Original Article

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Accuracy of angioboost software versus routine angiography for assessing the degree of coronary artery lesion occlusion

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Background: Accurate image extraction is essential for simplifying the diagnosis and treatment of coronary artery disease (CAD) and reducing the need for multiple imaging procedures. This study compared the diagnostic accuracy of AngioBoost knowledge-based software with routine angiography in assessing coronary artery lesions.
Methods: This cross-sectional study included 174 patients undergoing coronary angiography at Shahid Rajaei Heart Hospital, Tehran. Patients with signs and symptoms of ischemic heart disease and an indication for coronary angiography were enrolled. All underwent angiography using the Seldinger method. Angiographic films were reviewed by two independent cardiologists. AngioBoost was then applied to the same images, and its findings were interpreted by two additional cardiologists.
Results: Comparison of routine angiography and AngioBoost showed contingency coefficients of 74.7% (P = 0.01) and 90.1% (P = 0.01) for the first and second cardiologists, respectively. AngioBoost correctly identified 96.3% of patent vessels, 79.9% of mild lesions, 58.0% of moderate lesions, 91.2% of significant lesions, and 96.8% of occluded vessels. Overall diagnostic agreement was 88.2% (P = 0.01). Kappa coefficients for vascular occlusion were 46.8% for Left Main, 71.7% for LAD, 70.1% for LCX, and 77.8% for RCA (all P = 0.01).
Conclusion: AngioBoost demonstrated acceptable diagnostic accuracy in assessing coronary artery occlusion, showing strong agreement (88.2%) with routine angiography. These findings suggest that AngioBoost may serve as a useful complementary tool for CAD diagnosis, potentially reducing physician workload and improving diagnostic efficiency.
Keywords: Cardiovascular disease, Angiography, Diagnosis, AngioBoost, Coronary artery lesions.

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Cardiovascular disease (CVD) remains the leading cause of disability and mortality worldwide, including in Iran (1). It significantly impacts an individual's ability to maintain normal function and imposes a major burden on healthcare systems. In Iran, the prevalence of CVD is estimated at 3,500 cases per 100,000 people(2), with a worrying increase from 5.7% to 17.8% in recent years. About 50% of death in Iran is caused by coronary artery disease, which has the highest death rate among other diseases (3). CAD occurs primarily due to the obstruction of myocardial blood flow, leading to an inadequate oxygen and nutrient supply to the heart tissue. This obstruction results from excessive accumulation of atherosclerotic plaques and fatty deposits within the coronary arteries. The rupture of these plaques can trigger clot formation, further narrowing or completely blocking the arteries, leading to acute cardiovascular events such as myocardial infarction (4).Early detection of coronary artery lesions is crucial, as it provides valuable prognostic information and allows for timely intervention, potentially preventing heart failure progression (5).

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Several diagnostic imaging modalities are available for assessing coronary artery involvement, including computed tomographic angiography (CTA), magnetic resonance angiography (MRA), and x-ray coronary angiography (XCA). More advanced techniques, such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT), provide detailed insights into vessel morphology and plaque composition (6, 7). Despite these advancements, x-ray coronary angiography remains the gold standard for diagnosing CAD, given its cost-effectiveness, accessibility, and superior temporal and spatial resolution compared to other imaging methods (8). However, its accuracy can be affected by image noise, motion artifacts, and background complexity (9).

To improve the precision of coronary artery lesion assessment, vessel extraction techniques are often employed to enhance image quality by reducing background noise and isolating vessel structures. Enhancing angiographic images not only aids in better visualization of lesions but also minimizes the number of images required for diagnosis, thereby optimizing the diagnosis (10). Recent advancements in artificial intelligence and image-processing algorithms have led to improved diagnostic tools, such as Angioboost. This knowledge-based software is specifically designed to enhance coronary angiographic images. By utilizing advanced image enhancement techniques, Angioboost aimed to improve the detection and classification of lesions, potentially offering greater accuracy than conventional angiography.

AngioBoost is a knowledge-based image enhancement software developed by the Biomedical Engineering Department of Amirkabir University of Technology (Tehran Polytechnic), Iran. The software aimed to improve the visualization of coronary arteries in routine angiography by enhancing vessel edges and reducing background noise. It is currently available for clinical research use in selected imaging and cardiology centers in Iran, under institutional licensing, and is not yet distributed as a public or commercial software. Its main competitive advantages include compatibility with standard angiography equipment, independence from proprietary systems, and cost-effectiveness for use in both clinical and academic centers. Additionally, it enables more precise vessel visualization without increasing imaging time or radiation exposure, making it a practical diagnostic aid in routine cardiology settings.

Therefore, this study aimed to compare the accuracy of Angioboost software with routine x-ray angiography in assessing the degree of coronary artery lesion occlusion. The findings of this study could provide valuable insights into whether advanced software-based analysis can complement or even enhance conventional angiographic assessments, ultimately contributing to more accurate and efficient CAD diagnosis and treatment.

Methods

Study population: This cross-sectional study included 174 patients who were candidates for diagnostic coronary angiography at Shahid Rajaei Heart Hospital, Tehran, in 2022. The inclusion criteria were based on the clinical guidelines for the evaluation of ischemic heart disease and the indications for coronary angiography established by the American College of Cardiology (ACC) and the American Heart Association (AHA) (11-13).

These indications included the presence of angina pectoris or equivalent symptoms, positive non-invasive ischemia tests, abnormal ECG findings, and high clinical suspicion of coronary artery disease unconfirmed by other imaging modalities. Patients with contraindications to angiography or incomplete medical records were excluded. The diagnostic criteria for classifying the degree of coronary artery occlusion (patent, mild, moderate, significant, and cut) were also defined according to standard quantitative coronary angiography (QCA) criteria, consistent with previous studies.

Angiography protocol: Following the standard angiographic procedure, the AngioBoost software was employed to analyze the patients' angiographic films. The software-generated results were independently evaluated by two additional cardiologists. To ensure objectivity, all cardiologists were blinded to both the expert interpretations and the software-generated findings. The primary variable assessed in this study was the degree of coronary artery occlusion, categorized as follows:

- Patent
- Mild occlusion
- Moderate occlusion
- Significant occlusion
- Complete occlusion (cut)

Coronary lesions were evaluated across multiple arterial segments and branches, including:

Left Coronary Artery (LCA):

- Left Main Ostial part (LMO)
- Left Main Distal part (LMD)
- Left Anterior Descending Ostial part (LADO)
- Left Anterior Descending Proximal part (LADP)
- Left Anterior Descending Mid part (LADM)
- Left Anterior Descending Distal part (LADD)
- Left Circumflex Ostial part (LCXO)

- Left Circumflex Proximal part (LCXP)
- Left Circumflex Mid part (LCXM)
- Left Circumflex Distal part (LCXD)

Right Coronary Artery (RCA):

- Right Coronary Artery Ostial part (RCAO)
- Right Coronary Artery Proximal part (RCAP)
- Right Coronary Artery Mid part (RCAM)
- Right Coronary Artery Distal part (RCAD)

The AngioBoost software (Version 1.2, Amirkabir University of Technology, Tehran, Iran) was installed and operated in the imaging unit of Shahid Rajaei Heart Hospital. The software runs on standard Windows-based workstations and is specifically designed for post-processing of routine X-ray angiography images. Access is limited to authorized medical and research centers through institutional collaboration agreements.

Statistical analysis: All data were analyzed using SPSS version 26. The Chi-square test was used to compare the frequency distribution of occlusion categories between the AngioBoost software and routine angiography interpretations. Additionally, the Kappa agreement coefficient was calculated to assess the inter-rater agreement between the two methods. A p-value of <0.05 was considered statistically significant.

Results

Table 1 presents the findings of the first physician's observations using two diagnostic methods: routine angiography and Angioboost software. The results indicate a high level of agreement between the two methods in diagnosing vascular occlusion, with agreement rates ranging from 82.4% in LCXM to 99.4% in LADO, demonstrating a strong correlation between the diagnostic approaches.

Notably, the agreement percentage was higher in cases of moderate, significant, and cut occlusion, whereas in cases of mild occlusion, the level of agreement was comparatively lower. This suggests that the differentiation of less severe occlusions may be more challenging, potentially due to subtle variations in imaging interpretation. Furthermore, the Kappa coefficient analysis revealed the lowest agreement level (62.6%) in diagnosing LMO using routine angiography and Angioboost, while the highest agreement (88.7%) was observed in RCAO ($P < 0.001$).

These findings highlight the reliability and consistency of Angioboost in most cases, particularly for more severe occlusions.

Table 1. Frequency distribution and agreement of the first physician's observations using routine angiography and Angioboost

First physician			Angioboost					P-value	Kappa
			Patent	Mild	Moderate	Significant	Cut		
Standard angiography	LMO	Patent	(99.4) 167	1 (0.6)	0	0	0	<0.001	62.6
		Mild	2 (33.3)	3 (50.0)	0	1 (16.7)	0		
	LMD	Patent	151 (96.2)	4 (2.5)	0	2 (1.3)	0	<0.001	63.7
		Mild	3 (25.0)	8 (66.7)	0	1 (8.3)	0		
		Significant	1 (20.0)	1 (20.0)	0	3 (60.0)	0		
	LADO	Patent	158 (99.4)	1 (0.6)	0	0	0	<0.001	85.8
		Mild	1 (50.0)	1 (50.0)	0	0	0		
		Moderate	0	2 (100.0)	0	0	0		
		Significant	0	0	0	9 (100.0)	0		
		Cut	0	0	0	0	2 (100.0)		
	LADP	Patent	115 (97.5)	2 (1.7)	1 (0.8)	0	0	<0.001	80.0
		Mild	6 (20.7)	22 (75.9)	1 (3.4)	0	0		
		Moderate	1 (16.7)	2 (33.3)	3 (50.0)	0	0		
		Significant	0	1 (5.3)	3 (15.8)	15 (78.9)	0		
		Cut	0	0	0	0	2 (100.0)		
	LADM	Patent	80 (87.9)	10 (11.0)	0	1 (1.1)	0	<0.001	72.1
		Mild	6 (20.7)	22 (75.9)	0	1 (3.4)	0		
		Moderate	1 (10.0)	4 (40.0)	3 (30.0)	2 (20.0)	0		
		Significant	0	2 (5.9)	2 (5.9)	28 (82.4)	2 (5.9)		
		Cut	0	0	0	1 (10.0)	9 (90.0)		

First physician		Angioboost					P-value	Kappa
		Patent	Mild	Moderate	Significant	Cut		
LADD	Patent	137 (94.5)	8 (5.5)	0	0	0	0.001	75.3
	Mild	4 (16.7)	19 (79.2)	0	1 (4.2)	0		
	Significant	0	0	0	4 (00.0)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXO	Patent	163 (98.2)	3 (1.8)	0	0	0	<0.001	68.5
	Mild	0	1 (100.0)	0	0	0		
	Significant	0	0	1 (33.3)	2 (66.7)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXP	Patent	96 (90.6)	10 (9.4)	0	0	0	<0.001	64.0
	Mild	17 (28.3)	42 (70.0)	1 (1.7)	0	0		
	Moderate	0	(100.0) 3	0	0	0		
	Significant	0	0	0	4 (100.0)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXM	Patent	61 (82.4)	13 (17.6)	0	0	0	<0.001	68.1
	Mild	16 (25.8)	44 (71.0)	2 (3.2)	0	0		
	Moderate	0	2 (25.0)	3 (37.5)	3(37.5)	0		
	Significant	0	1 (4.2)	0	23 (95.8)	0		
	Cut	0	0	0	0	6 (100.0)		
LCXD	Patent	103 (90.4)	8 (7.0)	1 (0.9)	2 (1.8)	0	<0.001	67.5
	Mild	12 (23.1)	39 (75.0)	0	1 (1.9)	0		
	Moderate	0	1 (100.0)	0	0	0		
	Significant	1 (14.3)	1 (14.3)	0	5 (71.4)	0		
RCAO	Patent	166 (99.4)	1 (0.6)	0	0	0	<0.001	88.7
	Mild	0	(100.0) 2	0	0	0		
	Significant	0	0	0	1 (100.0)	0		
	Cut	0	0	0	0	1 (100.0)		
RCAP	Patent	90 (92.8)	7 (7.2)	0	0	0	<0.001	75.7
	Mild	14 (25.5)	39 (70.9)	2 (3.6)	0	0		
	Moderate	0	0	3 (75.0)	1 (25.0)	0		
	Significant	0	0	0	14 (100.0)	0		
	Cut	0	0	0	3 (100.0)	0		
RCAM	Patent	81 (87.1)	10 (10.8)	2 (2.2)	0	0	<0.001	69.6
	Mild	11 (20.0)	42 (73.7)	1 (1.8)	3 (5.3)	0		
	Moderate	1 (25.0)	1 (25.0)	2 (50.0)	0	0		
	Significant	0	0	2 (14.3)	12 (85.7)	0		
	Cut	0	0	0	1 (16.7)	5 (83.3)		

First physician		Angioboost					P-value	Kappa
		Patent	Mild	Moderate	Significant	Cut		
RCAD	Patent	102 (88.7)	11 (9.6)	2 (1.7)	0	0	<0.001	67/8
	Mild	10 (20.0)	41 (77.4)	1 (1.9)	1 (1.9)	0		
	Moderate	0	0	0	1 (100.0)	0		
	Significant	0	0	1 (20.0)	4 (80.0)	0		

LMO – Left Main Ostial; LMD – Left Main Distal; LADO – Left Anterior Descending Ostial; LADP – Left Anterior Descending Proximal; LADM – Left Anterior Descending Mid; LADD – Left Anterior Descending Distal; LCXO – Left Circumflex Ostial; LCXP – Left Circumflex Proximal; LCXM – Left Circumflex Mid; LCXD– Left Circumflex Distal; RCAO – Right Coronary Artery Ostial; RCAP – Right Coronary Artery Proximal; RCAM – Right Coronary Artery Mid; RCAD – Right Coronary Artery Distal; Kappa – Statistical measure of inter-rater agreement; p-value – Probability value (significance level); AngioBoost – Knowledge-based software for coronary angiography enhancement.

As The findings from the second physician's observations using routine angiography and Angioboost are presented in Table 2. The data demonstrate a high level of agreement in diagnosing vascular occlusion, with agreement rates ranging from 93.3% in LADD to 100% in most other cases, indicating strong consistency between the two diagnostic methods. The agreement percentage remained consistently high across all occlusion severities, including mild, moderate, significant, and cut occlusions. However, the Kappa coefficient analysis revealed the lowest agreement level (56.4%) in diagnosing LMO, while the highest agreement (95.8%) was observed in LADD (P < 0.001). These findings further support the reliability of Angioboost in coronary artery occlusion assessment, with particularly strong diagnostic concordance in more severe occlusion cases.

Table 2. Frequency distribution and agreement of the second physician's observations using routine angiography and Angioboost

Second physician			Angioboost					P-value	Kappa
			Patent	Mild	Moderate	Significant	Cut		
Standard angiography	LMO	Patent	169 (100.0)	0	0	0	0	<0.001	56.4
		Mild	3 (60.0)	2 (40.0)	0	0	0		
	LMD	Patent	156 (98.7)	2 (1.3)	0	0	0	<0.001	82.7
		Mild	3 (27.3)	8 (72.7)	0	0	0		
		Significant	0	0	0	5 (100.0)	0		
	LADO	Patent	160 (100.0)	0	0	0	0	<0.001	92.4
		Mild	0	3 (60.0)	2 (40.0)	0	0		
		Moderate	0	0	0	7 (00.0)	0		
		Significant	0	0	0	0	2 (100.0)		
		Cut	112 (94.9)	6 (5.1)	0	0	0		
	LADP	Patent	1 (3.4)	27 (93.1)	1 (3.4)	0	0		
		Mild	0	2 (28.6)	5 (71.4)	0	0		86.6
		Moderate	0	0	2 (10.5)	17 (89.5)	0	<0.001	
		Significant	0	0	0	0	1 (100.0)		92.4
		Cut	77 (100.0)	0	0	0	0		
	LADM	Patent	4 (11.4)	29 (82.9)	2 (5.7)	0	0	<0.001	86.6
		Mild	0	0	7 (77.8)	2 (22.2)	0		
		Moderate	0	0	1 (2.2)	45 (97.8)	0		
		Significant	0	0	0	0	7 (100.0)		
		Cut	146 (99.3)	1 (0.7)	0	0	0		

Second physician		Angioboost Patent	Mild	Moderate	Significant	Cut	P-value	Kappa
LADD	Patent	0	21 (100.0)	0	0	0	0.001	95.8
	Mild	0	1 (50.0)	1 (50.0)	0	0		
	Significant	0	0	0	3 (100.0)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXO	Patent	166 (98.8)	2 (1.2)	0	0	0	<0.001	68.4
	Mild	1 (100.0)	0	0	0	0		
	Significant	0	0	1 (25.0)	3 (75.0)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXP	Patent	108 (97.3)	3 (2.7)	0	0	0	<0.001	90.7
	Mild	4 (7.5)	49 (92.5)	0	0	0		
	Moderate	0	0	3 (100.0)	0	0		
	Significant	0	0	1 (16.7)	5 (83.3)	0		
	Cut	0	0	0	0	1 (100.0)		
LCXM	Patent	86 (96.6)	3 (3.4)	0	0	0	<0.001	86.6
	Mild	4 (8.2)	42 (85.7)	3 (6.1)	0	0		
	Moderate	0	1 (7.7)	8 (61.5)	4 (30.8)	0		
	Significant	0	0	0	19 (100.0)	0		
	Cut	0	0	0	0	4 (100.0)		
LCXD	Patent	127 (96.9)	4 (3.1)	0	0	0	<0.001	87.3
	Mild	4 (10.3)	35 (89.7)	0	0	0		
	Moderate	0	0	1 (14.3)	6(85.7)	0		
	Significant	171 (100.0)	0	0	0	0		
RCAO	Patent	0	0	1 (50.0)	1 (50.0)	0	<0.001	83.1
	Mild	0	0	0	0	1 (100.0)		
	Significant	100 (95.2)	5 (4.8)	0	0	0		
	Cut	5 (10.6)	41 (87.2)	1 (2.1)	0	0		
RCAP	Patent	0	0	6 (100.0)	0	0	<0.001	88.6
	Mild	0	0	0	14 (100.0)	0		
	Moderate	0	0	0	0	3 (100.0)		
	Significant	93 (95.9)	4 (4.1)	0	0	0		
	Cut	3 (6.4)	43 (91.5)	1 (2.1)	0	0		
RCAM	Patent	0	1 (14.3)	6 (85.7)	0	0	<0.001	91.5
	Mild	0	0	0	15 (100.0)	0		
	Moderate	0	0	0	0	8 (100.0)		
	Significant	118(98.3)	2 (1.7)	0	0	0		
	Cut	6 (13.0)	40 (87.0)	0	0	0		
RCAD	Patent	0	0	3 (100.0)	0	0	<0.001	89.6
	Mild	0	0	0	5 (100.0)	0		
	Moderate	0	0	0	1 (100.0)	0		
	Significant	0	0	1(20.0)	4(80.0)	0		

LMO – Left Main Ostial; LMD – Left Main Distal; LADO – Left Anterior Descending Ostial; LADP – Left Anterior Descending Proximal; LADM – Left Anterior Descending Mid; LADD – Left Anterior Descending Distal; LCXO – Left Circumflex Ostial; LCXP – Left Circumflex Proximal; LCXM – Left Circumflex Mid; LCXD– Left Circumflex Distal; RCAO – Right Coronary Artery Ostial; RCAP – Right Coronary Artery Proximal; RCAM – Right Coronary Artery Mid; RCAD – Right Coronary Artery Distal; Kappa – Statistical measure of inter-rater agreement; p-value – Probability value (significance level); AngioBoost – Knowledge-based software for coronary angiography enhancement.

The comparison of the first and second physicians' observations in diagnosing the degree of occlusion across different vessels using routine angiography and Angioboost is presented in Table 3. The analysis of the Kappa contingency coefficient revealed varying levels of agreement between the two physicians across different vascular regions.

The lowest agreement was observed in the LMO+LMD vessels, with a Kappa coefficient of 46.8%, indicating moderate consistency between the two observers. In contrast, the agreement was significantly higher in other vessel groups. The LADO+LADP+LADM+LADD vessels showed a good agreement of 71.7%, while the LCXO+LCXP+LCXM+LCXD vessels exhibited a similar agreement level of 71.0%. The highest agreement was observed in the LCAO+RCAP+RCAM+RCAD vessels, where the two physicians demonstrated a strong agreement of 77.8%.These findings suggest that the diagnostic consistency between the two physicians was stronger in larger and more proximal vessel segments, whereas agreement was lower in smaller or more complex regions, potentially due to greater subjectivity in interpretation.

Table 3. Frequency distribution and comparison of the first and second physicians' observations in diagnosing the degree of occlusion in different vessels using routine angiography and Angioboost

			Second physician						
			Cut	**Significant**	**Moderate**	**Mild**	**Patent**	**Kappa**	**P-value**
First physician	**LMO+LMD**	**Patent**	0	(0.5) 3	0	13 (2.0)	(97.5) 633	46.8	<0.001
		Mild	0	1(2.9)	0	14 (40.0)	(57.1) 20		
		Significant	0	(50.0) 6	0	1 (8.3)	5 (41.7)		
	LADO+LADP+LADM +LADD	**Patent**	0	(1.9) 19	8 (0.8)	50 (4.9)	(92.4) 945	71.7	<0.001
		Mild	0	2 (1.1)	12 (6.7)	(67.2) 121	(25.0) 45		
		Moderate	0	(19.4) 6	15 (48.2)	6 (19.4)	4 (12.9)		
		Significant	0	(89.1) 411	3 (2.4)	3(2.4)	8 (6.3)		
		Cut	22 (71.0)	(29.0) 9	0	0	0		
	LCXO+LCXP+LCXM +LCXD	**Patent**	0	5 (0.5)	0	45 (4.8)	(94.7) 885	71.0	<0.001
		Mild	0	2 (0.6)	14 (4.1)	(66.8) 229	(28.6) 98		
		Moderate	0	1 (5.0)	12 (60.0)	5 (25.0)	2 (10.0)		
		Significant	0	(83.3) 65	5 (6.4)	2 (2.6)	6 (7.7)		
		Cut	12 (75.0)	0	2 (12.5)	0	2 (12.5)		
	RCAO+RCAP+RCAM +RCAD	**Patent**	2 (0.2)	2 (0.2)	5 (0.5)	40 (4.2)	(94.9) 913	77.8	<0.001
		Mild	0	1(3.2) 0	10 (3.2)	(74.9) 236	(21.0) 66		
		Moderate	1 (4.2)	(12.5) 3	16 (66.7)	3 (12.5)	1 (4.2)		
		Significant	2 (2.8)	(90.1) 64	2 (2.8)	3 (4.2)	0		
		Cut	(100.0) 19	0	0	0	0		

LMO – Left Main Ostial; LMD – Left Main Distal; LADO – Left Anterior Descending Ostial; LADP – Left Anterior Descending Proximal; LADM – Left Anterior Descending Mid; LADD – Left Anterior Descending Distal; LCXO – Left Circumflex Ostial; LCXP – Left Circumflex Proximal; LCXM – Left Circumflex Mid; LCXD– Left Circumflex Distal; RCAO – Right Coronary Artery Ostial; RCAP – Right Coronary Artery Proximal; RCAM – Right Coronary Artery Mid; RCAD – Right Coronary Artery Distal; Kappa – Statistical measure of inter-rater agreement; p-value – Probability value (significance level); AngioBoost – Knowledge-based software for coronary angiography enhancement.

Table 4 presents the Kappa contingency coefficient for observations made using routine angiography and Angioboost, analyzed separately for the first and second physicians. The findings indicate that the second physician's observations consistently demonstrated a higher contingency coefficient across all cases compared to the first physician. This suggests greater consistency and agreement in the second physician’s evaluations when using both diagnostic methods. These results highlight potential differences in interpretation between the two physicians and emphasize the role of observer experience and judgment in assessing coronary artery occlusions.

Table 4. Kappa contingency coefficient for observations using routine angiography and Angioboost, compared between the first and second physicians

		Angioboost			
		First physician		Second physician	
		P-value	Kappa	P-value	Kappa
Standardangiography	LMO+LMD	<0.001	64.0	<0.001	78.0
	LADO+LADP+LADM+LADD	<0.001	78.2	<0.001	91.7
	LCXO+LCXP+LCXM+LCXD	<0.001	70.7	<0.001	88.4
	RCAO+RCAP+RCAM+RCAD	<0.001	74.5	<0.001	90.8

LMO – Left Main Ostial; LMD – Left Main Distal; LADO – Left Anterior Descending Ostial; LADP – Left Anterior Descending Proximal; LADM – Left Anterior Descending Mid; LADD – Left Anterior Descending Distal; LCXO – Left Circumflex Ostial; LCXP – Left Circumflex Proximal; LCXM – Left Circumflex Mid; LCXD– Left Circumflex Distal; RCAO – Right Coronary Artery Ostial; RCAP – Right Coronary Artery Proximal; RCAM – Right Coronary Artery Mid; RCAD – Right Coronary Artery Distal; Kappa – Statistical measure of inter-rater agreement; p-value – Probability value (significance level); AngioBoost – Knowledge-based software for coronary angiography enhancement.

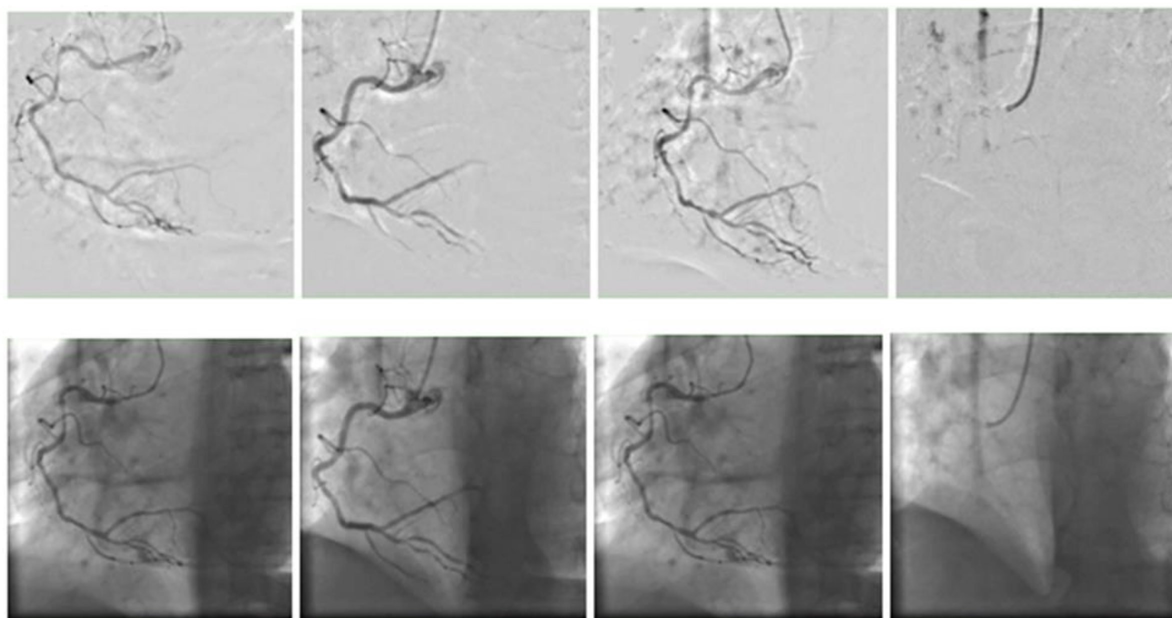

Figure 1. Angiography performed using the standard angiography system (upper row) was compared with the AngioBoost system (lower row), assessing the visualization of the RCA in terms of region, stent placement, restenosis, and stent positioning, with comparable results between the two methods.

Table 5 presents the Kappa contingency coefficient for the first and second physicians' observations using routine angiography and Angioboost. The contingency coefficient for the first physician's observations was 74.7%, while the second physician demonstrated a higher agreement level of 90.1% when using the two diagnostic methods. Additionally, the table provides an overall assessment of diagnostic consistency between the two methods.

The results indicate a high level of agreement in identifying patent vessels (96.3%), mild lesions (79.9%), moderate lesions (58.0%), significant lesions (91.2%), and cut vessels (96.8%). The overall Kappa contingency coefficient was 88.2%, reflecting a very strong level of agreement between routine angiography and Angioboost in diagnosing coronary artery occlusion. These findings further support the reliability and effectiveness of

Angioboost as a complementary tool for standard angiographic assessments.

Table 6 presents the Kappa contingency coefficient for the first and second physicians' observations, analyzed separately for routine angiography and Angioboost. The findings indicate that the overall diagnostic agreement using routine angiography is 80.3%, whereas the agreement using Angioboost is comparatively lower at 64.3%. These results suggest that while both methods demonstrate substantial diagnostic consistency, routine angiography exhibits a higher overall agreement between observers. This difference may be attributed to the learning curve associated with software-based analysis or variations in interpretation between the two methods.

Table 5. Over-all kappa contingency coefficient for the first and second physicians' observations using routine angiography and angioboost

		Diagnosis with Angioboost						
		Patent	Mild	Moderate	Significant	Cut	Kappa	P-value
First physician using standard angiography	Patent	(94.4) 1676	89 (5.0)	6 (0.3)	5 (0.3)	0	74.7	<0.001
	Mild	(23.0) 102	(73.2) 325	8 (8.1)	9 (2.0)	0		
	Moderate	3 (7.7)	(38.5) 15	14 (35.9)	7 (17.9)	0		
	Significant	2 (1.4)	6 (4.2)	9 (6.3)	124 (86.7)	2 (1.4)		
	Cut	0	0	0	2 (6.1)	(39.9) 31		
Second physician using standard angiography	Patent	(98.2) 1786	32 (1.8)	0	0	0	90.1	<0.001
	Mild	38 (9.8)	(87.6) 340	10 (2.6)	0	0		
	Moderate	0	5 (10.2)	37 (75.5)	7 (14.3)	0		
	Significant	0	0	7 (4.6)	145 (95.4)	0		
	Cut	0	0	0	0	(100.0) 29		
Total cases using standard angiography	Patent	(96.3) 3462	(3.4) 121	7 (0.2)	5 (0.1)	0	88.2	<0.001
	Mild	(16.0) 140	(79.9) 665	18 (2.2)	9 (1.1)	0		
	Moderate	3 (3.4)	(22.7) 20	51 (58.0)	14 (15.9)	0		
	Significant	2 (0.7)	6 (2.0)	16 (5.4)	269 (91.2)	2 (0.7)		
	Cut	0	0	0	2 (3.2)	(96.8) 60		

Table 6. Comparison of the Kappa contingency coefficient of the observations of the first and second physicians, separately from the two diagnostic methods of routine angiography and Angioboost

		Second physician			
		Angioboost		Standard angiography	
		P-value	Kappa	P-value	Kappa
First physician	LMO+LMD	<0.001	41.2	<0.001	52.1
	LADO+LADP+LADM+LADD	<0.001	66.2	<0.001	77.2
	LCXO+LCXP+LCXM+LCXD	<0.001	62.2	<0.001	79.6
	RCAO+RCAP+RCAM+RCAD	<0.001	64.33	<0.001	85.8
	Total	<0.001	64.3	<0.001	80.3

LMO – Left Main Ostial; LMD – Left Main Distal; LADO – Left Anterior Descending Ostial; LADP – Left Anterior Descending Proximal; LADM – Left Anterior Descending Mid; LADD – Left Anterior Descending Distal; LCXO – Left Circumflex Ostial; LCXP – Left Circumflex Proximal; LCXM – Left Circumflex Mid; LCXD– Left Circumflex Distal; RCAO – Right Coronary Artery Ostial; RCAP – Right Coronary Artery Proximal; RCAM – Right Coronary Artery Mid; RCAD – Right Coronary Artery Distal; Kappa – Statistical measure of inter-rater agreement; p-value – Probability value (significance level); AngioBoost – Knowledge.

Discussion

This study aimed to compare the diagnostic accuracy of AngioBoost software with conventional angiography in assessing the degree of coronary artery occlusion. A total of 174 patients underwent routine angiography, and their results were analyzed using both conventional angiography and Angioboost software by two independent cardiologists. The results demonstrated a high level of agreement between the two methods, with an overall Kappa coefficient of 88.2%, reflecting very good diagnostic consistency. These findings indicate that AngioBoost can reliably assist clinicians in the interpretation of angiographic data by enhancing vessel visibility and reducing background interference. The diagnostic performance of AngioBoost showing over 90% agreement in identifying significant and cut lesions suggests that the software can provide accuracy comparable to established quantitative coronary angiography (QCA) methods, but with lower operational complexity and faster image analysis (14, 15).

Previous studies have also explored the role of image-processing algorithms and computer-assisted systems in improving coronary lesion detection. For instance, Kiani et al. (16) and Salehi et al. (17) reported similar success in identifying coronary arteries and stenosis points using automated extraction techniques. However, unlike these methods, AngioBoost integrates both enhancement and diagnostic classification within a single framework, making it more practical for clinical use.

Compared with conventional QCA software such as CAAS and QAngio, which require manual delineation of vessel borders and operator training, AngioBoost's fully automated enhancement process reduces observer variability. The results of this study confirm that, while routine angiography remains the gold standard for coronary evaluation, post-processing with AngioBoost can significantly improve image interpretability, potentially minimizing diagnostic errors and the need for repeated imaging (18). The contingency coefficients were calculated to assess the agreement between the two diagnostic methods. For the first physician, the contingency coefficient ranged from 62.6% for LMO to 88.7% for RCAO, while for the second physician, the values ranged from 56.4% for LMO to 95.8% for LADD. When comparing the observations of both physicians, the lowest agreement (46.8%) was observed in the LMO+LMD vessels, while a higher level of agreement was seen in other vascular regions, including LADO+LADP+LADM+LADD (71.7%), LCXO+LCXP+LCXM+LCXD (71.0%), and LCAO+RCAP+RCAM+RCAD (77.8%).The overall Kappa agreement coefficient for the first and second physicians' observations using routine angiography and Angioboost was 74.7% and 90.1%, respectively. Additionally, the total diagnostic contingency across both methods was 88.2%, indicating a very high level of agreement. Specifically, agreement rates for patent vessels, mild lesions, moderate lesions, significant lesions, and completely occluded vessels were 96.3%, 79.9%, 58.0%, 91.2%, and 96.8%, respectively. Notably, the contingency coefficient for observations made using routine angiography was 80.3%, while with Angioboost, it was slightly lower at 64.3%.

Several studies have explored different diagnostic methods for assessing coronary artery occlusion. Abedi et al. reported an 84% diagnostic accuracy for myocardial perfusion scanning in detecting coronary artery disease (CAD) compared to angiography, highlighting its effectiveness as a non-invasive method (19). Similarly, Johansen et al. found an 88% accuracy rate for myocardial perfusion scans in CAD detection (20). Daghighi et al. examined the diagnostic accuracy of 64-slice computed tomography (CT) compared to invasive coronary angiography (ICA)**,** finding correlation rates of 86% in the RCA**,** 77% in the LM**,** 74% in the LAD**,** and 78% in the LCA**,** demonstrating its high diagnostic capability**.** However, it remains unable to fully replace invasive angiography (21). Hosseini et al. compared multislice 64 CT angiography with conventional angiography in detecting ≥50% stenosis in coronary graft vessels, demonstrating its high accuracy in evaluating venous and arterial grafts, thereby reducing the need for conventional angiography in post-CABG patients (22).

Parizad et al. examined the impact of comparative statistical iterative reconstruction methods on CT coronary angiography image quality and radiation dose reduction**,** showing that the ASiR method significantly lowered radiation exposure without compromising image quality (23). Other studies have also introduced machine learning and AI-based approaches for improving diagnostic accuracy, such as Kiani et al.'s phasic average classification algorithm, which accurately identified artery width, occlusion location, intensity, and blood flow speed (16), and Salehi et al.'s tree-tracing algorithm, which demonstrated superior performance in detecting coronary artery centers in cardiac angiography images (17). Over the past three decades, significant advancements in medical imaging technology have contributed to more accurate and efficient diagnostic methods (24). However, the high cost and limited accessibility of certain advanced technologies present challenges to their widespread adoption (25). Not all modern imaging techniques offer substantial improvements

over existing methods, and some lack strong evidence supporting better patient outcomes (26). Therefore, before integrating new diagnostic technologies, thorough safety and performance evaluations must be conducted to validate their clinical effectiveness.

The present study evaluated the diagnostic potential of Angioboost software, developed by researchers at Amir Kabir University, against routine angiography as the standard method. The findings demonstrated that Angioboost provides acceptable diagnostic accuracy and high contingency levels, suggesting its potential superiority over some foreign alternatives. While improvements in image quality and algorithmic performance are still needed, the software has shown promising clinical applications and could serve as a valuable tool for assisting physicians in CAD diagnosis. The AngioBoost software processes raw digital image data acquired directly from standard x-ray angiography systems (DICOM format) used during routine diagnostic procedures. No separate imaging sessions or external datasets are required. The software applies knowledge-based algorithms to improve vessel contrast, suppress background motion artifacts, and highlight lumen boundaries, allowing for clearer visualization of occlusions and stenosis.It is important to emphasize that AngioBoost does not replace routine angiography as an imaging modality; rather, it enhances the diagnostic value of existing angiograms. By improving image clarity and interpretability, it may reduce the need for additional angiographic projections, shorten analysis time, and improve inter-observer consistency. In the long term, such post-processing tools could lower procedural costs and patient exposure to contrast agents and radiation, particularly in centers lacking access to advanced quantitative coronary analysis (QCA) systems. Overall, the present results demonstrate that AngioBoost achieves diagnostic performance consistent with global benchmarks for computer-assisted angiographic interpretation, while offering greater accessibility and lower cost for regional cardiology centers.

Despite these promising results, the study has several limitations. The sample size of 174 patients, though informative, may not fully represent broader patient populations, and larger, multi-center studies are necessary for further validation. Observer variability was also evident, as the agreement levels varied between the two physicians, suggesting that experience and interpretation differences may influence diagnostic outcomes. The study also focused on diagnostic accuracy without assessing long-term patient outcomes, making it necessary to conduct follow-up studies evaluating patient prognosis and treatment efficacy based on Angioboost-assisted diagnoses. Furthermore, while this study compared routine angiography and Angioboost, it did not include comparisons with other advanced imaging modalities such as CT angiography, MRI angiography, or IVUS, which could provide a more comprehensive evaluation of Angioboost's performance.

The results suggest that Angioboost software demonstrates strong agreement with routine angiography in diagnosing coronary artery occlusion. While routine angiography remains the gold standard, Angioboost has shown significant potential as a complementary diagnostic tool. Further technological refinements, larger-scale studies, and multi-center trials are needed to optimize its performance and clinical applicability. If further developed, Angioboost could serve as a reliable and cost-effective alternative in CAD diagnosis, improving diagnostic efficiency and reducing physician workload while maintaining high accuracy in lesion detection.In summary, AngioBoost operates on the same angiographic data obtained during routine procedures, requiring no extra imaging or patient intervention. While it cannot fully substitute invasive angiography, its integration into the diagnostic workflow can significantly enhance the interpretation of angiograms by optimizing vessel visibility and diagnostic precision. Therefore, AngioBoost should be viewed as a complementary diagnostic aid that strengthens routine angiographic assessment rather than a replacement technique.

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Ethics approval: This study was conducted in accordance with the ethical standards of the Declaration of Helsinki and approved by the Ethics Committee of Iran University of Medical Sciences, Tehran, Iran (Ethics Code: IR.RHC.REC.1404.141). Written informed consent was obtained from all participants prior to inclusion in the study. All collected data were anonymized to ensure confidentiality. No additional procedures beyond standard diagnostic angiography were performed, and participants did not incur any additional risks or costs as part of this research.

Conflict of interests: The authors whose names are listed on the title page and shared in the manuscript entitled: "Comparing the Accuracy of Angioboost Software versus Routine Angiography for assessing the degree of Coronary Artery Lesion Occlusion" certified that they have no

affiliations with or involvement in any organization or entity with any financial or non-financial interests.

Authors' contribution: Corresponding Author: Dr Maedeh Dastmardi was conceived the ideas and design the study, Performed data analysis and interpretation, and interpretation of the data, statistical analysis, final revision of the manuscript. Co-Authors: Dr Vahid Akhondi performed data collection, statistical analysis and provided revision to scientific content of manuscript. Dr Farshad Shakerian wrote most of the paper. Dr Ali sarreshtehdari participated in the design of the study and performed statistical analysis. Dr Ebrahim Ghobadi provided revision. All authors read and approved the final manuscript.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent to participate: This study was approved by the Research Ethics Committee of Iran University of Medical. A consent form was completed by the legal guardians of all participants.

Consent for publication: All patients included in this research gave written informed consent to publish the data contained within this study.

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