

Functional measurement of intermediate coronary stenosis using fractional flow reserve: Based Technique

Ahmed Moyed Hussein ^{*1}, Mahdi S. Yaser Alzaidi ², Bashar Muhamad Abed ³

¹Lecturer, Department of Medicine, Ninevah College of Medicine; Interventional Cardiologist, Mosul, Iraq.

²Consultant Interventional Cardiologist, Ibn Al-Bitar Center for Cardiac Surgery and Cardiology, Mosul, Iraq.

³Interventional Cardiologist, Maysan Cardiac Center, Iraq.

* Corresponding author: ahmed.hussein@uoninevah.edu.iq

Article information:

Received 7 September, 2026

Received in revised form 2 October, 2026

Accepted 3 October, 2026

Final Proofreading 4 October, 2026

Published 6 October, 2026

DOI Online:

<http://doi.org/10.64554/nujms.2026.2.1.5>

Keywords:

coronary angiography; fractional flow reserve; intermediate coronary stenosis; quantitative coronary angiography; revascularization.

© THIS IS AN OPEN ACCESS ARTICLE UNDER THE CC BY LICENSE.

<http://creativecommons.org/licenses/by/4.0/>

ABSTRACT

Background: Coronary angiography has limited ability to determine the functional significance of intermediate coronary lesions. Fractional flow reserve (FFR) provides a physiological assessment that can complement angiographic evaluation. Objective: To evaluate the relationship between FFR and angiographic severity assessed by visual estimation and quantitative coronary angiography (QCA) in intermediate coronary lesions.

Methods: This cross-sectional observational study included 43 consecutive symptomatic patients with 53 intermediate coronary lesions evaluated at the catheterization laboratory of Ibn Al-Bitar Center for Cardiac Surgery and Cardiology between July and December 2013. Diameter stenosis was assessed visually by two interventional cardiologists and by QCA. Lesions were classified according to QCA into Group A (50–70% stenosis; 29 lesions) and Group B (30–49% stenosis; 24 lesions). FFR was measured during maximal hyperemia induced by intravenous or intracoronary adenosine using a pressure-wire system. A lesion was considered functionally significant when FFR was ≤ 0.80 .

Results: Mean FFR was 0.87 ± 0.068 (range, 0.65–0.99). FFR was ≤ 0.80 in 5 of 29 lesions (17%; 95% confidence interval [CI], 6–36%) in Group A and in none of the 24 lesions in Group B (0%; 95% CI, 0–14%). The difference between groups was not statistically significant (Fisher's exact test, $P = 0.056$), and agreement between angiographic group and FFR category was slight ($\kappa = 0.16$). QCA diameter stenosis showed a weak inverse correlation with FFR ($r = -0.40$, $P = 0.003$). Mean diameter stenosis was $50 \pm 10.25\%$ by QCA and $57 \pm 11.14\%$ by visual assessment. Adenosine-related adverse effects were predominantly minor; chest discomfort occurred in 15 patients (34.9%) and bradycardia below 50 beats/min in 8 (18.6%). No death or myocardial infarction occurred.

Conclusion: Angiographic severity showed only a weak relationship with the physiological significance of intermediate coronary lesions in this small single-center study. FFR may provide additional information when angiography alone is insufficient to determine lesion significance, although larger studies with clinical follow-up are required.

Introduction

Coronary angiography provides anatomical information about coronary artery stenosis but may provide limited information about the haemodynamic significance of intermediate lesions, particularly when the angiographic severity does not clearly indicate whether revascularization is required (1–5). Coronary blood flow varies substantially across the cardiac

cycle, and the relationship between an angiographic narrowing and its physiological effect is influenced by several factors (1,2).

Fractional flow reserve (FFR) is an invasive physiological index defined as the ratio of maximal blood flow in a stenotic coronary artery to the maximal blood flow that would occur if the artery were normal. An FFR value of 1.0 represents normal physiological conditions. An $FFR \leq 0.80$ has been widely used to identify lesions with physiological significance and to guide revascularization decisions (6–8).

Randomized clinical trials have demonstrated the clinical value of physiology-guided coronary intervention compared with angiography-guided decision-making in selected patients (13,14). Accordingly, invasive physiological assessment has been incorporated into major coronary revascularization guidelines for angiographically intermediate lesions (15,16).

The present study aimed to evaluate the relationship between FFR and angiographic severity, assessed both visually and by QCA, in intermediate coronary artery lesions.

Methods

Study design and population: This cross-sectional observational study included 43 consecutive symptomatic patients with 53 intermediate coronary lesions who underwent coronary angiography at the catheterization laboratory of Ibn Al-Bitar Center for Cardiac Surgery and Cardiology between July and December 2013. Thirty-three patients had one lesion and 10 patients had two lesions. All patients underwent a full history, physical examination, relevant basic investigations, and coronary angiography.

Angiographic assessment: Diameter stenosis was assessed visually by two interventional cardiologists and quantitatively by QCA. Based on QCA, lesions were classified into two groups: Group A, 50–70% diameter stenosis (29 lesions), and Group B, 30–49% diameter stenosis (24 lesions).

Fractional flow reserve measurement: FFR was measured after maximal hyperaemia induced by intravenous adenosine at 140 $\mu\text{g/kg/min}$ or by an intracoronary adenosine bolus of 20–30 μg for the right coronary artery and 60–100 μg for the left coronary artery. FFR was measured 2 minutes after initiation of intravenous adenosine and 5 seconds after intracoronary adenosine administration. A 6F guiding catheter and a pressure-wire system (St. Jude Medical or Certus) incorporating FFR/CFR modalities were used. A target lesion was considered functionally significant when $FFR \leq 0.80$ (6–8).

Ethical considerations

All patients were informed about their participation in the study, and written informed consent was obtained before the study procedures. Ethical approval was obtained from Ninevah University College of Medicine Ethical committee.

Statistical analysis

Continuous variables are presented as mean $\pm$ standard deviation (SD), with median and range where appropriate. Categorical variables are presented as numbers and percentages. Percentages in Tables 1 and 2 are based on the 43 patients, whereas percentages in Table 4 are based on the 53 lesions. The relationship between QCA diameter stenosis and FFR was assessed using Pearson's correlation coefficient. The association between angiographic severity group and functional significance ($FFR \leq 0.80$) was assessed using Fisher's exact test because two cells had expected counts below 5. Agreement between the two classifications was assessed using Cohen's kappa. Proportions are presented with exact (Clopper–Pearson) 95% confidence intervals. All lesions were analyzed as independent observations, although 10 patients contributed two lesions. A two-sided P value < 0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics:

Forty-three consecutive symptomatic patients were included. Baseline demographic and clinical characteristics are presented in Table 1.

Table 1. Baseline characteristics of the 43 patients.

Characteristic	n (%)
Total number	43
Male	21 (49%)
Female	22 (51%)
Diabetes mellitus	20 (46.5%)
Hypertension	30 (70%)
Smoking	18 (42%)
Dyslipidemia	23 (53%)
History of ischemic heart disease	27 (63%)
Baseline ECG — normal	19 (44%)
Baseline ECG — nonspecific ST- and T-wave changes	5 (11.6%)
Baseline ECG — bundle branch block	3 (7%)
Baseline ECG — ischemic ST/T changes	16 (37%)
Echocardiographic findings — normal	17 (39.5%)
Echocardiographic findings — ischemic heart disease ± LV dysfunction	10 (23%)
Echocardiographic findings — hypertensive heart disease	16 (37%)

Adverse effects during FFR assessment:

Adenosine-related adverse effects were generally transient. Chest discomfort was reported by 15 patients (34.9%), and bradycardia below 50 beats/min occurred in 8 patients (18.6%). Two patients developed brief 2:1 atrioventricular block with spontaneous recovery. Two patients received atropine for significant bradycardia. One patient developed atrial fibrillation, remained haemodynamically stable, and spontaneously returned to sinus rhythm after one hour. No sustained ventricular tachycardia or ventricular fibrillation occurred, and there were no significant blood pressure reductions, deaths, or myocardial infarctions.

Table 2. Adverse effects among the 43 patients during FFR assessment.

Adverse effect	n (%)
Chest discomfort	15 (34.9%)
Bradycardia <50 beats/min	8 (18.6%)
Nausea/vomiting	1 (2.3%)
Atrial fibrillation	1 (2.3%)
Second-degree heart block	2 (4.6%)
Shortness of breath	2 (4.6%)

Angiographic and physiological findings:

Among the 53 lesions, mean QCA diameter stenosis was $50 \pm 10.25\%$, mean visual diameter stenosis was $57 \pm 11.14\%$, and mean FFR was 0.87 ± 0.068 (range, 0.65–0.99). Overall, 5 lesions (9.4%) had an FFR ≤ 0.80 .

Table 3. Angiographic diameter stenosis and fractional flow reserve in the 53 lesions.

Measure	QCA (%)	Visual (%)	FFR
Mean $\pm$ SD	50 $\pm$ 10.25	57 $\pm$ 11.14	0.87 $\pm$ 0.068
Median	50	60	0.88
Minimum	23	30	0.65
Maximum	75	70	0.99
Reference diameter of coronary artery, distal diameter (mm)	2.82	2.1	—

QCA diameter stenosis correlated inversely and weakly with FFR ($r = -0.40$, $P = 0.003$). FFR was ≤ 0.80 in 5 of 29 lesions (17%; 95% CI, 6–36%) in Group A and in none of the 24 lesions in Group B (0%; 95% CI, 0–14%). The difference between groups was not statistically significant (Fisher's exact test, two-sided $P = 0.056$), and agreement between QCA-based angiographic group and FFR category was slight ($\kappa = 0.16$).

Table 4. Functional significance of intermediate coronary lesions according to QCA-defined angiographic severity.

QCA diameter stenosis	FFR >0.80	FFR ≤ 0.80	Total	P value
30–49% (Group B)	24 (100%)	0 (0%)	24	0.056
50–70% (Group A)	24 (83%)	5 (17%)	29	0.056
Total	48	5	53	—

Discussion

In this small, single-center observational study, angiographic severity showed only a weak relationship with the physiological significance of intermediate coronary lesions. All 24 lesions in the 30–49% QCA group had FFR >0.80 , whereas 5 of 29 lesions (17%) in the 50–70% group had FFR ≤ 0.80 . The weak inverse correlation between QCA stenosis and FFR indicates that anatomical severity alone did not reliably identify functional significance within the intermediate range.

FFR measurement was generally well tolerated in the present study. Most adverse effects were transient and related to adenosine administration. Bradycardia was particularly observed after intracoronary adenosine administration into the right coronary artery. Atropine and pacing capability should therefore be available when performing physiological assessment, consistent with the adverse events observed in this series.

The present findings are directionally consistent with the FAME study, in which the proportion of functionally significant lesions increased with increasing angiographic severity: 35% of lesions with 50–70% stenosis, 80% of lesions with 71–90% stenosis, and 96% of subtotal stenoses (91–99%) had an FFR ≤ 0.80 (9). The 17% proportion observed in our 50–70% group was lower than that reported in FAME; however, the sample size in the present study was small, and its 95% CI (6–36%) includes the FAME estimate.

Duran Karaduman et al. assessed 359 patients with intermediate coronary lesions and reported haemodynamic significance in 37.9% of lesions, with disagreement between visual assessment and FFR-based classification (10). Fischer et al. compared visual assessment and QCA with FFR in 83 intermediate coronary lesions; FFR was <0.75 in 18% of lesions, although

their lower physiological threshold limits direct comparison with the present study (11), they also reported that visual and QCA assessment agreed with FFR in approximately half of lesions, supporting the limited precision of angiography for intermediate stenoses.

Three-dimensional QCA has subsequently been investigated as an anatomical alternative when physiological assessment is unavailable or contraindicated, with reported better correlation with FFR than conventional two-dimensional QCA (12). Nevertheless, physiological assessment directly addresses the functional consequences of a stenosis and may provide information that angiographic appearance alone cannot provide.

Randomized trials have shown that FFR-guided PCI can reduce major adverse cardiac events compared with angiography-guided PCI in appropriate patients with multivessel disease (13), while FFR-guided revascularization in stable coronary disease reduced a composite of death, myocardial infarction, or urgent revascularization compared with medical therapy alone, mainly through fewer urgent revascularizations (14). Major guidelines have therefore recommended invasive physiological assessment of angiographically intermediate lesions in appropriate clinical settings (15,16). The present observational study is consistent with the concept that physiological assessment can complement angiography but cannot independently establish clinical outcome benefit.

Limitations

This study has several limitations. It was a single-center observational study with a small sample of 43 patients and 53 lesions. There was no clinical follow-up; therefore, the study cannot determine whether FFR-guided decisions altered subsequent clinical outcomes. In addition, 10 patients contributed two lesions, and lesions were analyzed as independent observations. The small number of functionally significant lesions also limited the precision of subgroup comparisons.

Conclusions

In this small, single-center study, angiographic stenosis severity assessed visually or by QCA was only weakly related to FFR in intermediate coronary lesions. Most lesions with 50–70% stenosis were not functionally significant, and no lesion with 30–49% stenosis was functionally significant. These findings support the use of physiological assessment when angiography alone does not clearly establish the significance of an intermediate lesion, while larger studies with clinical follow-up are needed.

Acknowledgements

The authors have no specific acknowledgements to declare.

Funding

No external funding was reported for this study.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Credit authorship contribution statement

Ahmed Moyed Hussein: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review and editing, Supervision. Mahdi S. Yaser Alzaidi: Methodology, Investigation, Data curation, Writing – review and editing. Bashar Muhamad Abed: Methodology, Investigation, Data curation, Writing – review and editing.

Declaration of artificial intelligence use

The authors used AI-assisted language editing to improve grammar, sentence structure, and readability. All suggested changes should be reviewed and approved by the authors, who retain full responsibility for the accuracy, integrity, and scientific content of the manuscript.

References

1. Canty JM Jr. Control of coronary blood flow. In: Libby P, Bonow RO, Mann DL, et al., editors. Braunwald's Heart Disease. 9th ed. Philadelphia: Saunders; 2012. p. 1049–74.
2. Canty JM Jr, Brooks A. Phasic volumetric coronary venous outflow patterns in conscious dogs. *Am J Physiol.* 1990;258(5 Pt 2):H1457–63. <https://doi.org/10.1152/ajpheart.1990.258.5.H1457>. PubMed.
3. Kern MJ. Nonangiographic coronary lesion assessment. In: Kern MJ, editor. The Interventional Cardiac Catheterization Handbook. 3rd ed. Philadelphia: Saunders; 2013. p. 244–90.
4. Shaw LJ, Iskandrian AE. Prognostic value of gated myocardial perfusion SPECT. *J Nucl Cardiol.* 2004;11(2):171–85. <https://doi.org/10.1016/j.nuclcard.2003.12.004>. PubMed.
5. Metz LD, Beattie M, Hom R, et al. The prognostic value of normal exercise myocardial perfusion imaging and exercise echocardiography: a meta-analysis. *J Am Coll Cardiol.* 2007;49(2):227–37. <https://doi.org/10.1016/j.jacc.2006.08.048>. JACC.
6. De Bruyne B, Pijls NH, Heyndrickx GR, et al. Pressure-derived fractional flow reserve to assess serial epicardial stenoses: theoretical basis and animal validation. *Circulation.* 2000;101(15):1840–7. <https://doi.org/10.1161/01.CIR.101.15.1840>. PMC.
7. Pijls NH, De Bruyne B, Peels K, et al. Measurement of fractional flow reserve to assess the functional severity of coronary-artery stenoses. *N Engl J Med.* 1996;334(26):1703–8. <https://doi.org/10.1056/NEJM199606273342604>. New England Journal of Medicine
8. Kern MJ, Donohue TJ, Aguirre FV, et al. Clinical outcome of deferring angioplasty in patients with normal translesional pressure-flow velocity measurements. *J Am Coll Cardiol.* 1995;25(1):178–87. [https://doi.org/10.1016/0735-1097\(94\)00328-N](https://doi.org/10.1016/0735-1097(94)00328-N). pubmed.ncbi.nlm.nih.gov.
9. Tonino PAL, Fearon WF, De Bruyne B, et al. Angiographic versus functional severity of coronary artery stenoses in the FAME study: fractional flow reserve versus angiography in multivessel evaluation. *J Am Coll Cardiol.* 2010;55(25):2816–21. <https://doi.org/10.1016/j.jacc.2009.11.096>. ScienceDirect.
10. Duran Karaduman B, Akcay M, Ayhan H, et al. Comparison between fractional flow reserve and visual assessment for moderate coronary artery stenosis. *Kardiol Pol.* 2017;75(6):545–52. <https://doi.org/10.5603/KP.a2017.0037>. pubmed.ncbi.nlm.nih.gov
11. Fischer JJ, Samady H, McPherson JA, et al. Comparison between visual assessment and quantitative angiography versus fractional flow reserve for native coronary narrowings of moderate severity. *Am J Cardiol.* 2002;90(3):210–5. [https://doi.org/10.1016/S0002-9149\(02\)02456-6](https://doi.org/10.1016/S0002-9149(02)02456-6). PubMed.

12. Ahmed MK, Emara AAA, Mena MB, et al. Quantitative coronary angiography for assessment of non-obstructive coronary artery disease: comparison to fractional flow reserve. *Int J Cardiovasc Res*. 2018;7(4). <https://doi.org/10.4172/2324-8602.1000385.scitechnol.com>.
13. Tonino PAL, De Bruyne B, Pijls NH, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. *N Engl J Med*. 2009;360(3):213–24. <https://doi.org/10.1056/NEJMoa0807611>. pubmed.ncbi.nlm.nih.gov.
14. De Bruyne B, Pijls NH, Kalesan B, et al. Fractional flow reserve-guided PCI versus medical therapy in stable coronary disease. *N Engl J Med*. 2012;367(11):991–1001. <https://doi.org/10.1056/NEJMoa1205361>. PubMed.
15. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J*. 2019;40(2):87–165. <https://doi.org/10.1093/eurheartj/ehy394>. Oxford Academic.
16. Lawton JS, Tamis-Holland JE, Bangalore S, et al. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization. *Circulation*. 2022;145(3):e18–e114. <https://doi.org/10.1161/CIR.0000000000001038>.