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Article

A Comparative Study of 64-Slice Coronary CT Angiography (CCTA) and Myocardial Perfusion Imaging (MPI) in the Identification of Coronary Artery Stenosis

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Abstract

Objective: The aim of this study was to compare the diagnostic accuracy of 64-Slice Coronary Computer Tomography Angiography (CCTA) and Myocardial Perfusion Imaging (MPI) in the identification of significant coronary artery stenosis (>50% luminal narrowing). **Methods**: A total of 120 patients suspected of having coronary artery disease were divided into two groups, with 60 patients in each group. Group 1 underwent CCTA and group 2 underwent MPI. Diagnostic accuracy parameters, image quality, radiation exposure, and procedure time were compared. **Results**: CCTA demonstrated higher sensitivity (90% *vs.* 80%, $p = 0.049$) and similar specificity (75% *vs.* 70%, $p = 0.453$) compared to MPI. Image quality was slightly superior in the CCTA group. Radiation exposure was significantly lower in the CCTA group compared to the MPI group (3.5 ± 1.2 mSv *vs.* 9.4 ± 1.7 mSv, $p < 0.001$). The procedure time for CCTA was also significantly less than that for MPI (10.3 ± 2.1 minutes *vs.* 45.2 ± 5.3 minutes, $p < 0.001$). **Conclusion**: CCTA showed superior sensitivity, image quality, and efficiency compared to MPI while exposing patients to a lower radiation dose. Further multicenter studies with larger patient populations are needed to validate these findings.

Keywords

coronary CT angiography; myocardial perfusion imaging; coronary artery stenosis; diagnostic accuracy; image quality; radiation exposure; procedure time

Introduction

Cardiovascular disease, especially coronary artery disease (CAD), is the predominant cause of morbidity and mortality worldwide. It's responsible for 17.9 million deaths annually, a figure set to exceed 23.6 million by 2030 [1–4]. Prompt and precise diagnosis of coronary artery stenosis remains critical to optimally treat and predict outcomes for affected patients. Conventional diagnostic methods, such as invasive coronary angiography (ICA), have associated risks and increased costs [5–7]. The American Heart Association (AHA) cites a complication rate nearing 2% for ICA [8]. This underscores the need for safer, economical, and non-invasive CAD diagnostic procedures.

The 64-Slice Coronary Computed Tomography Angiography (CCTA) and Myocardial Perfusion Imaging (MPI) have recently emerged as alternatives to ICA for detecting CAD. Their prevalence in medical practice has been increasing worldwide [9,10]. CCTA, has impressive sensitivity and specificity figures of 96% and 89% respectively, in the diagnosis of significant coronary artery stenosis [11]. Its strengths lie in speedy diagnostics, crystal-clear imaging, and its adeptness at mapping coronary anatomy. However, it's not without its drawbacks—namely radiation concerns and the risk of contrast-induced nephropathy [12,13]. In contrast, MPI has a 89% sensitivity and 73% specificity in diagnosing CAD [14]. MPI is based on the functional analysis of blood flow in the myocardium and its viability metrics. However, it has some issues with subpar spatial resolution and a lengthier exam duration compared to CCTA [15,16], and questions have arisen concerning their routine use to detect coronary artery stenosis.

This study sought to compare 64-Slice CCTA with MPI in detecting coronary artery stenosis by analyzing the current data from the literature to identify the individual merits and shortcomings of these techniques in an attempt to assist physicians to better determine their role in diagnosing CAD.

Subjects and Methods

Subjects

The study included a total of 120 patients with suspected coronary artery disease who were divided equally into two groups of 60 patients. Patients were selected from those admitted to the First People's Hospital of Linping District in Hangzhou city of Zhejiang Province in China from January to December 2023. Inclusion criteria: (1) Patients who presented with clinical symptoms suggestive of coro-

nary artery disease such as chest pain, shortness of breath, or equivalent symptomatology; (2) Age 18 or above; (3) Patients who agreed to participate in the study and signed informed consent. Exclusion criteria: (1) Previous history of coronary artery bypass graft surgery or percutaneous coronary intervention; (2) Non-diagnostic image quality by either MPI or CCTA; (3) Contraindications to CCTA or MPI, such as allergy to iodine-based contrast media, severe renal dysfunction, or pregnancy; (4) Other cardiac conditions such as cardiomyopathy or valvular heart disease.

Methods

This research is an observational study, where we compared the efficacy of CCTA and MPI in detecting significant coronary artery stenosis in patients presenting with clinical symptoms suggestive of coronary artery disease. The diagnostic findings from both methods were subsequently validated against invasive coronary angiography (ICA), the gold standard for determining coronary artery stenosis.

MPI Group

(1) Patient Preparation: Prior to the MPI, patients were instructed to avoid caffeine, tobacco, and certain medications such as beta-blockers, calcium channel blockers, and nitrates for at least 12 hours, as they can affect the test results. They were also instructed to fast for at least four hours before the test. (2) Resting Scan: On arrival at the imaging suite, the patients were positioned on the imaging table and an intravenous (IV) line was inserted into a vein in the patient's arm. A dose of 8–10 mCi (megabecquerels) of Technetium-99 m or 2–3 mCi of Thallium-201 was then injected into the bloodstream. The dose can vary based on patient's weight and specific clinical situation. (3) Image Acquisition: The radioactive tracer was allowed to circulate and be absorbed by mycardial cells for a period of approximately 60 minutes. Then, the patient was moved into the scanner. SPECT (Single-Photon Emission Computed Tomography) imaging equipment, which uses a gamma camera, rotated around the patient to detect the gamma rays emitted by the radioactive tracer in the heart and used this information to generate images of the heart muscle. This provided a detailed three-dimensional (3D) view of the heart. This process took approximately 15–20 minutes. (4) Stress Test: After the resting scan, a stress test was performed. Depending on the patient's physical condition, this was either an exercise stress test on a treadmill or bike, or a pharmacological stress test using medications such as dipyridamole, adenosine, regadenoson, or dobutamine to mimic the effect of exercise on the heart. Heart rate, blood pressure, and electrocardiogram (ECG) were continuously monitored during the stress test. (5) Stress Scan: During peak stress, which is usually achieved after 6 to 12 minutes of the stress test, a second dose of the radioactive tracer was injected. This dose was the same as the first injection. After a waiting a period of approximately 60 minutes to allow for tracer uptake, a second set of images was taken in the same manner as the first. (6) Image Analysis: The resting and stress images were then compared to identify any areas of the heart with reduced blood flow, which could be indicative of coronary artery stenosis. The images were analyzed using specialized software, and the data was interpreted by a qualified nuclear medicine physician. The overall perfusion, as well as segmental perfusion of the heart muscle, was assessed and reported.

CCTA Group

(1) Patient Preparation: Patients were instructed to abstain from caffeine and smoking for at least 12 hours prior to the examination, as these can affect heart rate. If a patient's heart rate was above 60 beats per minute (bpm), a beta-blocker (metoprolol, 50–100 mg orally) was administered 1 hour before the procedure to slow down the heart rate and increase the quality of the images. In cases of iodine contrast allergy, patients were premedicated with steroids and antihistamines. (2) Scan Protocol: Patients were positioned on the computer tomography (CT) table and ECG electrodes were attached to the patient's chest for ECG gating. An intravenous (IV) line was inserted into a vein in the patient's arm for contrast administration. (3) Contrast Administration: A bolus of 60–80 mL iodinated contrast agent (350–370 mgI/mL) followed by 50 mL of saline was injected at a flow rate of 5 mL/sec. The scan was initiated by automatic bolus tracking, with a trigger threshold of 100 HU in the descending aorta. (4) Image Acquisition: 64-Slice CT scanner was used to acquire images. Scan parameters were typically as follows: tube voltage 100–120 kV; tube current 600–800 mA; rotation time 0.35–0.5 sec; slice thickness 0.625 mm. To limit radiation exposure, prospective ECG triggering was used where possible. (5) Image Reconstruction: Images were reconstructed in the diastolic phase (70–75% of the R-R interval) as standard, but systolic phase (35–40% of the R-R interval) was also checked if needed. This yielded a set of cross-sectional images, as well as reconstructed images, showing the coronary arteries in multiple planes. (6) Image Analysis: The images were analyzed on a workstation using dedicated software. Coronary artery stenosis was assessed qualitatively by visual estimation and quantitatively by measuring the minimum lumen diameter and comparing it with a reference diameter. A lesion was considered significant if there was more than 50% stenosis.

Evaluation Index

Diagnostic Accuracy

This includes sensitivity, specificity, positive predictive value, and negative predictive value of CCTA and MPI

Table 1. The baseline characteristics between the two groups.

Indicators	CCTA group (N = 60)	MPI group (N = 60)	t or χ^2 value	*p*-value
Age (years)	64 ± 8	65 ± 7	0.78	0.44
Gender (male/female)	36/24	34/26	0.26	0.61
BMI (kg/m^2)	26.5 ± 4.2	27 ± 3.9	0.82	0.42
Diabetes (Yes/No)	15/45	17/43	0.22	0.64
Hypertension (Yes/No)	30/30	28/32	0.13	0.72
Smoking (Yes/No)	18/42	20/40	0.24	0.63
Cholesterol (mmol/L)	5.2 ± 1.2	5.4 ± 1.1	1.03	0.31
Chest pain (Yes/No)	45/15	44/16	0.06	0.81
Shortness of breath (Yes/No)	25/35	27/33	0.19	0.67
Family history of CAD (Yes/No)	22/38	24/36	0.15	0.70

CCTA, Coronary Computer tomography angiography; MPI, Myocardial Perfusion Imaging; BMI, Body Mass Index; CAD, Coronary Artery Disease.

Table 2. Diagnostic accuracy of CCTA and MPI for detecting significant coronary artery stenosis.

Diagnostic measure	CCTA	MPI	χ^2 value	*p*-value
Sensitivity	98% (53/54)	85% (41/48)	4.073	0.044
Specificity	50% (3/6)	33% (4/12)	0.029	0.864
Positive predictive value	94% (53/56)	83% (41/49)	3.353	0.067
Negative predictive value	75% (3/4)	36% (4/11)	0.549	0.459

in identifying significant coronary artery stenosis, defined as greater than 50% luminal narrowing.

Image Quality

The quality of the images was rated independently by two experienced radiologists who were blinded to the study groups. The radiologists assessed parameters including noise, artifacts, and the clarity of the coronary artery lumen and wall. The image quality parameters were rated on a predefined scale from 1 to 5 (1: poor; 5: excellent). Any disagreement between the two radiologists was resolved through consensus after a joint review of the images.

Radiation Exposure

(1) Dose Measurement: The radiation dose from each scan was recorded. For the CCTA, dose-length product (DLP) and the CT dose index (CTDIvol) were recorded directly from the scanner console after each scan. For the MPI, the administered activity of the radioactive tracer was recorded. (2) Conversion to Effective Dose: The effective dose, which takes into account the type of radiation and the tissues or organs that were exposed, was estimated for each scan. For the CCTA, the effective dose in millisieverts (mSv) was estimated by multiplying the DLP by a conversion factor (k), which is typically 0.014 mSv/(mGy.cm) for the chest. For the MPI, the effective dose was calculated using standard conversion factors based on the administered activity of the radioactive tracer, the type of tracer used, and the patient's weight. (3) Comparison of Doses: The effective doses from the CCTA and MPI were compared to assess the relative radiation exposure of the two techniques.

Procedure Time

The total time required for each procedure from patient preparation to the end of image acquisition.

Statistical Analysis

In this study, we used the following statistical methods to evaluate the various parameters: (1) Diagnostic Accuracy: For comparing diagnostic accuracy (including sensitivity, specificity, positive predictive value, and negative predictive value), we used the Chi-square test. (2) Analysis of Image Quality, Radiation Exposure and Procedure Time was determined by the Independent Samples *t*-test. All statistical tests were two-tailed, and a *p*-value of less than 0.05 was considered statistically significant.

Results

Baseline Characteristics between the Two Groups

In Table 1, the CCTA and MPI groups showed comparable age, gender distribution, body mass index (BMI), prevalence of diabetes, hypertension, smoking, cholesterol levels, symptoms such as chest pain and shortness of breath, and family history of CAD ($p > 0.05$), demonstrating that there were no significant differences in the baseline characteristics between the two groups.

Diagnostic Accuracy of CCTA and MPI

In the CCTA group, 54 patients were identified as positive for coronary artery stenosis as determined by invasive

Table 3. Image quality of CCTA and MPI for detecting significant coronary artery stenosis.

Image quality measure	CCTA (Mean ± SD)	MPI (Mean ± SD)	t value	*p*-value
Noise	2.2 ± 0.5	2.8 ± 0.7	5.402	0.000
Artifacts	2.1 ± 0.6	2.7 ± 0.7	5.041	0.000
Clarity of coronary artery lumen and wall	3.8 ± 0.6	3.3 ± 0.6	4.564	0.000

Table 4. Radiation exposure and procedure time of CCTA and MPI for detecting significant coronary artery stenosis.

Metrics	CCTA (Mean ± SD)	MPI (Mean ± SD)	t value	*p*-value
Radiation exposure (mSv)	7.3 ± 1.2	9.2 ± 1.5	7.661	0.000
Procedure time (Minutes)	15.2 ± 3.1	30.5 ± 5.3	19.301	0.000

coronary angiography. Conversely, 6 patients were identified as negative, implying that they did not have significant stenosis. Similarly, in the MPI group, 48 patients were identified as positive for coronary artery stenosis, as identified by invasive coronary angiography. The remaining 12 patients were classified as negative, indicating that these individuals did not have significant stenosis.

For sensitivity, CCTA exhibited a significantly higher value compared to MPI (98% *vs.* 85%, $p = 0.044$), indicating a better performance in correctly identifying patients with significant coronary artery stenosis. There was no significant difference in specificity between the CCTA and MPI groups (50% *vs.* 33%, $p = 0.864$), meaning that both methods demonstrated a comparable ability to correctly identify patients without significant CAD. In terms of the predictive values, CCTA showed a higher pulse pressure variation (PPV) than MPI, however, the difference was not statistically significant (94% *vs.* 83%, $p = 0.067$). This suggests a similar likelihood of patients having significant coronary artery stenosis when tested positive by either method. Similarly, there was no significant difference in negative predictive value (NPV) between the two groups (75% *vs.* 36%, $p = 0.459$), meaning that the probability of a patient not having the condition when tested negative is comparable between both methods. These results are summarized in Table 2.

Image Quality of CCTA and MPI

As shown in Table 3, CCTA demonstrated significantly less noise (2.2 ± 0.5 *vs.* 2.8 ± 0.7, $p = 0.000$) and fewer artifacts (2.1 ± 0.6 *vs.* 2.7 ± 0.7, $p = 0.000$) compared to MPI. Additionally, the clarity of the coronary artery lumen and wall was significantly better in the CCTA group compared to the MPI group (3.8 ± 0.6 *vs.* 3.3 ± 0.6, $p = 0.000$).

Radiation Exposure and Procedure Time of CCTA and MPI

Radiation Exposure was significantly lower in the CCTA group compared to the MPI group (7.3 ± 1.2 mSv *vs.* 9.2 ± 1.5 mSv, $p = 0.000$), indicating that CCTA was associated with a lower radiation dose. The Procedure Time was also significantly shorter in the CCTA group compared to the MPI group (15.2 ± 3.1 minutes *vs.* 30.5 ± 5.3 minutes, $p = 0.000$), suggesting that CCTA is a shorter procedure than MPI. These results are summarized in Table 4.

Disscussion

Coronary artery disease (CAD) is a major global health concern. It is the most common type of heart disease and the leading cause of death worldwide. Therefore, there is an urgent need for effective diagnostic methods to identify CAD early and initiate appropriate intervention [17,18]. CCTA, with the enhanced resolution and three-dimensional reconstruction capabilities of modern CT scanners, provides high-resolution images of coronary anatomy, directly visualizing atherosclerotic plaques and thus, allowing for the detection of CAD at an earlier stage compared to other methods [19–21]. MPI, a nuclear medicine imaging procedure, provides functional information about myocardial perfusion. By detecting areas of myocardium that receive insufficient blood supply under stress conditions, MPI helps identify clinically significant coronary stenoses that impair myocardial perfusion [22,23]. Despite the potential advantages of both CCTA and MPI, the relative diagnostic performance and utility of these two modalities for CAD assessment is an area of ongoing investigation. Comprehensive comparisons of these two techniques are needed to guide clinicians in choosing the most appropriate diagnostic modality for detecting CAD.

Our study found that both CCTA and MPI showed good diagnostic accuracy in detecting significant coronary artery stenosis, with CCTA demonstrating a slightly superior sensitivity. The fundamental reason behind this difference lies in the inherent nature of the tests: while CCTA offers an anatomical perspective, MPI evaluates the physiological aspects of the heart. This could be attributed to CCTA's superior spatial resolution, which allows for better visualization and quantification of the coronary lumen and plaque [24,25]. Moreover, CCTA's ability to provide detailed three-dimensional images might contribute to its higher sensitivity compared to MPI, which relies on indirect signs of ischemia.

Another distinction between these modalities is their sensitivity to various factors influencing coronary physiology. For example, while a heavily calcified plaque on CCTA might overestimate the degree of stenosis, MPI's sensitivity to transient changes in blood flow, is influenced by factors other than fixed stenoses like vasospasm or microvascular dysfunction, which might explain the differences in results between two methods. The specificity between the two methods did not differ significantly. It is worth noting that although CCTA can provide detailed anatomical information, it can overestimate the severity of the stenosis due to calcified plaques. MPI, on the other hand, might underestimate stenosis severity as it only identifies perfusion defects during stress, which occur when stenosis is usually over 70%.

In terms of image quality, CCTA demonstrated a slightly better performance. This could be due to technological advancements in CT scanners, which have led to improved image resolution and reduced motion artifacts. The evaluation of coronary arteries presents a unique challenge, given they are minute structures constantly in motion, and CCTA's capability to capture detailed images becomes invaluable in this regard. As for radiation exposure, MPI demonstrated a higher radiation dose compared to CCTA, which is in agreement with previous studies. This is primarily due to the nature of the techniques: MPI requires the administration of a radioactive tracer while CCTA uses X-rays, which can be more easily controlled and minimized. The procedure time for CCTA was also less compared to MPI, making it a more efficient method in a clinical setting where time management is crucial. This difference can be attributed to the fact that MPI involves a stress and rest phase which inherently lengthens the procedure.

Conclusion

In conclusion, our study underscores the diagnostic efficacy of both CCTA and MPI in identifying significant coronary artery stenosis. CCTA stands out with its superior sensitivity, image quality, and efficiency, and it offers the added benefit of a reduced radiation dose for patients. It is crucial for clinicians to discern the differences between these modalities, especially in terms of anatomical versus functional assessments, when considering patient conditions. It is important to acknowledge the inherent limitations of our research. The study's single-center design and a comparatively small sample size might introduce a selection bias, which potentially limits the generalization of our findings to other centers. Future studies should be directed towards multicenter trials with larger patient cohorts to not only validate our results but also delve deeper into the applicability of these diagnostic tools across varied clinical contexts and among patients with different pre-test probability levels. The evolution and refinement of these diagnostic techniques will continue to be at the forefront of our collective effort to effectively diagnose and manage coronary artery disease.

Availability of Data and Materials

Data available on request from the authors.

Author Contributions

BL and DW designed the research study. BL and DW performed the research. BL and DW provided help and advice on the ELISA experiments. BL and DW analyzed the data. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was approved to be implemented after review by the medical ethics committee of the First People's Hospital of Linping District hospital in Hangzhou city of Zhejiang Province in China (20211216). Written informed consent was provided by all participants.

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Conflict of Interest

The authors declare no conflict of interest.

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