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Original Paper

Coronary Artery Diameter is Inversely Associated with the Severity of Coronary Lesions in Patients Undergoing Coronary Angiography

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Key Words
Coronary artery diameter • Coronary artery disease • Angiography • Gensini score

Abstract
Background: The diameters of the coronary arteries have been suggested to be a potential predictor of coronary artery disease (CAD). However, whether the diameters of the coronary arteries are associated with the coronary lesion severity on angiography has not been determined. ***Methods:*** One hundred sixty-seven consecutive adult patients (109 men and 58 women) aged 31–84 years who underwent coronary angiography for suspected or known CAD were enrolled. The known catheter tip diameter was used as the calibration to measure the diameters of coronary arteries, and the severity of coronary lesions was evaluated with the vessel score and Gensini score. ***Results:*** In patients with a higher vessel score and Gensini score, the diameters of the left main (LM), left anterior descending (LAD), left circumflex (LCX), and right coronary arteries (RCA) were smaller (all $p<0.05$) than those in patients with lower scores. Multiple linear regression analysis indicated that the average coronary artery diameter was significantly associated with the Gensini score ($\beta=-0.444$, $p<0.00001$). Moreover, the diameters of the coronary arteries were potential predictors of CAD, with areas under the receiver operating characteristic curves of 0.268 for average diameter (95% confidence interval [CI]: 0.183–0.353, $p<0.00001$), 0.356 for the LM diameter (95% CI: 0.266–0.445, $p=0.005$), 0.214 for the LAD diameter (95% CI: 0.136–0.291, $p<0.00001$), 0.366 for the LCX diameter (95% CI: 0.271–0.461, $p=0.009$), and 0.346 for the RCA diameter (95% CI: 0.245–0.447, $p=0.003$). ***Conclusion:*** The diameters of coronary arteries are inversely associated with the severity of CAD.

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Introduction

Despite significant improvements in diagnosis and treatment, coronary artery disease (CAD) remains one of the most important causes of morbidity and mortality in both developed and developing countries [1]. Early detection of patients at risk for severe coronary lesions is of great clinical significance for the prophylaxis of CAD. CAD is characterized by the formation of atherosclerotic plaques in the coronary arteries that lead to partial or complete obstruction of the coronary blood flow and subsequent myocardial ischemia [2, 3]. Although CAD has been considered a systematic inflammatory disease of the vascular wall, endothelial dysfunction and related vascular remodelling of the coronary arteries have recently been suggested to be an initial process during the pathogenesis of atherosclerosis [4]. Indeed, accumulating evidence suggests that many harmful stimuli of the vasculature, such as the inflammatory response, oxidative injury, and shear stress of the blood flow, may contribute to the dysfunction of endothelium, and vascular dysfunction, which includes vascular anatomical changes, arterial stiffness, blood flow changes, and vascular elasticity, appears prior to changes in vascular morphology [5]. Endothelial dysfunction subsequently contributes to the impairment of endothelial-dependent vasodilatation, and vascular function measurements have been employed for early detection of atherosclerosis and assessment the potential risk of CAD [6]. However, measurement of endothelial function may require special equipment and is sometimes invasive, which limits its use in clinical practice. Interestingly, changes in endothelial function have further been related to a reduced lumen of the coronary artery and deterioration of the coronary blood supply, and it has been hypothesized that the diameters of the targeted artery, such as the coronary arteries, may be important predictors of CAD risk [7].

Some studies have investigated the association between the diameters of coronary arteries and the risk of CAD. An early study revealed that Asian-Indian patients with smaller coronary artery diameters were at higher risk for the development of CAD [8], which may be reflective of endothelial dysfunction in these patients. However, a recently published study indicated that coronary arterial diameters were larger in women and CAD patients with higher calcium levels [9], which is inconsistent with the previous findings that the coronary artery diameters are larger in men [7]. In this regard, coronary artery diameter measurement plays an important role in estimating the function of coronary arteries and is considered to be a predictor for detecting the early stages of CAD. However, the association between the lumen dimensions of coronary arteries and the severity of coronary lesions remains to be determined. Considering that intrinsic vascular pathology such as atherosclerosis generally tends to narrow vessel lumens, this study was designed to evaluate the potential association between the lumen diameters of coronary arteries and the severity of the coronary lesions as evidenced by coronary angiography. Moreover, the effects of patient age, gender, and traditional risk factors on coronary diameters were determined in patients with CAD.

Methods

The present study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University, Jiangsu Province, China, and conformed to the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from each patient.

Study participants

From February 4, 2015 to June 30, 2016, 167 consecutive adult patients (109 men and 58 women) aged 31–84 years who underwent coronary angiography for suspected or known CAD at the First Affiliated Hospital of Nanjing Medical University in China were enrolled in this study. The inclusion criteria were as follows: (1) clinical diagnosis of acute myocardial infarction, or (2) conventional atherosclerotic risk factors and typical angina or atypical chest pain, abnormal finding on ECG with ST-T changes or regional wall motion abnormality with left ventricular systolic dysfunction in echocardiography. Patients who suffered from any of the following conditions were excluded: spastic angina pectoris, heart failure, infectious processes within 2 weeks of enrollment, adrenal dysfunction, or thyroid dysfunction.

Laboratory measurements

Total cholesterol (TCH, mmol/L), triglycerides (TG, mmol/L), fasting blood glucose (FBG, mmol/L), creatinine (CR, umol/L), urea nitrogen (mmol/L), fasting high-density lipoprotein cholesterol (HDL-C, mmol/L), fasting low-density lipoprotein cholesterol (LDL-C, mmol/L), alkaline phosphatase (ALP, mmol/L) and lipoprotein a (Lp(a), mg/L) levels were determined by enzymatic procedures on an automated autoanalyzer (AU 2700 Olympus, 1st Chemical Ltd, Tokyo, Japan). Cardiac troponin T (hs-cTnT, ng/L) concentration was measured using the high-sensitivity HS-cTnT one-step electrochemiluminescence immunoassay on an Elecsys 2010 analyzer (Roche Diagnostics, Meylan, France). The levels of free triiodothyronine (FT3, pmol/L), free thyroxine (FT4, pmol/L), and thyroid-stimulating hormone (TSH, mIU/L) were measured with a fully-automatic immune analyzer (cobas e601, Roche, Berlin, Germany).

Coronary angiography

Coronary arteries were cannulated by either the Judkins technique [10] or through a radial approach with 6F catheters and recorded at a rate of 30 frames/s. CAD was diagnosed if at least one major coronary artery with >50% stenosis was detected, and the control was defined as none of the major coronary arteries having >50% stenosis [11]. Coronary angiograms were scored according to the vessel score and Gensini score [12]. The vessel score is the number of vessels with significant stenosis (50% or greater reduction in lumen diameter), ranging from 0–3 [13-15].

Measurement of coronary artery diameter

The coronary artery diameters of the 167 consecutive adult participants were evaluated by two interventional cardiologists who were blinded to the patients' clinical data, and the angiograms were analyzed using standard quality control analysis software with a digital acquisition system (GE Medical, Milwaukee, WI). Measurements were uniformly taken in diastole, and the widest dimension in each segment was used. The known catheter tip diameter (2.0 mm for a 6.0 F catheter) was used as the calibration object to assess the diameters of the coronary arteries, with the settings of the image intensifier kept constant. The diameters of the left main (LM), left anterior descending (LAD), and left circumflex (LCX) coronary arteries were evaluated in the 30° right anterior oblique projection, and the right coronary artery (RCA) diameter was evaluated in the 60° left anterior oblique projection. Three segments of the LAD were measured: the proximal LAD (PLAD) segment (before the first septal), the mid-LAD (MLAD) segment (between first septal and first diagonal), and the distal LAD (DLAD) segment after the diagonal branch of the LAD. The LCX also was divided into three segments: the proximal LCX (PCX) segment before the obtuse marginal, the distal LCX (DCX) segment after the origin of the obtuse marginal branch, and the first obtuse marginal. The RCA was divided into two segments, the proximal RCA (PRCA) and the distal RCA (DRCA), in which the maximum diameter of the posterior descending branch was measured [16]. The measurements for each segment of the LAD, LCX, and RCA were taken, and averaged results were employed as the diameters of the LAD, LCX, and RCA. Because their size, presence, and anatomical distribution were highly variable, measurement of the branches of major epicardial coronary arteries were not attempted in the present study.

Statistical analyses

Data were analyzed using Statistics Package for Social Sciences (ver. 16.0; SPSS Incorporated, Chicago, IL, USA). Participants were categorized into four or two groups according to the Gensini scores using quartile values as cutoff points, gender, CAD status, and vessel score. Normally distributed variables were presented as mean ± standard deviation (SD), and the comparisons were analyzed using the independent-samples t test or one-way analysis of variance (ANOVA). Variables with a skewed distribution were presented as median and quartile ranges, and the comparisons were made using the Mann-Whitney U test or the Kruskal–Wallis H test. Categorical variables were compared using chi-square analyses. The Spearman two-way test was used to assess the relationship between two quantitative variables, and we evaluated independent predictors of coronary artery diameter though multiple regression analysis. Receiver operator curve (ROC) analysis was also conducted to examine the predictive ability of coronary artery diameter for CAD and traditional risk factors [17]. Statistical significance was considered if the two-tailed p value was <0.05.

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Results

Coronary artery diameters and gender

Of the 167 study participants, 109 were male with a mean age of 60.61±10.85 years and 58 were female with a mean age of 64.28±10.19 years. Demographics and associated medical conditions are presented in Table 1. We found that the mean coronary artery diameters among the participants were 2.87±0.37 mm for the average diameter, 4.12±0.68 mm for the LM, 2.26±0.41 mm for the LAD, 2.14±0.43 mm for the LCX, and 2.95±0.60 mm for the RCA. For males, these values 2.88±0.37 mm for the average diameter, 4.11±0.71 mm for the LM, 2.30±0.42 mm for the LAD, 2.13±0.44 mm for the LCX, and 2.96±0.60 mm for the RCA, and for females, these values were 2.86±0.37 mm for the average diameter, 4.14±0.63 mm for the LM, 2.19±0.39 mm for the LAD, 2.18±0.42 mm for the LCX, and 2.93±0.60 mm for the RCA. No significant differences in the average overall diameter and the mean diameters of the individual coronary artery diameters were found between males and females.

Coronary artery diameters and Gensini score

The Gensini scores of the patients ranged from 0.00 to 174.00, with a median of 14.00 (quartile range, 5.00–44.00). Subjects with a higher Gensini score had generally smaller coronary arteries, with statistically significant differences in the average diameter ($p<0.00001$) and the mean diameters of the LM ($p=0.002$), LAD ($p<0.00001$), LCX ($p<0.00001$), and RCA ($p=0.004$),as indicated in Table 2.

Coronary artery diameters and CAD prevalence

Of the 167 participants, 124 were diagnosed as having CAD. Demographics and associated medical conditions according to the CAD status are presented in Table 3. Subjects with CAD had generally smaller coronary arteries than controls, with statistically significant differences in the average diameter ($p<0.00001$) and the mean diameters of the LM ($p=0.006$), LAD ($p<0.00001$), LCX ($p=0.007$), and RCA ($p=0.005$).

Table 1. Baseline characteristics of study participants according to gender. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CHD, coronary heart disease; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	Male (n=109)	Female (n=58)	Total (n=167)	F or chi-square test	p value
Age (years)	60.61±10.85	64.28±10.19	61.88±10.74	-2.126	0.035
Total cholesterol (mmol/L)	3.97±1.06	4.44±1.09	4.13±1.09	--2.659	0.009
Triglycerides (mmol/L)	1.27(0.95-1.90)	1.53(0.94-2.20)	1.33(0.94-1.99)	-1.101	0.271
Glucose (mmol/L)	5.17(4.71-6.14)	5.21(5.02-6.22)	5.19(4.72-6.18)	-0.922	0.356
Creatinine (μmol/L)	70.40(62.15-81.70)	54.75(49.58-63.30)	65.30(56.88-77.93)	-6.97	0.000
Urea nitrogen (mmol/L)	5.93(4.25-7.17)	4.74(4.05-5.33)	5.30(4.22-6.88)	-2.98	0.003
HDL-C (mmol/L)	0.95(0.83-1.13)	1.12(1.00-1.32)	1.00(0.86-1.23)	-3.562	0.000
LDL-C (mmol/L)	2.58±0.79	2.86±0.85	2.67±0.82	-2.108	0.037
Vessel score	2.00(1.00-3.00)	1.00(0.00-3.00)	2.00(0.00-3.00)	-1.593	0.111
Gensini score	14.00(6.50-48.25)	8.00(2.00-45.00)	14.00(5.00-44.00)	-1.480	0.139
CHD (yes vs. no)	87/22	37/21	124/43	5.084	0.024
ALP (mmol/L)	73.46±18.88	75.37±20.66	74.10±19.46	-0.590	0.556
Lipoprotein a (mg/L)	222.50(98.38-449..75)	215.50(95.75-441.50)	221.50(98.63-442.75)	-0.416	0.678
hs-cTnT (ng/L)	10.61(5.97-18.31)	5.77(3.00-10.97)	9.71(4.21-15.95)	-3.550	0.000
FT3 (pmol/L)	4.63±0.70	4.19±0.73	4.49±0.73	3.411	0.001
FT4 (pmol/L)	16.18(13.97-17.86)	16.55(13.73-17.94)	16.22(13.94-17.91)	-0.297	0.766
TSH(mIU/L)	2.08(1.44-2.87)	3.67(2.08-6.41)	2.38(1.58-3.82)	-3.872	0.000
Average diameter (mm)	2.88±0.37	2.86±0.37	2.87±0.37	0.277	0.782
Diameter of LM (mm)	4.11±0.71	4.14±0.63	4.12±0.68	-0.252	0.801
Diameter of LAD (mm)	2.30±0.42	2.19±0.39	2.26±0.41	1.048	0.101
Diameter of LCX (mm)	2.13±0.44	2.18±0.42	2.14±0.43	-0.685	0.495
Diameter of RCA (mm)	2.96±0.60	2.93±0.60	2.95±0.60	0.343	0.732

Table 2. Age, clinical characteristics, biochemical characteristics, and coronary artery diameters in patients grouped according to quartiles of Gensini score. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CHD, coronary heart disease; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	Gensini score				F or chi-square test	p
	0–5.00 (n=44)	5.01–14.00 (n=42)	14.01–44.00 (n=43)	≥44.01 (n=38)		
Age (years)	59.43±10.73	63.21±9.90	62.00±9.90	63.11±12.36	1.149	0.331
Total cholesterol (mmol/L)	4.23±1.06	3.91±1.13	4.22±1.12	4.17±1.06	0.763	0.516
Triglycerides (mmol/L)	1.45(0.90-2.05)	1.09(0.89-1.74)	1.54(0.89-2.51)	1.32(1.08-1.89)	3.580	0.311
Glucose (mmol/L)	5.17(4.71-5.61)	5.04(4.65-5.34)	5.22(4.74-6.42)	5.76(4.88-7.29)	10.545	0.014
Creatinine (μmol/L),	60.80(51.65-75.40)	65.20(60.60-71.25)	68.50(61.05-80.30)	72.20(56.80-82.80)	5.387	0.146
Urea nitrogen (mmol/L)	4.85(4.04-5.93)	5.23(4.23-6.95)	5.79(4.69-7.02)	6.13(4.25-7.05)	3.183	0.364
HDL-C (mmol/L)	1.02(0.91-1.29)	0.99(0.89-1.27)	1.00(0.88-1.14)	0.89(0.82-1.17)	5.816	0.121
LDL-C (mmol/L)	2.67±0.82	2.55±0.79	2.75±0.86	2.74±0.83	0.521	0.669
Vessel score	0.00(0.00-0.00)	1.00(1.00-2.00)	2.00(2.00-3.00)	3.00(3.00-3.00)	120.089	0.000
ALP (mmol/L)	72.97±20.84	70.78±15.34	71.02±19.81	82.58±19.90	3.268	0.023
Lipoprotein a (mg/L)	55.00(86.00-409.50)	175.00(74.50-397.00)	193.00(118.50-498.50)	274.00(136.50-475.00)	3.082	0.379
hs-cTnT (ng/L)	4.36(3.00-10.68)	7.52(3.47-11.67)	12.72(9.13-19.44)	31.52(9.34-404.44)	43.353	0.000
FT3 (pmol/L)	4.56±0.56	4.47±0.79	4.50±0.65	4.43±0.93	0.214	0.887
FT4 (pmol/L)	16.80(14.57-18.13)	15.67(13.68-17.00)	14.24(13.28-17.15)	16.71(14.91-18.99)	8.019	0.046
TSH (mIU/L)	2.50(1.91-3.86)	2.18(1.73-3.96)	2.13(1.12-3.41)	2.09(1.45-4.00)	0.953	0.813
Average diameter (mm)	3.12±0.34	2.92±0.31	2.75±0.34	2.66±0.31	15.995	0.000
Diameter of LM (mm)	4.43±0.60	4.12±0.59	3.93±0.68	3.97±0.76	5.106	0.002
Diameter of LAD (mm)	2.55±0.41	2.31±0.35	2.13±0.34	2.01±0.31	17.993	0.000
Diameter of LCX (mm)	2.34±0.44	2.23±0.43	2.04±0.36	1.93±0.39	7.824	0.000
Diameter of RCA (mm)	3.14±0.63	3.03±0.56	2.91±0.52	2.69±0.60	4.608	0.004

Table 3. Age, clinical characteristics, biochemical characteristics, and coronary artery diameters in study participants according to CAD prevalence. CHD, coronary heart disease; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	CHD status			F or chi-square test	p
	NCHD (n=43)	CHD (n=124)	Total (n=167)		
Age (years)	59.51±10.96	62.70±10.58	61.88±10.74	-1.688	0.093
Total cholesterol (mmol/L)	4.31±1.03	4.07±1.11	4.13±1.09	1.219	0.225
Triglycerides (mmol/L)	1.43(0.90-2.05)	1.32(0.94-1.96)	1.33(0.94-1.99)	-0.138	0.891
Glucose (mmol/L)	5.08(4.59-5.46)	5.21(4.75-6.70)	5.19(4.72-6.18)	-1.245	0.213
Creatinine (μmol/L),	62.20(50.95-75.40)	67.10(59.20-78.30)	65.30(56.88-77.93)	-1.806	0.071
Urea nitrogen (mmol/L)	4.85(4.19-6.11)	5.59(4.24-7.05)	5.30(4.22-6.88)	-1.023	0.306
HDL-C (mmol/L)	1.06(0.95-1.31)	0.97(0.83-1.18)	1.00(0.86-1.23)	-1.896	0.058
LDL-C (mmol/L)	2.78±0.75	2.64±0.84	2.67±0.82	0.969	0.334
ALP (mmol/L)	71.20±19.04	75.09±19.58	74.10±19.46	-1.108	0.270
Lipoprotein a (mg/L)	167.00(86.00-403.00)	223.00(104.00-460.00)	221.50(98.63-442.75)	-0.873	0.383
hs-cTnT (ng/L)	4.18(3.00-9.14)	10.60(6.62-21.43)	9.71(4.21-15.95)	-4.469	0.000
FT3 (pmol/L)	4.55±0.56	4.47±0.79	4.49±0.73	0.611	0.542
FT4 (pmol/L)	16.21(14.11-17.84)	16.23(13.93-18.00)	16.22(13.94-17.91)	-0.659	0.510
TSH (mIU/L)	2.51(2.04-5.01)	2.09(1.47-3.47)	2.38(1.58-3.82)	-1.774	0.076
Average diameter (mm)	3.10±0.36	2.79±0.34	2.87±0.37	5.043	0.000
Diameter of LM (mm)	4.37±0.58	4.03±0.70	4.12±0.68	2.788	0.006
Diameter of LAD (mm)	2.56±0.39	2.16±0.37	2.26±0.41	6.136	0.000
Diameter of LCX (mm)	2.30±0.43	2.10±0.42	2.14±0.43	2.743	0.007
Diameter of RCA (mm)	3.17±0.63	2.88±0.57	2.95±0.60	2.819	0.005

Coronary artery diameters and vessel score

The results in Table 4 suggest that patients with a higher vessel score had significantly smaller coronary arteries, with statistically significant differences observed in the average diameter ($p<0.00001$) and the mean diameters of the LM ($p=0.002$), LAD($p<0.00001$), LCX ($p<0.00001$), and RCA ($p=0.003$).

Correlations between severity of coronary lesions and coronary artery diameters

As shown in Table 5, the Spearman correlation analyses indicated that the Gensini score was significantly associated with the average diameter ($r=-0.489$, $p=0.000$) and the

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Table 4. Age, clinical characteristics, biochemical characteristics, and coronary artery diameters in study participants grouped according to vessel score. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CHD, coronary heart disease; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	Vessel score				F or chi-square test	p
	0 (n=43)	1(n=38)	2(n=35)	3 (n=51)		
Age (years)	59.51±10.96	60.89±9.88	62.97±9.84	63.86±11.54	1.519	0.212
Total cholesterol (mmol/L)	4.31±1.03	4.13±1.17	4.05±1.07	4.04±1.11	0.543	0.653
Triglycerides (mmol/L)	1.43(0.90-2.05)	1.17(0.89-1.85)	1.37(0.91-2.67)	1.32(1.03-1.74)	0.642	0.887
Glucose (mmol/L)	5.08(4.59-5.46)	5.05(4.71-5.93)	5.29(4.71-6.80)	5.29(4.80-6.79)	6.645	0.084
Creatinine (μmol/L),	62.20(50.95-75.40)	65.50(57.75-81.55)	68.80(60.35-75.15)	70.40(58.70-80.35)	3.796	0.284
Urea nitrogen (mmol/L)	4.85(4.19-6.12)	5.47(3.94-7.16)	6.37(4.74-7.33)	5.27(4.17-6.92)	1.936	0.586
HDL-C(mmol/L)	1.06(0.95-1.32)	1.02(0.89-1.21)	0.99(0.89-1.26)	0.90(0.81-1.13)	8.034	0.045
LDL-C(mmol/L)	2.78±0.75	2.66±0.85	2.59±0.84	2.64±0.86	0.360	0.782
ALP (mmol/L)	71.20±19.04	70.08±18.54	74.25±19.17	79.45±20.00	2.149	0.096
Lipoprotein a (mg/L)	167.00(86.00-403.00)	220.00(98.00-478.50)	205.00(63.50-536.00)	245.00(109.50-459.00)	0.824	0.844
hs-cTnT (ng/L)	4.18(3.00-9.14)	8.19(3.00-13.57)	10.48(6.82-18.78)	12.56(8.22-104.04)	30.824	0.000
FT3 (pmol/L)	4.55±0.56	4.35±0.76	4.73±0.76	4.42±0.81	1.559	0.202
FT4 (pmol/L)	16.21(14.11-17.84)	15.69(13.91-18.05)	16.12(13.20-17.32)	16.63(13.99-18.19)	1.662	0.645
TSH(mIU/L)	2.51(2.04-5.01)	2.67(1.81-4.19)	2.00(1.36-2.76)	2.07(1.18-3.49)	6.194	0.103
Average diameter (mm)	3.10±0.36	2.98±0.33	2.74±0.25	2.69±0.35	15.258	0.000
Diameter of LM (mm)	4.36±0.58	4.31±0.63	3.80±0.60	3.98±0.75	6.720	0.000
Diameter of LAD (mm)	2.56±0.39	2.30±0.37	2.14±0.30	2.06±0.38	16.539	0.000
Diameter of LCX (mm)	2.30±0.43	2.28±0.40	2.06±0.41	1.99±0.41	6.383	0.000
Diameter of RCA (mm)	3.17±0.63	3.01±0.54	2.97±0.54	2.72±0.58	4.969	0.003

Table 5. Spearman correlations between Gensini score, vessel score, and age, clinical characteristics, biochemical characteristics and coronary artery diameters. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CHD, coronary heart disease; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	Gensini score		Vessel score	
	Correlation coefficient	p	Correlation coefficient	p
Age	0.118	0.129	0.166	0.032
Total cholesterol	0.020	0.799	-0.131	0.099
Triglycerides	0.033	0.675	-0.020	0.804
Glucose	0.192	0.014	0.185	0.018
Creatinine	0.187	0.016	0.145	0.062
Urea nitrogen	0.137	0.080	0.071	0.364
HDL-C	-0.188	0.017	-0.204	0.009
LDL-C	0.028	0.723	-0.091	0.247
ALP	0.127	0.106	0.135	0.086
Lipoprotein a	0.111	0.158	0.063	0.426
hs-cTnT	0.552	0.000	0.461	0.000
FT3	-0.132	0.114	-0.060	0.470
FT4	-0.066	0.431	-0.007	0.934
TSH	-0.072	0.390	-0.183	0.028
Average diameter	-0.489	0.000	-0.446	0.000
Diameter of LM	-0.265	0.001	-0.274	0.000
Diameter of LAD	-0.510	0.000	-0.480	0.000
Diameter of LCX	-0.356	0.000	-0.314	0.000
Diameter of RCA	-0.289	0.000	-0.289	0.000

mean diameters of the LM (r=-0.265, p=0.001), LAD (r=-0.510, p<0.00001), LCX (r=-0.356, p<0.00001), and RCA (r=-0.289, p<0.00001), and the vessel score was also significantly associated with the average diameter (r=-0.446, p<0.00001) and the mean diameters of the LM (r=-0.274, p=0.001), LAD (r=-0.480, p<0.00001), LCX (r=-0.314, p<0.00001), and RCA (r=-0.289, p<0.00001), suggesting the potential inverse association between coronary artery diameter and the severity of coronary lesions. Subsequent multiple linear regression analyses also indicated that the Gensini score (β=-0.444, p<0.00001) was independently associated with the average coronary artery diameter (Table 6, Fig. 1).

Predictive effect of coronary artery diameter for CAD prevalence

Receiver operating characteristic (ROC) curve analyses showed that coronary artery diameters were predictive of the prevalence of CAD in our cohort, with areas under the curve (AUC) of 0.268 for average diameter (95% confidence interval [CI]: 0.183–0.353, p<0.00001), 0.356 for the LM (95% CI: 0.266–0.445, p=0.005), 0.214 for the LAD (95% CI: 0.136–0.291, p<0.00001), 0.366 for the LCX (95% CI: 0.271–0.461, p=0.009), and 0.346 for

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Table 6 Predictive values of average coronary artery diameters according to multiple linear regression among study participants

Variable	Unstandardized coefficient		Standardized coefficients	T	p
	B	Std. error	(Beta)		
Constant	2.929	0.050	----	58.424	0.000
Gensini score	-0.004	0.001	-0.444	-5.694	0.000
Creatinine	0.001	0.000	0.199	2.555	0.012

Table 7. Receiver operating characteristic curve analyses in CAD patients and controls. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; CHD, coronary heart disease; ALP, alkaline phosphatase; hs-cTnT, high-sensitivity cardiac troponin; FT3, free triiodothyronine; FT4, free thyroxin; TSH, thyroid-stimulating hormone; LM, left main; LAD, left anterior descending; LCX, left circumflex; RCA, right coronary artery

Variable	AUC (95% CI)	p	Optimal cut-off	Sensitivity	Specificity	Youden index
Age (years)	0.579(0.482-0.679)	0.122	65.5	0.452	0.698	0.150
Total cholesterol (mmol/L)	0.574(0.470-0.677)	0.162	4.410	0.500	0.628	0.128
Triglycerides (mmol/L)	0.507(0.404-0.610)	0.891	1.405	0.548	0.557	0.105
Glucose (mmol/L)	0.565(0.473-0.656)	0.213	5.565	0.361	0.858	0.218
Creatinine (μmol/L),	0.593(0.488-0.697)	0.071	65.3	0.556	0.651	0.207
Urea nitrogen (mmol/L)	0.553(0.456-0.650)	0.306	5.315	0.492	0.667	0.159
HDL-C (mmol/L)	0.599(0.501-0.698)	0.058	0.915	0.805	0.405	0.21
LDL-C (mmol/L)	0.567(0.466-0.669)	0.198	2.395	0.732	0.446	0.178
ALP (mmol/L)	0.527(0.423-0.630)	0.612	74.40	0.455	0.537	0.511
Lipoprotein a (mg/L)	0.546(0.448-0.644)	0.383	168.5	0.645	0.439	0.084
hs-cTnT (ng/L)	0.745(0.657-0.832)	0.000	6.840	0.705	0.703	0.408
FT3 (pmol/L)	0.543(0.447-0.640)	0.419	4.495	0.625	0.533	0.158
FT4 (pmol/L)	0.535(0.430-0.641)	0.510	16.520	0.525	0.562	0.087
TSH (mIU/L)	0.595(0.492-0.699)	0.076	2.160	0.675	0.524	0.199
Average diameter (mm)	0.732(0.647-0.817)	0.000	2.865	0.767	0.581	0.348
Diameter of LM (mm)	0.644(0.555-0.734)	0.005	4.075	0.721	0.556	0.277
Diameter of LAD (mm)	0.787(0.711-0.863)	0.000	2.385	0.698	0.774	0.472
Diameter of LCX (mm)	0.634(0.539-0.729)	0.009	2.235	0.558	0.677	0.235
Diameter of RCA (mm)	0.654(0.553-0.755)	0.003	3.188	0.651	0.718	0.369

the RCA (95% CI: 0.245–0.447, p=0.003). The predictive efficacies of the above parameters are listed in Table 7.

Discussion

In this hospital-based study of adult Chinese patients with angiographic evidence of the severity of coronary lesions, we found that the average diameter of the coronary arteries and the individual diameters of the LM, LAD, LCX, and RCA were all significantly inversely associated with the severity of CAD as estimated by the Gensini score or vessel score. Moreover, the predictive ability of coronary artery diameter for the prevalence of CAD was evaluated by ROC analyses, and the results indicated that coronary artery diameter was a significant determinant of CAD prevalence. To the best of our knowledge, this is the first study to explore the potential relationship between coronary artery diameter and the severity of coronary lesions in patients who underwent coronary angiography. Our results suggest that determination of coronary artery diameter may be used as a predictive marker for the risk of CAD.

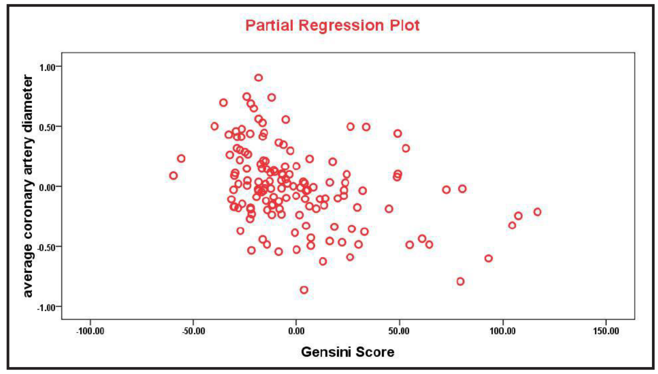

Fig. 1. Partial regression plot of Gensini score with average coronary artery diameter.

Most previous studies evaluated human coronary artery lumen diameter in cadaver hearts, and there have been very few reports regarding the estimation of the coronary artery dimensions by a quantitative angiographic method during clinical practice. Following the study published by MacAlpin et al. [18] in 1972, which demonstrated that the human coronary artery lumen diameter can be accurately measured by using the catheter tip as a calibrating object, we measured the coronary artery diameter in the present study using the catheter tip as a calibrating object. Our results were consistent with those of previous studies, which showed that the diameters of coronary arteries are highly variable [19-22], considering that genetic and environmental factors including age, sex, ethnicity, and race have all been correlated with the coronary artery diameter. Previous reports have also indicated a gender-related difference in coronary artery diameters [23], although the potential differences in coronary artery diameters between males and females remain controversial. In our study, we did not find significant differences in coronary artery diameters between males and females, which was not consistent with previous reports. The potential reasons are not clear, and differences in the studied populations may account for the inconsistency.

As mentioned before, there have been few reports evaluating the coronary artery diameter during life in CAD patients. If measured, the major purpose of the measurement of the luminal diameter of coronary arteries in previous studies was mainly for better treatment of CAD. It is necessary to be aware of the precise coronary artery diameter particularly during the percutaneous coronary intervention (PCI) process, in order to choose the appropriate sizes of the balloon and stent as well as the need for stenting. The results of our study expand previous knowledge regarding the potential clinical significance of coronary artery diameter by indicating that the coronary artery diameter is smaller in patients with CAD. Moreover, the coronary artery diameters were inversely associated with the severity of the coronary lesions. Most importantly, our results confirmed that a smaller coronary artery diameter was independently associated with the prevalence of CAD in our cohort. Although the potential mechanism underlying the association between coronary artery diameter and the severity of coronary lesions is not understood, a recently published study showed that coronary arterial diameters may be associated with the extent of coronary calcium levels in CAD patients[7]. Therefore, based on the current study, accurate evaluation of the coronary artery luminal diameter is not only essential of the treatment of CAD, but also a tool for diagnosis and prediction of the presence and extent of CAD. Future studies are needed to confirm our results and uncover the potential mechanisms underlying the association between coronary arterial diameters and CAD risk.

Limitations

We are aware that this study has some potential limitations that should be considered when interpreting the results. First, the sample size of the included patients was generally small, and we were therefore unable to determine whether the association between coronary diameters and the severity of CAD may differ in certain patient subgroups, such as those with diabetes mellitus. Secondly, our study was designed as a cross-sectional study. The results of our study only provide an inverse association between coronary diameters and the severity of CAD. Whether the association is causative deserves further evaluation in cohort studies. Thirdly, although we used multiple regression analyses to evaluate the potential relationships between coronary artery diameters and the severity of CAD and tried our best to overcome the potential influence of confounding factors, we were unable to exclude the possibility that some remaining confounding factors may have affected the association between coronary artery diameters and the severity of CAD. For example, the body surface of the individual participant may affect the lumen diameters of the coronary artery, and this could be easily determined if the coronary artery diameters were adjusted for body surface area. In addition, many therapies such as medications and kinesitherapy may affect the diameters of the coronary arteries and cardiac function [24, 25], and it would be optimal if we had obtained the data regarding the medications regularly taken by the included participants. Subsequent adjustment for medication use might minimize the potential confounding effect from the treatment. Finally, the potential mechanisms underlying the inverse association between the coronary diameters and the severity of CAD should be investigated in the future. This is particularly important since revealing the underlying mechanisms may provide potential targets for the prevention and treatment of CAD.

Conclusion

In conclusion, the results of the present study suggest that the diameters of coronary arteries are significantly inversely associated with the angiographic-based severity of CAD, and the diameters of coronary arteries may be an independent predictor of CAD risk. Future cohort studies with adequate sample sizes are needed to confirm the results of our study.

Abbreviations

CAD (coronary artery disease); LM (left main artery); LAD (left coronary anterior descending branch); LCX (left circumflex coronary artery); RCA (right coronary artery); CI (confidence interval); ECG (electrocardiogram); TCH (total cholesterol); TG (triglycerides); FBG (fasting blood glucose); CR (creatinine); HDL-C (high-density lipoprotein cholesterol); LDL-C (low-density lipoprotein cholesterol); ALP (alkaline phosphatase); LP-A (apolipoprotein A); hs-cTnT (high-sensitivity cardiac troponin T); FT3 (free triiodothyronine); FT4 (free thyroxine); TSH (thyroid-stimulating hormone); SPSS (Statistics Package for Social Sciences); ANOVA (analysis of variance); ROC (receiver operating characteristic); AUC (area under the curve); PCI (percutaneous coronary intervention).

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Disclosure Statement

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