ISSN 1949-8470 (online)

World Journal of *Radiology*

World J Radiol 2019 October 28; 11(10): 126-133

Published by Baishideng Publishing Group Inc

World Journal of Radiology

Contents

Monthly Volume 11 Number 10 October 28, 2019

MINIREVIEWS

Contents

World Journal of Radiology

Volume 11 Number 10 October 28, 2019

ABOUT COVER

Editorial Board Member of *World Journal of Radiology*, Barbara Palumbo, MD, Associate Professor, Department of Surgical, Radiological and Odontostomatological Sciences, University of Perugia, Perugia I-06124, Italy

AIMS AND SCOPE

The primary aim of *World Journal of Radiology* (*WJR*, *World J Radiol*) is to provide scholars and readers from various fields of radiology with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJR mainly publishes articles reporting research results and findings obtained in the field of radiology and covering a wide range of topics including state of the art information on cardiopulmonary imaging, gastrointestinal imaging, genitourinary imaging, musculoskeletal imaging, neuroradiology/head and neck imaging, nuclear medicine and molecular imaging, pediatric imaging, vascular and interventional radiology, and women's imaging.

INDEXING/ABSTRACTING

The *WJR* is now abstracted and indexed in Emerging Sources Citation Index (Web of Science), PubMed, PubMed Central, China National Knowledge Infrastructure (CNKI), China Science and Technology Journal Database (CSTJ), and Superstar Journals Database.

RESPONSIBLE EDITORS FOR THIS ISSUE

NAME OF JOURNAL
World Journal of Radiology

ISSN
ISSN 1949-8470 (online)

LAUNCH DATE
January 31, 2009

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Venkatesh Mani

EDITORIAL BOARD MEMBERS
https://www.wjgnet.com/1949-8470/editorialboard.htm

EDITORIAL OFFICE
Ruo-Yu Ma, Director

PUBLICATION DATE
October 28, 2019

INSTRUCTIONS TO AUTHORS
https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS
https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH
https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION MISCONDUCT
https://www.wjgnet.com/bpg/gerinfo/208

ARTICLE PROCESSING CHARGE
https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS
https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION
https://www.f6publishing.com

World Journal of Radiology

Submit a Manuscript: https://www.f6publishing.com

World J Radiol 2019 October 28; 11(10): 126-133

DOI: 10.4329/wjr.v11.i10.126

ISSN 1949-8470 (online)

MINIREVIEWS

Coronary artery calcium data and reporting system: Strengths and limitations

Subramaniyan Ramanathan

ORCID number: Subramaniyan Ramanathan (0000-0002-4317-2414).

Author contributions: Ramanathan S designed the outline and performed writing of the whole paper.

Conflict-of-interest statement: There is no conflict of interest associated with the author who contributed to this manuscript.

Manuscript source: Unsolicited manuscript

Received: May 18, 2019
Peer-review started: May 20, 2019
First decision: August 2, 2019
Revised: September 5, 2019
Accepted: September 13, 2019
Article in press: September 13, 2019
Published online: October 28, 2019

P-Reviewer: Bazeed MF, Gao BL, Mani V
S-Editor: Ma RY
L-Editor: Filipodia
E-Editor: Qi LL

Subramaniyan Ramanathan, Department of Clinical Imaging, Al-Wakra Hospital, Hamad Medical Corporation, Doha 82228, Qatar

Subramaniyan Ramanathan, Department of Radiology, Weil Cornell Medical College, Qatar Foundation - Education City, Doha 24144, Qatar

Corresponding author: Subramaniyan Ramanathan, MD, FRCR Department of Clinical Imaging, Al-Wakra Hospital, Hamad Medical Corporation, Doha 82228, Qatar.
sramanathan@hamad.qa
Telephone: +974-50117935
Fax: +974-40114509

Abstract

Coronary artery calcium data and reporting system (CAC-DRS) is a recently introduced standardized reporting system for calcium scoring on computed tomography. CAC-DRS provides four risk categories (0, 1, 2 and 3) along with treatment recommendations for each category. As with any other new reporting platform, CAC-DRS has both advantages and disadvantages. Improved communication, better clarity of details, organized management recommendations and utility in future research and education are the major strengths of CAC-DRS. It has many limitations such as questionable need for a new system, few missing components, use of a less accurate visual method and treatment suggestions based on expert opinion instead of clinical trials. In this contemporary review, we discuss the new reporting system CAC-DRS, its application, strengths and limitations and conclude with some remarks for the future.

Key words: Coronary artery calcium; Reporting system; Agatston score; Strengths; Limitations; Management

Core tip: Coronary artery calcium data and reporting system (CAC-DRS) is a new standardized reporting system for calcium scoring on computed tomography. Four CAC-DRS categories have been described ranging from CAC-DRS 0 to CAC-DRS 3 with progressively increasing cardiac disease risk. Better communication, clarity of details, clinical management recommendations, research and education are the major strengths. Few missing components, visual method, treatment recommendations and lack of clear necessity for a new reporting system are the major limitations.

Citation: Ramanathan S. Coronary artery calcium data and reporting system: Strengths and limitations. *World J Radiol* 2019; 11(10): 126-133
URL: https://www.wjgnet.com/1949-8470/full/v11/i10/126.htm
DOI: https://dx.doi.org/10.4329/wjr.v11.i10.126

INTRODUCTION

Coronary artery disease (CAD) is one of the leading causes of death and disability-adjusted life years lost[1]. Approximately 15.5 million persons ≥ 20 years of age in the United States have CAD as per 2016 Heart Disease and Stroke Statistics update of the American Heart Association (AHA)[2]. Every year, nearly the same number of people undergo diagnostic testing for suspected CAD. It is well established that CAD has a long asymptomatic latent period and mortality, and morbidity can be decreased by early detection and targeted preventive therapy[3].

Coronary artery calcium (CAC) represents calcific atherosclerosis in the coronary arteries and correlates well with the overall burden of coronary atherosclerosis. CAC quantified on electrocardiogram-gated non-contrast computed tomography (CT) examinations is the most robust predictor of CAD events in the asymptomatic population, especially in those with an intermediate-risk[4]. It has been shown that CAC increases the predictive value of the Framingham Risk Score and the 2013 American College of Cardiology (ACC)/AHA Pooled Cohort Equations[5]. It has now been integrated into various cardiovascular risk prediction scores and guidelines issued by the American College of Cardiology Foundation, the AHA, Society of Cardiovascular Computed Tomography (SCCT), American College of Radiology, and Society of Thoracic Radiology. This has created a need for more standardized performance and interpretation of CAC scoring CT. A new standardized reporting system CAC - data and reporting system (DRS) was introduced recently in 2018 for this purpose and was developed on the same lines of CAD - reporting and data system (RADS), breast imaging (BI)-RADS, prostate imaging (PI)-RADS, and liver imaging (LI)-RADS[6-8]. This review aims to explain the essential features of this new reporting system, followed by the discussion of its various strengths and limitations.

CURRENT STATUS OF CAC SCORE

CAC score has become more popular recently as there is more and more evidence accumulating in favor of its strong role in predicting atherosclerotic cardiovascular disease (ASCVD) risk. Various scores are available to identify high and low risk patients for CAD like Pooled Cohort Equations, Framingham General CVD Risk Profile, and Reynolds risk score[5,9]. Most of these are "Total risk scores", and they have been found useful as they take into account multiple risk factors. However, they are able to predict only 65%-80% of future cardiovascular events[10]. This led to a continuous search for a better predictor or predictor model. CAC is intimately related to atherosclerosis, and the extent of calcium deposition in the coronary arteries can be considered a good predictor of the total burden of coronary atherosclerosis. Many large prospective studies have already proven the prognostic value of CAC score in predicting serious cardiac events leading to mortality in a variety of populations.

It has been found that CAC performs better than other risk assessment tools to identify those asymptomatic populations that would benefit from pharmacological therapies. A new concept 'Power of zero', which denotes CAC score of 0, has been investigated, and it was concluded that patients with CAC = 0 have a low mortality risk over a period of 15 years in low to intermediate FRS risk group and over 5 years in high FRS risk group. CAC testing is recommended to assess the CAD risk in that group of individuals with the 10-year ASCVD risk between 5% and 20%, and it can be used selectively in patients with < 5% 10-year risk with a strong family history of ASCVD[11]. It also provides treatment recommendations that are adopted in the new scoring system CAC-DRS. In 2017, The Walter Reed Cohort Study assessed the long-term risk of death and ASCVD outcomes in 23637 subjects without ASCVD risk and found that CAC scoring is an accurate tool for predicting major adverse cardiovascular events and mortality in all age groups and with multiple risk factors[12]. These results encourage CAC screening for better ASCVD risk assessment and prevention in low-risk, young adults. Apart from risk stratification, CAC has been shown to play a prominent role in management decisions. This has been supported by

many large studies, and one of them is National Institutes of Health supported clinical trial of 13644 patients that showed that CAC identified patients who are more likely to benefit from statin therapy[13].

Apart from its proven predictive role, other reasons for wider acceptance of CAC scoring include: (1) Easily performed noninvasive test with very low radiation; (2) Highly reproducible test, as it is a system generated score with little human involvement; (3) Objective assessment based on the absolute score and risk percentiles; and (4) As calcium deposition in vessels is a slow process depending on multiple factors, CAC scoring provides a long term risk prediction as compared to other scoring tests, which depend on one time measures like blood pressure, blood glucose, and cholesterol values, which can vary widely over a period.

CAC-DRS

CAC-DRS was introduced recently in the first quarter of 2018 to standardize the reporting of CAC scoring in both dedicated CAC scans and non-gated non-contrast chest CT scans. It is based on the expert consensus document published by SCCT in 2017[6,14]. Both SCCT and Society of Thoracic Radiology jointly recommend the routine reporting of CAC score in routine non-contrast CT chest irrespective of indication for early detection of CAD and for future research potential[9]. Various methods have been used for evaluation of CAC and included Agatston score (AS), volume score, mass score, semi quantitative vessel score, and visual scores. Out of these, CAC-DRS recommends the usage of either Agatston or visual score. Four CAC-DRS categories have been described ranging from CAC-DRS 0 to CAC-DRS 3 with progressively increasing risk of ASCVD (Table 1)[6]. Although the method of CAC scoring is different between Agatston and visual method, final categories, risk prediction, and management are similar[6].

AS

AS is a well-established and widely used CAC scoring system. It was first introduced by Arthur Agatston and his colleagues in 1990 and has undergone modifications with advances in CT technology, with the current score based on multidetector CT scanners[15]. SCCT has laid down standards for the performance of CAC scans. Gated or non-gated non-contrast scans with 2.5 or 3 mm slice thickness, 120 kVp, and individualized mAs with filtered back projection is recommended[9]. In Agatston method, an individual calcified plaque is identified as an area of 1 mm^2 (two pixels) with 130 Hounsfield units (HU) or more along the coronary arteries. Each calcific plaque is given a value of 1, 2, 3, and 4 based on the highest densities 130-199 HU, 200-299 HU, 300-399 HU, and ≥ 400 HU, respectively. Score of each plaque is calculated by multiplying the area with the density score. Summing up the scores of all calcific plaques gives the total AS for that CAC scan[9,15,16]. Based on the total AS, five risk categories have been made: 0 = very low risk, 1-99 = mildly increased, 100-299 = moderately increased, 300-1000 = moderate to severely increased, and > 1000 = severely increased risk of cardiac disease[14,15].

Visual method

Although AS can be used in non-gated scans and was found to be accurate in few studies, still there is no strong evidence of its accuracy in non-gated scans. Also, it is not standardized yet for non-gated scans, and it needs special software. Other methods like ordinal scoring of individual coronary arteries and visual method were considered[9]. Visual method has been found to be a simple, quick, and reasonably accurate method of assessing the CAC in non-gated chest CT scans. In this visual method, CAC is categorized into none, mild, moderate, and severe based on the overall visual eyeball analysis of the entire coronary circulation and correspond to CAC-DRS categories 0, 1, 2, and 3 respectively[17]. No specific criterion has been described for this method unlike ordinal scoring. Visual method is applicable only for non-gated CT chest scans and not recommended in gated scans where AS is preferred.

Modifiers

Two modifiers have been added in the CAC-DRS. First denotes the method of CAC score and can be either Agatston (A) or visual estimation (V). The second modifier 'N' denotes the number of vessels involved and can vary from 1-4, with N4 indicating involvement of all coronary arteries, namely left main (LM), left anterior descending (LAD), left circumflex, and right coronary artery. Two modifiers need to be separated by symbol "/" slash. If there is no calcium, then N modifier is not used, and the final category will be CAC-DRS A0 or V0 depending on the method used[6].

Table 1 Coronary artery calcium data and reporting system categories based on the Agatston and visual scoring

CAC-DRS category	Agatston score	Visual score	Risk
0	0	0	Very low
1	1-99	1	Mild
2	100-299	2	Moderate
3	> 300	3	Moderate to severe

CAC-DRS: Coronary artery calcium data and reporting system.

Other features

CAC-DRS also recommends reporting of valvular, pericardial, and aortic calcification in the report with none, mild, moderate, and severe stratification. However, there are no further details on how it should be done, and these are not considered in assigning the CAC-DRS categories. It also mentions reporting of extra cardiac findings with follow-up recommendations. Standard reporting templates have been provided in the document with details on the indication, technique, and findings in individual coronary arteries along with CAC-DRS categories and management recommendations[6,9,14].

STRENGTHS

Communication

As with any other standard reporting systems, usage of CAC-DRS categories leads to better and more effective communication with the referring physicians. Instead of an absolute score used currently with variable reporting of AS grading, standardized CAC-DRS categories will lead to more uniform reporting both among cardiac and general radiologists[14]. Although the simple absolute CAC score is often enough for specialists (cardiologists), it is confusing for non-specialists regarding further management and referral decisions. CA-DRS definitely helps non-specialists make quicker and more appropriate referrals using the categories as compared to conventional reports. Even for specialists, the standard template report saves time in identifying the key information from the long report during their busy clinics. With routine use of CAC-DRS, it is expected that there will be a significant drop in phone calls from clinical colleagues complaining about inconclusive reports. Also, it will be easy for trainees and junior staff to learn and report in a standardized format within a short time.

Clarity and details

CAC-DRS does not stop just at providing risk categories. The final category includes the method used for CAC score, either Agatston or visual estimation, which is important to know to understand the reliability and reproducibility of the scores. Also, it mentions the number of vessels involved in the form of modifiers (N). This is important, as in addition to total calcium score, the number of vessels involved is linked with the prognosis in the Multi-Ethnic Study of Atherosclerosis involving more than 6000 men and women[18,19]. This in turn will reflect the management of, for example, patients with AS 98 involving all four vessels, who will be categorized as CAC-DRS A1/N4. Based on the category, the recommended treatment is only moderate intensity statins. However, one might consider adding low dose aspirin in an individual patient due to involvement of four vessels, which is an additive risk to total CAC score, although the CA-DRS category remains the same.

Clinical management

The most attractive component in the CAC-DRS is the addition of management recommendations based on CAC score. This can be considered both as a strength and limitation. Strengths are discussed here and limitations in the next section. Most of these recommendations are from expert opinion with some support from the 2013 ACC/AHA Prevention Guidelines[5]. CAC score has been proven to be one of the strongest predictors of ASCVD risk in the asymptomatic population. CAC-DRS 0 has a very high negative predictive value, called "Power of Zero", and helps in downgrading the risk of patients who might be considered high risk based on other parameters[20,21]. CAC score is being used to guide preventive pharmacotherapy using

statins and aspirin in asymptomatic patients. High intensity statins therapy is recommended in any patients with a CAC > 300, moderate to high intensity statins with CAC 100-299, and moderate intensity statins therapy with CAC 1-99. Aspirin (81 mg) is recommended with CAC > 100, while the risk of bleeding complications may outweigh its benefits with CAC < 100 in the absence of other risk factors[9,22].

Research and education

Using a structured reporting system will help in accumulating quality data that is essential for future research. There is significant data gap on the risk factor predictions in South Asian and Middle East population. Using a universal standard reporting platform can help in data collection across boundaries and can help bridge knowledge gaps. In addition, in the near future, it is possible to assess the clinical usefulness of this new reporting system, which can help in further modifications and fine tuning. Already CAC is a near automatic evaluation performed with minimal human interference. Now software can be modified to give the final risk categories thereby avoiding or minimizing human error and improving the daily workflow in busy departments. We are now in the era of artificial intelligence, and such automated risk prediction software will go a long way in giving quicker and more accurate risk prediction and treatment options, thereby improving patient care.

LIMITATIONS

Is there a need?

CAC scoring is a semi-automated system with absolute values and established grading methods. Reporting is usually uniform and highly reproducible, unlike other pathologies like breast cancer, prostatic cancers, and liver cancers. So, it becomes questionable if there is a necessity for a standard reporting system for CAC scoring. At least in CAD-RADS it is more justified, as there are multiple components, like percentage of stenosis, acute or chronic presentation, and the specific vessel and number of vessels, leading to reporting inaccuracies, and a reporting system can make things more consistent and reproducible[7,8]. Whereas in CAC, things are clear already, and the net benefit from a new reporting system is minimal, except that it is linked with few management recommendations. One would expect the new reporting system to be named CAC-RADS, like the other established breast imaging-RADS, prostate-RADS, and CAD-RADS. However, it was named as CAC-DRS, as RADS is a trademark of the American College of Radiology.

Visual method

CAC-DRS includes both Agatston and visual methods of CAC scoring in describing risk categories. Agatston method is the widely used technique of CAC scoring and has been used in most of the clinical trials[4]. Visual method is a very simple way of categorizing calcium deposition in coronary arteries as none, mild moderate, and severe. There is no specific method described or is there any reference to specific vessel or number of vessels involved[9,17]. Also, there is limited literature on the accuracy of this method. Only one study has compared the visual and Agatston methods to date, and it showed overall good agreement with assignment of same risk category as the AS in 73.0% and to within one category in 99.7% with good inter-observer agreement[17]. Disadvantages include an over simplistic approach and lack of strong supporting data. More head to head studies are needed before recommending this method as an alternative to Agatston as management decisions are based on these categories.

Missing component

CAC-DRS provides risk categories based on the overall CAC score and also highlight the method used for scoring and the number of vessels involved. However, the severity of calcium deposition in a particular vessel is not considered in risk prediction. Regional distribution of CAC can be very heterogenous from the total CAC score[23]. This can affect the clinical management, as one vessel, for example LM, can have severe calcium deposition while the remaining three (LAD, left circumflex, and right coronary artery) can have no or mild severity, with resultant overall category being mild in spite of severe disease in LAD. As LM is a major vessel with great impact on cardiac events compared to other vessels, vessel based risk category could be more useful in the future.

Although extra coronary calcification is reported in CAC-DRS, it is not considered in final risk categories. It has been shown that calcification in the valves and thoracic aorta is associated with increased risk of cardiac events. Currently, there is no agreed method of scoring these extra coronary calcifications[24,25].

Management

As mentioned previously, management recommendations in CAC-DRS can be considered both as a strength and limitation. It is considered the most attractive component in this new reporting system, but it must be used cautiously as these are consensus recommendations based on expert opinion and not on prospective randomized controlled trials. Most of these recommendations are based on those from The 2013 ACC/AHA Prevention Guidelines and 2017 SCCT recommendations[5,9]. One more thing that needs to be highlighted is that these recommendations are applicable primarily for a specific population - asymptomatic individuals between 40-75 years of age in the 5%-20% 10-year ASCVD risk group based on pooled cohort equation. It is also used in the < 5% ASCVD group with a family history of premature coronary artery disease[20-22,26]. Its utility outside these risk groups has not been widely investigated, and hence providing risk categories on CAC scans performed in other populations is not based on evidence. Also, there is lack of follow-up guidelines in CAC-DRS.

FUTURE IMPROVEMENTS

Like any other new reporting system, this CAC-DRS has many new positive features with some limitations as enumerated in the previous sections. With continuous usage in daily practice, more of these strengths and limitations will be identified and can be improved in the next version. As the authors of CAC-DRS stated, a simplistic approach was employed to enhance better clinical adoption. This makes sense, because if a new system is difficult to practice in a daily busy schedule, it gets ignored and will not be embraced by the radiology and clinical community. Some components that could be improved in the future are listed below: (1) Visual method is an over simplistic approach and until it is proven to be an accurate technique, it should not be recommended in CAC-DRS; (2) Severity in individual vessels needs to be taken into account while assigning risk category. This can either be done as separate risk category for specific vessels or averaging risk category of all vessels; (3) Management recommendations should be highlighted to communicate to the physicians that this is applicable in a specific population group and not a universal recommendation; (4) Clinical cardiology groups or societies need to be involved to understand their expectations and concerns so that a more widely acceptable scoring system will be possible in the future.

CONCLUSION

It is beyond doubt that a standardized reporting system is the future for providing uniform and reproducible conclusions. It has the added advantage of efficient data collection, which is essential for future outcome studies. Following the recent introduction of CAD-RADS, CAC-DRS is a new addition in coronary artery imaging. CAC scoring is gaining more attention in recent times due to its strong predictive value in asymptomatic patients with low to intermediate ASCVD risk. CAC-DRS improvises on the Agatston scoring system with more relevant categories along with linked treatment guidelines. As discussed above, it has both advantages and some limitations. We hope it will be widely used in daily clinical practice due to its simplicity, and only in the long run shall we know its effect on improving patient care.

REFERENCES

1 **Roth GA**, Huffman MD, Moran AE, Feigin V, Mensah GA, Naghavi M, Murray CJ. Global and regional patterns in cardiovascular mortality from 1990 to 2013. *Circulation* 2015; **132**: 1667-1678 [PMID: 26503749 DOI: 10.1161/CIRCULATIONAHA.114.008720]

2 **Writing Group Members**. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, Das SR, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Isasi CR, Jiménez MC, Judd SE, Kissela BM, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Magid DJ, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Rosamond W, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Woo D, Yeh RW, Turner MB; American Heart Association Statistics Committee; Stroke Statistics Subcommittee. Heart Disease and Stroke Statistics-2016 Update: A Report From the American Heart Association. *Circulation* 2016; **133**: e38-360 [PMID: 26673558 DOI: 10.1161/CIR.0000000000000350]

3 **Mark DB**, Anderson JL, Brinker JA, Brophy JA, Casey DE, Cross RR, Edmundowicz D, Hachamovitch R, Hlatky MA, Jacobs JE, Jaskie S, Kett KG, Malhotra V, Masoudi FA, McConnell MV, Rubin GD, Shaw LJ, Sherman ME, Stanko S, Ward RP. ACC/AHA/ASE/ASNC/HRS/IAC/Mended

Hearts/NASCI/RSNA/SAIP/SCAI/SCCT/SCMR/SNMMI 2014 health policy statement on use of noninvasive cardiovascular imaging: a report of the American College of Cardiology Clinical Quality Committee. *J Am Coll Cardiol* 2014; **63**: 698-721 [PMID: 24556329 DOI: 10.1016/j.jacc.2013.02.002]

4 **Hecht HS**. Coronary artery calcium scanning: past, present, and future. *JACC Cardiovasc Imaging* 2015; **8**: 579-596 [PMID: 25937196 DOI: 10.1016/j.jcmg.2015.02.006]

5 **Stone NJ**, Robinson JG, Lichtenstein AH, Bairey Merz CN, Blum CB, Eckel RH, Goldberg AC, Gordon D, Levy D, Lloyd-Jones DM, McBride P, Schwartz JS, Shero ST, Smith SC, Watson K, Wilson PW; American College of Cardiology/American Heart Association Task Force on Practice Guidelines. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2014; **63**: 2889-2934 [PMID: 24239923 DOI: 10.1016/j.jacc.2013.11.002]

6 **Hecht HS**, Blaha MJ, Kazerooni EA, Cury RC, Budoff M, Leipsic J, Shaw L. CAC-DRS: Coronary Artery Calcium Data and Reporting System. An expert consensus document of the Society of Cardiovascular Computed Tomography (SCCT). *J Cardiovasc Comput Tomogr* 2018; **12**: 185-191 [PMID: 29793848 DOI: 10.1016/j.jcct.2018.03.008]

7 **Cury RC**, Abbara S, Achenbach S, Agatston A, Berman DS, Budoff MJ, Dill KE, Jacobs JE, Maroules CD, Rubin GD, Rybicki FJ, Schoepf UJ, Shaw LJ, Stillman AE, White CS, Woodard PK, Leipsic JA. Coronary Artery Disease - Reporting and Data System (CAD-RADS): An Expert Consensus Document of SCCT, ACR and NASCI: Endorsed by the ACC. *JACC Cardiovasc Imaging* 2016; **9**: 1099-1113 [PMID: 27609151 DOI: 10.1016/j.jcmg.2016.05.005]

8 **Cury RC**, Abbara S, Achenbach S, Agatston A, Berman DS, Budoff MJ, Dill KE, Jacobs JE, Maroules CD, Rubin GD, Rybicki FJ, Schoepf UJ, Shaw LJ, Stillman AE, White CS, Woodard PK, Leipsic JA. CAD-RADS™: 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 Am Coll Radiol* 2016; **13**: 1458-1466.e9 [PMID: 27318576 DOI: 10.1016/j.jacr.2016.04.024]

9 **Hecht HS**, Cronin P, Blaha MJ, Budoff MJ, Kazerooni EA, Narula J, Yankelevitz D, Abbara S. 2016 SCCT/STR guidelines for coronary artery calcium scoring of noncontrast noncardiac chest CT scans: A report of the Society of Cardiovascular Computed Tomography and Society of Thoracic Radiology. *J Cardiovasc Comput Tomogr* 2017; **11**: 74-84 [PMID: 27916431 DOI: 10.1016/j.jcct.2016.11.003]

10 **Nasir K**, Clouse M. Role of nonenhanced multidetector CT coronary artery calcium testing in asymptomatic and symptomatic individuals. *Radiology* 2012; **264**: 637-649 [PMID: 22919038 DOI: 10.1148/radiol.12110810]

11 **Nasir K**, Bittencourt MS, Blaha MJ, Blankstein R, Agatson AS, Rivera JJ, Miedema MD, Sibley CT, Shaw LJ, Blumenthal RS, Budoff MJ, Krumholz HM. Implications of Coronary Artery Calcium Testing Among Statin Candidates According to American College of Cardiology/American Heart Association Cholesterol Management Guidelines: MESA (Multi-Ethnic Study of Atherosclerosis). *J Am Coll Cardiol* 2015; **66**: 1657-1668 [PMID: 26449135 DOI: 10.1016/j.jacc.2015.07.066]

12 **Mitchell JD**, Paisley R, Moon P, Novak E, Villines TC. Coronary Artery Calcium and Long-Term Risk of Death, Myocardial Infarction, and Stroke: The Walter Reed Cohort Study. *JACC Cardiovasc Imaging* 2018; **11**: 1799-1806 [PMID: 29153576 DOI: 10.1016/j.jcmg.2017.09.003]

13 **Mitchell JD**, Fergestrom N, Gage BF, Paisley R, Moon P, Novak E, Cheezum M, Shaw LJ, Villines TC. Impact of Statins on Cardiovascular Outcomes Following Coronary Artery Calcium Scoring. *J Am Coll Cardiol* 2018; **72**: 3233-3242 [PMID: 30409567 DOI: 10.1016/j.jacc.2018.09.051]

14 **Hecht H**, Blaha MJ, Berman DS, Nasir K, Budoff M, Leipsic J, Blankstein R, Narula J, Rumberger J, Shaw LJ. Clinical indications for coronary artery calcium scoring in asymptomatic patients: Expert consensus statement from the Society of Cardiovascular Computed Tomography. *J Cardiovasc Comput Tomogr* 2017; **11**: 157-168 [PMID: 28283309 DOI: 10.1016/j.jcct.2017.02.010]

15 **Agatston AS**, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol* 1990; **15**: 827-832 [PMID: 2407762]

16 **Schmermund A**. The Agatston calcium score: a milestone in the history of cardiac CT. *J Cardiovasc Comput Tomogr* 2014; **8**: 414-417 [PMID: 25467829 DOI: 10.1016/j.jcct.2014.09.008]

17 **Chiles C**, Duan F, Gladish GW, Ravenel JG, Baginski SG, Snyder BS, DeMello S, Desjardins SS, Munden RF; NLST Study Team. Association of Coronary Artery Calcification and Mortality in the National Lung Screening Trial: A Comparison of Three Scoring Methods. *Radiology* 2015; **276**: 82-90 [PMID: 25759972 DOI: 10.1148/radiol.15142062]

18 **Joshi PH**, Patel B, Blaha MJ, Berry JD, Blankstein R, Budoff MJ, Wong N, Agatston A, Blumenthal RS, Nasir K. Coronary artery Calcium predicts Cardiovascular events in participants with a low lifetime risk of Cardiovascular disease: The Multi-Ethnic Study of Atherosclerosis (MESA). *Atherosclerosis* 2016; **246**: 367-373 [PMID: 26841074 DOI: 10.1016/j.atherosclerosis.2016.01.017]

19 **McClelland RL**, Jorgensen NW, Budoff M, Blaha MJ, Post WS, Kronmal RA, Bild DE, Shea S, Liu K, Watson KE, Folsom AR, Khera A, Ayers C, Mahabadi AA, Lehmann N, Jöckel KH, Moebus S, Carr JJ, Erbel R, Burke GL. 10-Year Coronary Heart Disease Risk Prediction Using Coronary Artery Calcium and Traditional Risk Factors: Derivation in the MESA (Multi-Ethnic Study of Atherosclerosis) With Validation in the HNR (Heinz Nixdorf Recall) Study and the DHS (Dallas Heart Study). *J Am Coll Cardiol* 2015; **66**: 1643-1653 [PMID: 26449133 DOI: 10.1016/j.jacc.2015.08.035]

20 **Blaha MJ**, Cainzos-Achirica M, Greenland P, McEvoy JW, Blankstein R, Budoff MJ, Dardari Z, Sibley CT, Burke GL, Kronmal RA, Szklo M, Blumenthal RS, Nasir K. Role of Coronary Artery Calcium Score of Zero and Other Negative Risk Markers for Cardiovascular Disease: The Multi-Ethnic Study of Atherosclerosis (MESA). *Circulation* 2016; **133**: 849-858 [PMID: 26801055 DOI: 10.1161/CIRCULATIONAHA.115.018524]

21 **Blaha MJ**, Dardari ZA, Blumenthal RS, Martin SS, Nasir K, Al-Mallah MH. The new "intermediate risk" group: a comparative analysis of the new 2013 ACC/AHA risk assessment guidelines versus prior guidelines in men. *Atherosclerosis* 2014; **237**: 1-4 [PMID: 25173946 DOI: 10.1016/j.atherosclerosis.2014.08.024]

22 **Galper BZ**, Wang YC, Einstein AJ. Strategies for Primary Prevention of Coronary Heart Disease Based on Risk Stratification by the ACC/AHA Lipid Guidelines, ATP III Guidelines, Coronary Calcium Scoring, and C-Reactive Protein, and a Global Treat-All Strategy: A Comparative--Effectiveness Modeling Study.

PLoS One 2015; **10**: e0138092 [PMID: 26422204 DOI: 10.1371/journal.pone.0138092]

23 **Blaha MJ**, Mortensen MB, Kianoush S, Tota-Maharaj R, Cainzos-Achirica M. Coronary Artery Calcium Scoring: Is It Time for a Change in Methodology? *JACC Cardiovasc Imaging* 2017; **10**: 923-937 [PMID: 28797416 DOI: 10.1016/j.jcmg.2017.05.007]

24 **Dirrichs T**, Penzkofer T, Reinartz SD, Kraus T, Mahnken AH, Kuhl CK. Extracoronary Thoracic and Coronary Artery Calcifications on Chest CT for Lung Cancer Screening: Association with Established Cardiovascular Risk Factors - The "CT-Risk" Trial. *Acad Radiol* 2015; **22**: 880-889 [PMID: 25957500 DOI: 10.1016/j.acra.2015.03.005]

25 **Yeboah J**, Young R, McClelland RL, Delaney JC, Polonsky TS, Dawood FZ, Blaha MJ, Miedema MD, Sibley CT, Carr JJ, Burke GL, Goff DC, Psaty BM, Greenland P, Herrington DM. Utility of Nontraditional Risk Markers in Atherosclerotic Cardiovascular Disease Risk Assessment. *J Am Coll Cardiol* 2016; **67**: 139-147 [PMID: 26791059 DOI: 10.1016/j.jacc.2015.10.058]

26 **Pletcher MJ**, Pignone M, Earnshaw S, McDade C, Phillips KA, Auer R, Zablotska L, Greenland P. Using the coronary artery calcium score to guide statin therapy: a cost-effectiveness analysis. *Circ Cardiovasc Qual Outcomes* 2014; **7**: 276-284 [PMID: 24619318 DOI: 10.1161/CIRCOUTCOMES.113.000799]

Published By Baishideng Publishing Group Inc
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-2238242
E-mail: bpgoffice@wjgnet.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com