Journal of the American College of Cardiology
Vol. 46, No. 1, 2005

Published by Elsevier Inc.
ISSN 0735-1097/05/$30.00
doi:10.1016/j.jacc.2005.03.057

**Comparison of Cardiac Imaging**

# Head-to-Head Comparison of Three-Dimensional Navigator-Gated Magnetic Resonance Imaging and 16-Slice Computed Tomography to Detect Coronary Artery Stenosis in Patients

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**OBJECTIVES** The purpose of this research was to compare the diagnostic accuracy of three-dimensional navigator-gated magnetic resonance (MR) imaging and 16-slice multidetector row computed tomography (MDCT) versus quantitative coronary angiography (QCA) for the detection of coronary artery stenosis in patients.

**BACKGROUND** Both MR and MDCT are novel non-invasive tests, which have been proposed for noninvasive detection of coronary artery disease. Yet their diagnostic accuracy has not been directly compared in the same population.

**METHODS** Fifty-two patients underwent coronary MR and 16-slice MDCT before invasive coronary angiography. Diameter stenosis (DS) severity in vessels >1.5-mm reference diameter were graded visually and measured quantitatively on both MR and MDCT images. Diagnostic accuracy of both methods was compared using QCA as the reference test.

**RESULTS** According to QCA, 81 of 452 (18%) coronary segments with >1.5 mm diameter had >50% DS. By visual analysis, MR and MDCT had similar sensitivity (75% vs. 82%, $p = NS$), specificity (77% vs. 79%, $p = NS$), and diagnostic accuracy (77%, vs. 80%, $p = NS$) for detection of >50 % DS. Quantitative measures of DS by MR ($r = 0.60$, $p < 0.001$) and MDCT ($r = 0.75$, both $p < 0.001$) correlated well with QCA. Receiver-operating characteristic analysis demonstrated that quantification of DS severity improved the diagnostic accuracy of MDCT (area under curve [AUC] 0.81 vs. 0.92, $p < 0.001$) but not that of MR (AUC 0.78 vs. 0.83, $p = NS$).

**CONCLUSIONS** Visual assessment of coronary diameter stenosis severity by MR or MDCT allows identification of significant coronary artery disease with a similar high diagnostic accuracy. Quantitative analysis significantly further improves the diagnostic accuracy of MDCT but not that of MR. (J Am Coll Cardiol 2005;46:92–100) © 2005 by the American College of Cardiology Foundation

In recent years, considerable progress has been achieved in the field of noninvasive coronary imaging. Both navigator-gated three-dimensional magnetic resonance imaging (MRI) (1–3) and multidetector row spiral coronary computed tomography (MDCT) (4–9) have been proposed for this purpose. Several studies have suggested that both modalities have good diagnostic accuracy and that they might have clinical value (10). Yet, until now, there has been no direct comparison between these two approaches in the same patients.

The purpose of the present study was to compare the diagnostic ability of 16-slice MDCT and three-dimensional navigator-gated MRI to detect significant coronary artery stenosis in patients referred for conventional invasive coronary angiography. In order to provide a more objective assessment of the diagnostic performance of both tests, we not only evaluated coronary stenosis severity visually but also quantitatively. Finally, we evaluated whether the quantitative analysis improves the diagnostic accuracy of the visual assessment.

## METHODS

**Patient population.** Fifty-six consecutive patients (44 males, mean age 65 ± 10 years) who were referred to our institution for conventional diagnostic X-ray coronary angiography were enrolled in the study. Indications for cardiac catheterization were: typical angina and positive stress test in 35 patients, atypical chest pain or dyspnea with positive stress test in 6 patients, silent ischemia in 3 patients, and

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Manuscript received September 29, 2004; revised manuscript received February 28, 2005, accepted March 22, 2005.

**Abbreviations and Acronyms**

| | |
|---|---|
| CNR | = contrast-to-noise ratio |
| CT | = computed tomography |
| DS | = diameter stenosis |
| LAD | = left anterior descending coronary artery |
| LCx | = left circumflex coronary artery |
| LM | = left main coronary artery |
| MDCT | = multidetector row computed tomography |
| MLD | = minimal luminal diameter |
| MRI | = magnetic resonance imaging |
| QCA | = quantitative coronary angiography |
| RCA | = right coronary artery |
| RVD | = reference vessel diameter |

chest pain with negative stress test in 6 patients. Five patients were referred to evaluate coronary anatomy before noncoronary cardiac surgery and one patient because of ventricular tachycardia. Only patients who were in sinus rhythm and who had no prior revascularization procedure (no stents or bypass operation) were considered for inclusion into the study. Exclusion criteria were hemodynamic instability, constant arrhythmia (atrial fibrillation or more than five premature beats/min), heart failure in New York Heart Association functional class III or worse, renal insufficiency (serum creatinine >1.4 mg/dl), known allergy to iodated contrast agents, or any contraindication to MRI (cerebral aneurysm clips, pacemaker, or severe claustrophobia). All patients gave written informed consent to the study protocol, which had been approved by our local ethics committee.

**Study protocol.** Patients underwent MRI and MDCT in random order on the same day. Both tests were performed at a median of 1 day (range 0 to 30 days) before conventional coronary angiography. Atenolol 50 mg orally was given to patients with a resting heart rate >70 beats/min. Thirty-two (62%) patients received beta-blockers before computed tomographic imaging.

**MRI.** Magnetic resonance imaging was performed on a 1.5-T magnet (Intera CV, Philips Medical Systems, Cleveland, Ohio). Coronary images were acquired using a vectocardiogram-triggered, free-breathing navigator-gated multislice three-dimensional segmented axial balanced turbo-field-echo sequence with $T_2$ preparation as previously described (11). Imaging parameters were repetition time (TR) = 5.8 ms, echo time (TE) = 2.9 ms, flip angle = 110°, field of view = 270 mm, 272 × 272 × 10 image matrix reconstructed to 512 × 512 × 20 pixels, number of shots per heart beat = 16, resulting in an acquired reconstruction of 1 × 1 × 3 mm reconstructed to a resolution of 0.5 × 0.5 × 1.5 mm. Images were acquired in mid-diastole with a delay time = 0.3 · (RR interval − 350) + 350 and a temporal resolution of 90 ms. Four double oblique slice locations were prescribed using a three-point plan scan tool. Briefly, stack number 1 covered the right coronary artery (RCA) in the right atrioventricular groove. Stack number 2 covered the proximal left main (LM), the left anterior descending (LAD), and the left circumflex (LCx) arteries in an axial view. Stack number 3 covered the mid and distal LAD in the interventricular groove, whereas stack number 4 followed the LCx in the left atrioventricular groove.

**MDCT.** Multidetector row coronary computed tomography was performed on a 16-slice system (IDT, Philips Medical Systems). For imaging, a bolus of 120 ml of a nonionic contrast medium was intravenously injected at a rate of 4 ml/s. The patient was then instructed to maintain an inspiratory breath hold, during which the computed tomography data and electrocardiogram (ECG) trace were acquired. Tube rotation speed was 420 ms, detector collimation 16 × 0.75 mm, pitch 0.20 to 0.24, tube voltage 140 kV, and effective tube current 400 mAs. Spatial resolution was 0.8 × 0.8 × 0.8 mm. Images were reconstructed using a retrospective multicycle ECG gating algorithm using half of tube rotation and, depending on heart rate, information from two or three consecutive cardiac cycles. Temporal resolution was variable according to the heart rate of the patient (90 to 120 ms). Radiation exposure was approximately 8 to 9 mSv. For every patient, eight complete datasets were reconstructed every 12.5% of the cardiac cycle. All MDCT datasets were transferred onto a computer workstation (Mx-view, Philips Medical Systems) and were re-sliced into four multiplane volume stacks using the same orientations as the MRI. The dataset containing the fewest motion artifacts was selected for surface projection and for quantitative analysis. The optimal reconstruction window was at 75% of cardiac cycle in 46 patients, 50% of the cardiac cycle in 6 patients, and at 87% and 62% of the cardiac cycle in 2 and 1 patients, respectively.

**Coronary angiography.** Selective biplane coronary angiography was performed from the femoral approach. Coronary angiograms were acquired in multiple orthogonal projections. Data were evaluated by two blinded reviewers (J.K. and G.L.) with the use of the Quantitative Coronary Angiography software (QCA, Cardiovascular Angiographic Analysis System II, Pie Medical Equipment, Switzerland), which allows both for catheter-based image calibration and for automated vessel contour detection. Reference vessel diameter (RVD), minimal luminal diameter (MLD) were computed automatically. Diameter stenosis (DS) was computed in percent as:

$$DS = \frac{RVD - MLD}{RVD} \cdot 100$$

The standard 15-segment American Heart Association classification system was used (12). Only segments with a reference diameter >1.5 mm were evaluated. Segments with smaller diameter and segments distal to a proximal occlusion were considered to be absent; DS >50% were used as cutoff values to define significant stenoses.

**MDCT and MR data analysis.** Anonymous MR and MDCT datasets were analyzed by two blinded readers, a radiologist (E.C.) and a cardiologist (B.G.), who had both similar experience in reading MDCT and MR images. All measurements were performed in duplicate. Contrast-to-noise ratios (CNRs) were measured in four nondiseased coronary segments (proximal LM, mid-LAD, LCx, and RCA) and computed as the difference in mean signal intensity between the vessel lumen and the adjacent tissue, divided by the standard deviation of the background noise in the proximal aorta. A custom software tool (13) was used to produce oblique surface ("soap-bubble") projections of MR and MDCT coronary images, and to measure the length of reconstructed coronary segments with both techniques.

Analysis of coronary artery stenosis was performed both visually and quantitatively by the two readers. To avoid interpretation bias, MR and MDCT images were read at least 30 days apart. Both the raw axial and oblique images in all reconstruction phases as well as the reformatted surface projection images were available for analysis. Each reader graded whether segments were evaluable and estimated DS severity to be <50% or >50%. After analysis of interobserver agreement, discordant findings between the two readers were resolved by consensus reading. The quantitative analysis was performed on separate days, by the same two investigators, using dedicated analysis software (MX-view, Philips Medical Systems) (Fig. 1). The coronary segment was interactively traced on a maximum projection of the three-dimensional image stack. Using the traced vessel center as reference, the software automatically detected the contours of the vessel lumen based on an

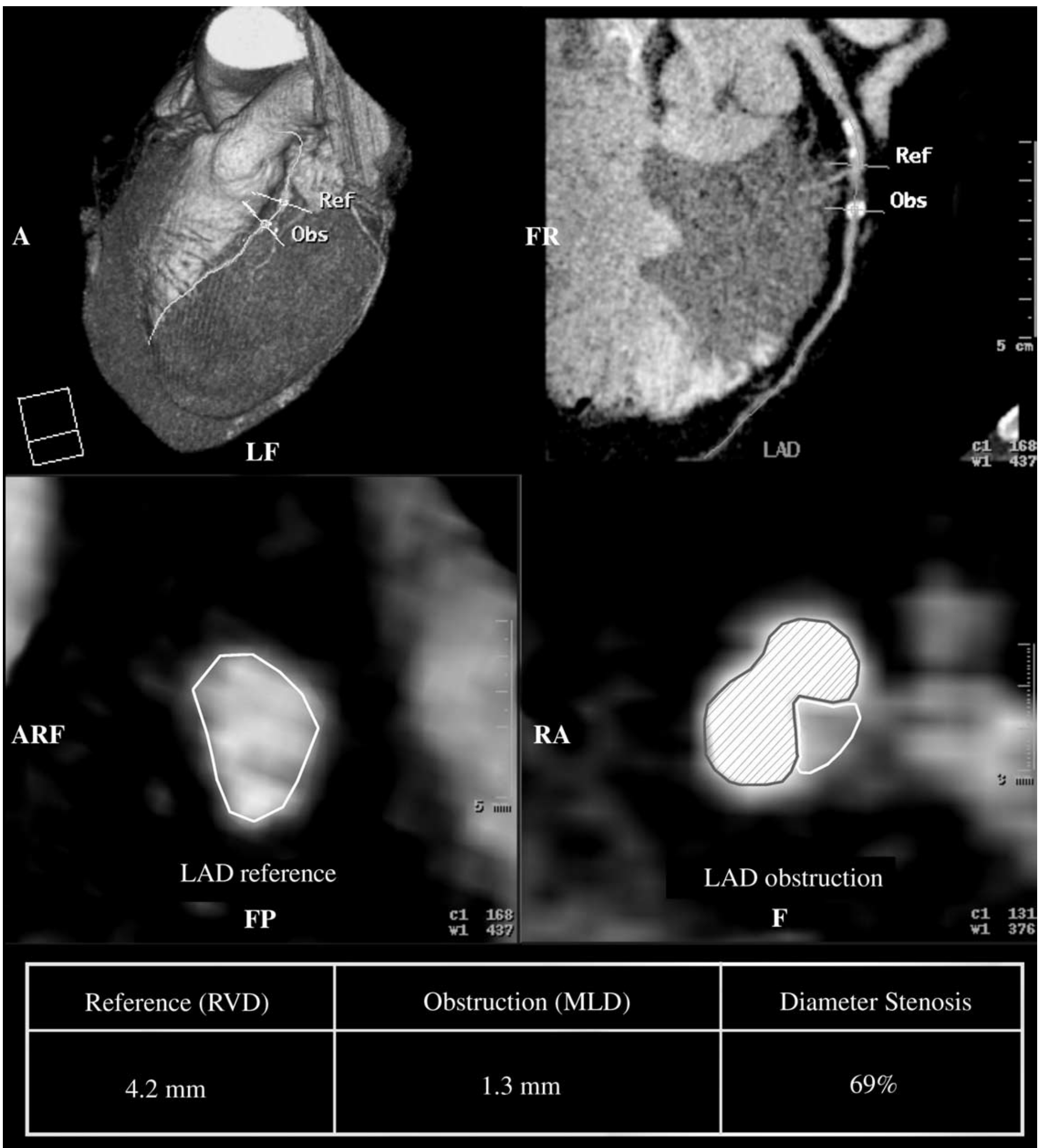


**Figure 1.** Quantitative analysis of left anterior descending coronary artery (LAD) stenosis by multidetector row computed tomography (MDCT). Calcified plaque **(gray striped)** was removed from lumen contours **(thick white border)**. MLD = minimal luminal diameter in area of obstruction (Obs); RVD = reference vessel diameter in non-diseased area (Ref).

algorithm that uses the full width at half-maximum of the vessel lumen as cutoff value. For MDCT, calcified plaques (defined as regions >350 HU), were excluded from lumen contours. For each segment, the maximum diameter of the traced contours represented the RVD, and the minimum diameter represented the MLD; DS was computed as previously described.

**Statistical analysis.** Values are reported as mean ± 1 standard deviation. Vessel length and CNR were compared using paired *t* tests. For the visual analysis, the interobserver agreement was evaluated on segmental basis using the kappa statistic. The agreement on the measurements of MLD, RVD, and stenosis severity by QCA, MR, and MDCT was expressed as intraclass correlation coefficient. The diagnostic accuracy of MR and MDCT was compared using QCA as the reference. For visual analysis, results of the consensus reading of both reviewers were reported. Differences in accuracy between MR and MDCT on segmental and vessel basis were compared using McNemar's chi-square test. Diagnostic accuracy of quantitative and visual assessment of stenosis severity by MR and MDCT was compared using receiver operating characteristic curves. Areas under the receiver operating characteristic curves were compared using a *z* test with corrections for paired data. All tests were two-sided, and a p value <0.05 was considered as statistically significant.

## RESULTS

**Study protocol.** Three patients without known history of claustrophobia could not undergo MR imaging because they developed claustrophobia; MDCT also failed in one of these patients. Conventional angiography was unsuccessful in another patient because of vascular access problems. Therefore, 52 patients successfully underwent all three tests and constituted the final study population. Mean heart rate was 66 ± 10 beats/min during MDCT and 67 ± 13 beats/min during MR (p = NS vs. MDCT). The duration of the complete MR examination (including localization and plane prescription) was 36 ± 6 min (range 25 to 47 min), while the comprehensive MDCT acquisition lasted 6 ± 2 min (range 5 to 10 min). The breath hold duration of the MDCT lasted 25 ± 3 s (range 19 to 30 s).

**Quantitative coronary angiography (QCA).** The intraclass correlation coefficients for the measurements of RVD, MLD, and DS by QCA were 0.83, 0.88, and 0.85, respectively. According to QCA and using the average of the measurements by the two blinded readers, 452 segments had RVD >1.5 mm and were considered for further analysis. Details of segmental coronary anatomy according to QCA are shown in Table 1. Twelve patients had single-vessel disease, 11 had two-vessel disease, 11 had three-vessel disease, and 18 were considered to be free of any significant coronary artery disease.

**Image quality and length of visualization of coronary arteries by MR and MDCT.** Typical sets of MR, MDCT, and conventional angiographic images of the proximal coronary arteries are shown in Figure 2. The LM was imaged with similar CNRs by MR and MDCT (8.5 ± 3.3 vs. 9.1 ± 2.1, p = NS). However, CNR in the LAD (8.6 ± 3.1 vs. 6.6 ± 3.2, p < 0.01), LCx (8.0 ± 2.5 vs. 5.9 ± 3.0, p < 0.001), and RCA (7.9 ± 2.8 vs. 5.9 ± 2.8, p < 0.001) were significantly higher by MDCT than by MR. While no significant differences in the length of visualization between MR and MDCT were found for the LM (11 ± 5 vs. 12 ± 4 mm, p = NS) and the LAD (66 ± 12 vs. 67 ± 13

**Table 1.** Details of Segmental Coronary Anatomy in the Patient Population as Defined by QCA and Diagnostic Accuracy of Visual Analysis

| | QCA | | MR | | MDCT | |
|---|---|---|---|---|---|---|
| | No. of Segments >1.5 mm | No. of Segments >50% DS | Sensitivity | Specificity | Sensitivity | Specificity |
| Left main | 50 | 7 | 7/7 (100%) | 37/43 (86%) | 7/7 (100%) | 41/43 (95%) |
| LAD | | | | | | |
| Proximal | 52 | 9 | 7/9 (78%) | 30/43 (70%) | 8/9 (89%) | 29/43 (67%) |
| Mid | 50 | 11 | 8/11 (73%) | 29/39 (74%) | 10/11 (91%) | 26/39 (67%) |
| Distal | 39 | 0 | — | 28/39 (72%) | — | 31/39 (79%) |
| Diagonal branches | 11 | 3 | 2/3 (67%) | 5/7 (71%)* | 3/3 (100%) | 6/8 (75%) |
| LCx | | | | | | |
| Proximal | 51 | 7 | 6/7 (86%) | 32/44 (73%) | 6/7 (86%) | 33/43 (77%)* |
| Distal | 12 | 4 | 3/4 (75%) | 5/8 (62%) | 4/4 (100%) | 4/8 (50%) |
| Marginal branches | 41 | 13 | 8/11 (73%) | 16/27 (59%)* | 7/10 (70%) | 17/27 (63%)* |
| RCA | | | | | | |
| Proximal | 51 | 7 | 5/7 (71%) | 42/44 (95%) | 4/7 (57%) | 39/44 (88%) |
| Mid | 47 | 13 | 10/13 (77%) | 29/34 (85%) | 10/13 (77%) | 31/34 (91%) |
| Distal and branches | 48 | 7 | 3/7 (43%) | 32/40 (80%)* | 5/7 (71%) | 36/41 (88%) |
| Total | 452 | 81 | 59/79 (75%) | 285/368 (77%) | 64/78 (82%)† | 293/369 (79%)† |

Counts are reduced for distal vessels because segments distal to occlusion and segments <1.5 mm size were not considered. *Three marginal, one diagonal, and one postero-lateral branch segment were not interpretable by magnetic resonance (MR); four marginal and one proximal circumflex segments were not interpretable by MDCT; †p = NS vs. MR.

LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; MDCT = multidetector row computed tomography; QCA = quantitative coronary angiography; RCA = right coronary artery.

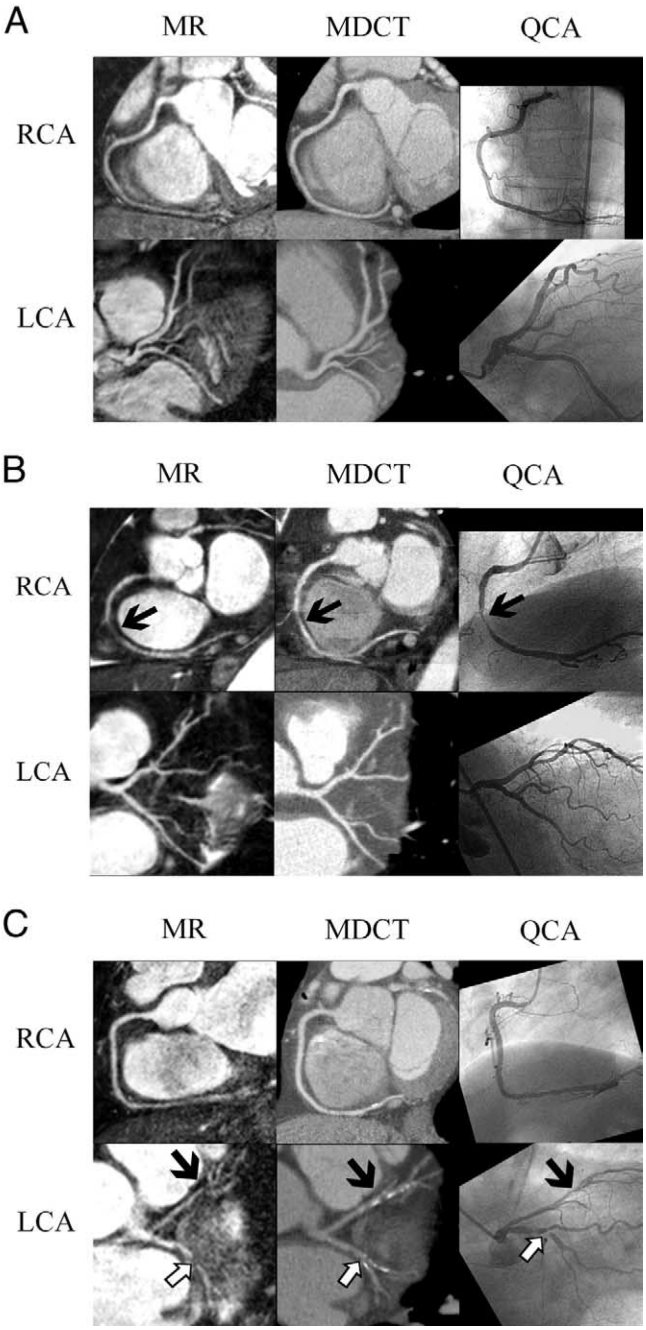


**Figure 2.** Typical examples of reformatted magnetic resonance (MR) **(left panels)**, and multidetector row computed tomography (MDCT) **(center panels)** and corresponding quantitative coronary angiography (QCA) images **(right panels)** of the right (RCA) **(top panels)** and left coronary artery systems (LCA) **(bottom panels)**. **(A)** Normal right and left coronary arteries by MR, MDCT, and QCA. **(B)** Isolated mid-RCA stenosis **(arrows)** evaluated at 40% diameter stenosis (DS) using MR, 58% DS using MDCT, and 86% DS by QCA. **(C)** Two-vessel disease involving the mid-LAD **(black arrows)**, evaluated at 37% DS using MR, 51% DS using MDCT, and 52% DS using QCA and left circumflex coronary artery **(white arrows)** evaluated at 64% DS using MR, 57% DS using MDCT, and 79% DS using QCA.

mm, $p$ = NS), MDCT allowed for a significant longer visualization of the LCx (55 ± 15 vs. 47 ± 10 mm, $p < 0.001$) and RCA (123 ± 22 vs. 115 ± 28 mm, $p < 0.01$) than MR.

**Visual assessment of coronary artery stenosis by MR and MDCT.** Five of the 452 coronary segments could not be analyzed using MR, and 5 other segments could not be interpreted using MDCT. The concordance between readers was 65% ($\kappa = 0.65$) for MR and 46% ($\kappa = 0.44$) for MDCT. After discordances were resolved by consensus between the two readers, the diagnostic accuracy of the visual assessment of DS by MR and MDCT images was computed both on a segmental (Table 1, Fig. 3A) and per-vessel basis (Fig. 3B). Using such visual assessment of DS, both tests had similar high sensitivity and specificity. Both tests had high negative predictive value on segmental and per-vessel basis. However, their positive predictive values on segmental basis were rather low. This could relate to the lower prevalence of coronary stenosis on segmental basis. The overall diagnostic accuracy of the visual assessment was similar for both tests. This was true both for analysis performed on per-segment and per-vessel basis. In addition, the diagnostic accuracy of MR and MDCT for detecting segmental stenosis was similar in the four major vascular territories (Table 1). On a per-patient basis, MDCT had a sensitivity of 92% (32 of 34), a specificity of 67% (12 of 18), an accuracy of 85% (48 of 52), a positive predictive value of 84% (32 of 38), and a negative predictive value of 86% (12 of 14) to correctly identify patients with

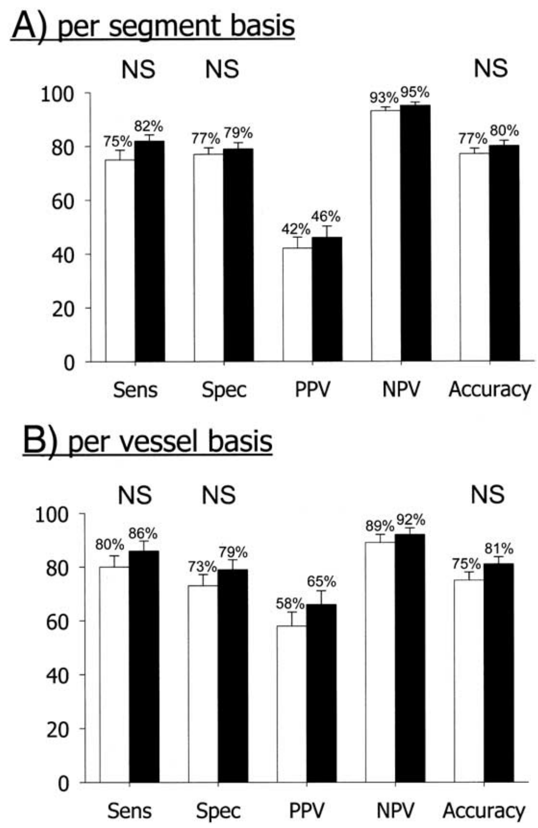


**Figure 3.** Visual diagnostic accuracies of magnetic resonance and multidetector row computed tomography for detection of >50% diameter stenosis on a per-segment basis **(A)** and per-vessel basis **(B)**. NPV = negative predictive value; PPV = positive predictive value; Sens = sensitivity; Spec = specificity.

coronary artery disease. Magnetic resonance had a sensitivity of 88% (30 of 34), a specificity of 50% (9 of 18), and an accuracy of 75% (39 of 52, p = NS vs. MDCT). Positive and negative predictive values for MR on a per-patient basis were 77% (30 of 39) and 69% (9 of 13), respectively.

Reasons for false positive and false negative readings are reported in Table 2. The main reasons for false positive readings by MR were poor opacification of small vessels and low CNR in segments distal to a proximal stenosis. The main reason for false positive readings by MDCT was the presence of significant amounts of coronary calcium. False negatives were rare with both modalities and most often related to short stenosis or vessel size.

In the subgroup of segments with heavy calcification (n = 82), MDCT had excellent sensitivity of 100% (23 of 23), but a low specificity of 31% (18 of 59) and a low overall accuracy of 50% (41 of 82). In such calcified segments, MR had a sensitivity of 74% (17 of 23, p not computable vs. MDCT because of low number of observations). Specificity (61% or 36 of 59, $p < 0.001$ vs. MDCT) and accuracy (65%, 52 of 82, $p < 0.05$ vs. MDCT) of MR in calcified segments was significantly higher than of MDCT.

**Quantitative assessment of coronary artery stenosis severity by MR and MDCT versus QCA.** Fifteen segments could not be analyzed quantitatively with MR, and nine could not be analyzed with MDCT. This included the 5 segments that were not identified visually, as well as 10 segments (8 marginal and 2 diagonal branches) for MR and 4 segments (all marginal branches) for MDCT, respectively, that were too small and had too low contrast to allow tracing in the quantification software.

With MR, interobserver agreement for the measurements of RVD, MLD, and stenosis severity by MR were 51%, 39%, and 22%, respectively. For MDCT, interobserver agreement for measurements of RVD, MLD, and stenosis severity were 58%, 63%, and 55%, respectively. Reference vessel diameter and MLD by MR (r = 0.69 and r = 0.61, respectively, both $p < 0.001$) and by MDCT (r = 0.67 and r = 0.73, respectively, $p < 0.001$) correlated well with measurements by QCA. Hence, stenosis severity evaluated by MDCT and MR correlated also reasonably well with stenosis severity by QCA (Fig. 4). As shown in Figure 4, the correlation of MDCT was slightly better (r = 0.75) and had closer limits of agreement than the correlation between stenosis severity by MR (r = 0.60, p = NS by analysis of variance vs. MDCT) and QCA. Both MDCT and MR overestimated low-grade stenosis and underestimated high-grade stenosis versus QCA. This effect was more pronounced for MR than for MDCT.

The diagnostic accuracy of quantitative measurements of DS severity by MR and MDCT was compared using receiver-operating characteristic analysis both on a segmental and a per-vessel basis (Fig. 5). Optimal cutoff values to detect >50% DS by QCA were 27% for MR and 41% for MDCT, respectively. Quantitative measurements of DS significantly improved diagnostic accuracy of MDCT as compared to visual analysis. This was true on both a segmental and a per-vessel basis. By contrast, quantitative measurements of DS did not improve the diagnostic accuracy of MR compared to visual analysis. As indicated by significantly greater area under the receiver-operating characteristic curve ($p < 0.05$), using quantitative analysis of DS, MDCT had a higher diagnostic accuracy to identify coronary artery disease than MR both on a segmental and on a per-vessel basis. Quantitative analysis, using a cutoff value of 41% DS, significantly increased specificity of MDCT to rule out segmental stenosis from 79% (293 to 369) to 87% (318 to 366, $p < 0.001$) as compared to visual analysis, while sensitivity to identify diseased segments remained similar (83% or 64 of 77) as for visual analysis (82% or 64 of 78, p = NS). The overall diagnostic accuracy of identifying diseased coronary segments by MDCT was significantly improved from 80% (357 of 447) to 86% (382 of 443, $p < 0.005$) by using quantitative versus visual analysis.

**Table 2.** Reasons for False Positive and Negative Evaluations by MR and MDCT

| | MR | MDCT |
|---|---|---|
| False positive | | |
| Heavy calcification | 7 (8%) | 41 (54%) |
| Motion artifact | 0 | 8 (10%) |
| Overestimation of a moderate stenosis | 6 (7%) | 3 (4%) |
| Poor opacification or small vessel | 49 (59%) | 24 (32%) |
| Low CNR distal to proximal stenosis | 21 (25%) | 0 (0%) |
| All | 83 | 76 |
| False negative | | |
| Motion artifact | 0 (0%) | 3 (21%) |
| Poor opacification or small vessel | 3 (14%) | 5 (36%) |
| Non-visualization or underestimation of a short stenosis | 17 (86%) | 6 (43%) |
| All | 20 | 14 |

CNR = contrast-to-noise ratio; MDCT = multidetector row computed tomography; MR = magnetic resonance.

## DISCUSSION

The salient findings of this study can be summarized as follows:

1. Multidetector row computed tomography offers better visualization of the coronary arteries than MR.
2. Using visual assessments of DS severity, both MDCT and MR have similar accuracy for detecting significant coronary artery disease by QCA.
3. Quantitative assessment of DS severity significantly improves the diagnostic accuracy of MDCT, but not that of MR, as compared to visual analysis alone.
4. Using quantitative assessment of DS severity, MDCT has significantly higher diagnostic accuracy than MR.

**Technical differences of coronary imaging by MR and MDCT.** Noninvasive imaging of coronary artery disease is technically demanding due to the small size of the coronary arteries and their complex motion during cardiac contraction and respiration. Magnetic resonance and MDCT differ

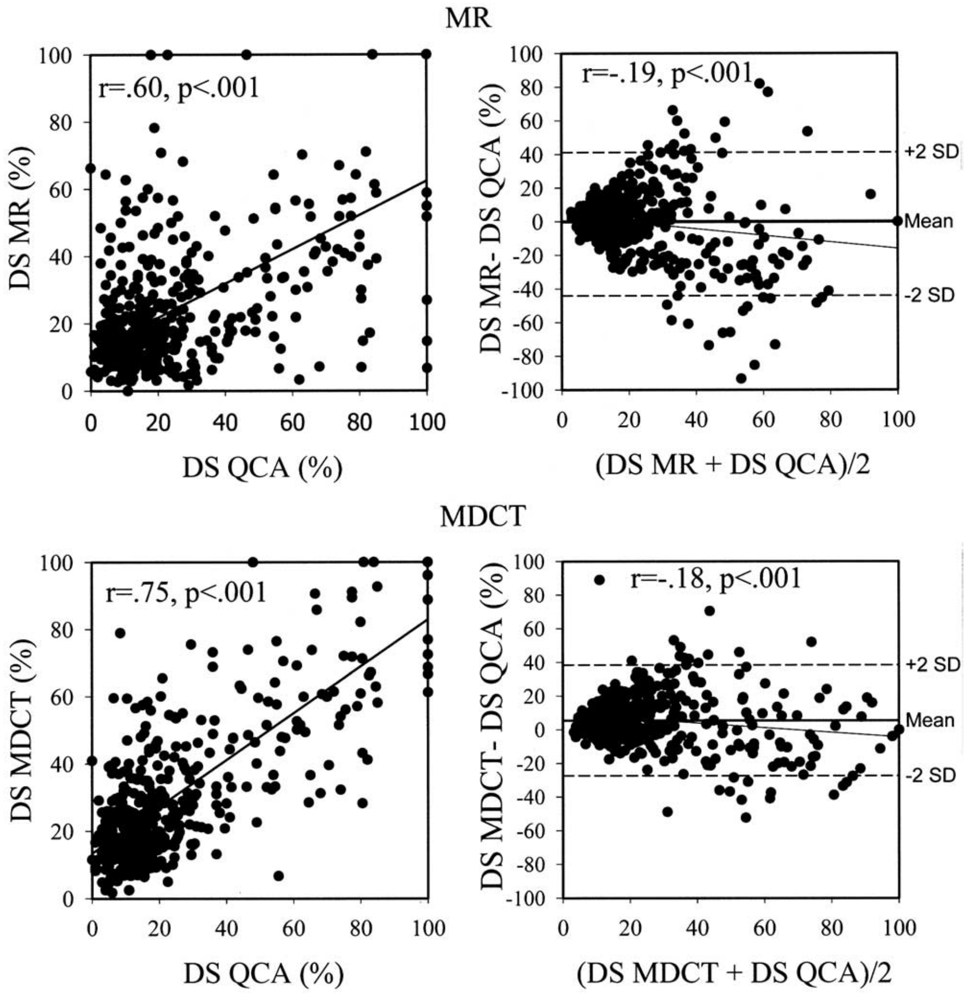


**Figure 4.** Correlations and Bland-Altman plots between measurements of diameter stenosis (DS) by magnetic resonance (MR) **(top)** and multidetector row computed tomography (MDCT) **(bottom)** versus quantitative coronary angiography (QCA).

not only in their physical principles but also in the strategies they employ to correct for coronary artery motion. In our study, MR was performed with the patient breathing freely, using respiratory navigator gating. By opposition, MDCT imaging was acquired during a breath hold. Correction for cardiac motion by MR was performed by prospective vectocardiographic gating. Motion correction by MDCT were obtained by retrospective rearrangement of multisection partial scan data relative to an ECG signal that is recorded during scan acquisition (14). Earlier studies using four-slice MDCT with 250 ms temporal resolution to image the coronary arteries reported that the RCA and the LCx were often affected by motion artifacts (4,5,9,15). This was not anymore the case with the 16-slice MDCT used in the present study, probably because of its improved temporal resolution (<120 ms). Although the temporal resolution of 16-slice MDCT and MR are approximately similar, MDCT has a higher spatial resolution and a higher CNR than MR. Because of these advantages, image quality of MDCT was better and allowed visualization of the LAD and the LCx over longer distances than MR.

**Visual assessment of coronary artery stenosis severity.** The diagnostic accuracy of the visual analysis of MR images was slightly higher than the one reported in a recent large multicenter study (1) (sensitivity 93% and specificity 42%). This is possibly related to our use of more recent pulse sequences, which allowed for a better image quality (11,16), to our inclusion of all branch segments, and to our use of more acquisition planes (four instead of two for the RCA and the proximal LCx). In other studies, the diagnostic accuracy of coronary MR has been quite varied, with sensitivity ranging from 38% to 83% and specificity from 57% and 95% (10). A recent meta-analysis reported a pooled sensitivity of 77% and a specificity of 71%, which is in line with our results (10).

As compared to studies reporting on the diagnostic accuracy of 16-slice MDCT (6,7), we report a slightly lower sensitivity, but a similar specificity for visual analysis of 16-slice MDCT images. These small differences are probably due to our inclusion of smaller vessels than in other studies (>1.5 instead of >2 mm) (6) and our infrequent exclusion of segments with poor image quality (7). They

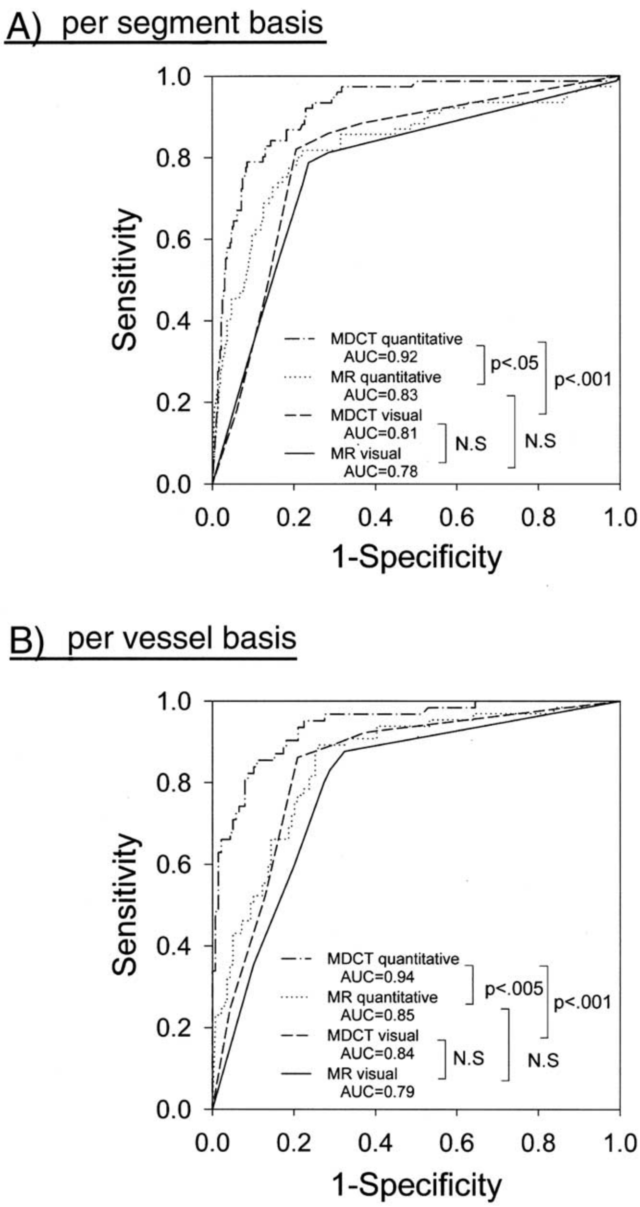


**Figure 5.** Receiver-operating characteristic curves comparing diagnostic accuracies of visual and quantitative measurement of diameter stenosis (DS) by magnetic resonance (MR) and multidetector row computed tomography (MDCT) for detection of >50% DS by quantitative coronary angiography on a per-segment basis **(A)** and per-vessel basis **(B)**. AUC = area under curve.

could also reflect our less frequent use of beta-blockers, although the heart rates reported here are quite comparable to those reported in the other studies (6,7).

Direct comparison of the accuracy of MR and 16-slice MDCT has not yet been reported. In preliminary work comparing four-slice MDCT and MR (11), we observed that four-slice MDCT had higher sensitivity, but lower specificity and overall diagnostic accuracy than MR detecting coronary artery disease. This occurred, because four-slice MDCT was often affected by motion artifacts due to insufficient temporal resolution. Such differences were not anymore observed in the present study, which compared 16-slice MDCT with MR. By opposition, diagnostic accuracy by visual analysis was slightly, although not significantly, higher for 16-slice MDCT than for MR. This likely reflects the better image quality of MDCT than of MR, facilitating visual image interpretation. Because the experience of both readers with both techniques was similar, it is unlikely that operator experience influenced the validity of our results. Interestingly, we observed that the two techniques were subject to different types of artifacts. Indeed, false positive readings by MDCT were most often related to intensive calcifications, while false positives by MR were due most often to low signal to noise ratio. In the population studied, both tests infrequently presented false negative readings. Consequently, both tests had high negative predictive values.

**Quantitative assessment of coronary artery stenosis severity.** The accuracy of the quantitative analysis of coronary DS severity using both MR and MDCT has not yet been reported. In this present work, we therefore sought to evaluate the feasibility as well as the accuracy of such an approach. Using a semiautomatic quantitative approach, we have demonstrated that it is indeed possible to quantify RVD, MLD, and DS severity, with both MR and MDCT. We also found that the correlation between MDCT and QCA measurements were better than that between MR and QCA. As with the visual analysis, this was most likely due to the better spatial resolution of MDCT. Interestingly, both quantitative techniques were found to overestimate non-significant stenosis and underestimate significant stenosis relative to QCA. Here again, limitation in the spatial resolution of the two noninvasive techniques probably played a role.

Finally, our study demonstrated that quantification improves the diagnostic accuracy of MDCT but not that of MR. This is likely because it allows for a more precise estimation of the luminal diameter in the stenotic coronary artery than the human eye. This may be especially true when the vessel presents eccentric calcified plaques.

**Clinical implications.** Our study indicates that both MDCT and MR are useful for the non-invasive detection of coronary artery stenoses on both a segmental and a per-vessel basis. Because neither technique is 100% accurate, these techniques are not ready yet to replace conventional coronary angiography. However, because of their high negative predictive values, both tests could be useful to better select patients who should not be referred to conventional X-ray angiography, thereby avoiding the performance of unnecessary normal coronary angiograms. In particular, these tests might be useful to better select coronary angiography in patients with atypical chest pain, in those with resting ECG abnormalities, and in those unable to exercise. Given its shorter acquisition time, lower cost, and better image quality, 16-slice MDCT might be preferred over MR in clinical practice. Yet MDCT has the disadvantage of requiring contrast injection and of exposing patients to radiation. Magnetic resonance could be a safe alternative in patients with contraindications to MDCT, as for instance in those with known allergy to contrast agents, or in whom the risk of renal insufficiency after administration of contrast agents is high. In addition, it might be used as a second test if extensive coronary calcifications hamper the interpretation of stenosis severity by MDCT. Finally, our study suggests that, because it increases the diagnostic accuracy, quantification should be used when interpreting MDCT images, in particular to discriminate stenosis of intermediate severity.

**Study limitations.** The present study was performed in patients with indications for cardiac catheterization and a high prevalence of coronary disease. Interpretations were performed by two reviewers who had similar good experience with both imaging techniques. The study findings may not necessarily be extrapolated to patients with less coronary artery disease, nor reflect readings of other reviewers with different experience with both techniques. Recently introduced whole heart axial MR imaging techniques might allow for a better visualization of small and curved coronary segments and, thus, for an increased diagnostic accuracy of coronary MR. Although raw axial images were also available for interpretation, slice matching of reformatted MDCT images with MR might have somewhat limited the diagnostic accuracy of MDCT.

**Conclusions.** The present study demonstrated that 16-slice MDCT and three-dimensional navigator MR have similar diagnostic accuracy for identifying coronary artery disease when visual analysis is used. Diagnostic accuracy of MDCT can be improved by using quantitative assessment of stenosis severity. Using such quantitative assessment of stenosis severity, MDCT provides better diagnostic performance to detect coronary artery stenosis on both a segmental and a per-vessel basis than MR.

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