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Review

The Role of Coronary CT Angiography in the Management of Patients with Coronary Atherosclerotic Disease

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Abstract: *Coronary CT angiography is a non-invasive method of analyzing the coronary lumen through which the atheromatous bur-den can be evaluated, with the analysis of the type of plaque (soft, calcified, mixed) and the impact on the arterial lumen (stenosis, occlusion). The anatomical evaluation by coronary CT is indicated in symptomatic patients with low and medium risk factors for coronary atherosclerotic disease, in those with inconclusive laboratory and EKG results, patients with un-certain stress test results, in the evaluation of coronary grafts and intrastent stenoses. Depending on the result of the angiography, the severity of the stenosis and the management of the patient are established. In the case of mild and medium stenoses, risk factors management and drug treatment are recommended. For severe stenoses, patients are referred for interventional coronary angiography or functional evaluation. Coronary CT angiography increases the certainty of coronary atherosclerotic disease diagnosis. It has a superior discriminative capacity of plaques with low attenuation, the main predictor of myocardial infarction, with almost five-fold higher risk. Coronary CT angiography increases the adaptation of medication, and the inclusion of statin therapy decreases the risk of fatal and nonfatal myocardial infarction at 5 years and increases the quality of life.*

Keywords: *coronary CT angiography, coronary atherosclerotic disease, calcium score, CAD-RADS*

INTRODUCTION

Atherosclerotic disease is the main cause of death in Europe [1]. Lifestyle factors (smoking, diet, level of physical activity) but also biological risk factors (hypertension, hypercholesterolemia, hyperglycemia) contribute to this [2].

The management of patients with coronary atherosclerotic disease is complex, including numerous investigative methods. Of these, coronary CT angiography has been analyzed more and more, over the last decade, due to technological progress. Coronary CT angiography is a non-invasive method of evaluating the heart and coronary arteries. Coronary CT angiography is performed using a computer tomograph that involves high-speed scans for moving organs and contrast material containing iodine, administered in injectable intravenous form to obtain the best images of the coronary arteries and the heart. Thus, the atheroma plaques in the coronary arteries can be identified, the type of plaques analyzed (soft, calcified, mixed), and the consequences on the arterial lumen (stenoses, occlusions) evaluated. Coronary anomalies can be detected, valve morphology can be analyzed, as well as the degree of myocardial perfusion.

MATERIALS AND METHODS

The main reference studies used in evaluating and managing patients with coronary atherosclerotic disease are extensive studies that have contributed to the current state of knowledge in this field, demonstrating the usefulness of the investigation in diagnosis, monitoring, and recommendations for the treatment of the disease.

The PROMISE study (Prospective Multicentre Imaging Study for Evaluation of Chest Pain) – from the year 2017 – showed that coronary CT angiography is a superior means of evaluation for identifying patients at risk with nonobstructive

coronary atherosclerotic disease, compared to classical functional exploration means, in patients with stable angina pectoris and with an average probability of coronary atherosclerotic disease. The patients were randomly divided into two groups, 4500 patients were investigated by coronary CT angiography and 4602 patients were evaluated by functional means (exercise electrocardiogram, exercise ultrasound, and exercise myocardial scintigraphy). The patients were subsequently monitored for 26 months. The significantly lower incidence of coronary events in patients investigated by coronary CT angiography compared to those evaluated by functional means (33.4% versus 78.0%) demonstrates that coronary CT angiography had a significantly higher discriminative capacity for predicting coronary events than functional explorations (c -index, 0.72; 95% CI, 0.68-0.76 versus 0.64; 95% CI, 0.59-0.69; P=0.04) [3].

The SCOT HEART study (Scottish Computer Tomography of the Heart) is large, started in 2010, and is still ongoing, which will continue until 2027, with some of the results already published. It is a randomized parallel study, which included, between 2010-2014, 9848 participants with angina pectoris suggestive of coronary atherosclerotic disease and with mild and medium risk factors. The patients were divided into two groups that were evaluated differently: 4146 patients by coronary CT angiography and the rest were managed by standard anatomical and functional means. The main diagnostic results showed that coronary CT angiography increased the certainty of the diagnosis of coronary atherosclerotic disease (relative risk [RR] = 1.79, 95% confidence interval [CI] 1.62-1.96, p < 0.001) and reduced the frequency of the diagnosis of angina due coronary atherosclerotic disease (RR = 0.93, 95% CI 0.85-1.02, p = 0.13) compared to standard care [4]. The main clinical result was a decrease in the risk of fatal and nonfatal myocardial infarction at 5 years, which was 2.3% in the coronary CT angiography group, compared to 3.9% in the group managed by standard means. The secondary results consisted of an increase in the quality of life, the adaptation of medication, and the inclusion of statin therapy. In those cases where the lesions were severe, patients were referred for angiography and stenting [5].

Other secondary, very important results emerged in 1769 patients, followed for 4-5.7 years, which proved that the presence of plaques with low attenuation is the main predictor of myocardial infarction, independent of the presence of cardiovascular disease risk factors, of the score of calcium or area of stenosis. Patients with low-attenuation plaques had an almost 5-fold higher risk of myocardial infarction (95% CI, 2.06-10.5; P<0.001). In 41 patients who suffered an acute myocardial infarction, both low-attenuation plaque load and calcium score were increased (336 [62-1064] versus 19 [0-217] Agatston units; P<0.001), and the presence of obstructive coronary artery disease (54% versus 25%; P<0.001) [6].

The UK's National Institute for Health and Care Excellence's 2016 NICE chest pain guideline recommended coronary CT angiography as the first line of evaluation in patients with new stable chest pain. Emphasis is placed on anatomic explorations over functional ones, a choice to which cost-effectiveness also contributes [7,8].

However, this approach raised concerns that, after the first evaluation with coronary CT angiography, there would be an increased referral to further investigations, such as invasive coronary angiography. To test this, a retrospective study was conducted on 652 patients who underwent coronary CT angiography from 2017 to 2018. The results showed that 92 patients had moderate (50-70%) or severe stenosis (>70 %). Of these, 69 were directly referred for invasive coronary angiography, of which 63 underwent the investigation, and severe atherosclerotic coronary disease was confirmed in 40 patients (63%). Among the patients with moderate stenosis, 18 were referred to cardiac stress echography, which was positive in one case. The remaining patients had mild stenosis in 62 cases, 36 studies were inconclusive, and the rest of them (462 patients) were normal or had minimal stenosis [9]. The study's conclusions showed that coronary CT angiography is an effective first-line method in the evaluation of patients with newly appeared stable angina pectoris, most of them having normal results or minimal coronary atherosclerotic disease. In patients with severe stenosis, it had an increased detective capacity, the stenosis being confirmed by invasive coronary angiography in 63% of cases.

The positive predictive value for coronary stenosis of coronary CT angiography, compared with stress tests, was evaluated and published in a study from 2019. A total of 800 patients with stable angina pectoris from two centers were included, one in the UK where 400 patients were investigated with coronary CT angiography and a center in Portugal where 400 patients were investigated with exercise tests (treadmill exercise stress test EST or stress imaging test). The patients in the two groups were equally distributed in terms of gender and BMI. Of the 400 coronary CT angiographic examinations, 387 (96%) were diagnostic. Of these, 92 patients (23%) had CAD-RADS 3-5 coronary obstruction, of which 67 (72%) underwent coronary angiography and 61 patients (91%) had atherosclerotic coronary obstructive disease confirmed. In the Portuguese group, 400 patients with stable angina evaluated by stress test with the positive result, recommended for interventional angiography, were included. On interventional angiography, the obstructive coronary disease was diagnosed in 51% of patients. In conclusion, the positive predictive value

of coronary CT angiography is 91%, statistically significantly higher ($p<0.0001$) than stress tests (51%) [10]. The study concludes that coronary CT angiography, due to its significantly higher predictive value than exercise tests, has a good indication as a first test for evaluating coronary stenosis, and could mean the avoiding of unnecessary interventional angiographic tests.

The AGATSTON coronary artery calcium score is a semi-automatic measurement of the degree of calcification of the coronary arteries. It is an investigation performed with a low dose of radiation at the beginning of the coronary CT angiographic examination, before the administration of contrast substance. The main role is an early stratification of the degree of coronary atherosclerotic infiltration.

An automatic calculation of coronary calcifications is made according to the density in Hounsfield units and the area occupied by the plaque.

Depending on the value of the total calcium score, coronary artery disease is divided into five degrees: no evidence of disease (calcium score 0), minimal damage (1-10), mild (11-100), moderate (101-400), severe (>400), the risk of major cardiac events increases in patients with an Agatston score greater than 160 (Table1) [11].

Table 1: Calcium score according to the Agatston scale

Agatston score	Coronary artery disease
0	no evidence of calcium
1-10	minimal
11-99	mild
100-399	moderate
400-999	severe
1000+	extensive calcium deposits increased risk of coronary events in the next year

The calcium score showed a good correlation with coronary CT angiography in the diagnosis of coronary plaques, with the limitation of not being able to evaluate the soft component of the plaque.

Special emphasis is given to the Agatston score of zero, there is the concept of "the power of zero", which means that patients are considered low risk and if there are no other risk factors, that leads to the avoidance of certain preventive drug therapies, such as statins. Another important role of the calcium score is personalizing the prescription of statins and aspirin among the general population but also the population with special conditions such as severe hypercholesterolemia or diabetes [12].

Coronary calcium score (CAC) has become a popular investigation due to its accessibility, speed, tolerability, low cost, reproducibility, and financial benefits due to the exclusion of complex coronary pathologies that involve more expensive investigations [13].

There are practice guidelines that include structured recommendations for the treatment and prevention of coronary atherosclerotic disease but there are some variations between countries in using coronary calcium score as a reference for inpatient treatment. However, there is a common agreement that coronary calcium scoring assessment is to begin in patients over 40 years. In asymptomatic patients with an intermediate risk of atherosclerotic coronary disease and a calcium score of over 100, the initiation of statin treatment is recommended. In patients with a calcium score of 0, the risk is decreased and the administration of statins is retained, with a repeat of the calcium score after 10 years. These conclusions were reached following the MESA study (Multi-Ethnic Study of Atherosclerosis) in which the 10-year risk of cardiac events was between 1.3-5.6% for a calcium score of 0 and 13-26.6% for a calcium score over 300. The MESA study concluded that in conditions of other cardiovascular disease risk factors maintained constant, the relative risk of cardiac events increases proportionally with the increment of the calcium score [14].

For the good management of patients with coronary atherosclerotic disease, the Guide of the European Society of Cardiology (ESC) was updated in 2019. It established coronary CT angiography as the first line of anatomical evaluation of patients with coronary atherosclerotic disease. The previous recommendations (ESC guide from 2013) proposed a combined approach between anatomical and functional means.

The current management of patients with angina pectoris and suspected obstructive coronary disease consists of a 6-step approach.

1. In the first stage, patients are evaluated through a clinical examination to identify patients with unstable angina or acute coronary syndrome, with the determination of symptoms.

2. The second step involves the evaluation of the general condition and the quality of life - patients with unstable angina or acute coronary syndrome are not included.

3. The third step includes performing some basic tests (blood tests, resting electrocardiogram, resting cardiac ultrasound) and evaluating the function of the left ventricle.

4. Step four consists of assessing the risk of clinical probability of obstructive coronary disease.

5. The fifth step involves diagnostic tests, which are chosen depending on the clinical probability of obstructive coronary disease but also multiple clinical factors, comorbidities, expertise, and access to examinations.

Thus, the anatomical evaluation by coronary CT is recommended as an initial diagnostic test in symptomatic patients in whom the coronary atherosclerotic disease cannot be excluded by clinical evaluation, in those with a low and medium probability of coronary atherosclerotic disease.

Functional tests are recommended in situations where coronary CT angiography is non-diagnostic or has shown stenoses whose functional significance is uncertain.

Invasive angiography is recommended for those with very high clinical probability, symptoms that do not respond to drug treatment, and typical angina at a low level of effort, in patients with an uncertain diagnosis on functional tests.

Coronary CT angiography is not recommended in extensive calcifications, irregular heart rhythm, significant obesity, the impossibility of performing respiratory commands, and any other situations in which qualitative images cannot be obtained.

6. The sixth step, depending on the result of the above tests, the management of the patient and the drug treatment are decided.

Severe calcifications and poor clinical images can lead to an overestimation of the severity of stenoses. In patients that present revascularization through stents and bypass grafts, the accuracy of the coronary CT angiographic examination is impaired in some cases due to the presence of blooming artifacts and the incomplete evaluation of the native vessels. Coronary CT angiography is not recommended in any situations in which qualitative images cannot be obtained: extensive calcifications, significant obesity, and the impossibility of performing respiratory commands [15].

CAD-RADS Coronary Artery Disease Reporting and Data System is a method of evaluating coronary atheromatous plaques developed by the American Cardiology Society with the main purpose of standardizing the reporting of coronary atherosclerotic disease.

Also, the method includes recommendations for patient management depending on the result of coronary CT angiography (Table 2).

Table 2: CAD Rads score for the quantification of stenoses and patient management

CAD-Rads	Stenosis	Additional test
0	0%	-
1	1-24% minimum	-
2	25-49% mild	-
3	50-70% moderate	functional evaluation
4A	70-90% in 1 or 2 vessels	functional evaluation or interventional coronary angiography
4B	>50% in the left main trunk >70% in 3 vessels	interventional coronary angiography
5	100% total occlusion	interventional coronary angiography and viability assessment
N	Non-diagnostic study	additional evaluations

Thus, stenoses are divided into 5 categories, as follows:

• CAD-RADS 0 means the absence of plaques or stenoses and implies the search for other causes of angina pectoris;

• CAD-RADS 1 are plaques without stenosis or minimal stenosis (1%-24%) and imply preventive therapy and risk factor management;

• CAD-RADS 2 includes mild stenoses (25-49%) and includes preventive therapy and risk factor management, especially in patients with non-obstructive plaques in several segments;

• CAD-RADS 3 are moderate stenoses (50-69%). Patient management consists of anti-ischemic pharmacological treatment, preventive with the treatment of risk factors;

• CAD-RADS 4 are severe stenoses, which include two sub-categories: A = severe stenoses (70-99%) and B = tri coronary stenoses (≥70%) or left common coronary trunk (>50%). For category A, interventional coronary angiography or functional evaluation is recommended and for category B, interventional coronary angiography is recommended, to which anti-ischemic drug treatment and treatment of risk factors are added;

• CAD-RADS 5 is total occlusion (100%), and interventional coronary angiography and/or viability assessment is recommended, to which anti-ischemic drug treatment and treatment of risk factors are added;

• CAD-RADS N includes non-diagnostic studies that cannot exclude obstructive coronary disease, and require additional/alternative investigation.

All vessels larger than 1.5 mm in diameter must be included in the classification.

CAD-RADS 1 category also includes plates with positive remodeling and no evidence of stenosis.

There are four modifiers of the CAD-RADS score that are mentioned in the result with the "/" symbol, these are 1 N (non-diagnostic), 2 S (stent), 3 G (graft), and 4 V (vulnerability)[16].

RESULTS

The selected studies show that coronary CT angiography increases the certainty of the diagnosis of coronary atherosclerotic disease. It can predict coronary events, decreases the risk of fatal and nonfatal myocardial infarction at 5 years, and increases the quality of life. Coronary CT angiography has a good indication for being the first test for evaluating coronary stenosis due to its higher predictive value than exercise tests, thus avoiding several unnecessary interventional angiographic tests. The management of patients with coronary atherosclerotic disease can be conducted depending on the result of coronary CT angiography. The detection of severe lesions by coronary CT angiography makes intervention possible in the next stage by angiography and angioplasty.

DISCUSSION

The indications for coronary CT angiography are numerous - from retrosternal pain, clarification of inconclusive non-invasive studies, and assessment of coronary atherosclerosis and by-passes or stents.

The management of the patient with coronary atherosclerotic disease involves a clinical examination and basic tests (blood tests, resting electrocardiogram, resting cardiac ultrasound). Anatomic evaluation by coronary CT is recommended as an initial diagnostic test in symptomatic patients with low and intermediate probability of atherosclerotic coronary artery disease. Functional testing is recommended in situations where coronary CT angiography is nondiagnostic or has revealed stenoses of uncertain functional significance. Depending on the severity of the stenosis, the management of the patient is established. For minimal and small stenoses, preventive therapy and the management of risk factors are chosen. For moderate stenoses, anti-ischemic pharmacological treatment is added, and for severe stenoses, interventional coronary angiography or functional evaluation is recommended.

Also, with the help of coronary CT angiography, other structures such as bones, soft tissues, lungs, or blood vessels can be visualized simultaneously during the scan, being useful for a possible differential diagnosis.

There are limitations of coronary CT angiography such as pregnancy or chronic renal failure, and other contraindications: cardiac arrhythmias, hyperthyroidism, and iodine allergy. In patients with revascularization through stents and bypass grafts, the accuracy of the coronary CT angiographic examination can be impaired due to blooming artifacts and incomplete evaluation of the native vessels. Coronary CT angiography is not recommended in any situations in which qualitative images cannot be obtained: extensive calcifications, significant obesity, and the impossibility of performing respiratory commands.

CONCLUSION

Numerous studies have proven coronary CT angiography as the main investigation for coronary anatomical evaluation. Coronary CT angiography provides important information about the presence and extent of coronary atheroma plaques. A major advantage is the early diagnosis of coronary atherosclerosis, based on which preventive treatment can be administered. Coronary CT angiography decreases the risk of myocardial infarction, allows drug treatment adaptation, and increases the quality of life.

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Authors' contribution
All authors have read and agreed to the published version of the manuscript.
The respective roles of each author are: ASC first/lead author performed the research, wrote the paper, and is the corresponding author, secondary authors DC and SMS supervised the paper, implemented feedback, and conceptualized some ideas.

Ethics approval and consent to participate
The manuscripts contain a study that hasn't been performed on humans, ethical review and approval were not applicable.

Patient consent for publication
Not applicable.

References:

1. Townsend N, Kazakiewicz D, Wright F et al. Epidemiology of cardiovascular disease in Europe. Nat Rev Cardiol 2022;19:133–143 https://doi.org/10.1038/s41569-021-00607-3

2. Tsao CW, Aday AW, Almarzooq ZI, Alonso A, Beaton AZ, Bittencourt MS et al. Heart Disease and Stroke Statistics-2022 Update: A Report from the American Heart Association. Circulation 2022;145(8):153-639 https://doi.org/10.1161/CIR.0000000000001052

3. Hoffmann U, Ferencik M, Udelson JE, Picard MH, Truong QA, Patel MR et al. PROMISE Investigators. Prognostic Value of Noninvasive Cardiovascular Testing in Patients With Stable Chest Pain: Insights From the PROMISE Trial (Prospective Multicenter Imaging Study for Evaluation of Chest Pain). Circulation 2017;135(24):2320-2332 https://pubmed.ncbi.nlm.nih.gov/28389572/ DOI:10.1161/CIRCULATIONAHA.116.024360. Epub 2017. PMID: 28389572; PMCID: PMC5946057

4. SCOT-HEART investigators. CT coronary angiography in patients with suspected angina due to coronary heart disease (SCOT-HEART): an open-label, parallel-group, multicentre trial. Lancet 2015;385(9985):2383-91 https://pubmed.ncbi.nlm.nih.gov/25788230/ DOI: 10.1016/S0140-6736(15)60291-4. Epub 2015 Mar 15. Erratum in: Lancet. 2015 Jun 13;385(9985):2354. PMID: 25788230

5. Investigators TS-H. Coronary CT angiography and 5-year risk of myocardial infarction. N Engl J Med 2018; 379:924-933 https://www.nejm.org/doi/full/10.1056/NEJMoa1805971

6. Williams MC, Kwiecinski J, Doris M, McElhinney P, D'Souza MS, Cadet S et al. Low-Attenuation Noncalcified Plaque on Coronary Computed Tomography Angiography Predicts Myocardial Infarction: Results From the Multicenter SCOT-HEART Trial (Scottish Computed Tomography of the HEART). Circulation 2020;141(18):1452-1462 https://pubmed.ncbi.nlm.nih.gov/32174130/ DOI:10.1161/CIRCULATIONAHA.119.044720. Epub 2020 Mar 16. PMID: 32174130; PMCID: PMC7195857

7. Stable angina: management. London: National Institute for Health and Care Excellence (NICE); 2016 Aug. PMID: 32207889 https://pubmed.ncbi.nlm.nih.gov/32207889/

8. Timmis A, Roobottom CA. National Institute for Health and Care Excellence updates the stable chest pain guideline with radical changes to the diagnostic paradigm. Heart 2017;103(13):982-986 DOI: 10.1136/heartjnl-2015-308341. Epub 2017 Apr 26. PMID: 28446550 https://pubmed.ncbi.nlm.nih.gov/28446550/

9. Fyyaz S, Hudson J, Olabintan O, Katsigris A, David S, Plein S et al. Yield of invasive coronary angiography following the UK NICE 2016 guideline expansion of CT coronary angiography. European Heart Journal - Cardiovascular Imaging 2020; 21(1):1589, jez319.1009 https://doi.org/10.1093/ehjci/jez319.1009.

10. Guerreiro RA, Morgan-Hughes G, Roobottom C, Neves D, Bento A, Fernandes R et al. Positive predictive value of computed tomography coronary angiography vs exercise stress test in the diagnose of obstructive coronary artery disease. European Heart Journal - Cardiovascular Imaging 2019; 20(3):275, jez148.006 https://doi.org/10.1093/ehjci/jez148.006

11. Goel A, Weerakkody Y, Knipe H, et al. Agatston score. Reference article, Radiopaedia.org (Accessed on 11 Dec 2022) https://doi.org/10.53347/rID-30926

12. Nasir K, Cainzos-Achirica M. Role of coronary artery calcium score in the primary prevention of cardiovascular disease. BMJ 2021; 373:n776 https://pubmed.ncbi.nlm.nih.gov/33947652/ doi: 10.1136/bmj.n776. PMID: 33947652

13. Cherukuri L, Birudaraju D, Budoff MJ. Coronary artery calcium score: pivotal role as a predictor for detecting coronary artery disease in symptomatic patients. Coron Artery Dis. 2021;32(6):578-585 https://pubmed.ncbi.nlm.nih.gov/33471470/

14. DOI: 10.1097/MCA.0000000000000999. PMID: 33471470.

15. Golub IS, Termeie OG, Kristo S, et al. Major Global Coronary Artery Calcium Guidelines. JACC Cardiovasc Imaging 2022 https://www.acc.org/latest-in-cardiology/ten-points-to-remember/2022/10/04/19/19/major-global-coronary-artery

16. Knuuti J, Wijns W, Saraste A, Capodanno D, Barbato E, Funck-Brentano C. et al. ESC Scientific Document Group. 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes: The Task Force for the diagnosis and management of chronic coronary syndromes of the European Society of Cardiology (ESC). European Heart Journal 2020;41(3): 407–477 https://doi.org/10.1093/eurheartj/ehz425

17. Cury RC, Abbara S, Achenbach S, Agatston A, Berman DS, Budoff MJ et al. CAD-RADS(TM) Coronary Artery Disease - Reporting and Data System. An expert consensus document of the Society of Cardiovascular Computed Tomography (SCCT), the American College of Radiology (ACR) and the North American Society for Cardiovascular Imaging (NASCI). Endorsed by the American College of Cardiology. J Cardiovasc Comput Tomogr 2016;10(4):269-81 https://pubmed.ncbi.nlm.nih.gov/27318587/ DOI:10.1016/j.jcct.2016.04.005. Epub 2016 Jun 15. PMID: 27318587.