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Correlation of Plaque Characteristics with Degree of Stenosis Evaluated by Coronary Angiography Using Computed Tomography

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Abstract: Coronary artery disease remains the leading cause of global mortality, and the diagnosis of acute chest pain continues to pose a challenge in emergency care due to the limitations of conventional methods in detecting acute coronary syndrome. Coronary computed tomography angiography (CCTA) has emerged as an efficient non-invasive diagnostic tool for evaluating coronary artery plaque characteristics and stenosis severity. This retrospective study analyzed the correlation between plaque types and degrees of stenosis detected by CCTA in 54 patients presenting with chest pain at Dr. Soetomo General Hospital, Surabaya, during January–December 2023. Plaque morphology was classified into calcified, non-calcified, and mixed types based on CAD-RADS 2.0 criteria. Data were analyzed using Spearman's correlation test. Mixed plaques were the most frequently observed (120 samples), followed by calcified (78 samples) and non-calcified (71 samples). Moderate stenosis was most commonly associated with mixed plaques, while severe stenosis was most frequently found in association with non-calcified plaques. Statistical analysis revealed a significant and very strong correlation between plaque type and stenosis severity in eight coronary segments. These findings highlight the diagnostic value of CCTA in evaluating plaque morphology and stenosis, particularly in identifying mixed plaques that are closely linked to more severe coronary obstruction. The results support the role of CCTA as a critical tool in the diagnostic workup of patients with acute chest pain.
Keywords: Chest pain; computed tomography; coronary angiography; degree of stenosis; plaque characteristics.

INTRODUCTION

Acute chest pain is one of the most frequent causes of emergency department visits, accounting for more than 8 million visits annually in the United States and over USD 10 billion in diagnostic health care costs. However, only 2–8% of these cases are eventually diagnosed as acute coronary syndrome (ACS), making it a complex and often ambiguous clinical presentation (Pursnani et al., 2015; Staniak et al., 2014). Globally, coronary heart disease (CHD) is a leading cause of death. In 2012, non-communicable diseases were responsible for 56 million deaths, with cardiovascular disease accounting for 46.2% of them (Kemenkes RI, 2021; WHO, 2021). In Indonesia, the prevalence of CHD reached 0.5% in 2013, with the highest concentration of patients found in East Java (Kemenkes RI, 2018; Nadasya et al., 2021).

Traditional diagnostic approaches for chest pain in the emergency department, such as clinical evaluation, ECG, and cardiac biomarkers, often fall short of the desired safety threshold and are time-consuming, especially when using serial troponin testing over 6–12 hours (Laudon et al., 2010; Pursnani et al., 2015). In this context, Coronary

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Computed Tomography Angiography (CCTA) has emerged as a reliable and non-invasive alternative to rule out ACS, enabling faster and safer patient discharge decisions (Yang et al., 2019).

Recent studies have highlighted the role of coronary artery calcification (CAC) in evaluating atherosclerotic disease burden. While CAC scoring provides insights into plaque burden, it does not correlate significantly with stenosis severity on CCTA. Instead, the morphological characteristics of plaques, such as calcified, non-calcified, and mixed, are more predictive of luminal narrowing and stenosis severity (Kwan et al., 2021). However, existing literature lacks in-depth analysis on the direct correlation between plaque characteristics and stenosis degree, particularly in the Indonesian population.

This study aims to analyze the correlation between plaque characteristics and the degree of coronary artery stenosis using CCTA in patients presenting with chest pain, and to determine the most frequently occurring plaque types and stenosis severities in this clinical setting.

MATERIALS AND METHODS

This retrospective study was conducted on patients with chest pain who underwent cardiac Coronary Angiography with Computed Tomography (CCTA/AKTK) using contrast at Dr. Soetomo General Hospital, Surabaya, from October 2023 to February 2024. The research was located at the Diagnostic Center (GDC) and the Integrated Heart Service Center (PPJT), Dr. Soetomo General Hospital, Faculty of Medicine, Universitas Airlangga, Surabaya. This study was approved by the RSUD Dr. Soetomo Ethics Committee at Surabaya (reference number: 0833/KEPK/XI/2023, Date: 13 November 2023).

The study population consisted of patients referred from the cardiac polyclinic presenting with chest pain complaints. The sample was obtained from medical records and CCTA images of these patients, where plaque characteristics were identified and analyzed for stenosis degree using the CAD-RADS 2.0 classification system. The sampling technique used was non-probability consecutive (total) sampling. Sample size estimation was calculated using the Lemeshow formula, considering a 20% margin of error, resulting in a minimum required sample of 31 subjects.

Inclusion criteria were patients with clinical symptoms of chest pain who underwent CCTA examination. Exclusion criteria included: (1) patients without chest pain symptoms; (2) patients with congenital heart defects, cardiomyopathy, or structural heart chamber abnormalities; and (3) patients with prior cardiac interventions such as stents, grafts, or bypass surgery.

The independent variable was the presence of chest pain, while the dependent variables included plaque characteristics on CCTA, Agatston calcium score, CAD-RADS 2.0 classification, and degree of coronary stenosis. CCTA examinations were conducted using a Philips 128-slice CT scanner located at the Radiodiagnostic Installation of Dr. Soetomo Hospital. Image analysis was performed using the Horos Viewer and RadiAnt DICOM Viewer, based on multiplanar reconstructions (axial, coronal, and sagittal).

All collected data were analyzed statistically using the Spearman correlation test to evaluate the relationship between plaque characteristics and degree of stenosis, and the mode was used to identify the most frequent (dominant) variables.

RESULTS AND DISCUSSION

The research sample consisted of 54 subjects, consisting of 26 men (48.1%) and 28 women (51.9%). The distribution of age ranges in this study varied, with as many as 5 people (9.3%) in the age range of less than 40 years, 11 people (20.4%) in the age range of 41-50 years, 21 people (38.9%) in the age range of 51-60 years, 14 people (25.9%) in the age range of 61-70 years, 3 people (5.6%) in the age range of more than 70 years. The largest age group in this study sample is in the age range of 51-60 years. The youngest was 27 years old, the oldest was 76, the average age was 54.98, and the median age was 56 (Table 1).

Table 1. Sample Characteristics Based on Gender and Age Range

Category	Frequency	Percentage
Gender		
Man	26	48.1
Woman	28	51.9
Age		
≤ 40 Th	5	9.3
41-50 Years	11	20.4
51-60 years	21	38.9
61-70 years	14	25.9
> 70 years	3	5.6

Table 2. Correlation of Plaque Images with Degree of Stenosis

Relationship Between Variables	R-value	P value
Characteristics of Plaque with Left Main (LM) Segment	0,989	0,000
Characteristics of Plaques with Proximal Left Anterior Descending (LAD) Segment	0,884	0,000
Characteristics of Plaque with Left Anterior Descending (LAD) Mid Segment	0,946	0,000
Characteristics of Plaques with Distal Left Anterior Descending (LAD) Segments	0,966	0,000
Characteristics of Plaque with Left Anterior Descending (LAD) Segment	0,939	0,000
Characteristics of Plaques with Proximal Left Circumflex (LCx) Segments	0,960	0,000
Characteristics of Plaque with Distal Left Circumflex (LCx) Segment	0,987	0,000
Characteristics of Plaque with Left Circumflex Segment (LCx)	0,976	0,000
Characteristics of Plaque with Proximal Right Coronary Artery (RCA) Segment	0,960	0,000
Characteristics of Plaque with Right Coronary Artery (RCA) Mid Segment	0,968	0,000
Characteristics of Plaque with Distal Right Coronary Artery (RCA) Segment	0,987	0,000
Characteristics of Plaque with Right Coronary Artery (RCA) Segment	0,973	0,000

Table 2, the correlation test results showed the highest correlation value in plaque characteristics with the left main (LM) segment and the lowest correlation in the characteristics of plaque with the left anterior descending (LAD) segment of Proximal. You can see the summary of the table below to learn more about the categories that often appear in the 9 coronary artery segments.

Table 3. Table of Categories of Mean Rank and Sum Rank Values of Plaque Characteristics in the Coronary Artery Segment

Segment	Category			
	Usual	**Calcified**	**Non-Calcified**	**Mixed**
LM	23	51,5	47,5	50,13
LAD All	51,5	132,98	134,64	131,3
LAD Prox	13,5	40,04	36	42,13
LAD Mid	19	48,6	45,75	44,5
LAD Distal	20	45,67	50	46
LCx All	40	96,08	89,5	95,57
LCx Proximal	17	42,88	39	45,88
LCx Distal	23,5	53,5	49,75	49
RCA All	61	141,75	144,25	140,1
RCA Proximal	19,5	47	47,17	45,79
RCA Mid	20	47,2	46,9	46,9
RCA Distal	22,5	48	50,33	48,33
The sum of the Mean Rank	330,5	795,2	780,79	785,63

The summary of the first table is based on the mean rank values of the categories in 9 segments (Table 3). The highest sum of the mean rank value indicates that the category is higher or more often gets a number in the high category or the severe category and total occlusion. From this category, it can be seen that calcified has a higher sum of mean rank value than others, followed by mixed and then non-calcified.

Assessment based on the mean of rank Based on the ranking of scoring data, but to find out the distribution and the number of samples in each category, a second tabulation was carried out based on the category of plaque characteristics and also carried out in 9 segments. This study displays plaque characteristics in the categories calcified, non-calcified, and mixed. From the tabulation table mixed, It can be seen that from the total of 9 segments, the most significant number of samples is 120. However, the highest for those in the category severe and total occlusion of 2 and moderate is 27. To calcify, The number of samples is smaller, namely 71, but the number of severe and total occlusion is more than 4 each, which is moderately lower than mixed, as many as 12. For those calcified, the number of samples is slightly more than non-calcified but less than mixed, namely 78, which is in the category of severe 3 and total occlusion 1, for moderate, lower than mixed, and higher than non-calcified, as many as 14.

Table 4. Table of Mean Rank and Sum Rank Values Category Characteristics of Plaque in Coronary Artery Segments

Segments	No Stenosis	Minimal Stenosis	Mild Stenosis	Moderate Stenosis	Severe Stenosis	Total Occlusion	Total
Mixed							
LM	0	2	1	1			4
LAD All	0	12	11	5			28
LAD Prox	0	4	5	3			12
LAD Mid	0	4	4	0			8
LAD Distal	0	4	2	2			8
LCx.All	0	3	8	2	1	1	15
LCx.Proximal	0	2	7	2	1	1	13
LCx.Distal	0	1	1	0			2
RCA. All	0	6	3	6	0	0	15
RCA. Proximal	0	3	1	3	0	0	7
RCA. Mid	0	2	1	2	0	0	5
RCA. Distal	0	1	1	1	0		3
Total	**0**	**44**	**45**	**27**	**2**	**2**	**120**
Non Calcified							
LM	0	2	0	0			2
LAD All	0	4	4	3			11
LAD Prox	0	2	1	0			3
LAD Mid	0	2	1	1			4
LAD Distal	0	0	2	2			4
LCx.All	0	4	4	0	0	0	8
LCx.Proximal	0	3	1	0	0	0	4
LCx.Distal	0	1	3	0			4
RCA. All	0	4	4	2	1	3	14
RCA. Proximal	0	2	1	2	1	0	6
RCA. Mid	0	3	0	0	1	1	5
RCA. Distal	0	0	3	2	1		6
Total	0	27	24	12	4	4	71
Calcified							
LM	0	0	3	0			3
LAD All	0	7	11	3			21
LAD Prox	0	5	7	1			13
LAD Mid	0	1	2	2			5
LAD Distal	0	1	2	0			3
LCx.All	0	2	1	2	1	0	6
LCx.Proximal	0	2	1	0	1	0	4
LCx.Distal	0	0	0	2			2
RCA. All	0	3	5	3	1	0	12
RCA. Proximal	0	1	1	0	0	1	3
RCA. Mid	0	1	3	1	0	0	5
RCA. Distal	0	0	1	0	0		1
Total	0	23	37	14	3	1	78

The analysis in Table 4 revealed the distribution of stenosis across three types of plaques, namely mixed, non-calcified, and calcified, with varying numbers of affected segments. In the mixed plaque group (n=120), most lesions were found in the

minimal (36.7%) and mild stenosis (37.5%) categories, with the highest involvement observed in the LAD (28 segments) and RCA (15 segments). In the non-calcified plaque group (n=71), the distribution was also dominated by minimal (38.0%) and mild stenosis (33.8%), with the greatest involvement in the LAD (11 segments) and RCA (14 segments). Meanwhile, in the calcified plaque group (n=78), there was a tendency toward a higher proportion of mild stenosis (47.4%) and minimal stenosis (29.5%), with the LAD (21 segments) and LCx (6 segments) being the most frequently affected. All three plaque types exhibited a dominant pattern of minimal to mild stenosis, with the LAD emerging as the most frequently involved artery. Nevertheless, cases of moderate to severe stenosis, including total occlusion, were also identified, although they occurred less frequently.

The sample of this study is patients with complaints of chest pain (chest pain) who come to the Cardiac IRD and the Heart Polyclinic of dr. Soetomo Hospital, which is then scheduled to be carried out AKTK (Coronary Angiography with Computed Tomography) in the period October 2023 to February 2024. After going through the inclusion and exclusion criteria, a total of 486 research samples were obtained from 54 subjects. Only cases that meet the inclusion criteria are used. This is following the literature of Yang et al. (2019) that CT Coronary Angiography (AKTK), in the literature it is stated that AKTK has developed into a viable alternative to get rid of acute coronary syndrome among patients who come with acute chest pain. So at this time at dr. Soetomo has been performed on patients with chest pain to get rid of other abnormalities.

This study demonstrated that mixed plaques were the most common type detected by CCTA, followed by calcified and non-calcified plaques. These findings are consistent with previous reports that mixed morphology is frequently observed in patients with coronary artery disease (Budoff et al., 2008; Saremi & Achenbach, 2015). The predominance of mixed plaques can be explained by the natural progression of atherosclerosis, in which lipid-rich non-calcified plaques gradually undergo calcification over time, resulting in partially calcified or mixed morphology (Virmani et al., 2000). Mixed plaques represent a transitional stage between unstable, lipid-rich lesions and stable, heavily calcified plaques, which is why they are often detected in symptomatic patients (Pundziute et al., 2007). In addition, mixed plaques have been shown to carry a higher risk than purely calcified plaques because the coexistence of soft and hard components indicates ongoing inflammatory activity and structural instability (Motoyama et al., 2015; Obaid et al., 2013). Thus, the predominance of mixed plaques in this study highlights their clinical relevance in evaluating stenosis severity and cardiovascular risk.

The age distribution of the patients in this study further supports existing evidence. The largest group was between 51–60 years, with a range from 27 to 76 years. This pattern aligns with Laudon et al. (2010), who reported that plaque prevalence rises from the fifth decade of life and peaks in older age. The underlying mechanism is related to the progressive nature of atherosclerosis, which develops over decades through lipid accumulation, endothelial dysfunction, and chronic inflammation. As patients age, repeated vascular injury and impaired repair mechanisms accelerate plaque growth and calcification, thereby increasing the prevalence of coronary artery disease (Virmani et al., 2000).

The comparable number of male and female patients in this study also reflects the equal prevalence of coronary plaque formation in both sexes. While men are traditionally considered at higher risk at a younger age, the protective effects of endogenous estrogen in premenopausal women diminish after menopause, leading

to a similar prevalence of atherosclerotic plaque in women beyond the fifth decade of life (Lakoski et al., 2006). Moreover, recent imaging studies have shown that sex differences are more pronounced in plaque composition than prevalence; women are more likely to present with non-calcified or mixed plaques, while men tend to have more calcified lesions (Shaw et al., 2006). These findings emphasize that both men and women are equally susceptible to plaque development in middle to older age, supporting the relevance of routine cardiovascular risk evaluation in both sexes.

A key finding of this study was the correlation between plaque type and stenosis severity. Non-calcified plaques were more frequently associated with severe stenosis, while mixed plaques predominated in moderate stenosis. This is in line with Motoyama et al. (2015), who reported that low-attenuation plaques are more prevalent in acute coronary syndrome and carry a higher clinical risk compared to calcified plaques. The biological explanation is that non-calcified plaques often contain large lipid-rich necrotic cores and thin fibrous caps, making them more vulnerable to rupture and more likely to cause luminal narrowing as they progress (Obaid et al., 2013; Virmani et al., 2000). In contrast, calcified plaques are more stable due to dense calcium deposits, and mixed plaques represent an intermediate stage in the atherosclerotic process, explaining their predominance in moderate stenosis (Saremi & Achenbach, 2015). Thus, the observed correlation in this study reflects the natural history of atherosclerosis, where non-calcified plaques contribute to higher-grade obstruction and clinical instability.

The clinical implication of these findings is important. Non-calcified plaques represent high-risk morphology due to their lipid-rich composition and tendency to rupture, whereas mixed plaques reflect more advanced disease progression with a combination of calcified and non-calcified components. Our results strengthen the understanding that plaque morphology is an essential factor in predicting coronary obstruction beyond stenosis alone.

This study adopted the CAD-RADS 2.0 classification system (Cury et al., 2022), which provides standardized reporting for coronary CT angiography. CAD-RADS 2.0 was developed as an update of the original 2016 version, expanding the system to not only categorize stenosis severity but also include plaque burden and modifiers related to lesion characteristics. The main advantage of using CAD-RADS is its ability to reduce interobserver variability and improve reproducibility, thereby allowing consistent interpretation of CCTA results across different clinical settings (Cury et al., 2016, 2022).

By focusing on plaque type and stenosis severity, our analysis offers clinically relevant information for patient risk stratification. Previous studies have demonstrated that CAD-RADS correlates well with invasive coronary angiography and functional testing, confirming its diagnostic accuracy in detecting obstructive coronary artery disease. Moreover, the integration of plaque morphology within CAD-RADS 2.0 enhances its prognostic value, as certain plaque types, such as non-calcified and mixed, are associated with a higher risk of future cardiac events.

The use of CAD-RADS also facilitates clinical decision-making by providing clear management recommendations linked to each category. For example, patients with minimal or mild stenosis may be managed conservatively with risk factor modification, whereas those with severe stenosis or high-risk plaque features may be referred for invasive angiography or revascularization. This structured approach ensures that diagnostic findings are translated into actionable clinical pathways, supporting personalized patient care.

Importantly, the adoption of CAD-RADS in research provides comparability with other studies and enhances the external validity of findings. By using a universally accepted reporting system, results from different centers can be meaningfully compared and potentially included in meta-analyses or guideline development. Thus, the use of CAD-RADS in this study not only strengthens the methodological rigor but also underscores the role of CCTA as a robust, standardized tool in both clinical and research domains.

CCTA has been widely acknowledged as a highly sensitive tool for detecting coronary plaques and assessing their morphology. Our findings confirm that CCTA not only visualizes stenosis but also characterizes plaque composition, making it a valuable modality for the early evaluation of chest pain. These results support the role of CCTA as a non-invasive diagnostic option that complements conventional invasive coronary angiography.

Despite its strengths, CCTA has recognized limitations. Highly calcified plaques can create blooming artifacts that reduce specificity and lead to false-positive results (Li et al., 2018; Sun et al., 2021). Although advanced reconstruction algorithms have been proposed to minimize these artifacts, their availability remains limited in routine clinical practice. These technical challenges need to be considered when interpreting CCTA results.

This study has several limitations that need to be acknowledged. First, the research design was retrospective and relied on secondary data obtained from medical records and CCTA images, which may introduce information bias and limit the control over confounding variables. Second, the sample size was relatively small (54 patients with 486 segments analyzed) and derived from a single-center setting at Dr. Soetomo General Hospital, Surabaya, which restricts the generalizability of the findings to broader populations. Third, although CAD-RADS 2.0 criteria were applied to classify plaque morphology and stenosis degree, advanced modifiers and functional assessments, such as myocardial perfusion CT, were not included, thereby limiting the comprehensive evaluation of coronary artery disease burden. Fourth, highly calcified plaques remain a diagnostic challenge in CCTA due to blooming artifacts, which may lead to overestimation of stenosis and reduce specificity. Finally, the cross-sectional nature of this study precludes establishing causal relationships between plaque characteristics and the progression of stenosis, highlighting the need for prospective, multicenter studies with larger cohorts and longitudinal follow-up to validate these findings.

CONCLUSION

There was a significant and strong correlation between plaque characteristics and the degree of stenosis across all coronary artery segments. Mixed plaques were the most common, predominantly found in LCx proximal, LAD proximal, and RCA proximal segments. Calcified plaques were more frequent in LAD proximal, RCA mid, and LCx proximal, while non-calcified plaques were the least common, mainly located in RCA and LAD segments. Mixed plaques most often led to moderate stenosis, with some cases of severe stenosis and total occlusion. Calcified and non-calcified plaques also showed tendencies toward moderate to severe stenosis and occlusion. These findings suggest the importance of early identification and classification of plaque characteristics in clinical practice to estimate stenosis severity. Further research with larger samples and multi-center settings is recommended to strengthen generalizability.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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