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Original Article

Assessment of the EAS Index for Diagnosis of Coronary Artery Disease in Elective Coronary Angiography Candidates

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ABSTRACT

Background: Coronary artery disease (CAD) is the leading cause of mortality, and its gold standard diagnostic method is invasive coronary angiography. Nonetheless, efforts are still in progress to find noninvasive methods for diagnosing CAD. The present study aimed to determine the EAS index as a novel diagnostic tool for CAD.

Methods: This study was performed on elective coronary angiography candidates. Patients underwent transthoracic echocardiography, and the EAS index was calculated. Coronary angiography films were interpreted, and the SYNTAX score was calculated by an interventional cardiologist blinded to echocardiography results.

Results: This study enrolled 60 patients: 32 were in the CAD group, and 28 were in the normal coronary group. The median age was 53 (IQR, 18) years, and 51.7% of participants were female. The SYNTAX score in patients with CAD was calculated as 16.7 (SD, 8.08). The median EAS in the CAD group (0.18 [IQR, 0.16]) was significantly greater than in the normal coronary group (0.15 [IQR, 0.12]; $P = .045$). A moderate negative correlation was observed between the SYNTAX score and left atrial (LA) volume ($r = -.26$; $P = .041$), LA volume index ($r = -.265$; $P = .04$), and left ventricular systolic tissue velocity (LV S') ($r = -.254$; $P = .05$) in the CAD group. Additionally, a positive association was found between the SYNTAX score and EAS ($r = .35$; $P = .005$) in patients with CAD.

Conclusions: The EAS index was higher in patients with CAD than in those with normal coronaries, suggesting potential diagnostic utility. Its positive correlation with the SYNTAX score indicates a possible role in severity assessment. Further studies are warranted to confirm these findings. ***(Iranian Heart Journal 2026; 27(3): 37-48)***

KEYWORDS: coronary artery disease; echocardiography; EAS index; SYNTAX score

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Heart disease is the world's leading reason of mortality, with coronary artery disease (CAD) being the most prevalent type.[1] Obstructive CAD is evaluated utilizing coronary angiography as the gold standard modality.[2] Accordingly, angiography-based SYNTAX scores are useful for assessing CAD severity.[3] Even though coronary angiography is an invasive procedure, it is generally considered a safe procedure, with a risk of major complications, such as embolization, myocardial infarction, acute renal failure, and arrhythmias, of less than 2%.[4, 5]

In recent years, echocardiographic parameters have been employed for noninvasive assessment of CAD.[6] The presence of ischemia can result in dysfunction of the systolic or diastolic function of the left ventricle (LV).[7] When diastolic dysfunction occurs, the left atrium (LA) is not emplaced correctly, the LV is not filled properly, lung pressure is raised, and exercise is not tolerated.[8] As a consequence of diastolic dysfunction, heart failure, hospitalizations, and mortality are also exacerbated.[9]

Echocardiographic parameters, particularly diastolic function parameters, have been investigated previously in relation to CAD.[10, 11] In this regard, Liu et al[12] showed a remarkable association between some echocardiographic parameters—namely E/A, deceleration time, and S'—and the SYNTAX score as an indicator of CAD severity.[12]

Recent attention has been centralized on the EAS index [E'⁄ (A' × S')], which can measure systolic and diastolic cardiac function.[13] In the population with cardiovascular risk factors, EAS has been shown to accurately predict cardiac function and mortality.[14] Additionally, Lee et al[15] demonstrated that this index effectively predicted functional capacity and prognosis in patients with heart failure. In contrast with other parameters limited to systolic or diastolic function, EAS simultaneously shows systolic and diastolic function.[16]

The present study aimed to evaluate the efficacy of the EAS index in diagnosing CAD in candidates for elective angiography compared with a normal coronary group.

METHODS

Study Population

In a 2-group cross-sectional investigation, we evaluated patients referred to our department for elective angiography. The exclusion criteria were previous revascularization (percutaneous coronary intervention or Coronary artery bypass surgery, previous myocardial infarction, heart failure, uncontrolled diabetes, uncontrolled hypertension, having pacemakers or implantable cardioverter-defibrillators, ejection fraction (EF) < 50%, atrial fibrillation or bundle branch block in electrocardiograms (ECG), moderate or severe valvular heart disease, and having inappropriate acoustic windows precluding transthoracic echocardiography.

Coronary Angiography

The coronary angiography procedure was performed by a cardiologist who specializes in interventional cardiology. After angiography, interpretations and SYNTAX scores were stated by the interventional cardiologist, who was blind to the echocardiography findings. The SYNTAX score is an angiographic tool used to quantify the anatomical complexity of CAD. It is calculated by assigning weighted points to each coronary lesion with ≥ 50% diameter stenosis in vessels ≥ 1.5 mm in diameter, considering lesion characteristics such as location, bifurcation involvement, vessel tortuosity, calcification, thrombus, and chronic total occlusion. The final score is the sum of all lesion scores, with higher values indicating more complex and severe CAD.

Based on the angiography results (presence or nonexistence of atherosclerotic plaque in the coronary artery), the study participants were categorized into 2 groups of normal coronary and CAD patients.

Echocardiography

Echocardiographic results were derived from the Echocardiography Registry (Mashhad University of Medical Sciences). Transthoracic echocardiography was performed in all participants by an expert echocardiography fellow. All echocardiography procedures were performed utilizing a Philips IE33 imaging system (Philips Healthcare, Andover, MA, USA) with an S5-1 probe (2.5 and 3.5 MHz). All echocardiographic measurements were collected in accordance with the American Society of Echocardiography (ASE) guidelines.[17]

Echocardiographic measurements included left ventricular internal diameter at end diastole (LVIDd), left ventricular internal diameter at end systole (LVIDs), interventricular septal thickness at diastole (IVSd), end-diastolic volume (EDV), EDV index, left ventricular ejection fraction (LVEF), LA area, LA volume, LA volume index (LAVI), right ventricular (RV) middle, RV S’, right atrial (RA) area, RA volume, E’, S’, A’, aortic annulus, ascending aorta, and LAVI/A’.

E velocity was measured using the ASE 2016 diastolic guideline (apical 4-chamber view with color flow imaging for optimal alignment of pulsed-wave Doppler with blood flow). The pulsed-wave Doppler sample volume (2-mm axial size) was placed between the mitral leaflet tips, and a low wall filter setting (100–200 MHz) and low signal gain were employed. For tissue Doppler imaging, the apical 4-chamber view was employed with a pulsed-wave Doppler sample volume (5-mm axial size) at the lateral and septal basal regions to compute the average E' velocity. Additionally, ultrasound system presets for wall filter and lowest signal gain were used.[18] The average E' was calculated by adding the septal and lateral E' and dividing the sum by 2.

Besides these parameters, EAS (Figure 1) was calculated using the following formula [19]:

$$EAS = \frac{E'}{A' * S'}$$

The EAS index is a novel indicator for the assessment of both systolic and diastolic function. It is also mentioned as an appropriate tool in addition to LVEF for risk classification.[20]

Estimation of the Sample Size

With a power (β) of 80% and a significance level (α) of .05, the sample size was calculated using the formula for comparing 2 mean values for 1 variable (EAS) based on a previous study.[21] The calculated sample size was 26 participants per group; therefore, an investigation including 52 participants was conducted

$$.N = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \times (\sigma_1^2 + \sigma_2^2)}{(\mu 1 - \mu 2)^2}$$

Which $Z_{1-\frac{\alpha}{2}}$ = 1.96, $Z_{1-\beta}$ = 0.84, $\mu 1$ = 0.11, $\mu 2$ = 0.08, σ_1= 0.05, and σ_2= 0.02.

Statistical Analysis

Data analysis was performed using SPSS software, version 22 (IBM Corp, Chicago, IL, USA). Figures were prepared using GraphPad Prism software, version 8.01 (GraphPad Software Inc, USA). Normality was assessed using the Shapiro-Wilk test. Continuous variables with normal distributions were analyzed by independent samples *t* tests and presented as mean (SD). Continuous variables with non-normal distributions were presented as median (IQR) and compared using Mann-Whitney *U* tests. The χ^2 test was applied to analyze categorical variables, which were presented as counts and percentages. Finally, the correlation between SYNTAX scores and measured parameters in participants with CAD was evaluated using Spearman correlation coefficients. Statistical significance was defined as $P < .05$.

RESULTS

Overall, 60 patients were recruited in the present investigation: 32 in the CAD group and 28 in the normal coronary group.

Demographic Characteristics

The median age was 53 (18) years, and 51.7% of participants were female. The demographic characteristics and comorbidities of the studied participants are represented in Table 1. No significant differences were observed in age, sex, height, weight, body mass index (BMI), body surface area (BSA), and other comorbidities between the 2 studied groups. Nevertheless, 5 cases (15.6%) of peripheral artery disease were found in the CAD group, and no cases were reported in the normal coronary group ($P = .029$) (Table 1).

Angiographic Results

The SYNTAX score in participants with CAD was 16.7 (SD, 8.08) (Figure 2A). Among the CAD group, 14 (43.8%) had single-vessel stenosis, 11 (34.4%) had double-vessel stenosis, and 7 (21.9%) had triple-vessel coronary artery stenosis (Figure 2B).

Echocardiographic Findings

Echocardiographic results for the 2 groups are summarized in Table 2. No marked differences were found in any echocardiographic parameters between the CAD and normal groups (Table 2).

EAS Calculation

The EAS index in the 2 studied groups are illustrated in Figure 3. The median of EAS in the CAD group (0.18 [0.16]) was meaningfully greater than that in the normal coronary group (0.15 [0.12]; $P = .045$).

Correlation Between the SYNTAX Score and Measured Variables

The correlation between the SYNTAX score and demographic and echocardiographic variables in patients with CAD are summarized in Table 3. Results showed a moderate and negative correlation between the SYNTAX score and LA volume ($r = -.26$; $P = .041$), LAVI ($r = -.265$; $P = .04$), and S' ($r = -.254$; $P = .05$) in the CAD group. Additionally, a meaningful positive correlation was observed between the SYNTAX score and EAS in participants with CAD ($r = .35$; $P = .005$).

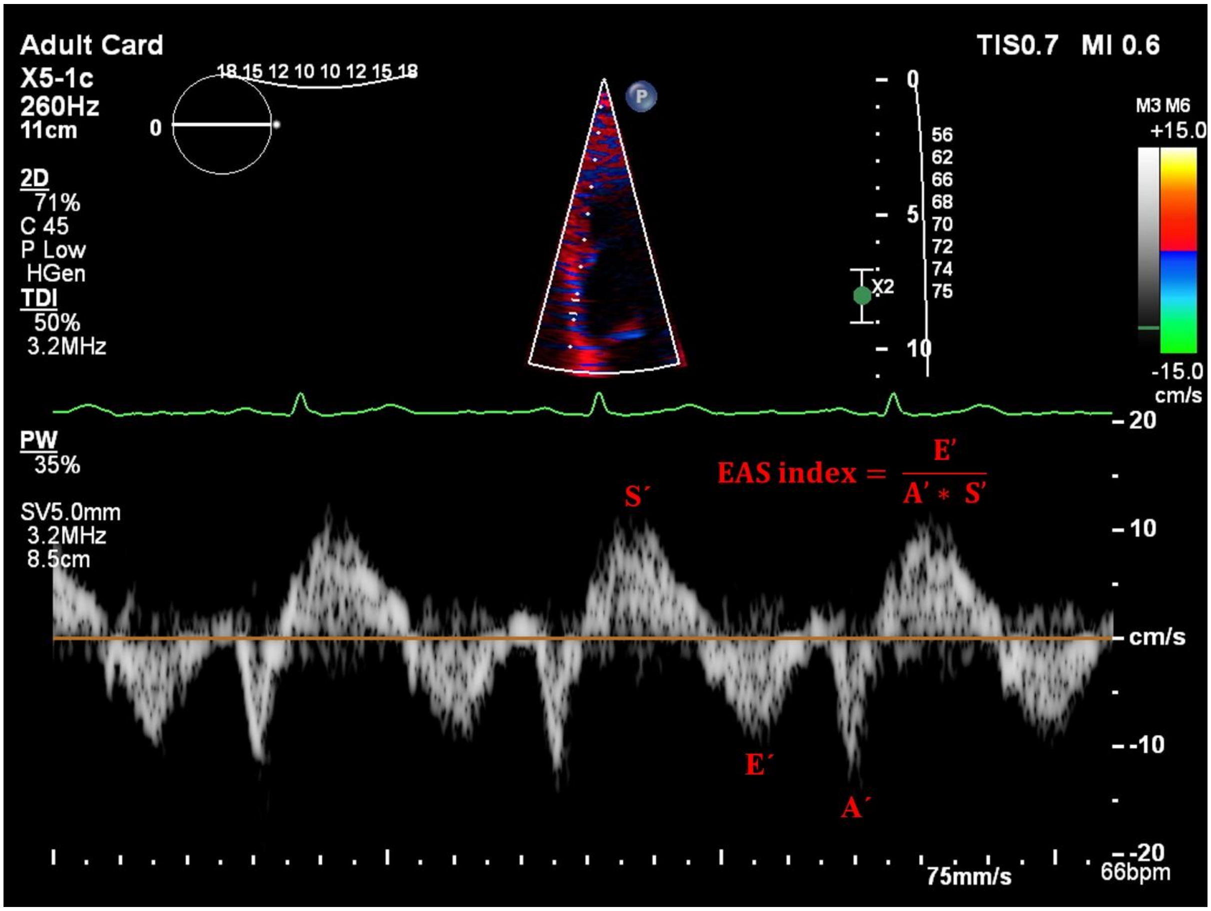

Figure 1. Transthoracic echocardiography measurements: The EAS index was calculated as [E'/(A' × S')].

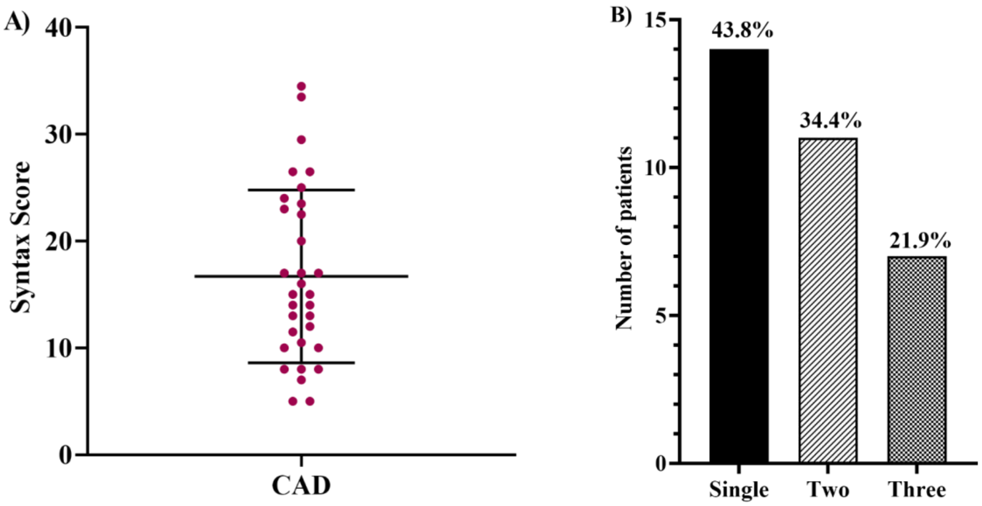

Figure 2. A) The SYNTAX score and **B)** the number of involved vessels in patients with coronary artery disease (CAD) Data are presented as mean (SD) and No. (%).

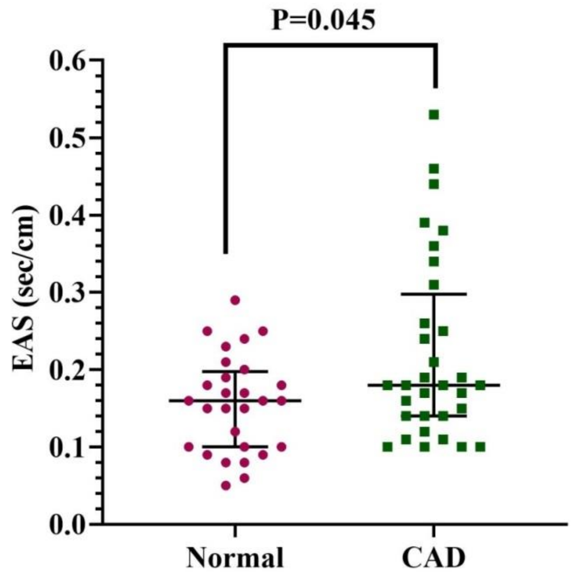

Figure 3. The EAS index in participants with coronary artery disease (CAD) and those with normal coronary arteries Data are presented as median (IQR) and analyzed using the Mann–Whitney *U* test.

Table 1. Demographic Characteristics of the Studied Participants

Characteristic		CAD (n = 32)	Normal (n = 28)	Total (n = 60)	*P*
Age, y⟂		53.5 (24)	52.5 (14)	53 (18)	.45 [a]
Sex †	Male	17 (53.1)	12 (42.9)	29 (48.3)	.42 [b]
	Female	15 (46.9)	16 (57.1)	31 (51.7)	
Height, cm ‡		164.7 (9.7)	165.7 (12.3)	164.88 (10.7)	.73 [c]
Weight, kg ‡		68.5 (18)	71.0 (30)	69.0 (24.0)	.27 [a]
BMI, kg/m^2 ‡		26.1(9.37)	27.5 (9.1)	26.5 (9.1)	.41 [c]
BSA, m^2 ‡		1.77 (0.29)	1.82 (0.39)	1.78 (0.21)	.35 [c]
Diabetes †	Yes	4 (12.5)	1 (3.6)	5 (8.3)	.21 [b]
	No	28 (87.5)	27 (96.4)	55 (91.7)	
Hypertension †	Yes	11 (34.4)	8 (28.6)	19 (31.7)	.23 [b]
	No	21 (65.5)	20 (71.4)	41 (68.3)	
Dyslipidemia †	Yes	13 (40.6)	6 (21.4)	19 (31.7)	.11 [b]
	No	19 (59.4)	22 (78.6)	41 (68.3)	
Familial history †	Yes	8 (25.0)	5 (17.9)	13 (21.7)	.5 [b]
	No	24 (75.0)	23 (82.1)	47 (78.3)	
Peripheral arterial disease †	Yes	5 (15.6)	0 (0.0)	5 (8.3)	.029 [b]
	No	27 (84.4)	28 (100.0)	55 (91.7)	
CKD †	Yes	3 (9.4)	0 (0.0)	3 (5.0)	.096 [b]
	No	29 (90.6)	28 (100.0)	57 (95.0)	
Smoker †	Yes	11 (34.4)	8 (28.6)	19 (31.7)	.45 [b]
	No	21 (65.6)	20 (71.4)	41 (68.3)	

[a] Mann–Whitney *U* test, [b] χ^2, and [c] independent samples *t* test
Data are presented as ⟂ median (IQR), † No. (%), and ‡ mean (SD).
BMI: body mass index; BSA: body surface area; CKD: chronic kidney disease; CAD: coronary artery disease

Table 2. The Echocardiographic Results of the Studied Participants

Characteristic		CAD (n = 32)	Normal (n = 28)	Total (n = 60)	*P*
LVIDd, cm ‡		4.73 (0.59)	4.87 (0.53)	4.79 (0.56)	.34 [a]
LVIDs, cm ‡		2.93 (0.4)	2.97 (0.55)	2.95 (0.47)	.76 [a]
IVSd, cm ‡		0.87 (0.18)	0.89 (0.18	0.88 (0.18)	.68 [a]
LVEF, % ⟂		19 (31.7)	19 (31.7)	60.0 (5.0)	.108 [b]
EDV, mL ‡		100.32 (26.45)	102.71 (43.17)	101.41 (34.68)	.81 [a]
EDV index, mL/m^2		56.82 (15.01)	55.48 (18.25)	56.19 (16.42)	.78 [a]
LA area, cm^2 ‡		19.84 (4.9)	20.89 (4.16)	20.34 (4.56)	.26 [a]
LA volume, mL ‡		58.81 (23.08)	65.25 (20.08	61.86 (21.77)	.26 [a]
LAVI ‡		33.43 (13.31)	35.32 (8.94)	34.33 (11.39)	.52 [a]
RV middle, cm ⟂		3.04 (0.67)	2.9 (0.55)	2.9 (0.55)	.77 [b]
RV S', cm/s ‡		12.56 (1.85)	12.54 (1.66)	12.6 (1.74)	.82 [a]
RA area, cm^2 ⟂		14.0 (4.8)	14.25 (6.3)	14.0 (5.0)	.31 [b]
RA volume, mL ⟂		34.5 (16)	38.0 (19)	35.0 (18.0)	.43 [b]
E', cm/s ‡		8.39 (2.31)	7.85 (2.61)	8.14 (2.47)	.4 [a]
S', cm/s ‡		6.7 (1.6)	7.37 (1.5)	7.01 (1.58	.109 [a]
A', cm/s ‡		7.17 (2.2)	7.5 (1.88)	7.32 (2.05)	.54 [a]
Aortic annulus, cm ⟂		2.1 (0.26)	2.1 (0.29)	2.1 (0.26)	.73 [b]
Ascending aorta, cm ⟂		3.07 (0.6)	3.1 (0.8)	3.1 (0.78)	.63 [b]
LAVI/A' ⟂		4.5 (3.43)	4.55 (1.7)	4.5 (2.3)	.52 [b]
Diastolic Dysfunction	Normal	10 (31.25)	11 (39.28)	21 (35.0)	.8 [c]
	1	18 (56.25)	14 (50.0)	32 (53.3)	
	2	4 (12.5)	3 (10.7)	7 (11.66)	
	3	0 (0.0)	0 (0.0)	0 (0.0)	

[a] Independent samples *t* test, [b] Mann–Whitney *U* test, and [c] χ^2 test
Data are presented as ⟂ median (IQR) and ‡ mean (SD).
LVIDd: left ventricular internal diameter end diastole; LVIDs: left ventricular internal diameter end-systole; IVSd: interventricular septum thickness in diastole; LVEF: left ventricular ejection fraction; EDV: end-diastolic volume; LA: left atrial; LAVI: left atrial volume index; RV: right ventricle

Table 3. The Correlation Between the SYNTAX Score and Measured Parameters in Participants With CAD

Parameter	*P*	*r* [a]
Age	.82	- .03
Height	.55	.08
Weight	.66	- .06
BMI	.61	- .066
BSA	.87	- .022
LVIDd	.25	- .15
LVIDs	.39	.11
IVSd	.38	- .16
LVEF	.22	.16
EDV	.38	.13
EDV index	.29	.15
LA area	.104	- .21
LA Volume	.041	- .26
LAV index	.04	- .265
RV Mid	.98	.003
RV S'	.85	- .02
RA area	.25	- .15
RA volume	.33	- .13
E'	.37	.11
S'	.05	- .254
A'	.09	- .21
Aortic annulus	.74	.043
Asc aorta	.52	- .84

EAS	.005	.356
LAVI/A'	.58	- .07

[a] Correlations were assessed using the Spearman correlation.
BMI: body mass index; BSA: body surface area; LVIDd: left ventricular internal diameter end diastole; LVIDs: left ventricular internal diameter end-systole; IVSd: interventricular septum thickness in diastole; LVEF: left ventricular ejection fraction; EDV: end-diastolic volume; LA: left atrial; LAVI: left atrial volume index; RV: right ventricle

DISCUSSION

The present investigation aimed to determine the relationship between echocardiographic indices and the presence and severity of CAD in candidates for elective angiography. The EAS index, recently proposed as an index of LV systolic and diastolic function, was strongly and positively associated with the presence and severity of CAD in these participants.

CAD is associated with high mortality rates worldwide. Coronary angiography is the gold standard for diagnosing CAD.[23] Be that as it may, angiography is an invasive procedure; regarding complications and costs, it may pose concerns for physicians and patients.[24, 25] Thus, investigating noninvasive methods that can more accurately predict CAD and assist in patient selection for angiography remains a significant research interest.[26, 27]

Echocardiography can be used as a simple and inexpensive method to diagnose CAD.[28] Tissue Doppler imaging provides a comprehensive assessment of diastolic function, which is impaired in the early stages of CAD.[29] Diastolic dysfunction and delayed filling lead to annular motion abnormalities, which can be detected by tissue Doppler imaging.[30] In this regard, Bolognesi et al[31] compared 16 participants with CAD and normal EF with 6 participants with normal coronary arteries in terms of diastolic function parameters. They concluded that parameters such as dp/dt, E-wave acceleration, peak E′ velocity, and E-wave deceleration in participants with CAD were significantly different from those in the control group. They reported that, despite preserved LV function, S′, representing longitudinal systolic function, was reduced in participants with CAD compared with the control group. Similarly, Biering et al[32] showed that S′ was significantly lower in participants with ST-segment elevation myocardial infarction (STEMI) treated with primary percutaneous coronary intervention, which was associated with higher mortality. In addition, Anderson et al[33] demonstrated that lower mean S′ in participants with diabetes who were referred for angiography was associated with higher mortality and hospitalization rates. Similarly, Hoffman et al[34] evaluated 296 participants with stable angina who underwent echocardiography with tissue Doppler imaging. The results showed that E′ and S′ (odds ratios of 1.5 and 1.7, respectively) were independent predictors of CAD, and S′ was lower in the CAD group. Overall, these studies support an association between lower S′ and CAD.

Our results also suggested a notable negative correlation between left ventricular systolic tissue velocity (LV S′) and the SYNTAX score in participants with CAD.

Our findings revealed no significant difference in E′ values between the groups of participants with CAD and the control group. In contrast, Hoffman et al[34] and Fernandez et al[35] identified E′ as a predictor of CAD. Similarly, Polak et al[36] emphasized the predictive value of E′ for CAD. The smaller sample size and stricter exclusion criteria in this investigation may explain the lack of statistical significance. Pathophysiologically, the relationship between E′ and CAD is explained by the fact that E′ is primarily dependent on myocardial relaxation, an active, energy-dependent process that is rapidly affected by ischemia.

A′ failed to predict CAD in the current study. Consistent with our findings, Hoffman et al[34] reported no such relationship. Other studies have reported biphasic A′ changes in response to CAD severity,[37] which may explain why A′ is not a reliable predictor of CAD.

Because the use of a single parameter is limited, combined variables have been investigated in recent studies.[38]

The EAS index calculated as E'/(A' × S') is a composite tissue Doppler index that has recently gained attention.[39] Our results revealed a strong and positive association between the SYNTAX score and EAS in patients with CAD (r = .35; P = .005). Chiming with our findings, Lee et al[15] examined echocardiographic indices, as well as the EAS index, in 230 patients with decompensated heart failure. Their results showed that the EAS index was able to accurately distinguish patients with NYHA functional classes III and IV from those with NYHA functional classes I and II. The EAS index also had a higher correlation with mortality rate and hospitalization than conventional indices.

In a population-based study of 1036 individuals, Mogelvang et al[37] investigated the association between the EAS index—as a marker of cardiac systolic and diastolic function—and mortality. The results supported the EAS index as an independent and robust predictor of mortality in this population. Another community-based study emphasized that preclinical systolic and diastolic functional abnormalities, which were not detectable with conventional indicators, were identified using the EAS index and pro–B-type natriuretic peptide (pro-BNP) levels.[40] Recently, Kong et al[20] investigated the prognostic value of the EAS index in patients with obstructive CAD. They evaluated 415 patients with obstructive CAD and followed them up for 25.9 months. The findings revealed that the EAS index was an independent predictor of major adverse cardiovascular events in patients with obstructive CAD. These studies are in line with our findings regarding the strong and positive association between the EAS index and the SYNTAX score.

The SYNTAX score is a measure of the anatomical complexity and severity of CAD, not a diagnostic tool per se. In our analysis, the diagnostic implication of the EAS index was derived from its ability to differentiate patients with angiographically proven CAD from those with normal coronary arteries, whereas its correlation with the SYNTAX score supports its potential role in reflecting disease severity.

CONCLUSIONS

In the present study, the EAS index was significantly higher in patients with angiographically confirmed CAD than in those with normal coronary arteries, suggesting its potential utility as a noninvasive parameter to help distinguish CAD from normal coronary status. Moreover, the EAS index showed a positive correlation with the SYNTAX score, which indicates that it may also reflect the angiographic severity of coronary artery lesions. Although these findings suggest both diagnostic and severity-assessment potential for the EAS index, we acknowledge that correlation with the SYNTAX score alone does not establish diagnostic value. Larger prospective studies are warranted to further validate the EAS index for both the detection and severity assessment of CAD.

Ethics Approval and Consent to Participate

Ethics committee approval was obtained from Mashhad University of Medical Sciences for this study (IR.MUMS.MEDICAL.REC.1400.165). In addition, written informed consent was obtained from all participants.

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Data Availability Statement
On reasonable request, the corresponding author is willing to share the data underlying this study.

Conflict of Interest
The authors declare no conflicts of interest.

Consent for Publication
Not applicable.

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Author Contributions
F. G.: conceptualization, methodology, supervision, funding acquisition, investigation; S. A.: conceptualization, methodology, supervision, investigation, writing–review and editing; A. G.: conceptualization, methodology, investigation; V. R. A.: formal analysis, data curation, writing–original draft; H. P.: conceptualization, methodology, investigation; N. R.: investigation, data curation, writing–original draft, writing–review and editing; V. B. R.: investigation, formal analysis, data curation, writing–original draft, writing–review and editing.

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