RSNA 2023 Edition

UNITED IMAGING

Issue Highlights

Disclaimer

The articles contained in this magazine are provided solely by the authors, and the author(s) of each article appearing in this magazine is/are solely responsible for the content thereof as well as personal data, which is used anonymously or in compliance with applicable data privacy laws or regulations. United Imaging Healthcare makes no representation or warranties, expressly or impliedly, with respect to the accuracy, timeliness, reliability, legitimacy, applicability, fitness, originality, or completeness of the contents of this magazine. United Imaging Healthcare assumes no legal responsibility or liability for any error, omission, or illegality with respect to the material contained within.

All articles contained in this magazine only represent the opinions and views of the authors and do not implicitly or explicitly represent any official positions or policies, or medical opinions of United Imaging Healthcare or the institutions with which the authors are affiliated unless this is clearly specified. Discussions of any brand, services, or products in the magazine should not be construed as promotion or endorsement thereof.

Articles published in this magazine are intended to inspire further general scientific research, investigation, understanding, and discussion only and are not intended to and should not be relied upon as recommending or promoting a specific medical advice, method, diagnosis, or treatment by physicians for any particular individual, nor to replace the advice of a physician or other healthcare professional. Any individual wishing to apply the information in this magazine for the purposes of improving their own health should not do so without consulting with a qualified medical practitioner. All patients need to be treated in an individual manner by their personal medical advisors. The decision to utilize any information in this magazine is ultimately at the sole discretion of the reader, who assumes full responsibility for any and all consequences arising from such a decision. United Imaging Healthcare makes no representations or warranties with respect to any treatment, action, or application of medication or preparation by any person following the information offered or provided within or through the magazine.

The articles included in this magazine may contain work in progress, which represents ongoing research and development. Such technologies are not available for sale in China or the United States for clinical use and also may not be available for such sales in other countries.

Please note that the magazine is intended to be distributed within a limited scope.

If you have any questions about the magazine, or simply wish to reach out to us for any other reasons, you may contact us at: compliance@united-imaging.com

Clinical Significance of Coronary Artery Calcium Score in Predicting Coronary Artery Disease: A CT Coronary Angiography Study

Anand H. K. [a], Ramachandra C. R. [a], Pooja B. P. [a], Arjun Raju[a], Akash Gandhamal[b], Dileep Kumar [b]
[a]Tenet Diagnostic Centre, Bengaluru, India
[b]Central Research Institute, Global Scientific Collaborations, United Imaging Healthcare

Abstract

Coronary Artery Disease (CAD) is a global health concern, contributing significantly to morbidity and mortality rates. The Coronary Artery Calcium Score (CACS) has emerged as a non-invasive predictive tool for coronary events. This study aimed to evaluate the clinical significance of CACS in predicting CAD in terms of coronary stenosis. A cohort of 153 subjects with varying CAD symptoms underwent Computed Tomography Coronary Angiography (CT-CAG) scans, and their CACS values were correlated with manual stenosis estimation. Sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were assessed. The results indicated that CACS is a robust predictor of coronary stenosis, with a sensitivity of 96.04% and specificity of 90.38%. These findings highlight the potential of CT-CAG combined with CACS as an initial screening method for CAD in patients with mild to moderate symptoms, reducing the need for invasive diagnostic procedures.

1. Introduction

Coronary Artery Disease (CAD) is a leading cause of morbidity and mortality worldwide, imposing a significant burden on healthcare systems and society at large [1]. The profound impact it exerts on healthcare systems and society at large is a reminder of the urgent need for effective strategies in its management and prevention. Recognizing the importance of early detection and risk assessment as pivotal components of these strategies, the medical community has turned to innovative non-invasive approaches.

Among these approaches, the Coronary Artery Calcium Score (CACS) has emerged as a promising tool for evaluating CAD risk [2]. By quantifying the extent of calcium deposits within the coronary arteries, CACS furnishes clinicians with valuable insights into a patient's susceptibility to CAD [3]. This ability to offer a predictive glimpse into an individual's CAD risk profile is pivotal in enabling timely interventions and ultimately enhancing patient outcomes. However, the landscape of CAD assessment has evolved further with the widespread adoption of Computed Tomography Coronary Angiography (CT-CAG) in recent years [4]. This imaging modality has become the gold standard for assessing the degree of coronary artery stenosis, providing detailed anatomical information that enhances diagnostic precision. The logical progression in the field of CAD evaluation has led to the exploration of integrating CACS with CT-CAG to offer a more comprehensive and precise assessment of CAD risk [5] [6].

In this context, our study sets out to examine the clinical significance of CACS in predicting the presence or absence of coronary stenosis in patients presenting varying degrees of CAD symptoms. Our working hypothesis is that CACS can serve as an effective predictor of coronary stenosis, particularly in patients with mild to moderate symptoms. This, in turn, has the potential to substantially reduce the necessity for invasive diagnostic procedures, thus improving both patient comfort and healthcare resource allocation. In the pages that follow, we delve deeper into our research findings and their implications, ultimately validating the role of CACS in optimizing CAD risk stratification and diagnostic accuracy.

2. Materials and Methods

2.1 Study Population

A total of 153 subjects (mean age 57.19 ± 11.74 years, 63% male and 37% female) with a range of CAD symptoms, from none to severe, were enrolled in this study. All participants underwent the CT-CAG scans using the uCT 780 scanner (Mfg. - United Imaging Healthcare Co. Ltd, Shanghai). These individuals represented a diverse patient population with varying levels of CAD risk.

2.2 CACS Calculation and Stenosis Estimation

CACS values were calculated using mass, volume, and Agatston Score estimation [7]. These approaches provide a comprehensive evaluation of calcium build-up within the coronary arteries, offering a nuanced understanding of a patient's coronary health. To complement this quantitative assessment, we engaged the expertise of a seasoned radiologist well-versed in cardiovascular imaging. This expert meticulously conducted manual stenosis estimations, a critical aspect of our study. Drawing upon his extensive experience and proficiency, the radiologist carefully evaluated the degree of coronary artery stenosis in each subject. Our classification of study participants was based on the results of these manual stenosis estimations. Specifically, we grouped individuals into two distinct categories: those with coronary artery disease (CAD) and those without CAD. The primary criterion for this classification was the presence or absence of non-zero stenosis, with the former serving as a clear indicator of CAD. In parallel to this manual assessment, we leveraged the CACS values obtained through our quantitative techniques to predict the likelihood of coronary stenosis. Notably, a CACS value greater than zero was indicative of the presence of coronary stenosis. This dual approach, combining expert radiological evaluation with quantitative CACS data, allowed us to comprehensively ascertain the CAD status of our study participants and form a robust foundation for our subsequent analyses. Few of the examples are shown in Figures 1 and 2 below differentiates the CAD and Non-CAD cases with zero and 2737 calcium scores respectively.

Figure 1 provides a notable observation: the CT-CAG under investigation by the radiologist displays an absence of any calcified structures within the arteries. This absence serves as a compelling indicator of the absence of CAD with Flow Limitations with zero CACS. Conversely, Figure 2 presents a markedly contrasting scenario. This image provides clear evidence of the presence of multiple eccentric calcified plaques, strongly suggestive of stenosis, particularly occlusions in the Left Anterior Descending Artery (LAD). Furthermore, the cumulative CACS, calculated as 2737, underscores the extent of calcification within the coronary arteries.

Figure 2 goes beyond merely pointing out the calcification in the LAD. It also reveals the presence of stenosis in multiple other arterial segments. Specifically, this image depicts 70-80% stenosis in the distal Right Coronary Artery (RCA), 60-70% stenosis in the distal LAD, 30-40% stenosis in the Left Circumflex Artery (LCX), 40-50% stenosis in the proximal RCA, and 20-30% stenosis in the Right Posterior Descending Artery (RPDA). These findings collectively contribute to a comprehensive assessment of the patient's coronary artery health and serve as crucial diagnostic information for clinical decision-making

2.3 Statistical Analysis

The quantitative evaluation of our study encompassed a meticulous analysis that involved an array of statistical parameters, each contributing to a comprehensive assessment of the effectiveness of the CACS as a predictive tool for coronary stenosis. These statistical metrics, including sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV), were harnessed to gauge the diagnostic performance of CACS.

Sensitivity, a crucial measure, quantified the ability of CACS to correctly identify individuals with coronary stenosis, thereby avoiding false negatives. It quantified the proportion of true positive predictions, highlighting the sensitivity of CACS in detecting coronary stenosis cases. Specificity, on the other hand, assessed the capacity of CACS to accurately identify individuals without coronary stenosis, minimizing false positives. It represented the proportion of true negative predictions, emphasizing the specificity of CACS in correctly ruling out coronary stenosis in non-CAD cases. Accuracy, as a fundamental metric, provided an overall measure of CACS's ability to correctly classify both positive and negative cases, offering insight into the overall diagnostic performance of this non-invasive tool. Positive Predictive Value (PPV) offered valuable insights into the likelihood of an individual with a positive CACS result truly having coronary stenosis. It highlighted the precision of CACS in identifying true CAD cases among those with positive test results. Conversely, Negative Predictive Value (NPV) evaluated the probability of an individual with a negative CACS result genuinely being free from coronary stenosis. NPV shed light on the capacity of CACS to effectively rule out coronary stenosis in those with negative test outcomes.

Together, these statistical parameters provided a comprehensive evaluation of CACS's diagnostic ability, with its sensitivity, specificity, accuracy, and predictive values in finding the presence or absence of coronary stenosis. This thorough analysis is fundamental in determining the clinical utility of CACS as a screening tool for CAD and in informing medical decision-making for patients with varying degrees of CAD symptoms.

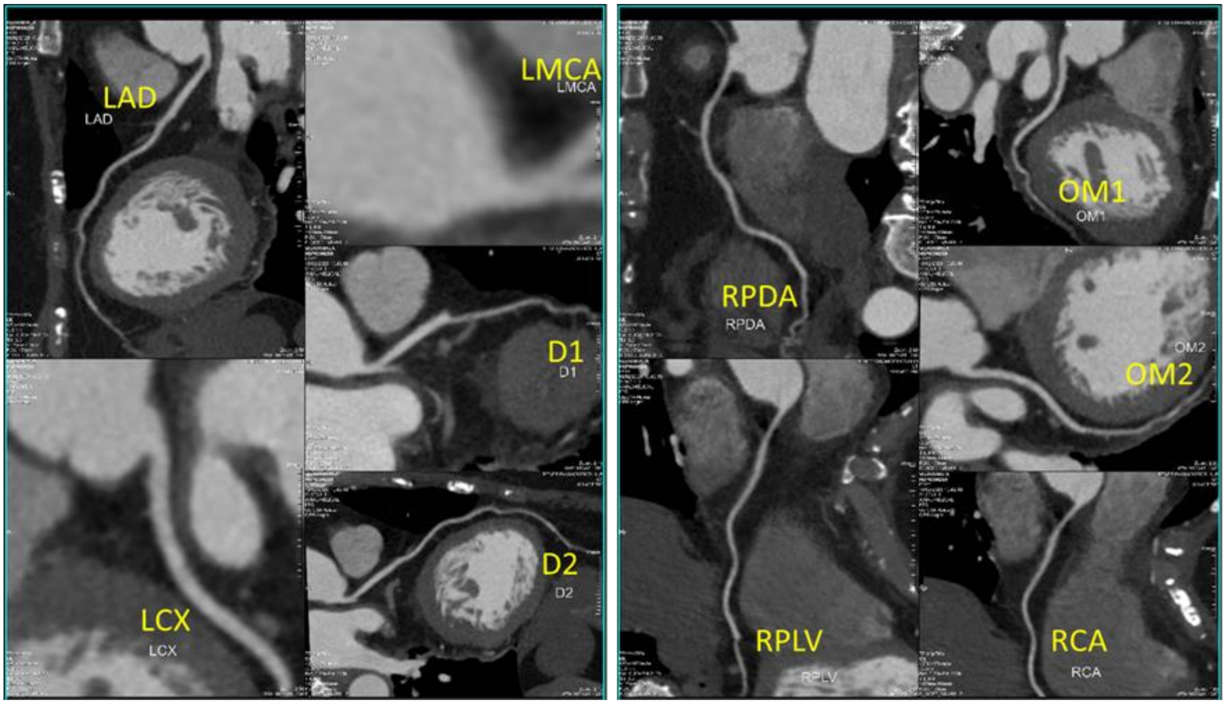

Figure 1. The progressive framework of the coronary segmentation model.

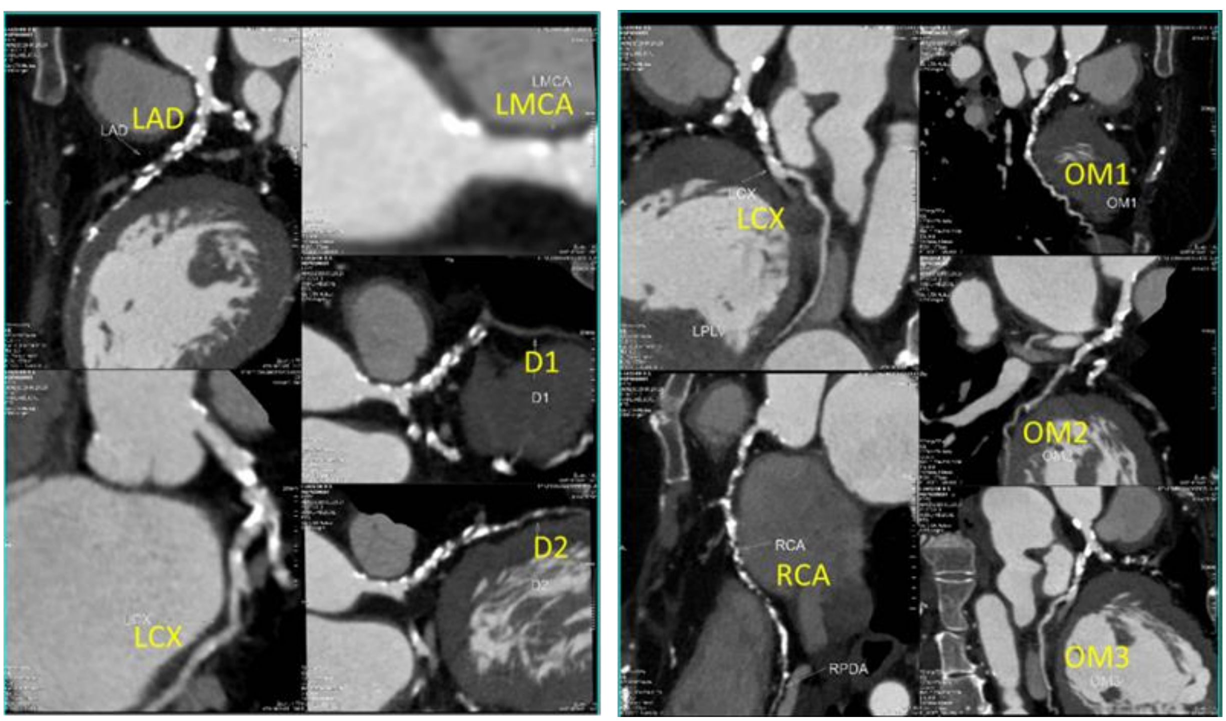

Figure 2. CT-CAG with the Calcium Score calculated as 2737 whereas, Diagnosis Impression reported by radiologists is the Occlusion of mid LAD with 70-80% stenosis of distal RCA, 60-70% stenosis of distal LAD, 30-40% stenosis of LCX and 40-50% stenosis on proximal RCA.

3. Results

Among the 153 patients included in our study, a substantial portion, 52 individuals (approximately 34%), displayed normal Computed Tomography Coronary Angiography (CT-CAG) results, indicating the absence of coronary stenosis. Notably, when we examined their CACS values, 51 of these patients were also classified as normal based on their CACS measurements. This congruence between CT-CAG and CACS findings reflected the high degree of agreement in identifying coronary health among these individuals. Impressively, 47 of these patients were correctly classified as having normal coronary arteries (True Positives), demonstrating the robustness of both CT-CAG and CACS in accurately identifying non-stenotic cases. However, four patients were misclassified as having coronary stenosis (False Negatives), emphasizing the importance of considering other clinical factors when making diagnostic decisions.

In contrast, 102 patients were classified as CAD-positive based on their non-zero CACS values, indicating the presence of coronary artery calcification. Among these individuals, 97 were correctly classified as having coronary stenosis (True Positives), highlighting the strong predictive capacity of CACS in identifying CAD cases. However, five patients were incorrectly classified as CAD-positive (False Positives) when compared to manual stenosis labelling. While this represented a small percentage of misclassified cases, it underscores the need for comprehensive evaluation in clinical practice. Figure 3 shows the comparative plot between the CACS and the Stenosis (%) showing the non-zero CACS values that indicates the presence of CAD. In addition, it can be validated from the plot that the zero CACS is indicative of no stenosis.

Our analysis of the data yielded compelling diagnostic statistics. The utilization of CACS as a predictor for coronary stenosis demonstrated an exceptional sensitivity of 96.04%, signifying its effectiveness in correctly identifying patients with coronary stenosis. Moreover, it exhibited a specificity of 90.38%, indicating its ability to accurately classify individuals without coronary stenosis. The overall accuracy of 94.12% reaffirmed the reliability of CACS as a diagnostic tool in CAD risk assessment through Table 1.

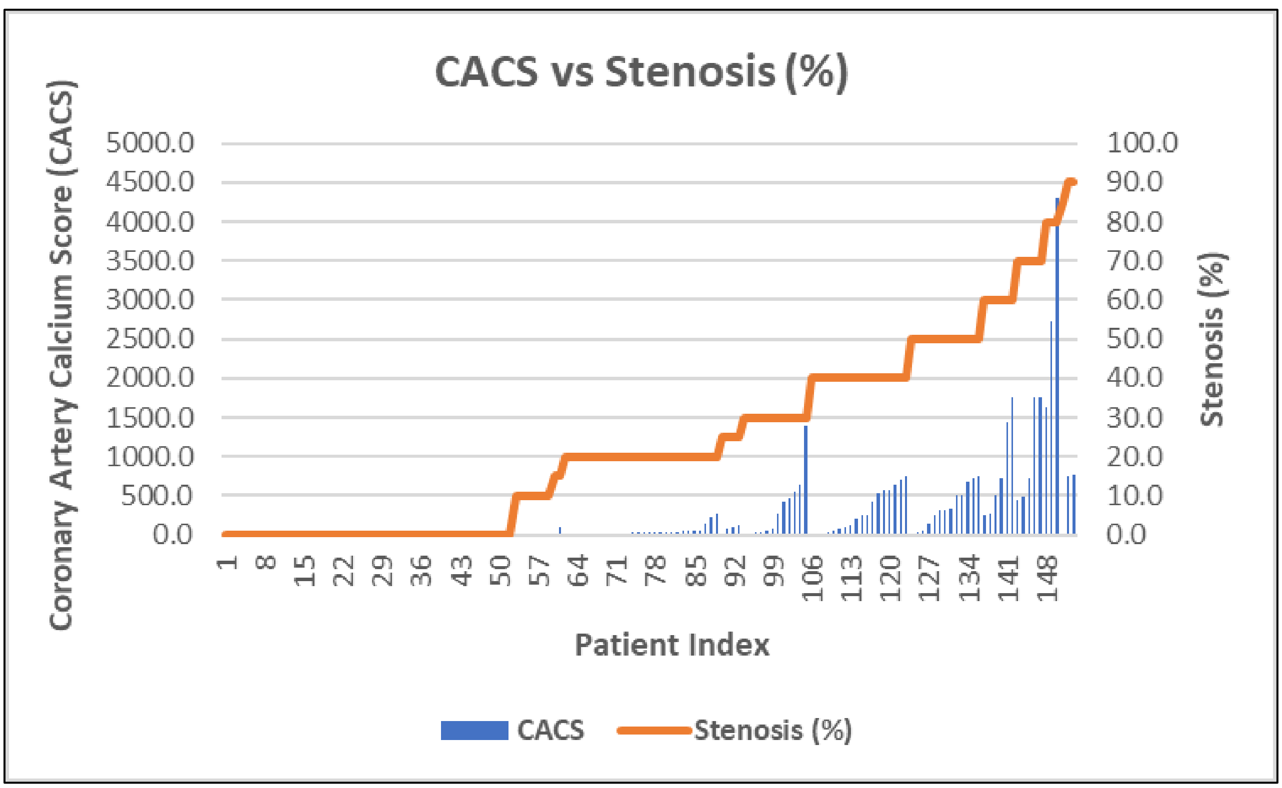

Figure 3. Comparative Plot CACS vs Stenosis (in %).

Table 1. Statistical Analysis CACS vs Stenosis.

	TP	FP	TN	FN	Sensitivity	Specificity	Accuracy	PPV	NPV
CACS > 0	97	5			**0.9604**	**0.9038**	**0.9412**	**0.951**	**0.9216**
CACS = 0			47	4					

TP: True Positive, FP: False Positives, TN: True Negatives, FN: False Negatives, PPV: Positive Predictive Value, NPV: Negative Predictive Value

The PPV of 95.10% highlighted the precision of CACS in identifying true CAD cases among those with positive test results. Simultaneously, the NPV of 92.16% underscored its ability to reliably exclude coronary stenosis in individuals with negative test results as shown in Table 1. These impressive results collectively underscore the robust predictive capability of CACS in effectively identifying coronary stenosis, demonstrating its clinical significance as a valuable tool in the realm of CAD diagnosis and risk assessment.

4. Conclusion

This extensive investigation demonstrated that the Coronary Artery Calcium Score (CACS) serves as a robust predictor of coronary stenosis across a diverse range of CAD symptoms. This highlights the versatility and clinical applicability of CACS, making it a valuable tool for identifying coronary stenosis in patients with varying CAD-related symptoms. Additionally, our study revealed the impressive accuracy of Computed Tomography Coronary Angiography (CT-CAG) in detecting coronary stenosis, with only a minimal 6% misclassification rate. These findings align with prior research, reinforcing the clinical significance of CACS in CAD risk assessment. Together, these results contribute to a better understanding of CAD diagnosis and emphasize the utility of CACS and CT-CAG for precise identification of coronary stenosis. Integrating these diagnostic approaches into clinical practice brings us closer to the goal of timely intervention, improved patient outcomes, and efficient healthcare resource allocation in CAD management.

5. Clinical Relevance

The combination of CT-CAG and CACS calculation holds clinical relevance as an initial screening method for detecting CAD in patients with mild to moderate symptoms. This approach offers several advantages, including its non-invasiveness, accuracy, and potential to reduce the need for invasive diagnostic procedures. Early identification of CAD risk through CACS can facilitate timely interventions and improve patient outcomes.

6. Limitations

It is essential to acknowledge certain limitations of this study. First, the study population was relatively small and heterogeneous. A larger and more diverse cohort may provide additional insights into the clinical utility of CACS. Additionally, the study did not assess the long-term outcomes of patients with varying levels of CAD risk. Further research is needed to determine the prognostic value of CACS in predicting cardiovascular events and mortality.

7. Image/Figure Courtesy

All images are courtesy of Tenet Diagnostic Centre, Bengaluru, India.

8. References

1. H Brown JC, Gerhardt TE, Kwon E. Risk Factors for Coronary Artery Disease. 2023 Jan 23. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 32119297.

2. Yasuyuki Suzuki, Naoya Matsumoto, Shunichi Yoda, Yasuo Amano, Yasuo Okumura, Coronary artery calcium score: Current status of clinical application and how to handle the results, Journal of Cardiology, Volume 79, Issue 5, 2022, Pages 567-571, ISSN 0914-5087.

3. Liu W, Zhang Y, Yu CM, Ji QW, Cai M, Zhao YX, Zhou YJ. Current understanding of Coronary artery calcification. J Geriatr Cardiol. 2015 Nov;12(6):668-75. PMID: 26788045; PMCID: PMC4712374.

4. Sato A. Coronary plaque imaging by coronary computed tomography angiography. World J Radiol. 2014 May

28;6(5):148-59. doi: 10.4329/wjr.v6.i5.148. PMID: 24876919; PMCID: PMC4037541.

5. Divakaran S, Cheezum MK, Hulten EA, Bittencourt MS, Silverman MG, Nasir K, Blankstein R. Use of cardiac CT and calcium scoring for detecting coronary plaque: implications on prognosis and patient management. Br J Radiol. 2015 Feb;88(1046):20140594. doi: 10.1259/bjr.20140594. Epub 2014 Dec 12. PMID: 25494818; PMCID: PMC4614250.

6. Kiani R, Pouraliakbar H, Alemzadeh-Ansari MJ, Khademi A, Peighambari MM, Mohebbi B, Firouzi A, Zahedmehr A, Shakerian F, Hosseini Z, Rashidinejad A. The significance of coronary artery calcium score as a predictor of coronary artery stenosis in individuals referred for CT angiography. J Cardiovasc Thorac Res. 2020;12(3):203-208. doi: 10.34172/jcvtr.2020.34. Epub 2020 Sep 3. PMID: 33123326; PMCID: PMC7581835.

7. Neves PO, Andrade J, Monção H. Coronary artery calcium score: current status. Radiol Bras. 2017 May-Jun;50(3):182-189. doi: 10.1590/0100-3984.2015.0235. PMID: 28670030; PMCID: PMC5487233aase R, Schlattmann P, Gueret P et al (2019) Diagnosis of obstructive coronary artery disease using computed tomography angiography in patients with stable chest pain depending on clinical probability and in clinically important subgroups: meta-analysis of individual patient data. Bmj 365:l1945

Author Biography

Dr. Anand H. K.

Chief of Medical Services and CEO,
Tenet Diagnostics,
Ex-President of Indian Radiological and Imaging Association (IRIA), Karnataka
Bengaluru, India

Dr. Anand H. K. is an experienced Radiology and Imaging expert with over 22 years in the field. He is the Chief of Medical Services and CEO at Tenet Diagnostics in Bengaluru. He completed his MBBS in 1996 and earned an MD in Radiology with a Gold Medal in 2000 from Kasturba Medical College, Manipal, India. Dr. Anand co-founded Clumax Diagnostics and has worked as a Consultant Radiologist at various healthcare institutions. He also served as an Assistant Professor at Kasturba Medical College and is an accomplished researcher in areas like Neuro Radiology, Body and Musculoskeletal Imaging, and Cardiac Imaging. He received multiple Radiologists Fellowships for CT Coronary Angiography and has presented and published research at national and international conferences. His contributions demonstrate his dedication to advancing the field of Radiology.

PASSION for CHANGE

If you have any questions about the magazine, or simply wish to reach out to us for any other reasons, you are welcome to contact us at the following email address: uinnovation-global@united-imaging.com