Multimodality Imaging of Anatomy and Function in Coronary Artery Disease

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Chapter 16

A Comparative Regional Analysis of Non-Invasive Coronary Angiography and Calcium Score by Multi-Slice Computed Tomography with Myocardial Perfusion Imaging by SPECT

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Abstract

Background

For the non-invasive evaluation of coronary artery disease (CAD), both multi-slice computed tomography (MSCT) and gated single photon emission computed tomography (SPECT) are available. How these 2 modalities relate however is yet unclear. The purpose of the study was to perform a head-to-head comparison between MSCT and gated SPECT results on a regional basis (per vessel distribution territory) in patients with known or suspected CAD.

Methods

140 patients underwent both MSCT for coronary calcium scoring and coronary angiography and gated SPECT for myocardial perfusion imaging. Coronary calcium score was determined for each coronary artery. Coronary arteries on MSCT angiography were classified as having no CAD, non-significant stenosis (<50% luminal narrowing), significant stenosis, or total or subtotal occlusion (≥90% luminal narrowing). Gated SPECT examinations were classified as normal or abnormal (reversible and/or fixed defects) and allocated to one of the territories of the different coronary arteries.

Results

In coronary arteries with a calcium score ≤10, corresponding myocardial perfusion was normal in 87% (n=194 of 224). In coronary arteries with extensive calcifications (>400), percentage vascular territories with normal myocardial perfusion was lower, 54%, (n=13 of 24). Similarly, in the majority of the normal coronary arteries on MSCT angiography, corresponding myocardial perfusion on SPECT was normal (156 of 175, 89%). In contrast, percentage normal SPECT was significantly lower in coronary arteries with obstructive lesions (59%) and total or subtotal occlusions (8%) (P<0.01). Nonetheless, only 48% of vascular territories with normal perfusion corresponded to normal coronary arteries on MSCT angiography, whereas non-significant and significant stenoses were present in respectively 40% and 12% of corresponding coronary arteries.

Conclusion

Although a relation exists between the severity of CAD on MSCT and myocardial perfusion abnormalities on SPECT, analysis on a regional basis showed only moderate agreement between observed atherosclerosis and abnormal perfusion. Accordingly, MSCT and gated SPECT provide complementary rather than overlapping information and further studies should address how these 2 modalities can be integrated to optimize patient management.

Introduction

Choice of treatment strategy in patients with suspected or known coronary artery disease (CAD) stems from the integration of both the extent and severity of anatomical disease and the functional significance of the coronary lesions, i.e. signs of ischemia. Coronary anatomy used to be accessible only through invasive coronary angiography while several imaging techniques can detect inducible ischemia, among which myocardial perfusion imaging using single photon emission computed tomography (SPECT). Because of its invasive nature, coronary angiography comes second and the presence/absence of ischemia is the gatekeeper that determines access to the anatomical information.

This paradigm is challenged with the emergence of non-invasive coronary angiography using multi-slice computed tomography (MSCT). Because coronary anatomy can now be obtained non-invasively, MSCT coronary angiography is increasingly often performed at earlier stages of the disease, in the absence of functional evaluation [1]. Preliminary data comparing MSCT with SPECT show that in fact a large discrepancy exists between the anatomic extent of CAD and ischemia, and that a considerable number of stenoses do not result in abnormal perfusion [1;2]. Thus, it remains undetermined in which sequence tests should be performed and ultimately, who will benefit from the performance of non-invasive coronary angiography. In order to design proper evaluation strategies, it will be necessary to understand how anatomical and functional findings relate to each other on a regional basis, per vessel distribution territory.

Therefore, we have further explored in an unselected patient population, the relation between the severity of anatomical CAD based on coronary calcium and MSCT angiography and perfusion abnormalities assessed by SPECT.

Methods

Patients and study protocol

The study group consisted of 140 consecutive patients (84 male, average age 59 ± 11 years) who were referred for both gated SPECT and MSCT due to clinical suspicion of CAD and who underwent these investigations within 1 month of each other. CAD was known in 32 (23%) patients, and suspected in the remaining 108 patients. Characteristics of the study population are summarized in Table 1. Average left ventricular ejection fraction during resting gated SPECT was 60% ± 13%.

Exclusion criteria were contra-indications to MSCT [3], and the occurrence of unstable angina, myocardial infarction or revascularization between both procedures. The study protocol was approved by the local ethics committee and informed consent was obtained in all patients.

Table 1. Clinical characteristics of the study population (n=140).

	n (%)
Gender (M/F)	84/56
Age (years)	59 ± 11
Heart rate (bpm)	57 ± 8
Suspected CAD	108 (77%)
Known CAD	32 (23%)
Previous myocardial infarction	30 (21%)
Previous PCI	28 (20%)
Previous stent placement	24 (17%)
Stent in RCA	10 (7%)
Stent in LAD	18 (13%)
Stent in LCx	4 (3%)
Previous CABG	2 (1%)
Graft to RCA	1 (1%)
Graft to LAD	2 (1%)
Graft to LCx	1 (1%)
Type of stress (SPECT)	
Exercise	90 (64%)
Adenosine	41 (29%)
Dobutamine	9 (6%)
LVEF during rest (SPECT)	60% ± 13%
Average coronary calcium score (Agatston)	310 ± 775

Abbreviations: bpm: beats per minute, CABG: coronary artery bypass grafting, CAD: coronary artery disease, LAD: left anterior descending coronary artery, LCx: left circumflex coronary artery, LVEF: left ventricular ejection fraction, PCI: percutaneous coronary intervention, RCA: right coronary artery, SPECT: single photon emission computed tomography.

MSCT coronary angiography

First, a prospective coronary calcium scan was performed prior to MSCT angiography with a collimation 4 x 3.0 mm, gantry rotation time 500 ms, the tube voltage 120 kV and tube current 200 mA. The temporal window was set at 75% after the R-wave for electrocardiographically triggered prospective reconstruction. Coronary calcium score was derived using dedicated software (Vitrea2, Vital Images, Plymouth, Minn. USA). Coronary calcium was identified as a dense area in the coronary artery exceeding the threshold of 130 HU. The global Agatston score as well as per coronary artery was recorded for each patient. Coronary calcium scores were classified into 4 categories: ≤10, 11-100, 101-400, and >400.
For the contrast enhanced helical scan, data were acquired with a collimation of either 16 x 0.5 mm or 64 x 0.5 mm and a tube rotation time of 400 ms, 450 ms or 500 ms (depending on the heart rate), respectively. The tube current was 300 mA, at 120 kV. In 31 patients 16-slice MSCT (Aquilion 16, Toshiba Medical Systems, Japan) was used [3] and in 109 patients, 64-slice MSCT (Aquilion 64, Toshiba Medical Systems, Japan) was used. Non-ionic contrast material was administered in the antecubital vein with an amount of 120 to 140 ml for 16-slice MSCT and 80 to 110 ml for 64-slice MSCT, depending on the total scan time, and a flow rate of 5 ml/sec (Iomeron 400 ®), followed by a saline flush. Subsequently, data sets were reconstructed and transferred to a remote workstation as previously described [3].

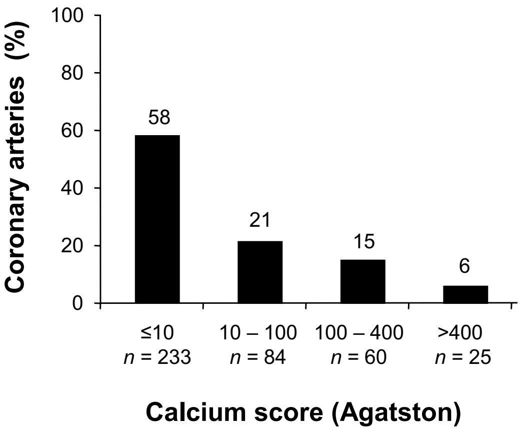


Figure 1. Distribution of the different coronary calcium score categories (per coronary artery).

MSCT angiographic examinations were evaluated by an interventional cardiologist blinded to the SPECT data for the presence of 1) no atherosclerosis, 2) atherosclerosis without significant (≥50% luminal narrowing) stenoses, 3) significant (≥50% luminal narrowing) stenoses or 4) (sub)total (≥90% luminal narrowing) occlusion. In the analysis, the left main coronary artery was considered part of the left anterior descending coronary artery. In patients with previous coronary bypass grafting, the graft as well as its distal run-off was evaluated. In case of an occluded or stenosed graft, also the native coronary artery proximal of the anastomosis was included in the analysis.

Stress-rest Gated SPECT

In all patients, stress-rest gated SPECT (2x 500 MBq technetium-99m tetrofosmin) was performed using symptom-limited exercise or pharmacological (adenosine or dobutamine) stress as previously described [4]. Data were acquired with a triple-head SPECT camera (GCA 9300/HG, Toshiba Corp., Tokyo, Japan) followed by reconstruction in long- and short-axis projections perpendicular to the heart-axis. The short-axis data were displayed in polar map format; the polar maps were divided in 17 segments [5] and normalized to peak myocardial activity (100%). The 17 segments were allocated to the territories of the different coronary arteries as previously described [5]. Perfusion defects were identified on the stress images (tracer activity <75% of maximum) and divided into ischemia (reversible defects, with ≥10% increase in tracer uptake on the resting images) or scar tissue (fixed defects, no ≥10% increase in tracer uptake on the resting images). Accordingly, examinations were classified as being either normal or abnormal, the latter being further divided in reversible or irreversible defects. The gated images were used to assess regional wall motion to improve differentiation between perfusion abnormalities and attenuation artifacts. For irreversible defects, it was recorded whether the defects were located in a region with documented previous myocardial infarction. The left ventricular ejection fraction was derived from the gated SPECT data using previously validated and automated software (quantitative gated SPECT [QGS]; Cedars-Sinai Medical Center, Los Angeles, CA); gating was only performed at rest.

Statistical analysis

Continuous variables were described by mean ± SD. Comparisons between patient groups were performed using 1-way ANOVA for continuous variables and the χ^2 test with Yates' correction for categorical variables. A P-value <0.05 was considered statistically significant.

Results

Analysis on a vessel basis

MSCT and SPECT findings

Coronary calcium score was available in 134 (96%) patients and accordingly in 402 coronary arteries. Average coronary calcium score per coronary artery was 102.6 ± 311.2 (range 0 - 3739). The distribution of the different coronary calcium scores per coronary artery is provided in Figure 1. In Figure 2A, average coronary calcium scores for the 3 coronary arteries are depicted, demonstrating more calcium in the left anterior descending coronary artery as compared to the right and left circumflex coronary artery (P<0.001, Kruskall-Wallis).

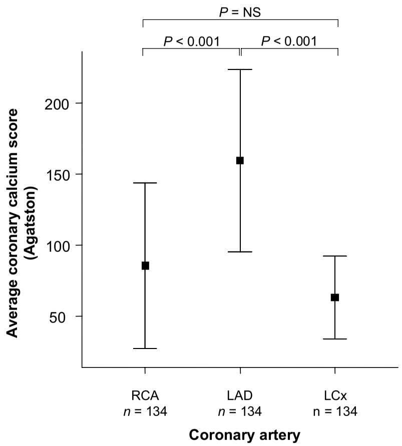
With MSCT angiography, a total of 420 vessels were evaluated. All coronary arteries were included. No abnormalities were observed on MSCT angiography in 175 (42%) vessels, whereas 245 vessels revealed either atherosclerosis without significant stenosis (n=165, 39%) or at least 1 significant stenosis (n=80, 19%). In the latter, total or subtotal occlusions were present in 13 vessels. Results per coronary artery are displayed in Figure 2B.

On SPECT, 420 vascular territories were available, of which 327 (78%) showed normal myocardial perfusion. Abnormal perfusion was observed in the remaining 93 (22%) territories. In 20 territories fixed defects corresponding to territories with known previous myocardial infarction were observed. In the remaining 73 vascular territories, 41 territories revealed ischemia, 27 showed fixed defects, while 5 territories showed both. Figure 2C shows the distribution of perfusion findings among the territories of the different coronary arteries.

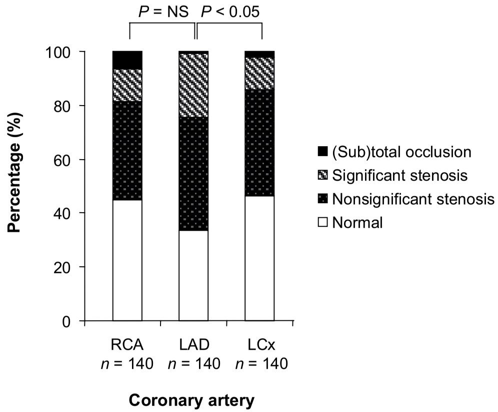
Stenoses on MSCT angiography versus coronary artery calcium score

Average coronary artery calcium score was 1.4 ± 6.0 for normal coronary arteries and increased to 111.6 ± 212.9 and 313.3 ± 600.4 for coronary arteries with non-significant and significant stenoses, respectively (P<0.001 Kruskall-Wallis). Considering only (sub-)total lesions, the extent of coronary calcifications was even higher, 656.5 ± 280.9 (P<0.001). In the majority (n=284, 90%) of coronary arteries with a coronary calcium score below 100, no significant stenoses were demonstrated. In 33 of 60 coronary arteries with a calcium score between 100 and 400, significant stenoses was present in 45%. This percentage further increased to 60% in 25 coronary arteries with a calcium score above 400.

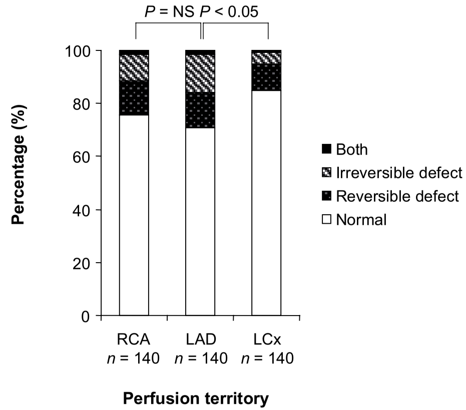
Figure 2. Results per coronary artery and perfusion territory.



(A) Average coronary calcium scores (+95% CI) per coronary artery.



(B) MSCT results per coronary artery.



(C) SPECT results per coronary perfusion territory.

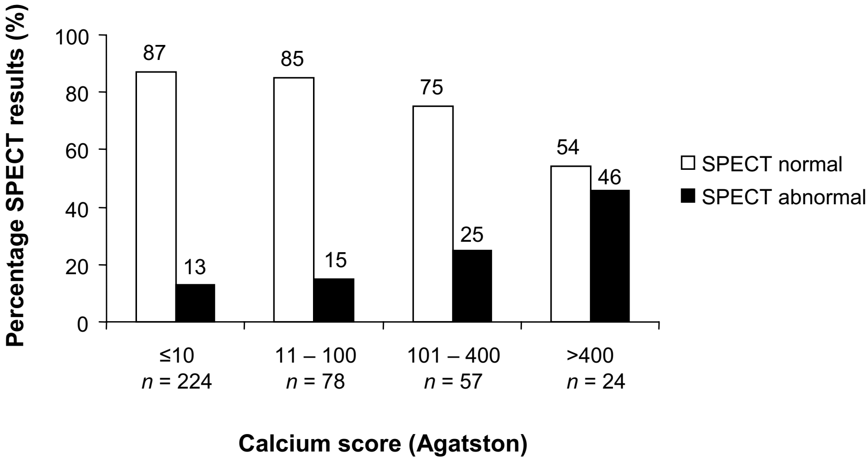


Figure 3. Distribution of normal (n=316) and abnormal (n=67) myocardial perfusion (vessel based) on SPECT between the different coronary calcium score categories.

Perfusion on SPECT versus coronary artery calcium score

The average calcium score in coronary arteries with normal myocardial perfusion on SPECT was 69 ± 167, whereas a significantly higher calcium score of 272 ± 646 was noted for coronary arteries with abnormal SPECT (P<0.001, Mann-Whitney).

Figure 3 shows the distribution of normal and abnormal myocardial perfusion (with exclusion of 19 vascular territories with previous myocardial infarction) according to the different calcium scores. In the majority (n=194, 87%) of coronary arteries with no or minimal calcium (≤10), a normal SPECT was obtained. Percentage normal perfusion was only slightly lower (85%) in coronary arteries with a calcium score between 11 and 100 (P=NS). In coronary arteries with more extensive calcifications,

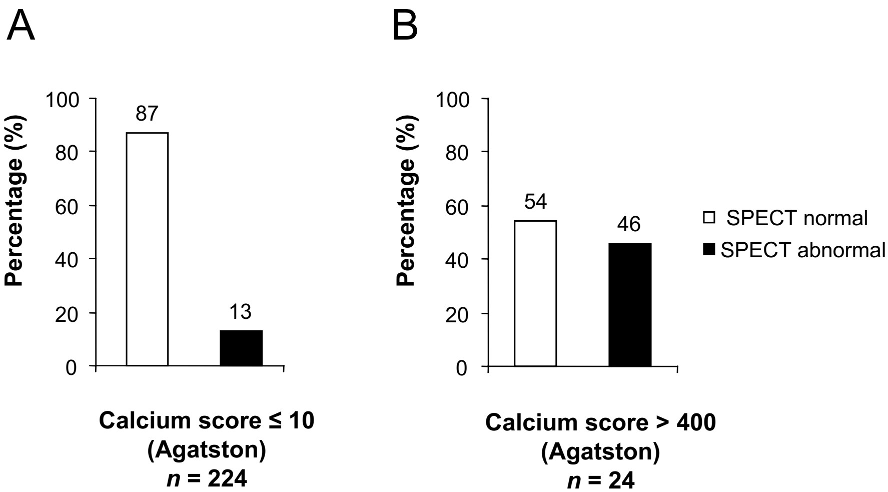


Figure 4. Relation between calcium and perfusion.
(A) Prediction of normal perfusion.
(B) Prediction of abnormal perfusion

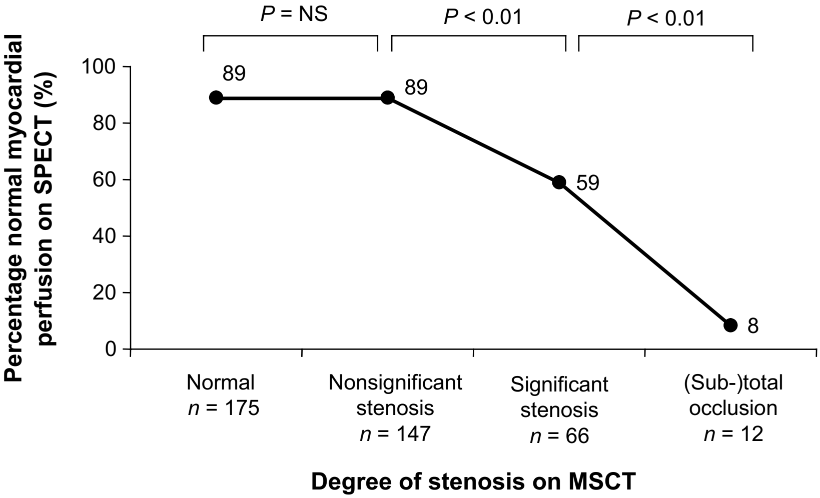


Figure 5. Relation between stenosis severity on MSCT and myocardial perfusion on SPECT.

percentage normal myocardial perfusion on SPECT was significantly lower: 75% and 54% for coronary arteries with calcium scores between 100 and 400 and >400, respectively (P=0.008).
Thus, the likelihood of normal perfusion on SPECT decreased in parallel to an increasing calcium score on MSCT. The predictive value of absence of calcium (score ≤10) for normal perfusion was 87% (Fig. 4A), but the value of significant calcium (score >400) for prediction of abnormal perfusion was only 46% (Fig. 4B).

Perfusion versus stenoses on MSCT angiography

In the majority of normal coronary arteries on MSCT angiography, myocardial perfusion on SPECT in the corresponding territories was normal (156 of 175, 89%). In coronary arteries with stenoses (regardless of severity, n=225) on MSCT (with exclusion of 20 vascular territories with previous myocardial infarction), myocardial perfusion on SPECT was still normal in 171 (76%) corresponding territories. However, the likelihood of normal perfusion in coronary arteries with a significant stenosis or (sub-)total occlusion decreased significantly (Fig. 5). Of the 78 coronary arteries with significant stenoses on MSCT, abnormal perfusion on SPECT was present in 38 (49%) of the corresponding territories, and perfusion on SPECT was abnormal in almost all coronary arteries with (sub-)total occlusion (11 of 12, 92%).
Thus, a normal MSCT had a high predictive value for normal myocardial perfusion (89%, Fig. 6A); however, normal perfusion on SPECT did not exclude abnormalities on MSCT and the value of normal perfusion to predict a normal MSCT was only 48% (Fig. 6B).
In Figure 7 the relation between MSCT and SPECT is depicted per coronary artery/vascular territory. No significant differences were observed between the different coronary arteries. However, significant stenoses located in the right coronary artery tended to result more frequently in abnormal myocardial perfusion on SPECT as compared to the left anterior descending and left circumflex coronary artery, although no statistical significance was reached (P=0.056).

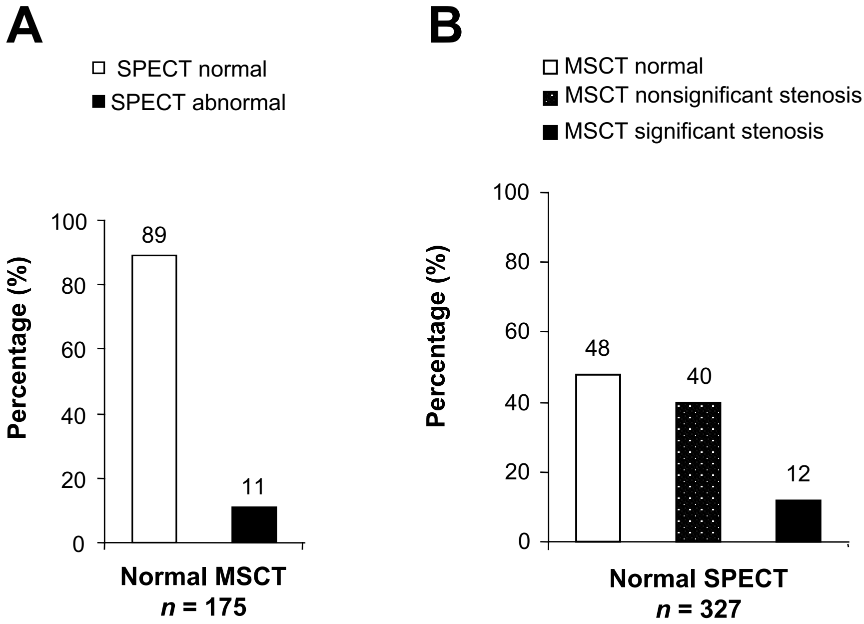


Figure 6. Relation between MSCT and SPECT.
(A) Prediction of normal and abnormal perfusion.
(B) Prediction of normal and (non-) significantly stenosed coronary arteries.

Disagreement between MSCT angiography and SPECT

A normal MSCT angiogram but abnormal SPECT:

In 19 (5%) vascular territories, abnormal myocardial perfusion was observed whereas MSCT showed no atherosclerosis in the corresponding coronary artery. In the majority of these vascular territories with abnormal SPECT, the observed abnormality was predominantly a small fixed defect (n=12, 63%, Fig. 7) with inferior or septal location in respectively 6 and 4 patients.

A normal SPECT but CAD on MSCT angiography:

Only 48% of vascular territories with normal SPECT corresponded to normal coronary arteries. In the majority of abnormal coronary arteries with normal perfusion (131, 77%), lesions were non-significant and did not result in ischemia. In 40 (10%) vascular territories, myocardial perfusion was completely normal despite significant lesions in the corresponding coronary artery on MSCT. In these cases, coronary lesions may not have been hemodynamically relevant. Importantly, in 2 patients with a discrepancy between MSCT and SPECT on a vessel basis, stenosis of both the right coronary artery and left main coronary artery was present; only the lesion in the right coronary artery was detected by abnormal perfusion. Finally, in 2 patients with a completely normal SPECT, 3-vessel disease was demonstrated on MSCT.

Analysis on a patient basis

MSCT and SPECT findings

Average coronary calcium per patient was 310 ± 775 (range 0 to 6264). MSCT coronary angiography was normal in 43 (31%) patients, whereas non-obstructive and obstructive CAD was noted in respectively 51 (36%) and 46 (33%) patients. A normal SPECT study was obtained in 77 (55%) patients, whereas abnormal perfusion was noted in 63 (45%) patients, corresponding to previous myocardial infarction in 15 (11%) patients.

Stenoses on MSCT angiography versus coronary artery calcium score

Average coronary artery calcium score was 3.8 ± 11 for patients with normal coronary arteries and increased to 207 ± 271 and 726 ± 1239 in patients with non-significant and significant stenoses, respectively (P<0.001 Kruskall-Wallis). In the majority (n=45, 88%) of patients with a coronary calcium score ≤ 10, no significant stenoses were demonstrated. In 20 of 57 patients with a calcium score between 11 and 400, significant stenoses were present in 35%. This percentage further increased to 65% in patients with a calcium score above 400.

Perfusion on SPECT versus coronary artery calcium score

The average calcium score in patients with normal myocardial perfusion on SPECT was 162 ± 332, whereas a significantly higher calcium score of 580 ± 1232 was noted for patients with abnormal SPECT (P<0.05, Mann-Whitney).

In the majority (n=49, 78%) of patients without extensive calcium (≤100), a normal SPECT was obtained. Percentage normal perfusion was slightly lower (60%) in patients with a calcium score between 101 and 400 (P=NS). In coronary arteries with calcium scores >400, percentage normal myocardial perfusion on SPECT was even lower (41%, P=NS).

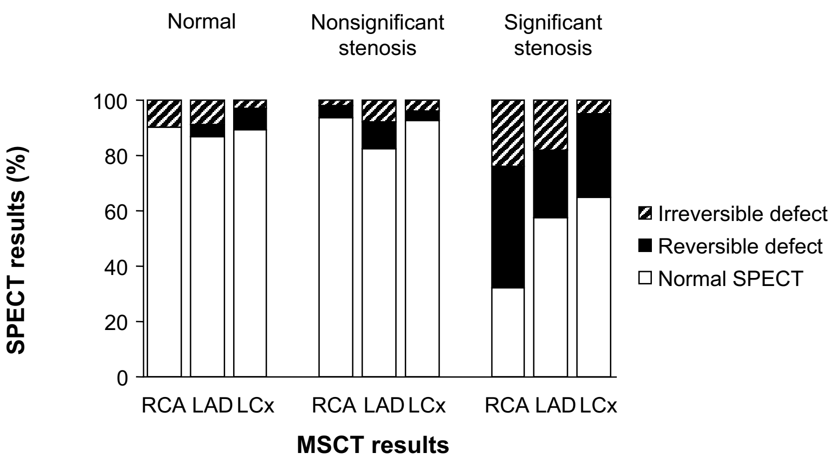


Figure 7. Relation between MSCT and SPECT per coronary artery/vascular territory.

Perfusion versus stenoses on MSCT angiography

In the majority of patients with normal MSCT angiography, the corresponding SPECT study was normal as well (37 of 43, 86%). In patients with non-significant stenoses on MSCT angiography (n=38, with exclusion of 13 patients with abnormal perfusion corresponding to previous myocardial infarction), myocardial perfusion on SPECT was normal in 24 (63%) patients. The percentage normal perfusion studies further decreased to 36% in patients with at least 1 significant stenosis ($P<0.05$). Thus, a normal MSCT angiogram had a high predictive value for normal myocardial perfusion (86%). However, similar to the vessel-based analysis, normal perfusion on SPECT did not exclude abnormalities on MSCT angiography as a normal MSCT angiogram was obtained in only 37 (48%) of 77 patients with normal perfusion.

Discussion

In the present study, atherosclerosis imaging with MSCT was compared to myocardial perfusion imaging with gated SPECT on a coronary artery and corresponding vascular territory basis. Normal coronary arteries on MSCT were associated with normal perfusion in the majority (89%) of vascular territories. Moreover, the likelihood of an abnormal SPECT study increased gradually in relation to increasing abnormalities on MSCT, with 92% of SPECT studies being abnormal in (sub-)total occlusions on MSCT. Still, 76% of the coronary arteries with atherosclerosis on MSCT did not exhibit perfusion abnormalities on SPECT, indicating that atherosclerosis does frequently not result in ischemia. Normal perfusion on SPECT was associated with normal MSCT in only 48% of vascular territories; 52% of territories with normal SPECT had atherosclerosis on MSCT, with 40% having non-obstructive and 12% having obstructive CAD.

These observations highlight that normal perfusion on SPECT does not exclude atherosclerosis. Accordingly, MSCT and gated SPECT provide complementary rather than redundant information, since the techniques reflect distinct functional and anatomical patho-physiological processes.

An abnormal MSCT does not necessarily imply ischemia

The vast majority (76%) of lesions on MSCT did not result in perfusion abnormalities or ischemia on SPECT imaging. In particular, 89% of non-obstructive lesions on MSCT were not associated with perfusion abnormalities on SPECT. This observation underscores that MSCT permits detection of CAD at an earlier stage than SPECT imaging: the detection of atherosclerosis while perfusion is not yet compromised. Similar results were reported recently by Hacker et al, using 16-slice MSCT, and demonstrated in 25 patients that only 8 (47%) of 17 significant stenoses on MSCT resulted in abnormal perfusion on SPECT [2]. Yet, in the present study, a stepwise increase in the incidence of SPECT perfusion abnormalities was observed in relation to an increasing severity of MSCT abnormalities (Fig. 5). In particular, (sub-) total occlusions were in 92% of cases associated with abnormal myocardial perfusion on SPECT. Also, less severe but still significant lesions resulted in abnormal perfusion in 41% of vascular territories. These findings illustrate the relation between the stenosis severity on MSCT and hemodynamic consequences as assessed by SPECT, but the results simultaneously highlight the discrepancy between atherosclerosic plaque burden and ischemia. As a result of variations in stenosis length and composition, angle and location, as well as the presence or absence of collateral vessels, an apparently identical stenosis may be incapable of producing symptoms in one patient while causing severe ischemia in another. Indeed, several studies comparing invasive coronary angiography findings to functional testing revealed at best a fair agreement with approximately half of significant lesions showing abnormal myocardial perfusion [2;6]. This can also result from the fact that SPECT, by virtue of its relative nature, merely detects severe reductions in coronary flow reserve while modest reductions in flow reserve may not result in detectable defects [7]. Thus, an abnormal MSCT does not necessarily result in abnormal perfusion, but more frequently represents non-obstructive atherosclerosis, and functional testing is mandatory in patients with abnormal MSCT to determine the hemodynamic consequences of the MSCT abnormalities.

A normal SPECT does not exclude CAD

In the present study, atherosclerosis was present in 52% of coronary arteries with normal SPECT results. Moreover, advanced CAD with at least 1 significant, obstructive lesion was noted in 12% of territories with normal perfusion, underlining that a normal SPECT does not invariably exclude the presence of CAD. Indeed, studies correlating atherosclerosis assessment (based on coronary artery calcium scoring) to SPECT revealed similar observations, namely that (extensive) coronary calcifications are frequently observed in patients with normal SPECT studies [8;9]. These observations may initially appear in conflict with the extremely low annual event rate that is associated with a normal SPECT study, which is approximately 0.6% for patients without known CAD [10]. Nonetheless, among those patients with normal SPECT studies, certain subgroups, including those patients referred for pharmacological testing or with substantial comorbidity, have been identified that may actually be at elevated risk (1.2% to 2.0%) [11]. In addition, patients with subclinical CAD, as demonstrated by MSCT, may constitute another category of patients that may have an elevated long-term risk of developing coronary events despite a normal SPECT; this hypothesis needs to be addressed by further outcome-based studies. However, knowledge concerning the presence and extent of subclinical CAD is still relevant and will help to identify patients with a normal SPECT who yet have atherosclerosis in whom optimized medical therapy and aggressive life-style modification is indicated, in contrast to individuals with a normal SPECT without atherosclerosis, who may be re-assured without the need for further routine visits to the outpatient clinics.

Regional analysis

Concerning the different coronary arteries and corresponding vascular territories, a relatively larger plaque burden, as reflected by a higher coronary calcium score, was observed in the left anterior descending coronary artery as compared to the right and left circumflex coronary artery.

Also slightly more abnormalities were encountered in this coronary artery and corresponding vascular territory during coronary angiography and perfusion imaging, respectively. Nonetheless, in the present study significant stenoses located in the right coronary artery tended to result most frequently in abnormal myocardial perfusion on SPECT, which may be attributable to the higher frequency of severe, (sub)total occlusions in this coronary artery as compared to the left anterior and left circumflex coronary arteries.

Limitations

Some limitations need to be defined. First, myocardial perfusion on SPECT was related to atherosclerosis in coronary arteries and perfect alignment between these methods is difficult, since precise definition of vascular territories is hampered by variations in coronary anatomy. Also, a threshold of 50% luminal narrowing on MSCT was applied, while a threshold of 70% might have resulted in increased agreement between the 2 techniques. Second, the study population consisted of patients with various clinical presentations with both suspected and known CAD. Studies performed in more homogenous study populations may provide more uniform results, yet may not be generalizable to a "real life" population referred for evaluation of CAD, such as the one included in the present study. Similarly, applied stress protocols for gated SPECT were not identical, as these were performed as part of standard clinical routine.

Other limitations include the lack of attenuation correction for SPECT, which may (partially) explain the abnormal SPECT findings in the presence of a completely normal MSCT, albeit a relatively unfrequent finding. Also, no comparison to conventional coronary angiography was available. In addition, data were acquired with 2 different generations of MSCT scanners, while ideally all patients would have been evaluated with 64-slice MSCT. Finally, several limitations of MSCT in general need to be acknowledged. The technique involves radiation, and further technical developments are needed to lower the radiation burden. Also, motion artifacts as well as severe coronary calcifications have been demonstrated to reduce diagnostic accuracy [12;13].

Conclusions

The current analysis on a regional basis underscores that although a relation exists between the 2 modalities, MSCT and SPECT provide complementary information, namely the presence of (subclinical) atherosclerosis versus the presence of ischemia. Further studies should address how these 2 modalities may be integrated to optimize patient management.

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