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Comparison of Clinical Interpretation with Visual Assessment and Quantitative Coronary Angiography in Patients Undergoing Percutaneous Coronary Intervention in Contemporary Practice: The Assessing Angiography (A2) Project

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Abstract

Background—Studies conducted decades ago described substantial disagreement and errors in physicians' angiographic interpretation of coronary stenosis severity. Despite the potential implications of such findings, no large-scale efforts to measure or improve clinical interpretation were subsequently made.

Methods & Results—We compared clinical interpretation of stenosis severity in coronary lesions with an independent assessment using quantitative coronary angiography (QCA) in 175 randomly selected patients undergoing elective percutaneous coronary intervention (PCI) at 7 U.S. hospitals in 2011. To assess agreement, we calculated mean difference in percent diameter stenosis between clinical interpretation and QCA and a Cohen's weighted kappa statistic. Of 216 treated lesions, median percent diameter stenosis was 80.0% (Q1 and Q3, 80.0 and 90.0%) with 213 (98.6%) assessed as ≥70%. Mean difference in percent diameter stenosis between clinical interpretation and QCA was +8.2 ± 8.4%, reflecting an average higher percent diameter stenosis

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by clinical interpretation (P<0.001). A weighted kappa of 0.27 (95% CI, 0.18 to 0.36) was found between the 2 measurements. Of 213 lesions considered ≥70% by clinical interpretation, 56 (26.3%) were <70% by QCA though none was <50%. Differences between the 2 measurements were largest for intermediate lesions by QCA (50 to <70%) with variation existing across sites.

Conclusions—Physicians tended to assess coronary lesions treated with PCI as more severe than measurements by QCA. Almost all treated lesions were ≥70% by clinical interpretation, while approximately a quarter were <70% by QCA. These findings suggest opportunities to improve clinical interpretation of coronary angiography.

Keywords

Health policy and outcomes research; Quality improvement; Coronary angiography; Percutaneous coronary intervention; Quantitative coronary angiography

Millions of coronary angiograms are performed annually to obtain information that, when combined with clinical data, guides treatment decisions for patients with coronary artery disease.[1] These tests are performed, in large part, to determine the presence and severity of coronary stenoses, which in turn plays a key role in selection of patients for revascularization.[2] In clinical practice, stenosis severity is typically determined during or shortly after the procedure, and most commonly relies on visual estimation by physicians. This approach, however, has well-known limitations.[3,4] Older studies, conducted a decade or more ago, described interobserver and intraobserver variation in visual estimations of stenosis severity and inaccuracies when compared with computer-assisted techniques, expert panel review, autopsy results, or simulations.[5–13] Despite the potential implications of these findings – particularly regarding the consistency and quality of treatment decisions for revascularization[13] – no widespread efforts have been undertaken to improve clinical interpretations of coronary angiograms nor has there been further study of the issue.

We lack contemporary information about the quality of clinical interpretations of coronary angiograms. Since studies were last performed in the early 1990s, significant advances in digital technology have transformed angiographic imaging.[14] Whether this has led to concomitant improvements in clinical interpretations is largely uncertain, however. Understanding this issue is relevant given that stenosis severity, as assessed by physicians, remains a pivotal variable for framing treatment options – even in the current era where pre- or intra-procedural functional testing of a stenosis is widely available. Moreover, the percent diameter stenosis continues to be used as an entry criterion for clinical trials of revascularization and its reliable measurement is a key assumption of current Appropriateness Use Criteria for revascularization.[15] Errors in the clinical interpretation of coronary angiograms therefore have important consequences for treatment decisions, potentially leading to both overuse and underuse of revascularization.

To explore the quality of clinical interpretation in the modern era of interventional cardiology, we designed the Assessing Angiography (A2) project. We randomly selected coronary angiograms from patients undergoing percutaneous coronary intervention (PCI) at seven large US hospitals. The clinical interpretation of stenosis severity among lesions with PCI by physicians was compared with measurements made by an independent, blinded review using state-of-the-art quantitative coronary angiography (QCA) – a computer-assisted technique for measuring stenosis severity employed for decades for quality assurance within clinical trials.[16] We purposely selected QCA as a benchmark tool given its high reproducibility and potential freedom from observer influence and bias.[17]

Methods

Data Sources and Clinical Abstraction

We enrolled seven PCI hospitals participating in the CathPCI Registry® of the National Cardiovascular Data Registry® (NCDR®), sponsored by the American College of Cardiology (ACC) and the Society for Cardiovascular Angiograpy and Intervention (SCAI). We selected sites for this study to ensure diversity in regional location. We only included sites that had digital storage capability and could transfer coronary angiograms digitally for further assessment and interpretation. The Aetna Foundation provided funding for the study. The investigators were responsible for all data collection and analyses, as well as the decision to publish the findings. The study was initially designed to produce information that could be used for a future quality improvement initiative by initiating feedback to participating hospitals on the correlation of their clinical interpretation of coronary angiograms with QCA from a core laboratory. When a decision to publish these findings was made, we obtained approval from the Institutional Review Board of the Saint Luke's Hospital (Kansas City, Missouri) where analyses were conducted as an exempted study, since all data were de-identified at this point.

From each of the hospitals, we obtained coronary angiograms on patients who underwent PCI during calendar year 2011. Data managers at the NCDR generated a random list of patients at each hospital after excluding patients undergoing PCI for urgent or emergency indications. For each patient, we obtained the clinical report of the coronary angiogram and catheterization laboratory log, after they were stripped of all unique patient identifiers, as well as a de-identified digital copy of the coronary angiogram. Data abstracted directly from the clinical records (not the CathPCI Registry) included information on: catheter size, lesion location, maximal percent diameter stenosis before and after PCI, and use of fractional flow reserve (FFR). In cases where multiple lesions were described and treated, we abstracted data pertaining to each lesion. We obtained supplemental information on the clinical characteristics and presentation of each patient from each site as part of the data that they routinely collected and provided to the CathPCI Registry.

Quantitative Coronary Angiography

The de-identified clinical records and angiograms were managed by ImageCor, LLC (Bradenton, FL) and analyzed by the Yale Cardiovascular Research Group (New Haven, CT), an experienced core laboratory. The trained analysts at the core laboratory were blinded to the clinical records and worked independently of the sites and other investigators. The analysts first subjectively evaluated the overall technical quality of the images and stenosis visualization in multiple views using standardized criteria based on: availability of imaging a calibration catheter, the presence of excessive foreshortening, vessel or side-branch overlap, contrast streaming or streaming artifact, limited ostial bifurcation imaging (excessive overlap or inadequate separation of vessels), and over- or under-exposure.

The core laboratory then used the Cardiovascular Measurement System (QAngio XA 7.2, MEDIS, Leiden, The Netherlands), a PC-based system, for off-line quantitative angiographic analysis. Specific features of the CMS include 2-point user-defined pathline (centerline) identification, arterial contour detection using a minimal cost matrix algorithm, and an "interpolated" reference vessel diameter. The interpolated reference vessel diameter is broadly accepted and a well validated method of measuring reference diameter by QCA; it is obtained at the site of minimal lumen diameter and derived by an iterative linear regression technique that is operator independent and accounts for vessel tapering.[18,19] The minimal lesion diameter was used to calculate percent diameter stenosis relative to the interpolated reference vessel diameter of the lesion of interest. The core laboratory assessed

the reference and minimal lesion diameters from the single-best, available projection with least foreshortening that best demonstrated the stenosis as selected by the analyst. At the Yale Cardiovascular Research Group core laboratory, repeated QCA analyses of reference and minimal lumen diameters have demonstrated good reproducibility within a range of 3.7% to 5.8% for estimates of percent diameter stenosis (Personal Communication: Alexandra J. Lansky, MD).

Data Analysis

We used univariate statistics to describe the study population. We then used a lesion-specific approach to compare the percent diameter stenosis by the two methods of assessment and this was expressed as the difference between the clinical interpretation and QCA using Student t-tests. Concordance was further analyzed using 2 quantitative methods. First, we evaluated the correlation between clinical interpretation and QCA as continuous variables using Pearson's correlation coefficient and graphically presented these data, including a simple linear regression analysis. Second, we categorized percent diameter stenosis from two methods according to the following cutoffs: <50%, 50 to <70%, 70 to <90%, 90 to <100%, and 100% (but explored additional cutoffs in sensitivity analyses). We then assessed concordance between clinical interpretation and QCA using Cohen's weighted kappa statistic,[20] a statistical measure of interrater agreement for categorical items. The kappa statistic is generally considered a more robust measure than a simple percent agreement calculation, since it considers agreement occurring by chance. Because the kappa statistic takes the observed categories' frequencies as givens, it may underestimate agreement for a category that is also commonly used. Given this concern, the kappa statistic is considered an overly conservative measure of agreement.[21]

We also performed subgroup analyses. We first repeated our analyses after excluding patients with lesions thought to be associated with a recent non-ST elevation myocardial infarction or within coronary artery bypass grafts, since the thresholds for revascularization based on percent diameter stenosis may be different in these circumstances. We also examined variation in angiographic interpretation across differences in stenosis severity, lesion location in the coronary vasculature, lesion reference vessel diameter, lesion length, quality of the coronary angiogram determined by the core laboratory, presence of a stress test or FFR, and individual hospital sites. The sample size for this study was difficult to estimate, given the study's intent to generate basic descriptive information about agreement between clinical interpretations and QCA. We proposed to collect 25 studies from each of eight hospitals, and seven hospitals ultimately participated in the quality improvement initiative. All analyses were conducted with SAS (Version 9.3) and R (Version 2.15.0) software.

Results

Study Population

The study sample included 175 patients who underwent PCI of 228 lesions at the 7 sites. A list of baseline characteristics is displayed in Table 1. The mean age of patients was 66.7 ± 10.7 years with 59 (33.7%) women, and 20 (11.4%) non-white patients. A history of prior PCI was present in 73 (41.7%) patients and prior coronary artery bypass grafting in 42 (24.0%). At the time of PCI, 26 (14.8%) patients were asymptomatic or had symptoms unlikely to be ischemic; 48 (27.4%) patients had stable angina; 87 (49.7%) had unstable angina; and 14 (8.0%) had a NSTEMI. A stress test was performed before PCI in 100 (57.1%) patients.

Table 2 lists characteristics associated with the 228 lesions that were treated by PCI in the study population. Most treated lesions were in the left anterior descending coronary artery followed by the right coronary artery and left circumflex coronary artery. There were 16 FFR assessments performed, of which 13 were abnormal with values less than or equal to 0.80. In 216 lesions, a clinical interpretation with percent diameter stenosis was available while the remaining 12 lesions were reported in qualitative terms (e.g., “severe” or “critical”) (Table 2). These 12 were excluded from analyses evaluating concordance.

Of the 216 lesions treated with PCI where stenosis severity by clinical interpretation was reported, median percent diameter stenosis was 80.0% (first and third quartiles, 80 and 90%) and mean percent diameter stenosis was 84.2% (± 10.1). The most commonly reported percent diameter stenoses were in the range of 70 to <90% followed by 90 to <100%. In only 3 (1.4%) lesions was the percent diameter stenosis reported to be <70% by clinical interpretation; a stress test was documented (although information on specific results is unavailable) and/or an FFR was performed in these 3 patients. No lesion was reported to be <50%.

Comparison of Clinical Interpretation and QCA

QCA was performed in all 228 lesions treated with PCI with a median percent diameter stenosis of 74.6% (first and third quartiles, 69.5 and 82.5%) and mean percent diameter stenosis was 76.1% (± 10.9). Similar to clinical interpretation, the most commonly calculated percent diameter stenosis was in the range of 70 to <90% (Table 2). The next most frequent category of stenosis severity by QCA was 50 to <70% with 61 (26.8%) lesions in this category; of these, 35 (57.4%) had documentation of stress testing or FFR before PCI, and rates of stress testing did not vary across categories of stenosis severity (see Supplementary Material: Table A). No lesion was calculated to be <50% by QCA. There was no significant difference by QCA between the 12 lesions where stenosis severity by clinical interpretation was reported in qualitative terms (e.g., “severe” or “critical”) and others (77.4% versus 76.0%; p=0.66).

The mean difference in percent diameter stenosis between the clinical interpretation and QCA was +8.2% ± 8.4% (n=216), reflecting an average higher percent diameter stenosis by the clinical interpretation (P<0.001). The distribution of this difference across the lesions is shown in Figure 1. Of the 213 lesions considered 70% or greater by clinical assessment, 56 (26.3%) were measured at less than 70% by QCA and 10 (4.7%) were less than 60%.

A scatter plot of the clinical interpretation and quantitative assessment by QCA is displayed in Figure 2, demonstrating a Pearson correlation coefficient of 0.68. Clinical interpretations had a discrete distribution with most of the reported values being divisible by 10% (e.g., 70%, 80%, etc.) while QCA stenoses were continuously distributed. Table 3 lists a comparison between the 2 methods after categorizing each assessment according to clinically meaningful cutoffs and showing agreement. In this analysis, a weighted kappa of 0.27 (95% CI, 0.18 to 0.36) was found between the 2 measurements.

Our findings were essentially unchanged when we repeated our analyses after excluding patients with lesions associated with non-ST elevation myocardial infarction or within coronary artery bypass grafts (see Supplementary Material: Tables B and C; and Figures A and B). Finally, we found the mean difference in percent diameter stenosis between the clinical interpretation and QCA was greatest for lesions between 50 to <70% by QCA, but diminished with higher stenosis severity (Table 4). Less variation in the mean difference in percent diameter stenosis between the 2 methods was noted across several other subgroups (Table 4), with the exception of variation across individual hospital sites that ranged from 5.6% to 11.2% (Figure 3). Using alternative cutoffs to categorize lesions by percent

diameter stenosis from two methods did not lead to substantial differences in our results (Supplementary Material: Table D).

Discussion

We found significant differences between the percent diameter stenosis of a lesion as assessed by clinical interpretation and QCA in patients undergoing PCI at seven U.S. hospitals. In general, the clinical interpretation by physicians was 70% or greater in most treated lesions, whereas approximately a quarter of the measurements by QCA were below that level. However, the extent of differences was +8% on average and no lesion was less than 50% by QCA. Overall, findings from our study suggest potential opportunities for improving the clinical interpretation of coronary angiograms in routine practice, and thus, optimizing the selection and care of patients considered for revascularization.

The clinical value of any imaging test depends upon several factors, including acquisition and interpretation of the images and incorporation of this information into clinical decision-making. Despite many technical advances that have transformed the ways in which image acquisition now occurs with coronary angiography, little work has been done on developing strategies for improving its interpretation over the years. Indeed, interpretation may be even more challenging today as more decisions about revascularization are made during or just after the procedure is performed, in order to maximize efficiency and minimize costs (i.e., *ad hoc* PCI).[22] This may limit what formerly occurred through collective discussions (e.g., "cath conference"), despite earlier evidence that "group" reads significantly improves the accuracy of interpretations.[23,24]

Thus, our findings of the inconsistency between the clinical interpretation and an independent measurement by QCA, particularly for lower severity stenoses, raise concerns. Despite its limitations, newer-generation systems of QCA have high reproducibility and precision in quantifying stenosis severity even in complex lesions,[25] which has contributed its widespread use in clinical trials of revascularization. Although differences between the clinical interpretation and QCA in an isolated patient should never be considered an automatic "flag" for inappropriate PCI, identifying where inconsistencies exist may provide opportunities for clinicians to understand ways to improve. For example, routine feedback on 'over-reads' of coronary angiograms through educational initiatives could enhance clinical decision-making about the need for further testing (e.g., FFR) prior to PCI. In our study, for example, use of FFR was relatively uncommon despite its growing role in the assessment of the physiological significance of angiographic lesions and determinations of revascularization. Expanded use of FFR, as well as techniques like digital calipers and online QCA, may be tools that could improve assessment of stenosis severity by clinical interpretation.[1]

Providing feedback to hospitals also may be useful for improving clinical interpretation, as we did notice facility-level variation in the mean difference in percent diameter stenosis between the 2 methods despite the small number included in this analysis. In this context, our findings may be particularly important for quality assurance programs. Although earlier efforts have focused on improving the selection and quality of care for PCI patients through clinical registries,[26] practical constraints have forced such programs to focus largely on evaluating data obtained via chart abstraction, rather than validating the accuracy of the primary data on which clinical decisions are made – in this case, stenosis severity. Recently, these concerns were exacerbated by high-profile cases in which cardiac surgeons and cardiologists were accused of performing revascularization on patients with coronary artery disease of questionable severity.[27,28] Moreover, some of these providers have consistently reported better than expected outcomes,[29] since treating mild coronary artery disease is

almost always safe for patients, despite providing little benefit. This underscores the limitations of quality assurance tools that focus largely on chart abstraction and assessing complications.

Challenges exist when considering the potential next steps that may result from our findings. New approaches need to be developed for improving clinical interpretation through innovative educational initiatives or quality assurance programs. Given its potential scalability, QCA may offer be an efficient method for achieving these objectives, but this is unknown. In particular, it is necessary to examine how QCA or other methods to improve clinical interpretation may be integrated into the busy workflow of interventional cardiology. This must be done in a critical and rigorous manner, as the addition of such tools does not necessarily result in improvement. For example, data on the clinical value of computer-assisted screening mammography in routine practice have been mixed.[30,31]

Our study should be interpreted in the context of the following limitations. First, we only examined patients undergoing PCI. We did not perform QCA in lesions that were considered clinically insignificant or managed medically or surgically; our findings are not relevant to those settings, which will require additional investigations. Second, QCA itself has limitations. As such, this study was focused specifically on assessing the quality of the clinical interpretation of the coronary angiogram, not the appropriateness of the clinical decision to intervene. For example, QCA does not include information on the hemodynamic significance of a stenosis. In isolation, it does not account for many factors that should influence clinical decisions on revascularization nor does it alone predict long-term outcomes after treatment.[32] Nevertheless, accurate assessment of stenosis severity is essential for physicians and patients, as this remains arguably the most critical factor in practical, day-to-day decisions about revascularization. Even current Appropriateness Use Criteria that emphasize the importance of symptoms and functional testing assume the presence of a “significant” stenosis of “greater than or equal to 70% luminal diameter narrowing, by visual assessment” prior to revascularization. Of course, future work will need to tie findings such as ours directly to clinical decisions and outcomes.

Third, calculating stenosis severity by QCA still requires satisfactory image acquisition and minimal user input to identify imaging frames for analysis, which may introduce variability as well. For this reason, our assessments were performed using analysts blinded to the clinical interpretation and at a core laboratory with broad experience in regulatory studies involving QCA. Fourth, our study was limited to 7 hospitals. These were primarily high-volume and recognized PCI centers, and importantly, each volunteered to participate as part of a pilot quality improvement initiative. Whether our findings are applicable to a more broadly representative group of hospitals is uncertain, though the results may represent a best-case scenario. For example, it may be that coronary angiograms at other hospitals may have technical deficiencies not found here, particularly with more complex lesions. Finally, due to our limited sample size we were unable to examine variability in assessments of stenosis severity by physician. Future work will need to better quantify the effects of both hospital- and physician-level variation on clinical interpretation.

In conclusion, we found that physicians tended to assess lesions treated by PCI as more severe than measurements by QCA. Findings from our study are consistent with older work and suggest possible opportunities to further improve clinical interpretation of coronary angiography and optimize the selection and care of patients undergoing PCI in contemporary practice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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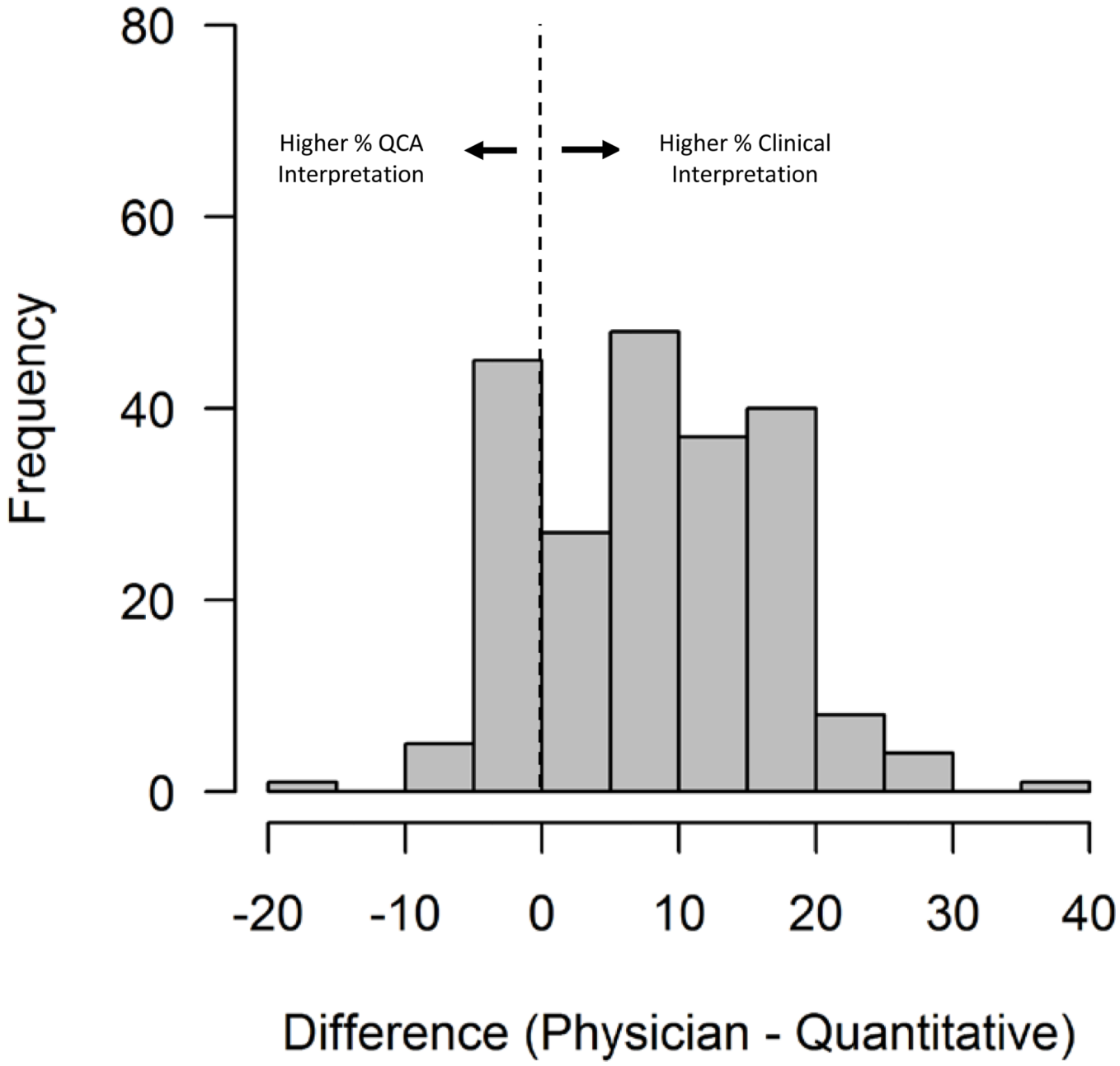

Figure 1.
Distribution of mean difference in percent diameter stenosis between clinical interpretation and Quantitative Coronary Angiography (QCA).

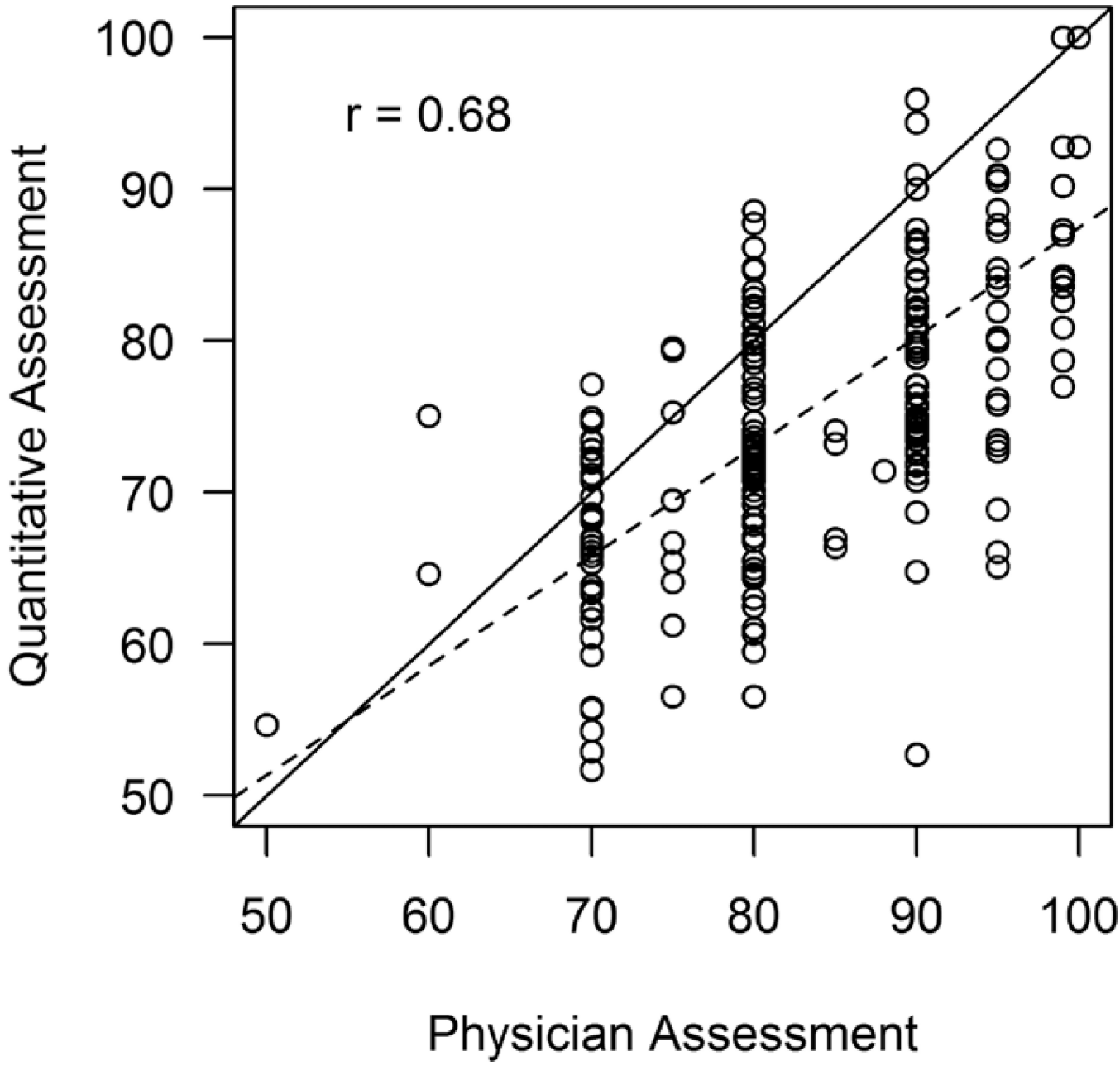

Figure 2.
Comparison of percent diameter stenosis between clinical interpretation and Quantitative Coronary Angiography (QCA). Pearson's correlation coefficient (r).

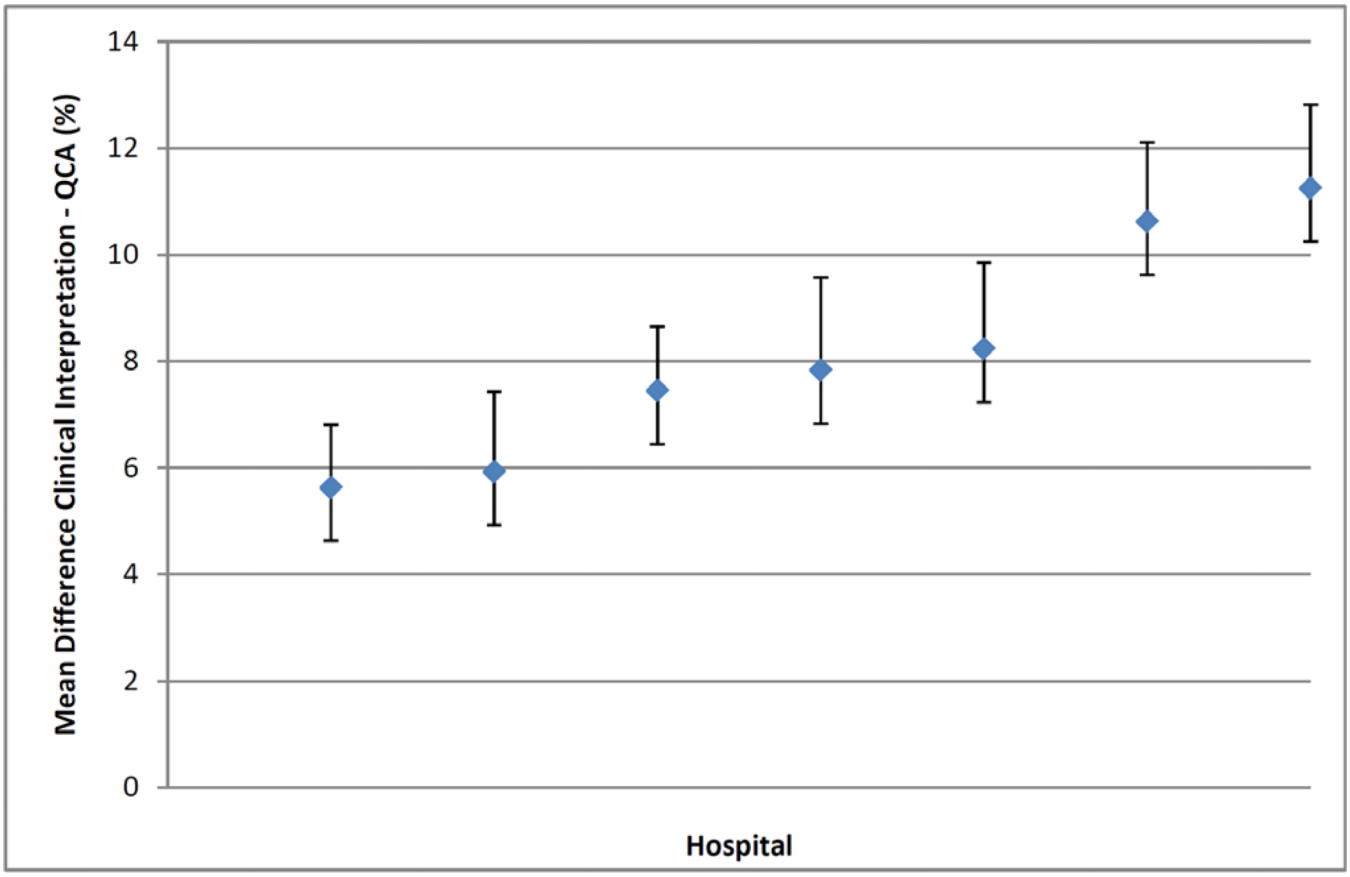

Figure 3.
Variation by hospital in differences in mean percent diameter stenosis and 95% confidence intervals between clinical interpretation and Quantitative Coronary Angiography (QCA).

Table 1

Baseline characteristics of 175 patients undergoing PCI.

	Total n = 175
Age	
Mean ± standard deviation	66.7 ± 10.7
Median (interquartile range)	66.0 (58.0, 75.0)
Age category	
34 to <50	7 (4.0%)
50 to <60	46 (26.3%)
60 to <70	47 (26.9%)
70 to <80	51 (29.1%)
80 to 92	24 (13.7%)
Women	59 (33.7%)
Race	
White/Caucasian	155 (88.6%)
Black/African-American	17 (9.7%)
Other	3 (1.7%)
Hispanic or Latino ethnicity	3 (1.7%)
Current/recent smoker (<1y)	37 (21.1%)
Hypertension	154 (88.0%)
Dyslipidemia	151 (86.3%)
Family history of premature coronary artery disease	54(30.9%)
Prior myocardial infarction	55(31.4%)
Prior heart failure	22 (12.6%)
Prior PCI	73 (41.7%)
Prior coronary artery bypass grafting	42 (24.0%)
Body mass index	
Mean ± standard deviation	30.3 ± 6.7
Cerebrovascular disease	18 (10.3%)
Peripheral arterial disease	23 (13.1%)
Diabetes	53 (30.3%)
Clinical presentation	

	Total n = 175
No symptoms, no angina	20 (11.4%)
Symptoms unlikely to be ischemic	6 (3.4%)
Stable angina	48 (27.4%)
Unstable angina	87 (49.7%)
Non-ST elevation myocardial infarction	14 (8.0%)
Angina classification in past 2 wks	
No symptoms	25 (14.3%)
CCS I	9 (5.1%)
CCS II	44 (25.1%)
CCS III	64 (36.6%)
CCS IV	33 (18.9%)
Stress or imaging studies performed	100 (57.1%)
Staged PCI	15 (8.6%)
Angiogram image quality	
Excellent	25 (14.3%)
Good	121 (69.1%)
Satisfactory	29 (16.6%)
SYNTAX Score (for lesion)	
Mean ± SD	9.2 ± 6.0
Median (Q1-Q3)	8.0 (5.0, 12.0)

PCI = Percutaneous Coronary Intervention, CCS = Canadian Classification System

Table 2

Characteristics of 228 lesions undergoing PCI.

	Total n = 228
Vessel territory	
Left circumflex	65 (28.5%)
Left anterior descending	86 (37.7%)
Left main	2 (0.9%)
Ramus intermedius	2 (0.9%)
Right	73 (32.0%)
Pre-PCI stenosis (Clinical Interpretation)	
No quantitative report	12 (5.3%)
50 to <70	3 (1.3%)
70 to <90	113 (49.6%)
90 to <100	87 (38.2%)
100	13 (5.7%)
Pre-PCI stenosis (QCA)	
50 to <70	61 (26.8%)
70 to <90	141 (61.8%)
90 to <100	11 (4.8%)
100	15 (6.6%)
FFR Performed	16 (7.0%)
FFR Abnormal (≤0.80)	13 (81.3%)

PCI = Percutaneous Coronary Intervention, QCA = Quantitative Coronary Angiography, FFR = Fractional Flow Reserve

Table 3

Comparison between quantitative assessments across categories of percent diameter stenosis by Clinical Interpretation and QCA. Each cell represents the number of lesions in agreement in that category between the 2 methods.

	Pre-PCI stenosis (%) by QCA				
Pre-PCI stenosis (%) by Clinical Interpretation	**50 to <70**	**70 to <90**	**90 to <100**	**100**	**Total**
50 to <70	2 (0.9)	1 (0.5)	0 (0)	0 (0)	3 (1.4)
70 to <90	50 (23.2)	63 (29.2)	0 (0)	0 (0)	113 (52.3)
90 to <100	6 (2.8)	70 (32.4)	9 (4.2)	2 (0.9)	87 (40.3)
100	0 (0)	0 (0)	1 (0.5)	12 (5.6)	13 (6.0)
Total	58 (26.9)	134 (62.0)	10 (4.6)	14 (6.5)	216* (100)

* 12 lesions not compared due to missing quantitative information on stenosis severity in the clinical record

PCI = Percutaneous Coronary Intervention, QCA = Quantitative Coronary Angiography

Table 4

Mean difference in stenosis severity (%) between clinical interpretation and QCA across subgroups.

		N	Mean Difference	SD	P-Value
Total Population		216	+8.2	8.4	<0.001
Subgroup Category					
Percent Diameter Stenosis, QCA	50 to <70	58	+12.3	8.4	<.0001
	70 to <90	134	+7.7	8.0	
	90 to <100	10	2.6	4.9	
	100 Left	14	−0.1	0.4	
Lesion Location	Left circumflex	61	+8.1	8.0	0.7014
	Left anterior descending	82	+9.0	9.0	
	Left main	1	+7.5	--	
	Ramus intermedius	2	+11.6	2.1	
	Right	70	+7.1	8.0	
Lesion Reference Vessel Diameter, QCA	<2.5mm	87	+8.8	9.0	0.6800
	2.5 to <3mm	73	+7.9	7.6	
	3 to <3.5mm	39	+8.1	9.1	
	>3.5mm	17	+6.1	6.5	
Lesion Length, QCA	<10mm	65	+9.8	8.7	0.1003
	10 to <20mm	98	+8.2	8.5	
	>20mm	50	+7.5	7.5	
Angiogram Quality by QCA Core Lab	Excellent	31	+7.2	8.5	0.5898
	Good	148	+8.1	8.5	
	Satisfactory	37	+9.3	7.9	
Stress Test or FFR Performed	No	88	+9.1	8.6	0.1836
	Yes	128	+7.5	8.2	
Hospital Site	1	35	5.6	7	0.0437
	2	28	5.9	8	

	N	Mean Difference	SD	P-Value
3	30	7.4	6.6	
4	29	7.8	9.4	
5	30	8.2	8.8	
6	28	10.6	7.8	
7	36	11.2	9.4	

* QCA = Quantitative Coronary Angiography, FFR = Fractional Flow Reserve