Coronary Blood Flow, Pressure and Resistance: How to Integrate, Interpret, and Apply in Practice

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Disclosure Statement of Financial Interest

Within the past 12 months, I or my spouse/partner have had a financial interest /arrangement or affiliation with the organization(s) listed below

Affiliation/Financial Relationship
Grant/ Research Support:

Consulting Fees/Honoraria:

Major Stock Shareholder/Equity Interest:

Royalty Income:

Ownership/Founder:

Salary:

Intellectual Property Rights:

Other Financial Benefit:

<u>Company</u> St. Jude Medical/Medtronic

Medtronic, HeartFlow, Cathworks



FFR and IMR to Assess the Entire Coronary Circulation





De Bruyne, et al. J Am Coll Cardiol 2016;67:1170-2.

Index of Microcirculatory Resistance

Advantages:

- Readily available in the cath lab
- Relatively easy to perform
- Specific for the microvasculature
- Defined normal value
- Quantitative
- Reproducible
- Predictive of outcomes



Estimation of Coronary Flow



Derivation of IMR:

• Resistance = Δ Pressure / Flow

• Δ Pressure = P_d-P_v Flow \cong 1 / T_{mn}

•
$$IMR = P_d - P_v / (1 / T_{mn})$$

 $\blacksquare IMR = P_d \times T_{mn} \qquad \begin{array}{l} at \ maximal \\ hyperemia... \end{array}$



Circulation 2003;107:3129-3132.

Practical Measurement of IMR





IMR: Normal Value

An IMR < 25 is considered normal

- The mean IMR measured in 15 subjects (22 arteries) without any evidence of atherosclerosis and no/minimal risk factors was 19±5.
- The mean IMR measured in 18 subjects with normal stress tests and normal coronary angiography was 18.9±5.6.
- The mean IMR in 20 subjects with no CAD or risk factors was 14.0 with all values <23.</p>

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Melikian, et al. Eurointervention 2010;5:939-945. Luo, et al. Circ Cardiovasc Interv 2014;7:43-48. Solberg, et al. Eurointervention 2014;9:1069-75.

IMR Before PCI in Stable Patients

IMR predicts peri-PCI MI in 50 stable patients undergoing LAD PCI





Ng, et al. Circ Cardiovasc Interv 2012;5:515-22.

IMR After PCI in Unstable Patients

IMR predicts peri-PCI MI in 57 unstable angina patients



Wu Z, et al. Int J Cardiovasc Imaging 2014;30:995-1002.

Correlation between measures of microvascular function and peak CK and 3-month wall motion score

Variable	Peak CK	3-Month WMS
IMR	0.61*	0.59†
TMPG	0.05	0.12
CFR	-0.32	-0.35
ST-segment resolution	-0.35	-0.34
cTFC	-0.02	0.06

*p = 0.0005, †p = 0.002, p = NS for all others.



J Am Coll Cardiol 2008;51:560-5.

Relation between IMR and PET viability in 40 STEMI patients



Lim HS, et al Eur Heart J 2009;30:2854-60.

Correlation between IMR and cardiac MR assessment of microvascular obstruction in 57 patients after STEMI





McGeoch, et al. J Am Coll Cardiol Intv 2010;3:715-22.

Correlation between IMR and cardiac MR assessment of microvascular obstruction in 40 patients after STEMI



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Ahn SG, et al. J Am Coll Cardiol Intv 2016;9:793-801.

IMR Predicts Mortality post STEMI

Multicenter study evaluating relationship between IMR and longer-term outcomes in 253 STEMI patients





Circulation 2013;127:2436-41.

FFR/IMR in Chest Pain and NOCAD:

59 year old man with HTN, dyslipidemia, chest pain and abnormal stress test with no obstructive CAD (NOCAD)









Chest Pain and "No Obstructive CAD"

- 139 patients referred for coronary angiography because of symptoms and/or abnormal stress test and found to have "normal" appearing coronaries
- FFR, IMR, CFR, IVUS and acetylcholine challenge were performed down the LAD



Chest Pain and "Normal Coronaries"

Patient Characteristic	n=139
Age (years)	54 ±11
Female	77%
Hypertension	53%
Diabetes	23%
Dyslipidemia	63%
Tobacco Use	8%



Lee BK, et al. Circulation 2015;131:1054-60.

Chest Pain and "Normal Coronaries"

- The mean IMR was 19.6 ±9.1
- Microvascular dysfunction was present in 21% (defined as IMR ≥ 25)
- Patients with microvascular dysfunction were older and more often hypertensive and diabetic



Chest Pain and "Normal Coronaries"

77% of patients had at least one occult coronary circulatory abnormality



Lee BK, et al. Circulation 2015;131:1054-60.



Importance of the Microvasculature

230 patients (516 vessels) with FFR>0.80 had CFR and IMR measured





Lee JM, et al. J Am Coll Cardiol 2016;67:1158-69.

Conclusion

Take Home Messages:

- Simultaneous measurement of pressure and flow allows determination of FFR and IMR and independent interrogation of the epicardial system and microvasculature
- IMR predicts outcomes in a variety of settings.
- FFR and IMR aid in the evaluation of chest pain with no obstructive CAD
- High IMR and low CFR predicts outcomes in patients with CAD and FFR > 0.80

