrhosis ($n = 5$), liver mass ($n = 5$), ascites ($n = 5$), splenomegaly ($n = 2$), renal mass ($n = 1$), hydronephrosis ($n = 1$), adrenal mass ($n = 3$), and bone metastasis ($n = 1$). As low dose 64-slice CT scans used for attenuation correction in MPI with SPECT reveal a high prevalence of noncardiac pathologic findings with potential clinical relevance, a systematic review of the CT scans appears mandatory.

Keywords Incidental findings · Computed tomography · Attenuation correction · Myocardial perfusion imaging · SPECT

Abbreviations

CAD	Coronary artery disease
CT	Computed tomography
MPI	Myocardial perfusion imaging
SPECT	Single-photon emission computed tomography

Introduction

Recently, electrocardiogram (ECG)-triggered, low dose 64-slice computed tomography (CT) has been

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introduced and established for attenuation correction in myocardial perfusion imaging (MPI) with single-photon emission computed tomography (SPECT) (Fig. 1) [1–6]. The CT data used for attenuation correction is acquired with a large field-of-view, thus including large portions of the great vessels, the lungs, the chest wall, the mediastinum, the vertebra, and the upper abdomen. Although these CT scans are performed with low radiation dose and without contrast material, it can be assumed that incidental relevant or non-relevant noncardiac findings might be found if CT data is adequately reconstructed and reviewed. To our knowledge, no information currently exists on the rate of incidental findings in patients undergoing low dose CT scans for attenuation correction in MPI. Therefore, the purpose of our study was to assess the prevalence of relevant and non-relevant noncardiac findings in the field-of-view of attenuation correction CT scans used for MPI with SPECT.

Methods

Patients

We prospectively enrolled 582 consecutive patients (211 female, 371 male), who underwent low dose CT scanning of the heart used for attenuation correction of MPI with SPECT in a time period between February, 2007, and February, 2008. MPI was performed for evaluation of known or suspected coronary artery disease (CAD); in 10% of patients MPI was part of preoperative evaluation before noncardiac surgery. The study protocol was approved by the institutional review board and written informed consent was obtained.

CT scanning

All CT scans for attenuation correction were performed with a 64-slice CT on a LightSpeed VCT XT scanner (GE Healthcare, Milwaukee, WI, USA) using prospective ECG-triggering (70% of the R–R interval) and the following scanning parameters: gantry rotation time 350 ms, 2.5-mm section thickness, 120 kV tube voltage, 200 mA effective tube-current. Scanning was performed at breath-hold in inspiration with elevated arms from below the tracheal bifurcation to the diaphragm. CT images were reconstructed at a 2.5-mm section thickness by using a reconstruction algorithm with a 512×512 matrix and a full-chest-size-adapted field-of-view of 50×50 cm. Reconstructed images were transferred to the external workstation for further analysis (AW 4.4, GE Healthcare).

Image analysis

One board-certified radiologist, blinded to the patient's history, reviewed all examinations for noncardiac findings using standard soft tissue (window width W400/level L40 Hounsfield Units), lung (W1600/L600), and bone window (W1700/L250) settings. All noncardiac findings were recorded and rated as relevant, when further clinical or radiological work-up or follow-up was deemed appropriate by this experienced radiologist, similar to previous reports [7–9]. Equivocal findings were categorized as relevant or non-relevant according to the following criteria:

Noncalcified pulmonary nodules larger than 4 mm were considered relevant and radiological follow-up was recommended [10]. Noncalcified pulmonary

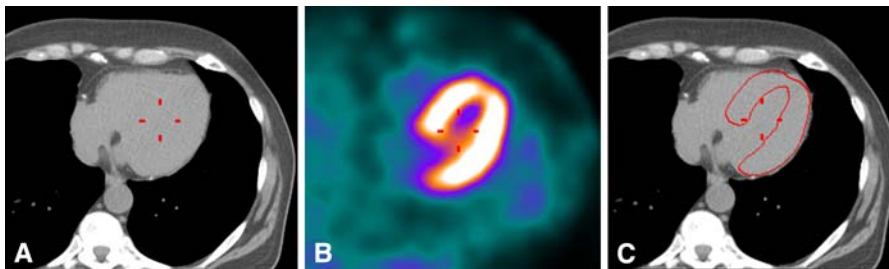


Fig. 1 Axial CT- (a) and SPECT-images (b) are fused (c), for attenuation correction in myocardial perfusion imaging with SPECT. This method is routinely performed in clinical practice

to compensate for possible attenuation artefacts in myocardial perfusion images

nodules larger than 10 mm and nodules smaller than 10 mm, but with irregular margination were considered potentially malignant and further work-up was suggested. Mediastinal lymph nodes were described as enlarged if their short axis measured more than 10 mm [11]. Aortic aneurysm was defined as a dilation equalling or exceeding twice the normal diameter. Dissections were suspected if they had a medial displacement of calcifications in the aorta [12].

A clinical follow-up of all relevant findings was performed in August 2008 by reviewing of individual medical records.

Statistical analysis

Quantitative variables were expressed as mean \pm standard deviation and categorical variables as frequencies, or percentages, using SPSS software (SPSS 15.0, Chicago, ILL, USA).

Results

CT for attenuation correction was successfully performed in all 582 patients. The patients mean age was 64 ± 11 years (range 30–89 years) and their body mass index was 27.7 ± 5.3 kg/m² (range 15–54 kg/m²). In patients without previous bypass surgery or stent placement (390 patients, 67.0%) the mean coronary artery calcium scoring was 564.6 ± 942.4 (range 0–6,728). Further clinical characteristics of the patient population are summarized in Table 1.

Noncardiac findings

A total of 832 findings were detected in 400 of the 582 patients (68.7%). Two hundred and twenty-six findings were classified as having potential clinical relevance, 196 (33.7%) patients had at least one relevant finding (16 patients had two, 5 patients had three, and 1 patient had five relevant findings).

One hundred and fifty-six patients (26.8%) had one or more noncalcified pulmonary nodules, rated as relevant findings, as a follow-up was recommended.

CT revealed an abnormality in the mediastinum in eight patients (1.3%), mediastinal lymph nodes adenopathy in five, retrosternal mass in two, and a tumor in the middle mediastinum in one patient. Nine

Table 1 Clinical characteristics of the patients

	<i>n</i> (%)
Symptoms	
Chest pain	195 (34)
Dyspnea	50 (9)
Combination of both	53 (9)
History of CAD	
Previous PCI	245 (42)
Previous bypass surgery	55 (9)
Previous myocardial infarction	107 (18)
Coronary risk factors	
Hypertension	329 (57)
Smoking	235 (40)
Dyslipidemia	217 (37)
Positive family history	159 (27)
Diabetes	112 (19)

PCI percutaneous coronary intervention, CAD coronary artery disease

findings in the ascending and descending aorta were documented in eight (1.3%) patients, five aneurysms and four dissections.

In patients with liver cirrhosis ($n = 5$) and splenomegaly ($n = 2$) clinical or radiological follow-up was recommended. In patients with suspected liver tumor ($n = 5$), renal tumor ($n = 1$), adrenal tumor ($n = 3$), hydronephrosis ($n = 1$), or ascites ($n = 5$) further investigation was suggested.

Eleven (1.9%) patients had bone abnormalities. Eight had vertebral hemangioma, and 2 had rib fractures. One patient had vertebral osteolysis suspicious for metastasis.

The total number of incidental noncardiac findings and of relevant findings are summarized in Table 2, examples are shown in Fig. 2.

Follow-up of relevant findings

During a follow-up period of 6–18 months, 129 of 226 relevant findings were lost to follow-up (57.1%). Seventy-four findings were already known prior to CT scanning (32.7%). Three findings (1.3%) were not confirmed on follow-up, i.e. one kidney tumor, and two pulmonary nodules <10 mm. Adequate detection of previously unknown relevant findings was confirmed in 20 cases (8.8%) (Table 2), interestingly, 3 of 5 lung nodules >10 mm turned out to be a newly detected bronchial carcinoma.

Table 2 Total and relevant noncardiac findings

Region	Organ	Incidental findings	Total relevant	Previously known	Lost to follow-up	Not confirmed	Confirmed	
Abdomen	Liver	Hypodense lesion	63					
		Calcification	20					
	Fatty liver		35					
		Cirrhosis	5	5				
	Tumor	5	5	4	1			
	Gall bladder	Stone	6					
		Cyst	7					
	Kidney	Stone	2					
		Hydronephrosis	1	1		1		
	Spleen	Tumor	1	1			1	
		Cyst	2	2				
		Calcification	5	5				
		Accessory	5	5				
		Splenomegaly	2	2				
		Tumor	3	3	1	2		
		Hernia	13	13				
	Others	Ascites	5	5				
Scarring		187	187					
Lung	Parenchyma	Atelectasis	14					
		Bulla	97					
	Pneumonia	1	1					
	Fibrosis	6	6					
	Emphysema	64	64					
	Calcified nodules <10 mm	40	40					
	Non-calcified nodules <10 mm	133	133	20	103	2	8	
	Nodules >10 mm	23	23	8	10		5	
	Bronchi	Ectasia	4					
	Pleura	Calcification	22	22				
		Thickening	8	8				
		Effusion	20	20	9	6		5

Table 2 continued

Region	Organ	Incidental findings	Total relevant	Previously known	Lost to follow-up	Not confirmed	Confirmed
Mediastinum	Lymph nodes	Adenopathy	5	2	3		
	Aorta	Ectasia or aneurysm	5	5			
	Others	Dissection	4	4			
		Tumor	3	3		1	
Mammae	Others	Calcification	2				
		Tumor	3	1	2		
Bone	Others	Rib fracture	2				
		Vertebral hemangioma	8				
Total relevant	Total	Metastasis	1	1			
			832	74	129	3	20

Regular font represents the number of total findings; bold font represents the number of relevant findings

Discussion

This study demonstrates for the first time that the prevalence of non-relevant and clinically relevant noncardiac findings is high in 64-slice CT scans used for attenuation correction in MPI with SPECT.

Several previous studies have assessed the frequency of incidental findings in the context of various types of cardiac CT examinations [7–9, 13, 14], most of them involved electron beam CT or full dose coronary CT angiography. Our study revealed a higher prevalence of incidental (68.7%) and clinically relevant incidental findings (33.7%) as compared to previous electron-beam CT studies for calcium scoring [7–9]. In the latter reports, the detection rates for abnormalities ranged from 20 to 53% for all findings and from 4.2 to 9.3% for relevant findings. However, in those studies, electron-beam CT images were focused on the heart and a smaller field of view was used (26–35 cm) compared to our study (50 cm). Furthermore, electron-beam CT is known to have a lower spatial resolution as compared to 64-slice CT. Both, the smaller field-of-view and the lower spatial resolution might explain the lower prevalence of noncardiac findings in electron-beam CT studies compared to our study.

In cardiac multidetector CT examination using a large field-of-view including the chest wall, Onuma et al. [13] found in 58.1% of the patients at least one noncardiac finding, and in 22.7% of patients CT follow-up was recommended. Similarly, Goetze et al. [15] described noncardiac findings in 59% of patients on low-dose single-slice CT scans for MPI attenuation correction, suggesting that this “non-diagnostic” CT portion will likely become more important once higher quality CT scanners are used. In fact, the prevalence of noncardiac findings in our 64-slice CT study proved to be higher than their results. Especially, the rate of noncalcified nodules smaller than 10 mm in our study (22.8%) was much higher than in previous reports (9.7%) [13], in which CT images with relatively thick slices (5 mm) compared to our study (2.5 mm) were used, which may have lead to underestimating the prevalence of small size lung nodules.

Gil et al. [14] also examined patients who underwent cardiac CT angiography using a large field of view, and 56.2% of patients were found to have a relevant noncardiac finding. In that report, the

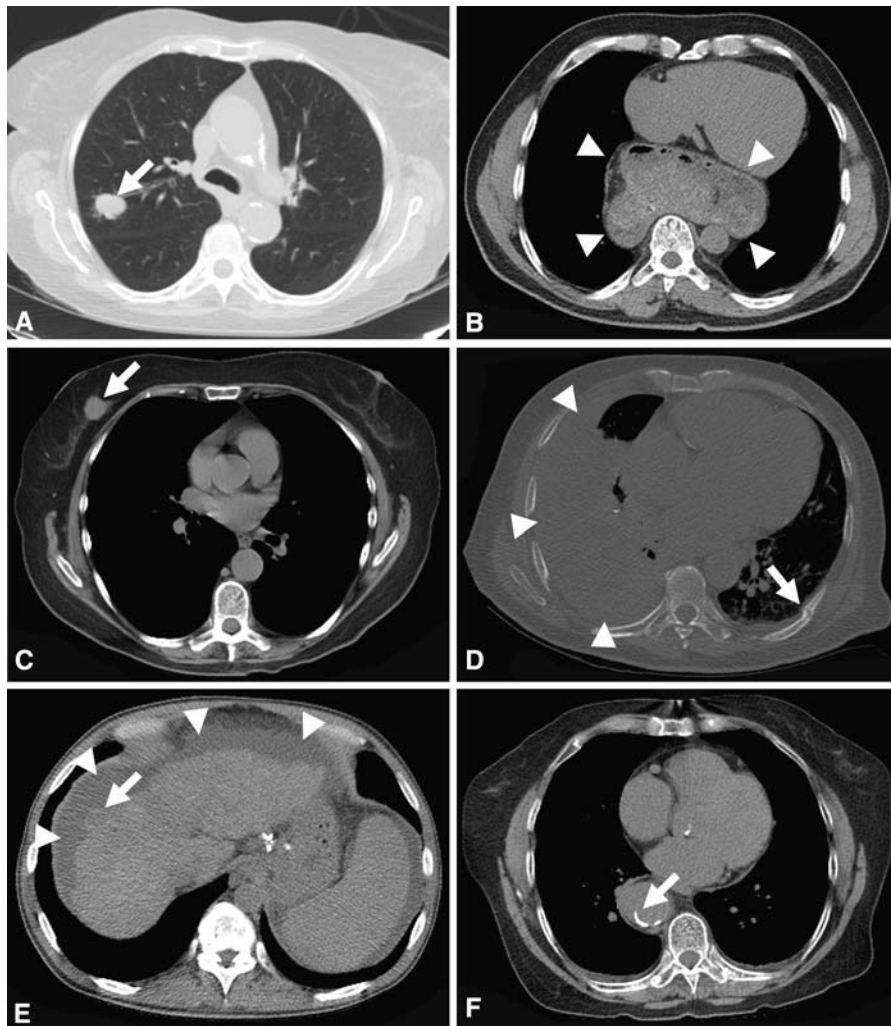


Fig. 2 Incidental noncardiac findings on low-dose 64-slice CT scans used for attenuation correction in MPI with SPECT. **a** Lung tumor. **b** Large hiatal hernia. **c** Breast tumor. **d** Large

pleural effusion (*arrow heads*) and dorsal rib fracture (*arrow*). **e** Ascites (*arrow heads*) and liver tumor (*arrow*). **f** Aortic dissection

scan volume was determined from the apex of the lungs to the diaphragm including the upper lobes and thyroid, which could explain the higher prevalence of noncardiac relevant findings compared to our study.

Limitations of the study

The incidence of findings may be influenced by the patient selection as a large proportion of patients referred for preoperative evaluation before surgery due to an existing disease would confer a high prevalence of findings. In our study, however, only

10% of patients fall into this category. Certainly, the relatively advanced age of our study population may have favoured the incidence of comorbidity.

Another limitation of this study is that clinical follow-up was not available in all patients with relevant clinical findings.

Conclusions

In conclusion, low dose 64-slice CT scans used for attenuation correction in MPI with SPECT provide an image quality sufficient to detect a high prevalence of

noncardiac pathologic findings with potential clinical relevance in a population typically evaluated for CAD. Therefore, a systematic review of the scans appears mandatory.

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