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Assessment of Coronary Artery Stenosis by Coronary Angiography

A Head-to-Head Comparison With Pathological Coronary Artery Anatomy

Song Jiangping, MD, PhD*; Zheng Zhe, MD, PhD*; Wang Wei, MD, PhD; Song Yunhu, MD; Huang Jie, MD, PhD; Wang Hongyue, MD; Zhao Hong, MD; Hu Shengshou, MD, PhD

Background**—**Conventional coronary angiography (CCA) has been considered as a gold standard for the diagnosis of coronary artery diseases; however, its diagnostic accuracy is still unknown.

Methods and Results**—**Between July 2004 and December 2011, 97 patients underwent CCA within 15 days before heart transplantation in Fuwai hospital. A head-to-head comparison study was performed to examine the diagnostic accuracy of CCA as compared with that of pathological coronary artery anatomy. As confirmed by pathological coronary artery anatomy, 44 (45.4%) patients had coronary artery diseases. The patient-based diagnostic accuracy evaluation showed that the area under the receiver-operating characteristic curve of CCA for detecting ≥50% stenosis was 0.91, with a sensitivity of 91%, a specificity of 93%, and high concordance (κ=0.83). A per-vessel analysis of 291 vessels yielded an AUC of 0.79, the agreement of 3 vessels >0.6 (κ statistic). The area under the receiver-operating characteristic curve was 0.88 for proximal and middle segments, and was 0.62 for distal segments, κ was calculated to detect the distal segments with lower concordance than proximal and middle segments. The patient- and vessel-based evaluations showed similar diagnostic accuracy of CCA in detecting ≥75% stenosis. Per-segment evaluation found CCA was more accurate for detecting ≥50% and ≥75% stenosis in proximal and middle segments than in distal segments, and the diagnosis ability decreased in more severe stenosis segments and more complex lesions.

Conclusions**—**The accuracy of CCA is quite high in detecting coronary artery stenosis in patients- and vessels-based levels. However, the diagnosis ability decreased in more severe and complex lesions, especially for distal segments. **(*Circ Cardiovasc Interv*. 2013;6:262-268.)**

Key Words: coronary angiography ■ coronary artery ■ diagnosis ■ pathology

Coronary artery disease (CAD) is a major cause of mortality, resulting in an estimated 7.6 million deaths every year all over the world.[1] Conventional coronary angiography (CCA) is the only undisputed means of visualizing the coronary arterial system in vivo and is regarded the gold standard for the assessment of modality of coronary arteries since CCA was first discovered by Werner Forssmann in 1929.[2] However, CCA has its limitations. It gives only information of the site and degree of luminal narrowing, providing no data on the extent of atherosclerotic change within the vessel wall. Images are obtained in only 2 dimensions, although the use of multiple projections enables a more comprehensive assessment of an individual lesion. In addition, the coronary arteries move in a complex pattern during each cardiac cycle. Each coronary artery moves at a different velocity and in a different pattern from the others, and even the individual segments of each coronary arteries do not move uniformly.[3] All these reasons may mislead the disease assessment.[4,5] As the gold standard, the diagnostic accuracy of CCA is not clear.

As we know, the real gold standard to diagnose the coronary artery disease is the pathological coronary artery anatomy (PCA), which is almost impossible to perform because the heart samples were hard to obtain. The application of heart transplantation gave us a chance to collect these heart samples after transplantation for postoperative PCA examination. Some of the patients underwent CCA before the transplantation because of suspected CAD. We investigated the diagnostic accuracy of CCA in the detection of coronary artery stenosis by comparing with postoperative PCA. We aimed to test whether CCA could detect >50% or 75% stenosis in coronary arteries larger than 1.5 mm in diameter.

Methods

Study Design and Patients

Between July 2004 and December 2011, patients with cardiomyopathy who underwent heart transplantation because of end-stage heart failure in Fuwai Hospital of the Peking Union Medical College were included for the analysis. Patients with previous bypass surgery,

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WHAT IS KNOWN

- Conventional coronary angiography (CCA) is the gold standard for in vivo assessment of coronary arteries.
- The diagnostic accuracy of CCA is affected by many variables, including the orientation of the heart, angle selection for cardiac planes, and shape of the lesions.

WHAT THE STUDY ADDS

- A head-to-head comparison of CCA with pathological coronary artery anatomy was performed in patients CCA before the heart transplantation.
- The accuracy of CCA for detecting coronary artery stenosis is high; however, the diagnostic ability is decreased in more severe and complex lesions, especially for distal segments.

previous stent placement, an unstable clinical condition, coronary anatomy not fit for 15-segment American Heart Association classification,[6] bad quality image of the CCA, or a contraindication to the administration of contrast agent were excluded. Patients who underwent CCA before transplantation were included for the analysis. Their heart samples were subjected to PCA examination.

The study protocol was approved by the Institutional Ethics Committee of the Fuwai Hospital of the Peking Union Medical College. All patients gave informed consent before transplantation; informed consent was also obtained from patients to allow the use of their clinical records and heart samples for investigation.

Acquisition and Analysis of Data From Conventional Coronary Angiography

Some patients underwent CCA within 15 days before heart transplantation using standard techniques to determine the obstructive CAD may be a concomitant disease with cardiomyopathy. Multiple projections were recorded for each vessel. The diameters of the catheters were documented for calibration. Cine-fluoroscopic images were analyzed at the angiography core laboratory. The severity of artery stenosis was determined using Two-Dimensional System Quantitiative Coronary Analysis (CAAS II QCA) Research version 2.0.1 Software (Pie Medical Imaging). Investigators were unaware of the results of pathological anatomy of coronary arteries. Results of the 2 experienced cardiologists were averaged; cases with disputed results from the 2 cardiologists were re-examined by a third observer.

Acquisition and Analysis of Data From Pathological Coronary Artery Anatomy

During the heart transplantation, the patient's heart was removed from the thoracic cavity. Water was injected at pressures of 50 to 100 mm mt repeatedly through a plastic cannulae inserted into the coronary arteries to make sure no new thrombosis was formed in vitro. The heart was then fixed in 10% phosphate buffered formaldehyde. The major epicardial coronary arteries (left main trunk, left anterior descending, left circumflex branches, and right coronary artery) were visually inspected with respect to their origin and course, and cut transversely at 2-mm intervals to the severity of artery stenosis by 2 experienced pathologists, using American Heart Association 15-segment model, each of segments were graded by the percentage of cross-sectional area of stenosis. The cross-sectional area was determined by software Image Pro Plus (version 5.0.2, Media Cybernetics). Cutting the lesions into slides and hematoxylin and eosin staining were performed microscopically to confirm the macroscopic observations, especially for exact stenosis in vessel ≤3 mm in diameter, and to distinguish the in vitro–formed thrombosis from the in vivo–formed thrombosis in coronary arteries. The luminal stenosis of coronary diseases was classically categorized into 4 degrees on the basis of the percentage of cross-sectional area stenosis: 1% to 25%, 26% to 50%, 51% to 75%, and 76% to 100%.[7–9] Using stenosis 50% cutoffs considered have coronary diseases or not, 75% cutoffs considered have severe luminal narrowing (Figure 1). The pathologists were blinded to the CCA results. Results for the 2 pathologists were averaged; cases disputed with results from the 2 pathologists were re-examined by a third pathologist.

Patient-, Vessel-, and Segment-Based Evaluation

For patient-based analysis, a true positive was defined as having at least 1 positive segment by both modalities, regardless of location. Vessel-based analysis means among right, left anterior descending, and left circumflex coronary arteries in the study group who had at least 1 segment with >50% or 75% stenosis by CCA or PCA. Segment-based analysis refers to comparison for each segment with >50% or 75% stenosis using AHA 15 segments model. As described by Garcia et al,[10] we consider that the 61 nonevaluable segments as positive. The detail methods of patient-, vessel-, and segment-based evaluations were performed as described in the references.[10–12]

Statistical Analysis

The diagnostic accuracy of CA for CAD was determined by measuring the area under the receiver-operating characteristic curve (AUC), 95% confidence interval, sensitivity, specificity, positive, negative predictive values and accuracy. Data were analyzed using weighted κ statistics to test the agreement between PCA and CCA. Continuous variables were expressed as mean (SD). The receiver-operating

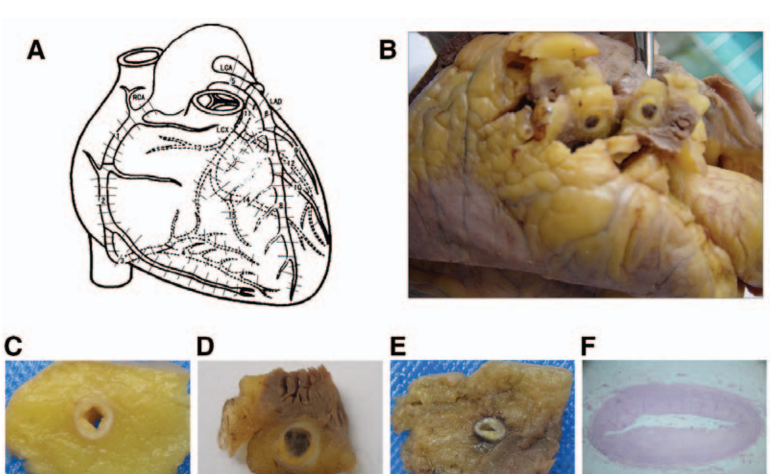

Figure 1. Pathological coronary artery anatomy for a patient with coronary artery disease (CAD). **A** and **B**, The major epicardial branches of the coronary arteries (left main trunk [LM]; left anterior descending [LAD]; left circumflex branches [LCX]; and right coronary artery [RCA]) were visually inspected with respect to their origin and course, and were cut transversely at 2-mm intervals to examine the severity of artery stenosis. **C**, 25% to 50% stenosis. **D**, 51% to 75% stenosis. **E**, 76% to 99% stenosis. **F**, Microscopy with hematoxylin and eosin staining was performed to calculate cross-sectional area of stenosis and distinguish the in vitro–formed thrombosis from the in vivo–formed thrombosis in the coronary arteries. LAD indicates left anterior descending, LCX left circumflex branches; LM, left main trunk; and RCA, right coronary artery.

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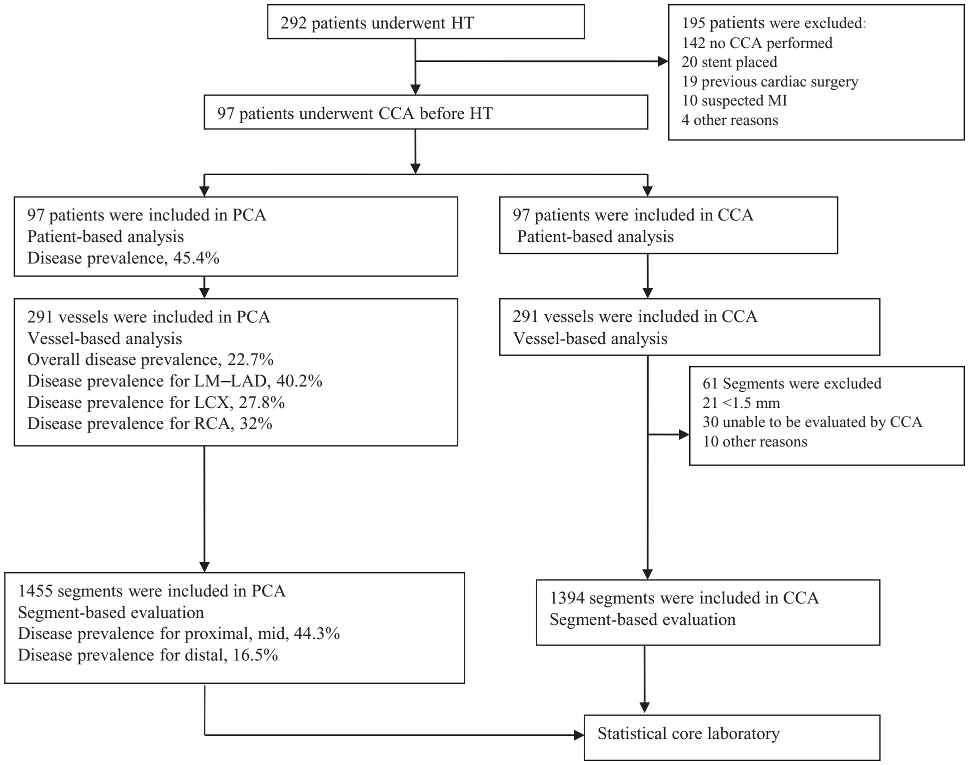

Figure 2. The process of selecting patients who underwent heart transplantation (HT) for conventional coronary angiography (CCA) and pathological coronary artery anatomy (PCA) examinations and comparison. LAD indicates left anterior descending, LCX left circumflex branches; LM, left main trunk; and RCA, right coronary artery.

characteristic–AUC was calculated for CCA to detect obstructive lesions at the PCA-defined 50% and 75% thresholds. $P<0.05$ was considered significant. All probability values were 2-sided, and 95% confidence intervals are also presented. SAS software version 9.1 and Microsoft Excel 2003 (Microsoft Corp, Redmond, WA) were used for data management and statistical analyses.

Results

Descriptive Data

Between July 2004 and December 2011, a total of 292 patients underwent heart transplantation in Fuwai Hospital because of end-stage heart failure. Among them, 150 underwent conventional CA within 15 days before operation to determine whether the obstructive CAD may be a concomitant disease with cardiomyopathy. Of the 150 patients, 20 had previous stent placement, 19 had previous bypass surgery, 10 had suspected myocardial infarction during the operation, and 4 patients had coronary anatomy not fit for the 15-segment American Heart Association classification (Figure 2). Thus, 97 patients were eligible and included in the analysis.

Demographic and clinical characteristics of the 97 patients are shown in Table 1. The median age was 50 years (range, 39–67), and 83.5% were males. The main reasons for heart transplantation were dilated cardiomyopathy (43.3%) and ischemic cardiomyopathy (39.2%). Most patients (85.6%) had end-stage heart failure (New York Heart Association-III, -IV). Smoking was the most common risk factor. The patients were injected with 56 to 98 mL (median, 68 mL) of contrast medium before CA; 52.8% of them were injected with nitroglycerin into the coronary artery to prevent coronary artery spasm during angiography. The patients underwent PCA 5 to 10 days (median, 8 days) after CA.

Accuracy of Patient-Based Coronary Angiography Evaluation

Both CCA and PCA showed that 44 patients (45.4%) had ≥50% coronary artery stenosis. However, 4 CCA-positive cases were confirmed negative, and 4 CCA-negative cases were confirmed positive by PCA. CCA showed ≥75% stenosis in 37 patients, but PCA showed ≥75% stenosis in only 35 patients. When examining patients with coronary artery stenosis of either ≥50% or ≥75% by CCA, the AUC was >0.8, the sensitivity, specificity, positive and negative predictive values were all ≈90%; the agreement of the 2 methods was >0.8 (Table 2). Patient-based evaluation demonstrated that CCA was sensitive and accurate for the diagnosis of coronary artery stenosis.

Accuracy of Vessel-Based Coronary Angiography Evaluation

Of the 44 patients with artery stenosis, 13 had 1 stenosed artery, 9 had 2 stenosed arteries, and 22 patients had 3 stenosed arteries as detected by PCA. A per-vessel analysis of 291 vessels yielded an AUC of 0.79. Of the 97 involved arteries, 39 were left main trunk–left anterior descending, 27 were left circumflex branches, and 31 were right coronary artery; 77 arteries showed ≥75% stenosis. When detecting coronary arteries of ≥50% stenosis. On a per-vessel basis, the AUC was similar for the 3 vessels; the sensitivity and positive predictive value were higher for left main trunk–left

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Table 1. Baseline Characteristics of the 97 Patients

Characteristics	No. (%) of Patients
Male	81 (83.5)
Reason for HT	
Dilated cardiomyopathy	42 (43.3)
Hypertrophic cardiomyopathy	2 (2.1)
Restrictive cardiomyopathy	4 (4,1)
Ischemic cardiomyopathy	38 (39.2)
ARVC	2 (2.1)
Other	9 (9.2)
Risk factors	
Hypertension	10 (11.2)
Diabetes mellitus	10 (11.2)
Hypercholesterolemia	12 (13.6)
Smoking (current)	22 (23.8)
NYHA class	
NYHA class I	2 (2.1)
NYHA class II	12 (12.4)
NYHA class III	23 (23.7)
NYHA class IV	60 (61.9)
Distribution of disease by PCA	
None	
1 vessel	13 (13.4)
2 vessel	9 (9.3)
3 vessel	22 (22.7)
Nitroglycerin administered, no. (%)	51(52.8)

ARVC indicates arrhythmogenic right ventricular cardiomyopathy; HT, heart transplantation; NYHA, New York Heart Association; and PCA, coronary arteries pathological anatomy.

anterior descending than for left circumflex branches and right coronary artery; the specificity and negative predictive value for the 3 vessels were all as high as ≈90%. The agreement of 3 vessels was >0.6 (κ statistic). Similar results were obtained when detecting coronary arteries of ≥75% stenosis by CCA (Table 3).

Accuracy of Segment-Based Coronary Angiography Evaluation

The accuracy parameters for segment-based evaluation using a 50% and 75% stenosis threshold are shown in Tables 4 and 5. All accuracy parameters were lower when detecting ≥50% stenosis in distal segments. According to the American Heart Association 15-segment model, segments 1, 2, 5, 6, 7, 9, 11, and 12 were defined as proximal and middle segments; segments 3, 4, 8, 10, 13, 14, and 15 as distal segments. When detecting ≥50% stenosis in proximal and middle segments by CCA, the AUC was 0.88, the sensitivity and positive predictive value were all >80%, and both the specificity and negative predictive value were as high as 94%. κ was calculated to detect the distal segments with lower concordance than proximal, middle segments (0.25 versus 0.76 at stenosis≥50% level and 0.45 versus 0.55 at stenosis≥75% level). All accuracy parameters were lower when detecting ≥50% stenosis in distal segments. Interestingly, when detecting ≥75% stenosis, the specificity, positive and negative predictive values were all higher in distal segments than in proximal and middle segments. Figure 3 showed the AUC curves of CCA for detecting coronary artery stenosis in proximal, middle, and distal segments.

Discussion

CCA has been used as a gold standard examination to measure myocardial perfusion and coronary anatomy for nearly half a century.[13] However, its diagnostic accuracy is affected by the orientation of the heart, angle selection for cardiac planes, number of segments, nomenclature for segments, and assignment of segments to coronary arterial territories. Usually, the hearts examined in previous studies to test the diagnostic accuracy of CCA for CAD through heart specimens were obtained from patients after death.[14,15] Thrombosis might form in the postmortem coronary arteries. In our study, the explanted hearts from patients who underwent heart transplantation contained no new thrombosis formation because of systemic heparinization during the operation and water injection while removing the hearts from the thoracic cavity. We observed that the rate of coronary artery stenosis in examined hearts was 45.4%, which was higher than the rates in previous autopsy studies.[16,17] Another strength of our study was the patients underwent PCA 5 to 10 days (median, 8 days) after CCA, the short time interval between was to avoid progression of disease, that is to say distort correlation between CCA and PCA disturbed by time interval would not have happened in this study. The visual estimation of coronary artery cross-sectional area narrowing is accurate and has been used as the standard of measurement for this study, and it may be another strength. To date, available literature comparing CCA with PCA with larger sample size (97 patients) and in a more detailed manner (patient, vessel, and segment based) is almost nonexistent. Overall, the larger sample size and more detailed manner in our study may explain the difference.

The pending question concerning the accuracy and usefulness of CCA posed by cardiologists many years is as follows: "With how much precision can clinically applied CCA reveal areas of luminal narrowing, and obstructive

Table 2. Accuracy Parameters for Patient-Based Detection of >50% and 75% Coronary Stenosis

Patient-Based Detection (n=97)	AUC (95% CI)	TP	TN	FP	FN	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)	κ (95% CI)
Stenosis>50%	0.91 (0.85–0.98)	40	49	4	4	91 (82–99)	93 (82–99)	91 (82–99)	93 (83–98)	92 (86–97)	0.83 (0.72–0.94)
Stenosis>75%	0.93 (0.87–0.99)	33	58	4	2	89 (74–96)	97 (89–99)	94 (80–99)	93 (85–99)	94 (89–98)	0.86 (0.76–0.99)

AUC indicates area under the receiver-operator characteristic curve; CI, confidence interval; FN, false-negative; FP, false-positive; NPV, negative predictive value; PPV, positive predictive value; TN, true negative; and TP, true positive.

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Table 3. Accuracy Parameters for Vessel-Based Detection of >50% and 75% Coronary Stenosis

Vessel-Based Detection (n=291)		AUC	TP	TN	FP	FN	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)	κ (95% CI)
Stenosis >50%	LM-LAD (n=97)	0.83 (0.74–0.93)	35	52	6	4	90 (80–99)	89 (82–98)	85 (74–96)	93 (86–96)	90 (83–96)	0.79 (0.66–0.91)
	LCX (n=97)	0.82 (0.72–0.93)	21	63	6	7	74 (66–82)	91 (88–94)	76 (60–93)	90 (84–97)	86 (79–93)	0.66 (0.49–0.83)
	RCA (n=97)	0.83 (0.73–0.93)	23	60	8	6	75 (65–83)	90 (86–94)	78 (64–94)	88 (78–95)	91 (84–96)	0.66 (0.50–0.82)
Stenosis >75%	LM-LAD (n=97)	0.89 (0.80–0.97)	28	60	6	3	82 (69–95)	95 (87–99)	90 (74–97)	91 (81–96)	90 (84–97)	0.79 (0.66–0.92)
	LCX (n=97)	0.92 (0.66–0.91)	20	70	2	5	89 (66–88)	94 (88–99)	77 (59–94)	97 (91–99)	93 (87–97)	0.78 (0.63–0.93)
	RCA (n=97)	0.84 (0.72–0.95)	14	73	7	3	72 (62–83)	96 (88–99)	86 (63–86)	91 (82–96)	89 (83–95)	0.72 (0.55–0.87)

AUC indicates area under the receiver-operator-characteristic curve; FN, false-negative; FP, false-positive; LCX, left circumflex artery; LM-LAD, left main and left anterior descending coronary arteries; NPV, negative predictive value; PPV, positive predictive value; TN, true negative; TP, true positive; and RCA, right coronary artery.

lesions in the coronary arteries. How specifically can it thus be determined whether significant coronary artery disease is or is not present?" These are questions are as yet unanswered. The objective of this study was a careful patient-, vessel-, segment-based and clinical score comparison of PCA and CCA findings in transplanted hearts in an attempt to provide an answer to these questions.

In this head-to-head comparison study, we found that the AUC of conventional CCA examination in diagnosing obstructive coronary disease was >0.9 in a patient-based evaluation and >0.8 in a vessel-based evaluation. In a segment-based evaluation, the AUC of CCA for detecting ≥50% stenosis in proximal and middle segments was also high (AUC=0.88). The same results also can be seen in segment-based evaluation in Table 4. CCA was more accurate for detecting ≥50% stenosis in proximal and middle segments than distal segments. Furthermore, the diagnosis ability decreased in more severe stenosis (at ≥75% stenosis level) can see from Table 5. Overall, the AUC and concordance were always higher in diagnosing proximal and middle segment stenosis than in diagnosing distal segment stenosis.

Indeed, CCA has generally been found to reveal less extensive disease than postmortem examination does in previous study.[15] The majority of these previous studies have reported a tendency of CCA to underestimate the severity of the coronary lesions.[17,18] In our study, we also observed results similar to a previously published study in which the stenosis of coronary arteries was underestimated by CCA because of angulation of image acquisition. Saxer et al[19] have reported that nearly at 33% lesions stenosis of coronary arteries underestimated by CCA. In vessel-based evaluation, we observed the errors were 4/97 (left main trunk–left anterior descending), 7/97 (left circumflex branches), and 6/97 (right coronary artery), respectively. In segments-based evaluation, false-negative segments detected by CCA were easily observed in the Tables 4 and 5, especially for distal segments.

Table 4. Accuracy Parameters for Segment-Based Detection of >50% Coronary Stenosis (n=1455, All Segments for Analysis with 61 Nonevaluable Segments as Positive)

Coronary Segment (n=1455)	TP	TN	FP	FN	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)	κ (95% CI)
LM	9	88	0	0	100	100	100	100	100	1.00
LAD										
Proximal	32	59	3	3	92 (82–100)	95 (86–98)	91 (76–98)	95 (90–100)	94 (89–98)	0.87 (0.76–0.96)
Middle	31	59	4	3	91 (76–98)	94 (84–98)	89 (73–96)	95 (80–98)	93 (88–98)	0.84 (0.73–0.95)
Distal	22	59	7	9	71 (51–85)	89 (79–95)	76 (56–89)	87 (76–94)	84 (76–91)	0.61 (0.44–0.78)
First diagonal	20	72	2	3	86 (66–97)	97 (90–99)	91 (70–98)	97 (94–99)	95 (94–99)	0.85 (0.73–0.97)
Second diagonal	27	56	5	9	75 (57–87)	92 (81–97)	84 (71–96)	86 (75–93)	86 (79–93)	0.68 (0.53–0.84)
LCX										
Proximal	19	73	0	5	80 (60–92)	100 (95–100)	100 (82–100)	94 (85–97)	95 (90–99)	0.85 (0.72–0.97)
Distal	6	84	2	5	55 (25–83)	97 (94–100)	75 (44–100)	94 (80–99)	93 (88–98)	0.59 (0.32–0.86)
First obtuse marginal	17	70	5	5	77 (54–92)	93 (87–98)	77 (59–94)	93 (85–97)	89 (84–96)	0.71 (0.53–0.87)
Second obtuse marginal	18	67	5	7	72 (54–89)	93 (87–98)	78 (61–95)	90 (81–96)	88 (81–94)	0.67 (0.49–0.84)
RCA										
Proximal	21	73	2	1	95 (77–99)	97 (90–99)	91 (71–98)	98 (96–100)	96 (93–100)	0.91 (0.81–1.00)
Middle	22	70	1	4	84 (65–95)	98 (92–99)	96 (78–99)	95 (86–98)	95 (90–99)	0.86 (0.75–0.98)
Distal	16	67	4	10	61 (40–79)	94 (86–98)	80 (56–94)	87 (77–93)	86 (79–93)	0.60 (0.41–0.79)
RPDA	18	66	4	9	66 (46–83)	94 (86–98)	81 (65–97)	88 (80–95)	87 (79–94)	0.64 (0.47–0.82)
PLA	16	67	5	9	64 (42–82)	93 (84–97)	76 (57–94)	88 (78–94)	85 (78–92)	0.60 (0.41–0.78)

FN indicates false-negative; FP, false-positive; LAD, left anterior descending artery; LCX, left circumflex; LM, left main; NPV, negative predictive value; PLA, posterolateral artery; PPV, positive predictive value; RCA, right coronary artery; RPDA, right posterior descending artery; TN, true negative; and TP, true positive.

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Table 5. Accuracy Parameters for Segment-Based Detection of >75% Coronary Stenosis (n=1455, All Segments for Analysis With 61 Nonevaluable Segments as Positive)

Coronary Segment	TP	TN	FP	FN	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)	κ (95% CI)
LM	6	91	0	0	100	100	100	100	100	1.00
LAD										
Proximal	29	59	3	6	82 (70–95)	95 (89–100)	91 (80–100)	91 (90–100)	91 (85–97)	0.79 (0.66–0.92)
Middle	28	58	6	5	85 (72–97)	90 (78–100)	80 (72–99)	92 (85–98)	87 (82–95)	0.74 (0.61–0.88)
Distal	3	82	3	9	25 (5–58)	96 (92–100)	50 (9–90)	90 (83–96)	88 (81–94)	0.21 (0.01–0.56)
First diagonal	4	80	7	6	40 (9–70)	92 (91–100)	37 (7–64)	93 (85–97)	87 (79–93)	0.30 (0.02–0.59)
Second diagonal	1	79	6	11	8 (0–23)	93 (85–97)	14 (0–40)	88 (81–94)	83 (75–90)	0.01 (0.00–0.21)
LCX										
Proximal	19	73	0	5	80 (60–92)	100 (95–100)	100 (82–100)	94 (85–97)	96 (93–100)	0.90 (0.82–1.00)
Distal	6	84	2	5	55 (25–83)	97 (94–100)	75 (44–100)	94 (80–99)	93 (88–98)	0.59 (0.32–0.86)
First obtuse marginal	9	73	6	9	50 (26–73)	92 (86–98)	60 (35–84)	89 (82–95)	85 (79–92)	0.45 (0.22–0.68)
Second obtuse marginal	3	73	8	13	19 (0–37)	90 (83–96)	77 (6–60)	84 (77–92)	78 (70–86)	0.10 (0.01–0.32)
RCA										
Proximal	21	73	2	1	95 (77–99)	97 (90–99)	91 (71–98)	98 (96–100)	93 (89–98)	0.85 (0.73–0.96)
Middle	20	72	1	4	83 (68–98)	98 (95–100)	95 (86–100)	94 (89–99)	95 (90–99)	0.83 (0.72–0.95)
Distal	4	77	6	10	29 (24–52)	93 (84–97)	89 (80–95)	60 (27–98)	83 (74–90)	0.24 (0.07–0.51)
RPDA	3	74	9	1	22 (4–51)	89 (82–95)	25 (5–57)	87 (78–93)	79 (71–87)	0.12 (0.00–0.34)
PLA	4	74	10	9	31 (9–61)	88 (81–95)	29 (4–52)	89 (80–94)	80 (72–98)	0.18 (0.00–0.43)

FN indicates false-negative; FP, false-positive; LAD, left anterior descending artery; LCX, left circumflex; LM, left main; NPV, negative predictive value; PLA, posterolateral artery; PPV, positive predictive value; RCA, right coronary artery; RPDA, right posterior descending artery; TN, true negative; and TP, true positive

The explanations of discrepancy between PCA and CCA may be addressed as follows. First, CCA lacks sufficient projections to permit an objective assessment of the configuration of the lesions, which may seem normal or nearly normal in 1 projection, but greatly obstructed in other projections. These errors can be commonly detected in this study. Second, different lesion shapes may easily cause the discrepancy. For example, a star-shaped lesion is almost impossible to be assessed accurately by angiography because it seems normal in any projection.[20] Third, overlapping of CCA images of the 2 vessels

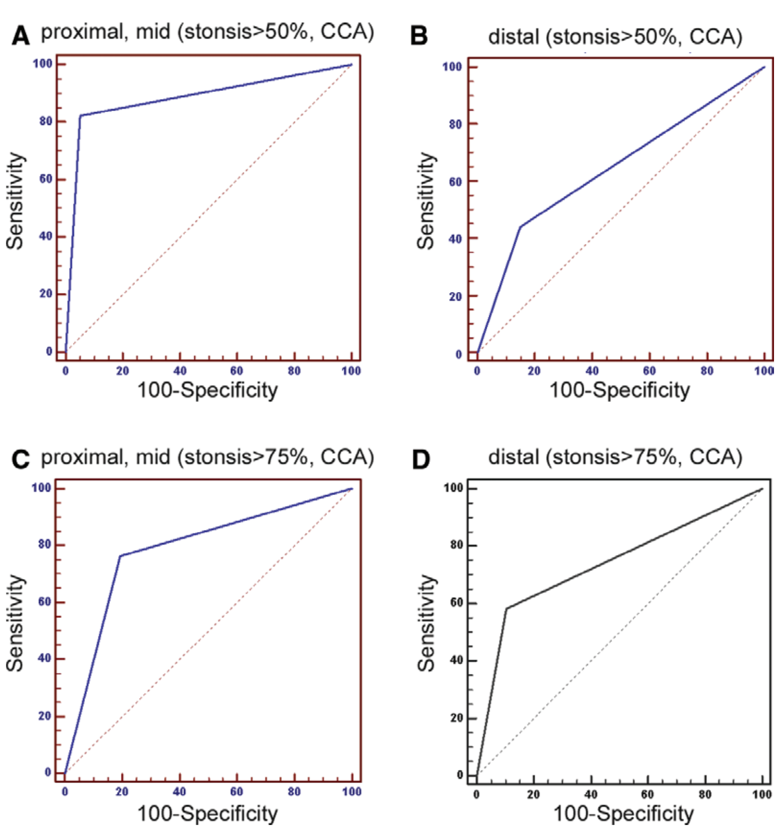

Figure 3. Area under the receiver-operating characteristic curves (AUC) of CCA for detecting coronary artery stenosis in proximal, middle, and distal segments. **A**, AUC is 0.88 (95% confidence interval [CI], 0.80–0.96) for ≥50% stenosis in proximal and middle segments. **B**, AUC is 0.62 (95% CI, 0.49–0.74) for ≥50% stenosis in distal segments. **C**, AUC is 0.77 (95% CI, 0.66–0.87) for ≥75% stenosis in proximal and middle segments. **D**, AUC is 0.76 (95% CI, 0.61–0.96) for ≥75% stenosis in distal segments. Proximal and middle segments: segments 1, 2, 5, 6, 7, 9, 11, 12; distal segments: 3, 4, 8, 10, 13, 14, 15 (American Heart Association 15-segment model).

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near the branch point may cause the mistake. Unless the site of a branch is perpendicular to the angle of viewing, such overlap may occur.[15] Fourth, some false-positive segments in this study may be attributable to catheter tips causing coronary spasm.[21] Finally, we encountered an overestimation of the lumen diameter by angiography in severe diseased artery because of lack of a true normal frame of reference distal to the affected segment; this is why the diagnosis ability decreased in more severe stenosis (at ≥75% stenosis level) segments and distal segments.

This is only a single-center experience on diagnostic performance of CCA. Disease prevalence impacts diagnostic accuracy. First, 54.6% patients with cardiomyopathies with no disease also underwent CCA because of chest pain, tightness, and palpitation. Present clinical guidelines recommend invasive coronary angiography for patients with heart failure and angina (class I, level B) and patients with heart failure and chest pain or suspected CAD (class IIa, level C).[22] Second, this group of no disease patients can test the diagnosis ability of CA to rule out the symptomatic patients with or without coronary stenosis. Third, predictive values heavily depend on disease prevalence within the study population. A limitation of the study is that patients were enrolled on the basis of availability in the clinical database of PCA and CCA, having higher prevalence in our population than in the general population. Our disease prevalence is consistent with previous studies that may draw proper predictive values.[10,12]

In summary, our head-to-head comparison study showed that conventional CCA can precisely detect coronary artery stenosis at both patient and vessel levels. However, its accuracy in detecting complicated stenosis, stenosis in distal segments, needs to be improved.

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Disclosures

None.

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