

Original Article

Relationship Between Left Ventricular Diastolic Dysfunction Echocardiographic Indices and SYNTAX Score in Triple-Vessel CAD: A Cross-Sectional Study

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ABSTRACT

Background: Whether left ventricular diastolic dysfunction (LVDD) relates to anatomic coronary disease burden remains uncertain. We examined the association between echocardiographic diastolic indices and the Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (SYNTAX) score among patients with triple-vessel coronary artery disease (CAD).

Methods: We performed an analytical cross-sectional study of 153 consecutive patients with angiographically confirmed triple-vessel disease at the Dr Heshmat Rasht Heart Training Center (Iran) from 2022 through 2023. Eligible patients had blood pressure below 140/90 mm Hg and preserved systolic function; standard exclusions applied. We recorded demographics and cardiac risk factors and measured diastolic indices (left ventricular ejection fraction, E/A, average E/e', left atrial volume index, deceleration time, tricuspid regurgitation velocity, septal and lateral e', and left ventricular end-diastolic volume index). Coronary complexity was graded by the SYNTAX score (≤ 22 , low and > 22 , high). We used χ^2 , t , and Mann–Whitney tests and logistic regression (adjusted for age and sex; secondarily for diabetes and hyperlipidemia).

Results: Of 153 patients, 68 (44.4%) had low SYNTAX scores and 85 (55.6%) had high SYNTAX scores. None of the diastolic echocardiographic parameters differed between SYNTAX score groups or were independently associated with high SYNTAX scores on multivariable analysis. In contrast, diabetes and hyperlipidemia were associated with high SYNTAX scores: diabetes adjusted odds ratio (aOR) 3.71 (95% CI, 1.84 to 7.50) and hyperlipidemia aOR 2.83 (95% CI, 1.31 to 6.10).

Conclusions: In patients with triple-vessel CAD, echocardiographic indices of LV diastolic function were not associated with anatomic disease complexity, whereas diabetes and hyperlipidemia were. Larger studies across a broader spectrum of LVDD severity are warranted. (*Iranian Heart Journal* 2026; 27(4): 6-15)

KEYWORDS: diastolic dysfunction; left ventricle; coronary artery disease; severity of coronary artery involvement; SYNTAX Score

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Received: May 5, 2025

Accepted: June 21, 2026

Coronary artery disease (CAD) is the leading cause of death and the most prevalent type of cardiovascular disease globally.¹⁻³ It is classified as an atherosclerotic disease.^{4,5} When endothelial function of the arterial wall is compromised, lipoprotein droplets accumulate in the intima of the coronary arteries, initiating atherosclerosis.⁶ CAD can manifest as stable or unstable angina, myocardial infarction (MI), or sudden death,⁵ and it is the primary contributor to disability-adjusted life-years (DALYs) worldwide.⁴

Systolic function is a widely recognized factor for assessing the prognosis of patients with CAD. Nonetheless, in many cases, systolic function remains normal or preserved in patients who have undergone percutaneous coronary intervention (PCI). As myocardial ischemia often leads to diastolic dysfunction before it affects systolic function, diastolic dysfunction may serve as a more sensitive indicator of the effects of revascularization than systolic function.⁷

Left ventricular diastolic dysfunction (LVDD) is a common form of myocardial dysfunction. Evidence suggests that LVDD frequently represents the initial cardiac manifestation of myocardial ischemia,⁸ highlighting a diminished capacity of the myocardium to relax and the LV to fill adequately without elevated filling pressures. This dysfunction can stem from various factors, including LV geometry, myocardial stiffness and fibrosis, molecular mechanisms, delayed myocardial relaxation, and impaired ventricular-arterial coupling.⁹ Diastolic dysfunction is categorized into several grades: mild (grade 1, impaired relaxation), moderate (grade 2, pseudonormal), and severe (grade 3, restrictive).¹⁰ As the severity of this condition escalates, so does filling pressure, resulting in more severe consequences for patients. Echocardiography serves as an

effective tool for assessing diastolic dysfunction.¹¹

The SYNTAX score quantifies anatomic coronary complexity and guides revascularization strategies and prognosis. Whether echocardiographic diastolic indices reflect this anatomic disease burden remains uncertain: prior studies report mixed findings regarding the association of LVDD with SYNTAX score and CAD severity. Because diastolic abnormalities often precede systolic impairment, establishing whether diastolic indices track SYNTAX-defined complexity could improve risk stratification among patients with preserved systolic function. We, therefore, focused on a homogeneous cohort with angiographically confirmed triple-vessel CAD, in whom the SYNTAX score is clinically salient and anatomic disease burden is uniformly high.

This analytical cross-sectional study in patients with triple-vessel CAD aimed to:

Primary objective: Evaluate the association between echocardiographic diastolic parameters (E/A, average E/e', left atrial volume index [LAVI], deceleration time, tricuspid regurgitation velocity, septal and lateral e' velocities, LV end-diastolic volume index, and left ventricular ejection fraction [LVEF]) and SYNTAX score (≤ 22 , low; 23–32, intermediate; ≥ 33 , high; and a priori dichotomy of ≤ 22 vs > 22).

Secondary objective: Examine associations between cardiovascular risk factors (diabetes mellitus, hyperlipidemia, hypertension, smoking, and family history of CAD) and high SYNTAX score.

Prespecified hypothesis: Worse diastolic function (higher E/e', larger LAVI, abnormal E/A, shorter deceleration time, higher tricuspid regurgitation velocity, and lower e' velocities) would be associated with a higher SYNTAX score, independent of age and sex.

METHODS

Study Design and Participants

This was a single-center analytical cross-sectional study of consecutive adults with angiographically confirmed triple-vessel CAD. Patients were enrolled at Dr Heshmat Rasht Heart Training Center (Rasht, Iran), from April 2022 through May 2023. Coronary angiography and data abstraction occurred during the index admission. Comprehensive transthoracic echocardiography was performed the next day at the same center by trained cardiology fellows under attending supervision.

Inclusion criteria were age 18 years or older, angiographically confirmed triple-vessel CAD at the index procedure, blood pressure less than 140/90 mm Hg, and preserved systolic function (LVEF $\geq 50\%$). Exclusion criteria included acute MI at presentation, decompensated heart failure, atrial fibrillation, moderate-to-severe valvular disease, prior coronary artery bypass grafting, recent PCI (< 3 months), congenital heart disease, poor echocardiographic windows, and missing key data.

We aimed to include consecutive eligible patients and obtained written informed consent. The study was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1401.199).

The primary outcome was SYNTAX score (continuous), categorized a priori as low (less than 22), intermediate (23–32), or high (≥ 33) and secondarily dichotomized as ≤ 22 vs > 22 .

Primary exposures were echocardiographic indices of LV diastolic function: E/A, average E/e', LAVI (mL/m^2), deceleration time (ms), tricuspid regurgitation velocity (m/s), septal and lateral e' (cm/s), LV end-diastolic volume index (mL/m^2), and LVEF (%). Diastolic dysfunction grading followed American Society of Echocardiography and European Association of Cardiovascular Imaging (ASE/EACVI) recommendations.¹²

Covariates included age, sex, hypertension (history, systolic blood pressure ≥ 140 mm Hg, diastolic blood pressure ≥ 90 mm Hg, or treatment), diabetes mellitus (clinical diagnosis or treatment), dyslipidemia (clinical diagnosis or treatment), current smoking, and family history of premature CAD.

Data Collection and Echocardiographic Assessment

Demographic information, including age and sex, and cardiovascular risk factors were collected from the medical record and patient interview at index admission. Risk factors included smoking status, family history of CAD, hypertension, diabetes mellitus, dyslipidemia, unstable angina, stroke, and acute coronary syndrome.

Echocardiography was performed the day after angiography following ASE/EACVI recommendations, with 3 cardiac cycles averaged for Doppler measurements. Average E/e' was calculated from septal and lateral e'. Echocardiographic parameters included LVEF, LV end-diastolic volume index, LAVI, deceleration time, average E/e', tricuspid regurgitation velocity, E/A ratio, and septal and lateral e' velocities.

Diastolic dysfunction was categorized into 3 grades: mild (grade 1, impaired relaxation), moderate (grade 2, pseudonormal), and severe (grade 3, restrictive).

SYNTAX scoring was performed from diagnostic angiograms by 2 interventional cardiologists blinded to echocardiographic data, with disagreements resolved by consensus.

To reduce selection bias, we enrolled consecutive eligible patients using prespecified criteria. To limit measurement bias, SYNTAX assessors were blinded to echocardiographic data, and echocardiograms followed a standardized protocol. We addressed confounding using prespecified multivariable models (age- and sex-adjusted, then additionally adjusted for

risk factors). Performing echocardiography 1 day after angiography standardized the timing of assessment.

Study Size

We calculated the required sample size using assumptions from prior literature (reference 40 in the thesis) to detect a difference in means of 4.34 with a standard deviation of 11.1, $\alpha = .05$ (2-sided), and 90% power. The minimum sample size was 138; allowing for an approximately 10% contingency, the target sample size was 153, which we achieved.

Quantitative Variables

Echocardiographic and clinical variables were analyzed primarily as continuous measures. SYNTAX score was analyzed categorically using standard thresholds (less than 22, 23–32, and ≥ 33) and secondarily dichotomized (≤ 22 vs > 22) to facilitate regression modeling and interpretability. Variable distributions were inspected, and nonparametric tests were used when assumptions were not met.

Statistical Analysis

Continuous variables are presented as mean (SD) or median (IQR), and categorical variables as number (percentage). Between-group comparisons (high vs low SYNTAX score) used *t* tests or Mann-Whitney U tests for continuous variables and χ^2 tests for categorical variables. Three-group comparisons used analysis of variance or Kruskal-Wallis tests, as appropriate.

The primary analysis examined the association between echocardiographic diastolic indices and high SYNTAX score (> 22) using binary logistic regression. Model 1 adjusted for age and sex; model 2 additionally adjusted for diabetes, dyslipidemia, hypertension, current smoking, and family history of CAD. We report odds ratios (ORs) with 95%

confidence intervals. Model assumptions were checked, including linearity in the logit for continuous predictors and absence of problematic multicollinearity. The Hosmer-Lemeshow test was used to assess model fit.

Missing Data

There were no missing data for variables used in the analyses. All categorical counts sum to 153 (eg, smoking, $56 + 97 = 153$; hypertension, $87 + 66 = 153$; diabetes, $71 + 82 = 153$; dyslipidemia, $49 + 104 = 153$; family history, $45 + 108 = 153$), and the SYNTAX dichotomy totals $68 + 85 = 153$. Therefore, all analyses were performed on the full cohort without imputation.

RESULTS

Participants

A total of 153 patients with angiographically confirmed triple-vessel disease met the eligibility criteria and were included in the analysis. All variables used in the analyses were complete; no data were missing.

Descriptive Data

Of the 153 patients, 88 (57.5%) were men and 65 (42.5%) were women. The mean (SD) age was 61.2 (9.0) years (range, 26–80 years). Risk factors included smoking in 56 patients (36.6%), hypertension in 87 (56.9%), diabetes mellitus in 71 (46.4%), hyperlipidemia in 49 (32.0%), and a family history of CAD in 45 (29.4%). There were no missing data for these variables.

Outcome Data

Based on the SYNTAX score, 68 of 153 patients (44.4%) had low scores (≤ 22), 59 (38.6%) had intermediate scores (23–32), and 26 (17.0%) had high scores (≥ 33). For the primary analysis, the SYNTAX score was dichotomized as low (≤ 22) vs high (> 22): 68 patients (44.4%) and 85 (55.6%), respectively. Diastolic dysfunction grading

was normal in 16 patients (10.5%), mild in 134 (87.6%), and moderate in 3 (2.0%).

Main Results

In univariable comparisons, none of the echocardiographic diastolic indices (E/A, average E/e', LAVI, deceleration time, tricuspid regurgitation velocity, septal and lateral e', LV end-diastolic volume index, and LVEF) differed between the high and low SYNTAX score groups (all $P > .05$). In logistic regression, these indices were not associated with high SYNTAX score (>22) after adjustment for age and sex and remained nonsignificant in models adjusted for cardiovascular risk factors. In contrast, diabetes mellitus and hyperlipidemia were independently associated with high SYNTAX score: adjusted odds ratio (aOR), 3.71 (95% CI, 1.84 to 7.50) and aOR, 2.83 (95% CI, 1.31 to 6.10), respectively. Table 2 presents SYNTAX score category distributions and LV diastolic dysfunction grades.

Table 1 presents the frequency and percentage of patient demographic characteristics. The low SYNTAX score group (≤ 22) comprised 44.4% of patients, and the high SYNTAX score group (>22) comprised 55.6%. Mean age did not differ significantly between the low and high SYNTAX score groups.

Hypertension status did not differ significantly between the low and high SYNTAX score groups ($P = .433$) (Table 3). Diabetes mellitus and hyperlipidemia were significantly associated with the severity of coronary involvement as measured by the SYNTAX score. Specifically, patients with diabetes mellitus had 3.7-fold higher odds of high SYNTAX score than those without diabetes mellitus, whereas patients with hyperlipidemia had 2.8-fold higher odds than those without hyperlipidemia. No significant associations were observed for hypertension or smoking.

None of the echocardiographic parameters listed in Table 4 exhibited a normal distribution within the 2 SYNTAX score groups. Consequently, the Mann-Whitney U test was used for initial comparisons. No significant differences were observed between the 2 groups for any echocardiographic parameter.

To further explore the relationship between LV diastolic dysfunction and coronary involvement while controlling for age and sex, we analyzed the association between echocardiographic parameters and severity of coronary involvement using logistic regression. According to Supplementary Table S1, sex was statistically significant; however, no significant associations were observed for the severity of coronary involvement or other variables. The odds of high SYNTAX score were approximately 55% lower among men than among women. Other risk factors did not show significant associations.

The prevalence of risk factors, including smoking, blood pressure, diabetes mellitus, hyperlipidemia, and family history, was assessed in relation to the severity of coronary involvement based on the SYNTAX score. Of these, only diabetes mellitus and hyperlipidemia differed significantly between the 2 groups. To further investigate the relationship between echocardiographic parameters and severity of coronary involvement while controlling for cardiovascular risk factors, the significant variables from the initial analysis were included in the logistic regression model. None of the echocardiographic parameters was significantly associated with severity of coronary involvement based on the SYNTAX score after adjustment for cardiovascular risk factors.

Other Analyses

No subgroup, interaction, or sensitivity analyses were prespecified or conducted.

Table 1. Demographic Information of the Studied Patients

Variable	Mean	SD
Age, y	61.2	9.0
Variable	No.	%
Sex (male)	88	57.5
Smoking	56	36.6
Hypertension	87	56.9
Diabetes mellitus	71	46.4
Hyperlipidemia	49	32.0
Familial history of coronary artery disease	45	29.4

Table 2. SYNTAX Categories and Left Ventricular Diastolic Dysfunction Grades

SYNTAX Categories		
Category	No.	%
Low (≤ 22)	68	44.4
Intermediate (23–32)	59	38.6
High (≥ 33)	26	17.0
Left Ventricular Diastolic Dysfunction Grades		
Grade	No.	%
Normal	16	10.5
Mild	134	87.6
Moderate	3	2.0
Severe	0	0.0

Primary dichotomy: Low (≤ 22) vs High (> 22) = 68 (44.4) vs 85 (55.6)

Notes: SYNTAX categories are defined as low ≤ 22 , intermediate 23–32, and high ≥ 33 . Values are No. (%).

Table 3. Cardiovascular Risk Factors by SYNTAX Score (Low vs High)

Variable	Low (≤ 22) No. (%)	High (> 22) No. (%)	Total No. (%)	P
Hypertension	41 (60.3)	46 (54.1)	87 (56.9)	.43
Diabetes mellitus	20 (29.4)	51 (60.0)	71 (46.4)	<.001
Hyperlipidemia	14 (20.6)	35 (41.2)	49 (32.0)	.007

Notes: Values are No. (%). Percentages in Low and High columns are within-group percentages (denominators: Low n = 68, High n = 85). P values from χ^2 tests.

Table 4. Echocardiographic Indices by SYNTAX Score (Low vs High)

Echocardiographic Parameter	SYNTAX Score	Number	Mean	Standard deviation	Minimum	Maximum	1st Quartile	2nd Quartile (Median)	3rd Quartile	P
LVEF	Low-risk	68	53.68	2.53	50	60	50	55	55	.56
	High-risk	85	54	3.16	45	65	50	55	55	
E/A	Low-risk	68	0.99	0.42	0.44	3	0.67	0.87	1.22	.051
	High-risk	85	0.87	0.36	0.42	2.2	0.65	0.77	1	
Average E/E'	Low-risk	68	11.01	4.36	3.8	25	8	9.90	13	.32
	High-risk	85	11.37	6.44	0.12	38	7.92	9.5	13.75	
LA volume index	Low-risk	68	28.98	8.07	17	57	23	27	33.75	.86
	High-risk	85	28.50	7.66	14	50	21.50	28	33.15	
Deceleration time	Low-risk	68	213.78	62.40	79	433	169	207.5	245.25	.80
	High-risk	85	212.59	63.53	70	406	167	208	253.50	
Tricuspid	Low-risk	68	2.30	0.20	1.93	2.80	2.17	2.23	2.50	.12

regurgitation velocity	High-risk	85	2.35	0.21	1.87	2.95	2.23	2.32	2.50	
Septal E'	Low-risk	68	5.93	1.70	2.60	10	4.92	5.85	7	.28
	High-risk	85	5.72	2.01	2.40	13	4	5.4	7	
Lateral E'	Low-risk	68	8.98	2.20	4.60	14	7.2	9	11	.85
	High-risk	85	9.07	2.60	4	14	7	9	11	
LVEDV index	Low-risk	68	49.35	10.37	30	72	41.5	47.75	57.5	.17
	High-risk	85	46.95	10.33	26	74	39.15	45	55.25	

LA: left atrial; LVEDV: left ventricular end-diastolic volume; LVEF: left ventricular ejection fraction

Supplementary Table S1. Multivariable Logistic Regression for High SYNTAX Scores (>22)

Predictor	aOR	95% CI	P	Model
Diabetes mellitus	3.71	1.84–7.50	<.001	Model 2
Hyperlipidemia	2.83	1.31–6.10	.008	Model 2

aOR: adjusted odds ratio; CAD: coronary artery disease; LAVI: left atrial volume index; LVEDV: left ventricular end-diastolic volume; LVEF: left ventricular ejection fraction; TR: tricuspid regurgitation

Notes: Outcome is high SYNTAX score (>22). Model 1 (not shown) adjusted for age and sex. Model 2 adjusted for age, sex, hypertension, diabetes mellitus, hyperlipidemia, current smoking, and family history of CAD.

Echocardiographic diastolic indices (E/A, average E/e', LAVI, deceleration time, TR velocity, septal and lateral e', LVEDV index, and LVEF) were not significant in multivariable models and are omitted for brevity.

DISCUSSION

In this cross-sectional cohort of 153 patients with triple-vessel disease, we found no association between echocardiographic diastolic indices (E/A, average E/e', LAVI, deceleration time, tricuspid regurgitation velocity, septal and lateral e', LV end-diastolic volume index, and LVEF) and high SYNTAX score (>22). In contrast, diabetes mellitus and hyperlipidemia were independently associated with high SYNTAX score (aOR, 3.71; 95% CI, 1.84 to 7.50 and aOR, 2.83; 95% CI, 1.31 to 6.10, respectively). The SYNTAX score distribution was 44.4% low (≤ 22) and 55.6% high (>22).

Echocardiography plays a crucial role in assessing LVDD. Our study investigated the relationship between the severity of LVDD and the extent of coronary artery involvement in patients with triple-vessel disease referred to the Dr Heshmat Heart Training Center in Rasht from 2022 through 2023. Our findings indicated a statistically significant association between the severity of coronary artery involvement, as measured by the SYNTAX score, and diabetes mellitus and hyperlipidemia. Nevertheless,

we found no significant association between the severity of coronary artery involvement and LVDD. This lack of significance may be attributable to the fact that 87.6% of patients had mild LVDD.

This single-center, convenience-sampled, cross-sectional study cannot establish temporal relationships between diastolic function and anatomic disease complexity and may be prone to selection bias. The sample size was relatively small ($n = 153$), limiting statistical power to detect modest associations. Moreover, patients with more than grade I diastolic dysfunction were rare: only 3 of 153 patients (2.0%) had grade II dysfunction, and none had grade III dysfunction. This further reduced our ability to detect associations across the higher-severity LVDD spectrum.

The study population was restricted to patients with triple-vessel disease and preserved systolic function, which limits variability in anatomic disease burden and may reduce generalizability. The distribution of diastolic dysfunction was highly skewed (approximately 88% had mild dysfunction), which likely reduced power to detect

associations across the full LVDD spectrum and may have biased estimates toward the null. Potential measurement limitations include the lack of formal interobserver and intraobserver reproducibility testing and reliance on routine-care images; however, standardized protocols were used. Residual confounding by unmeasured factors is possible despite multivariable adjustment.

Within this homogeneous triple-vessel disease cohort, diastolic indices did not track anatomic complexity as graded by the SYNTAX score, whereas diabetes mellitus and hyperlipidemia-established atherosclerotic risk factors-were associated with higher anatomic burden. Together with prior reports showing mixed relationships between diastolic parameters and SYNTAX score, our findings suggest that, in patients with uniformly extensive triple-vessel disease and largely mild LVDD, diastolic function assessed by resting echocardiography may provide limited incremental information about coronary anatomic complexity beyond clinical risk factors. Confirmation in broader populations and across greater LVDD severity is warranted.

While prior larger cohorts have used deformation imaging (strain and strain rate), our study focused on conventional diastolic indices. Future studies integrating deformation measures in larger samples with greater variation in LVDD severity may be more sensitive to anatomic disease complexity.

Liu et al¹³ reported that early identification of diastolic dysfunction through echocardiographic parameters is clinically significant for predicting the burden of CAD. Unlike our study, they found a statistically significant relationship between high SYNTAX scores and echocardiographic parameters, such as the E/A ratio and deceleration time. A key distinction in their research was its focus on patients with triple-vessel disease based on SYNTAX scores.

Bouthoorn et al¹⁴ indicated that the prevalence of LVDD is similar in men and

women with heart failure, suggesting that LVDD is not influenced by sex. This finding aligns with our study. In contrast, the results of Cho et al⁸ conflict with ours, as they established a significant relationship between LVDD and the severity of CAD, particularly in women, reporting a statistically significant association between sex and disease severity ($P = .025$).

Ginting et al¹⁵ reported a statistically significant difference between LVDD and SYNTAX score ($P < .001$). Additionally, unlike our study, their research demonstrated significant associations between SYNTAX score and factors such as age and echocardiographic parameters, including LVEF, LV end-diastolic diameter, E/A ratio, average E/e' ratio, maximum tricuspid regurgitation velocity, and LAVI.

Abali et al¹⁵ reported findings similar to ours, with no significant association between SYNTAX score and echocardiographic parameters. Conversely, Mukhopadhyay et al¹⁶ reported a significant association between the severity of CAD, as determined by the SYNTAX score, and LVDD. In their study, LVDD was assessed using echocardiographic parameters such as the E/A ratio, E/e', and LAVI.

If future studies with larger sample sizes and greater variation in LVDD severity identify a significant relationship between the severity of diastolic dysfunction and the extent of coronary artery involvement, these findings may have implications for clinical risk assessment. In patients with triple-vessel disease, more severe diastolic dysfunction may warrant closer evaluation of coronary anatomic complexity. However, further evidence would be needed before recommending treatment prioritization based solely on diastolic dysfunction severity.

These results are most applicable to patients with angiographically confirmed triple-vessel disease undergoing evaluation in a tertiary center similar to ours. Extrapolation

to populations with single-vessel or two-vessel disease, different LVDD severity distributions, or other care settings should be undertaken cautiously. Multicenter studies with broader inclusion criteria and balanced representation across LVDD grades will help clarify generalizability.

CONCLUSIONS

Our findings indicate that there was no statistically significant association between the severity of LVDD and echocardiographic parameters in patients with triple-vessel disease, as assessed by the SYNTAX score. Most patients exhibited mild diastolic dysfunction, which may explain the discrepancy between our results and those reported in previous studies. Specifically, the severity of coronary involvement based on the SYNTAX score did not correlate with echocardiographic indicators of diastolic dysfunction. Further research involving larger samples and greater variation in diastolic dysfunction severity is needed to draw more definitive conclusions.

Funding

This study received no external funding. Institutional support covered the cost of echocardiography performed after angiography. The funder had no role in the study design; data collection, analysis, or interpretation; manuscript writing; or the decision to submit the manuscript for publication.

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