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The diagnostic accuracy of coronary angiography to detect left anterior descending artery myocardial bridging in coronary artery bypass grafting: a retrospective single-center study

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ABSTRACT

Aims: The left anterior descending artery is the most involved vessel in the myocardial bridging of the coronary arteries. Revascularization of the left anterior descending artery (LAD) is considered an essential component of coronary artery bypass grafting (CABG) procedures. This study aims to evaluate the correlation between angiographic views of the coronary artery and intraoperative findings of the left anterior descending artery myocardial bridge (LADMB).

Methods: The records of patients who underwent the CABG procedure between January 2015 and October 2022 were reviewed retrospectively. A total of 349 patients who had LADMB on coronary angiography (CAG) images and/or intraoperatively were evaluated. Patients were divided into two groups. The CAG group (n=50) consisted of patients with angiographic LADMB, and the CABG group (n=40) consisted of patients with LADMB that was detected intraoperatively. The correlation between myocardial bridge signs of the LAD in CAG and intraoperative observations was investigated.

Results: In the coronary angiography group, 50 patients had signs of depression on coronary angiography, of whom 35 had LADMB intraoperatively. In the CABG group, 40 patients were found to have a myocardial bridge intraoperatively, and 5 had normal CAG images. The prevalence of LADMB was 11.5%. The sensitivity of CAG was 87.5%, the specificity was 95.15%, the positive predictive value was 70%, and the negative predictive value was 98.32%.

Conclusion: The myocardial bridge signs of the LAD on CAG correlate with intraoperative observations with high sensitivity and specificity.

Keywords: Coronary artery bypass, coronary angiography, myocardial bridging, prevalence

INTRODUCTION

The main coronary arteries run subepicardially at the cardiac surface and penetrate the myocardium almost at the terminal segment.[1] However, in some cases, intramyocardial coronary arteries can be observed in proximal and middle segments or throughout the entire course.[2,3] The intramyocardial course of coronary arteries has always been a challenge during coronary artery bypass graft (CABG) procedures because of the difficulties in exposing the distal anastomosis segment, which may lead to inadequate coronary artery flow and intraoperative complications such as prolonged ischemic period, ventricular perforation, coronary artery injury, and intraoperative hemorrhage.[1,4,5] Coronary angiography (CAG) is the gold standard for the diagnosis of coronary artery disease (CAD).[1-4] Images of coronary arteries often demonstrate characteristic anatomical variation. For example, a depression sign of the left anterior descending artery (LAD) would indicate an intramyocardial course, particularly in the right anterior oblique view of CAG. The purpose of this study was to investigate the correlation between the characteristic image of the LAD myocardial bridge (LADMB) on CAG and the intraoperative finding of the course of the LAD. Many studies in the literature investigate the intramyocardial course of the LAD and possible complications during surgical procedures.[6-12] However, this is the first study to investigate the sensitivity and specificity of CAG in predicting the progression of LADMB.

METHODS

The study was carried out with the permission of Bozok University Hospital Ethics Committee (Date: 17.02.2023, Decision No: 2017-KAEK-189_2023.02.17_6). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

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Study Design and Population

This observational retrospective study was conducted in the Department of Cardiovascular Surgery of Bozok University Hospital. A total of 468 patients who underwent CABG procedures between January 2015 and October 2022 were analyzed.

Coronary angiographies were performed by an interventional cardiologist with a transfemoral approach and standard Judkins' technique. All patients received 2500 to 5000 units of unfractionated heparin. A total of 100-200 µg of nitroglycerin was administered depending on blood pressure. A biplane cine-angiography system was used to obtain standard angiography images.

Identification of LADMB

The presence of LADMB in CAG images was identified visually by our interventional cardiologists who were blinded to the intraoperative findings and was based on the following findings: (1) systolic compression or milking effect, which is defined as a diameter narrowing limited to a restricted vessel segment with contrast agent extraction that is not interpretable by normal coronary artery flow. (2) A wide-U-shaped image or the step-down-step-up phenomenon, which is described as a localized change in vessel course into the ventricle.

Other measurements, such as intramyocardial segment length and depth, or other imaging modalities were not performed.

Intraoperative LADMB was identified as not being visible on the cardiac surface in any part of its overall course.

According to that definition, patients without LADMB were excluded (n=119). A total of 349 patients who had LADMB in CAG images and/or intraoperatively were assessed separately. First, we evaluated all CAG images, and reports of those patients and individuals with LADMB were identified. Then, we reviewed the operative notes that were reported by a single surgeon who performed the procedures, and patients who were reported to have LAMB were identified. The studied population was divided into two groups: the CAG group (n=50), consisting of patients with angiographic LADMB, and the CABG group (n=40), consisting of patients with LADMB that was detected intraoperatively. The standard for reporting diagnostic accuracy (STARD) flow chart of the cases enrolled in the study is shown in **Figure 1**.

Data Collection and Endpoints

Data regarding baseline characteristics such as sex, age, EuroSCORE II, patient comorbidities (diabetes mellitus, dyslipidemia, systemic hypertension, smoking), echocardiography features, and clinical indications for coronary angiography were obtained from the computerized database and patient files. Our endpoint was to estimate the diagnostic value of CAG by evaluating the correlation between the sign of depression of the left anterior descending artery on coronary angiography and intraoperative observations, along with the prevalence of intraoperative LADMB.

Statistical Analysis

Descriptive statistics are presented as the mean with SD or median with İQR for numerical variables, while frequencies and percentages are used for the categorical variables. The distribution of variables was assessed by Kolmogorov-Smirnov and Shapiro-Wilk tests. For analytical statistics, the Mann-Whitney test was used to compare two numerical variables based on the normality assumption, while the Pearson chi-square test was used to compare two categorical variables. Diagnostic test evaluation parameters for CAG were calculated. The data were analyzed using IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp. and MedCalc Statistical Software version 20 (MedCalc Software Ltd, Ostend, Belgium). A P value <0.05 was considered to indicate statistical significance.

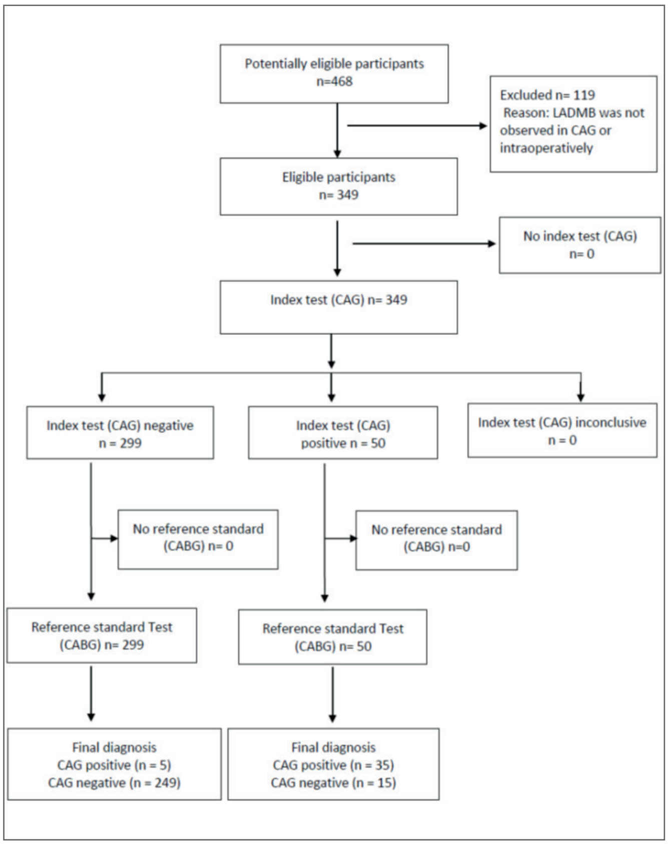

Figure 1. Standard for Reporting Diagnostic Accuracy (STARD) flow chart of the cases enrolled in the study. CAG: coronary angiography, CABG: coronary artery bypass grafting, LADMB: LAD myocardial bridge

RESULTS

Table 1 presents the baseline characteristics and clinical data of all patients included in the study. A total of 349 patients had LADMB on either coronary angiography or detected intraoperatively. The patients' median age was 61.64 years, and the majority were male (55%). The mean Euroscore II was 1.2%. The median body mass index (BMI) was 27,7 kg/m². Systemic hypertension, diabetes mellitus, and dyslipidemia were the most common comorbidities, with prevalence rates of 38%, 36%, and 27.5%, respectively. The clinical indication for CAG included acute coronary syndrome (ACS) in 39.5% of cases, angina in 50%, arrhythmia in 2.3%, and ventricular dysfunction in 7.7%. Echocardiography features showed a mean ejection fraction (EF) of 50%±15.

Table 1. Baseline characteristics and clinical data of the patients

	LADMB in CAG and/or CABG n=349
Age (y), Median (İQR)	61.64 (12.2)
Sex, n (%)	
Male	193 (55)
Female	156 (44.6)
Euroscore II (%), Mean (±SD):	1.2 (0.5)
BMI (kg/m2), Median (İQR):	27.7 (4.9)
Comorbidities, n (%):	
Systemic hypertension	136 (38)
Diabetes milletus	127 (36)
Dyslipidemia	96 (27.5)
Pulmonary disease	36 (10)
Smoking	105 (30)
Carotid stenosis	18 (5)
Clinical indication for CAG:	
ACS, n (%)	138 (39.5)
Angina, n (%)	176 (50)
Arrhythmia, n (%)	8 (2.3)
Ventricular dysfunction, n (%)	27 (7.7)
Echocardiography features, Mean (±SD):	
EF (%)	50 (15)
EDD, mm	46 (9)
ESD, mm	28 (11)
Extent of coronary lesions, n (%)	
1 vessel	11 (3)
2 vessels	91 (26)
3 vesseles	162 (46)
> 3 vessels	85 (24)
LMCA, n (%)	7 (2)
Type of emergency, n (%)	
Elective	259 (74)
Urgent	68 (19.5)
Emergent	22 (6)

LADMB: Left anterior descending myocardial bridge BMİ: Body mass index, ACS: Acute cronary sendrome, EF: Ejection fraction, EDD: End diastolic diameter, ESD: End systolic diameter, LMCA: Left main coronary artery.

According to intraoperative or CAG image observations regarding LADMB, the patients were divided into two groups. A total of 349 patients were included in the study. LADMB was detected in CAG images in 50 patients (50/349, 14%); 66% of patients were males, and the median age was 67.5 years. Forty patients were confirmed to have LADMB during intraoperative assessment (LADMB-CABG) (40/349, 11.5%). The median age was 67.5 years. 70% males, Table 2. Of these 40 patients, 35 were correctly identified with LADMB during coronary angiography (LADMB-CAG), while 5 were missed. Additionally, among the 309 patients without LADMB during the intraoperative assessment, 294 were correctly identified as negative for LADMB in the coronary angiography images, while 15 were false-positive Table 3.

Table 2. Demographic characteristics of the study groups

	Total n=90	CAG group n=50	CABG group n=40	P value
Age (y), Median (IQR)	67 (12)	65.5 (13)	67.5 (12)	>0.999*
Sex, n (%)				
Male	61 (68)	33 (66)	28 (70)	0.688**
Female	29 (32)	17 (34)	12 (30)	

CAG: coronary angiography, CABG: coronary artery bypass graft. * Mann-Whitney U test, ** Pearson Chi-Square test.

Table 3. Contingency table of the data used to calculate sensitivity and specificity*.

LADMB (CAG)	LADMB (CABG)		
	Yes	No	Total
Yes	35	15	50
No	5	294	299
Total	40	309	349

LADMB: left anterior descending artery myocardial bridge, CAG: coronary angiography, CABG: coronary artery bypass graft. * Sensitivity=35/40=0.875, Specificity=294/309=0.951.

The sensitivity of coronary angiography in detecting LADMB was calculated as 35/40, resulting in a sensitivity of 87.5% (95% CI, 73.20-95.81). The specificity of coronary angiography was calculated as 294/309, yielding a specificity of 95.1% (95% CI, 92.12-97.26). Tables 3 and 4. The prevalence of LADMB in patients who underwent CABG procedures was 11.5%. The positive predictive value (PPV) and negative predictive value (NPV) of CAG were 70% and 98.32%, respectively (Table 4, Figure 2).

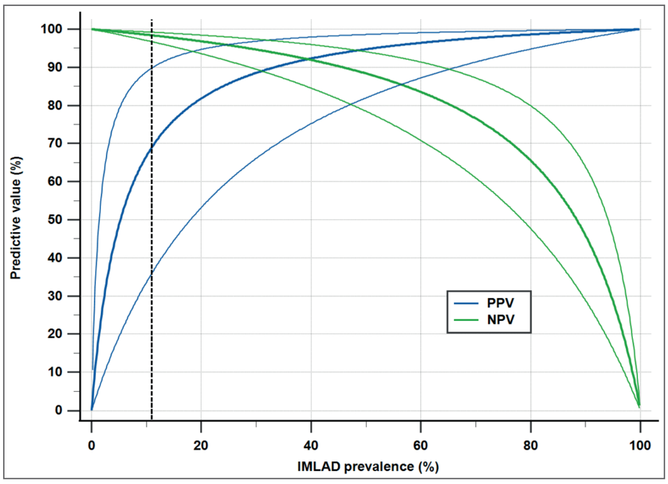

Figure 2. Plot versus prevalence graph for PPVs and NPVs with confidence intervals; dashed line represents the prevalence, PPV: positive predictive value, NPV: negative predictive value.

Table 4. Summary estimates of diagnostic values of LADMB in CAG.

	Value	95% CI (lower limit-upper limit)
Sensitivity	87.5%	73.20%-95.81%
Specificity	95.15%	92.12%-97.26%
AUC	0.913	0.88-0.94
PPV	70.08%	58.51%-79.55%
NPV	98.32%	96.27%-99.255
Prevalence	11.46%	8.31%-15.27%
+LR	18.03	10.85-29.94
-LR	0.13	0.06-0.30
Accuracy	94.27%	91.28%-96.46%

CI: confidence interval, AUC: area under the curve, PPV: positive predictive value, NPV: negative predictive value, +LR: positive likelihood ratio, -LR: negative likelihood ratio

In CAG images, the milking sign of LADMB was observed in 13 patients (13/50, 26%), while the wide-U-depression image was observed in 37 patients (37/50, 74%) (**Figure 3**).

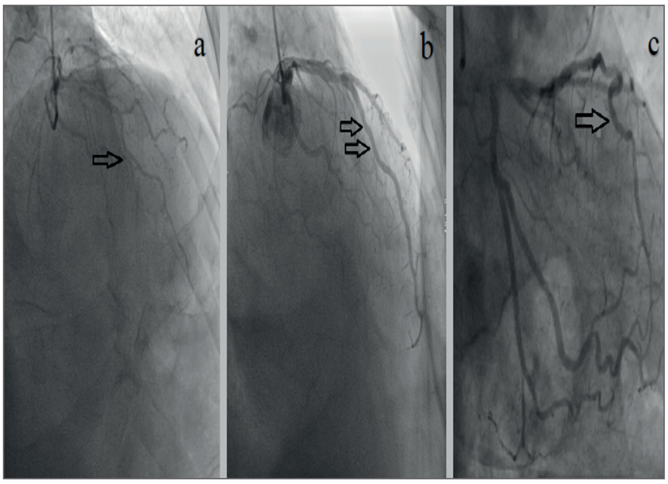

Figure 3. CAG images in different patients with LADMB. a, b: LAD depression sign, c: Right anterior oblique view demonstrates a typical wide-U shaped image. The black arrows indicate intramyocardial LAD location.

Twenty-five (62.5%) of the 40 LADMB-CABG cases had a superficial course, while 15 (37.5%) had a deeper progression inside the interventricular septum. In 19 cases, the LAD was grafted distally in the visible segment of the LAD. In 21 cases, the LAD was not visible in the distal portion. The great cardiac vein was used as a landmark to identify LADMB. There were no intraoperative or postoperative complications in any of the cases.

DISCUSSION

The primary objective of this study was to assess the diagnostic accuracy of CAG in detecting LADMB during CABG procedures. Our findings revealed a significant correlation between the characteristic image of LADMB on CAG and intraoperative observations with a high sensitivity value of 87.5% and a high specificity value of 95.1%.

The myocardial bridge (MB) is considered a congenital coronary anomaly and is described as a segment of a major epicardial coronary artery that passes deeply into the myocardium.[13,14] Although myocardial bridges can occur in any epicardial artery, the LAD is the most commonly involved (70% to 98%).[15] The prevalence of intramyocardial course ranges from 5% to 86% in autopsy series[8,16], and from 0.5% to 12% in coronary angiographic series.[17] Vanker et al.[1] identified LADMB in 293 out of 1349 CABG patients and reported a prevalence of 21.7%. In this study, the prevalence of LADMB in CABG patients was 11.5% (40/349). In our CAG series, the prevalence was 14% (50/349), while other studies reported lower prevalence rates ranging between 1-2% in CAG.[18,19] It has been demonstrated that the extent and frequency of MB can vary depending on imaging modalities. Lu et al.[20] in their study on the same population, found that the frequency of MB with CAG was 6% and 30% with computed tomography coronary angiography (CTCA). Furthermore, the prevalence of MBs was reported to differ according to the method used during CAG. For example, Şenöz et al.[21] Demonstrated that the detection rate of MBs by the transradial approach to CAG was significantly higher than that of the transfemoral approach (10.2% vs 1.8%). The main reason for this variation is the diversity in the sensitivity of CAG procedures in detecting MB. Additionally, the size and ethnicity of the study population may influence the prevalence of MBs.[21] In studies conducted in Turkish population higher than the size of the current study, the prevalence of MB was reported to be approximately 1%.[21-23] Moreover, provocative tests by nitroglycerin and diltiazem might increase the detection rate of MB.[17,21] Other factors that may affect the variations in the reported prevalence of MBs are the depths of the bridging segment. It was assumed that the systolic compression sign might be absent in superficial MB but prominent in deep MB,[24] which to some extent depends on the observer's experience.[25] Leschka et al.[26] reported that the percentage of systolic compression correlated with MB depth, whereas bridged segment length did not correlate with the degree of systolic compression. Furthermore, conventional angiography missed more than 50% of the MBs, suggesting that diagnosis of MBs by visual assessment in CAG can only be performed for segments with more than 20% systolic compression. These findings revealed that conventional CAG is not sufficiently sensitive to detect LADMB, particularly the mild or superficial type.[27] However, the detection rate of LADMB in the present study was higher than that in previously reported studies. In addition, the high sensitivity in our study indicates that CAG correctly identified a substantial proportion of cases with LADMB. In essence, CAG effectively minimizes the risk of false negatives, ensuring that a large majority of patients with LADMB are correctly identified. The observed high sensitivity value along with PPV increases confidence that a positive test result is reliable and likely corresponds to the true presence of LADMB. Moreover, the high specificity and NPV indicated that CAG is capable of differentiating patients without LADMB, minimizing the occurrence of false positives. This is crucial in avoiding unnecessary interventions during surgery for patients who do not have LADMB, thus enhancing the precision of the diagnostic method. The possible explanation for these results might be evaluating angiographic images with the specific goal of locating the MB and the frequent use of nitroglycerin, particularly in hypertensive patients. In addition, although cardiologists were blinded to surgical reports, including patients with documented evidence of MB in these reports instead of randomly selected patients might result in selection bias and increase the true positive cases. Hence, these results should be interpreted with caution.

In the context of diagnosing LADMB, various imaging modalities present distinct advantages and limitations. While our research primarily focused on the diagnostic accuracy of coronary angiography, it is crucial to acknowledge the strengths and weaknesses of alternative diagnostic techniques. Although CAG continues to be the gold standard among imaging modalities for the diagnosis of coronary artery disease due to its advantages in revealing the characteristics of obstructive coronary artery lesions,[28] it may pose some challenges in terms of diagnosing MBs. CAG can provide both an anatomic and dynamic assessment. However, the tunneled segment cannot be functionally evaluated.[29] In addition, observers have to rely on indirect signs during vessel assessment, which may result in underestimation of MB prevalence, particularly in the shallow type.[17,26,30] Intracoronary imaging methods, such as intravascular ultrasound (IVUS) 2, optical coherence tomography (OCT),[31] and fractional flow reserve (FFR) measurement,[32] as well as emerging modalities such as coronary computed tomography angiography (CCTA) and magnetic resonance imaging (MRI), play pivotal roles in comprehensively assessing the complex anatomical and functional aspects of LADMB.[29]

IVUS offers high-resolution cross-sectional images of coronary arteries and reveals the systolic compression of the bridge segments (half-moon phenomenon) and atherosclerosis, providing valuable insights into plaque morphology, vessel dimensions, and intraluminal structures. IVUS enables accurate assessment of the degree of intramyocardial penetration of the LAD and provides real-time information during interventions. However, the invasive nature of IVUS and potential procedural complications may limit its widespread adoption.[29] A previous study revealed that IVUS could identify bridging in 23% of patients, while angiographic systolic compression was only seen in 3%.[33] OCT provides even higher resolution images, facilitating detailed visualization of coronary artery walls and luminal structures, and can precisely determine the extent of intramyocardial course and offer insights into plaque composition. Nevertheless, the invasive nature and technical complexity could potentially hinder its routine clinical use. OCT has been investigated in previously published reports regarding the diagnosis of MBs, which concluded that MBs were longer, but the diameter stenosis was lower than with angiography-based measures.[31] Using the FFR technique is debatable since MB is a dynamic stenosis that depends on the degree of extravascular compression and intramyocardial tension and can be revealed by provocative pharmacologic tests.[32,34,35] CCTA offers noninvasive three-dimensional images of coronary anatomy, enabling visualization of the course of LADMB with exceptional spatial resolution 8. Moreover, CCTT imaging of myocardial bridging has found intramyocardial segments at substantially higher rates than conventional angiography.[36-38] Conversely, cardiac MRI often employs techniques such as late gadolinium enhancement and contributes to identifying myocardial bridges and assessing their functional implications, providing valuable insights into ischemia. However, due to spatial resolution limitations and technological issues, it cannot provide accurate and strong insight into the LAD's intramyocardial depth.[29] Moreover, functional imaging techniques, including myocardial perfusion imaging through single-photon emission computed tomography (SPECT) and stress echocardiography, provide an assessment of the functional significance of LADMB by evaluating induced ischemia. Integrating both anatomical and functional evaluations enhances diagnostic accuracy and informs clinical decision-making.[39] In the present study, we could not perform other imaging methods to compare our findings in terms of CAG diagnostic accuracy with other imaging modalities, which limits the evaluation of our findings.

Surgical myotomy and CABG are two surgical procedures for myocardial bridging refractory to medical therapy.[17] Myotomy involves the dissection of the overlying muscle fibers. However, perforation of the right ventricle, particularly with deep MBs, may occur during dissection. None of the patients in our sample required a myotomy since all of them, including those with one vascular disease, were operated on due to severe lesions proximal to the MB rather than symptoms related to the MB itself. CABG, which commonly involves anastomosis of the left internal mammary artery to the LAD, has also been recommended as an effective treatment for MB.

particularly for patients with long (>25 mm), deep (>5 mm) MBs, or patients with accompanied severe coronary artery disease.[17] Nevertheless, there may be compelling situations for the surgeon in the case of LADMB as a target artery for distal anastomosis. There are several methods to expose the LADMB. One method is "blind dissection", which involves dissection of the myocardium in the anterior interventricular groove. This technique can lead to severe damage to the myocardium, resulting in ventricle perforation.[12,40] Another option is to use the great cardiac vein as a guide point, which usually runs in the epicardial adipose tissue and is more superficial than the artery. Another method is to insert a coronary probe from the distal visible portion of the artery. However, the risk of coronary artery perforation can cause serious intraoperative morbidities.[11] Other less invasive but more expensive techniques to expose the intraoperative LADMB include Doppler ultrasound with a color Doppler microprobe, intraoperative fluorescein angiography, and cine angiography.[4,41-43]

Study Limitations

The main limitations of this study are the small number of patients for statistical analysis and the single-center retrospective nature of the study. which might impact the generalizability of the findings. Additionally, the reliance on visual assessment of CAG images for diagnosing LADMB could introduce subjectivity and potential observer bias. The absence of other imaging techniques, such as IVUS or CCTA, to confirm the LADMB diagnosis might also be seen as a limitation. Last, the study primarily focuses on CABG patients, potentially limiting the applicability of the findings to a broader population of patients with different clinical profiles. Therefore, patients will continue to be enrolled, and we plan to produce an annual report of results and statistics every 12 months.

CONCLUSION

Our study highlights the diagnostic accuracy of CAG in detecting LADMB during CABG procedures. The high sensitivity and specificity of LADMB imaging on CAG underscore the potential of CAG as a valuable invasive method for the preoperative diagnosis of LADMB, facilitating surgical planning and potentially reducing intraoperative complications. However, the study also highlights the importance of considering the limitations of CAG, such as potential false-negative results. Further investigation is needed to explore the diagnostic accuracy of various imaging modalities, which could shed light on the most successful diagnostic approach. Furthermore, research on the interaction between anatomical and functional assessments may lead to more complete diagnostic techniques for LADMB detection.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Bozok University Hospital Ethics Committee (Date: 17.02.2023, Decision No: 2017-KAEK-189_2023.02.17_6).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version.

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