Letters to the Editor

True Fractional Flow Reserve of Left Coronary Artery Stenosis in the Presence of Downstream Coronary Stenoses

With great interest I read the recent paper by Fearon et al. (1) in which they assessed the impact of downstream left anterior descending (LAD) or left circumflex (LCX) coronary stenosis on the assessment of fractional flow reserve (FFR) of an left main coronary artery (LMCA) stenosis. They concluded that if the apparent FFR of the LMCA (FFRapp) is >0.85, the true FFR of the LMCA (FFRtrue) is always >0.80. If FFRapp is between 0.81 and 0.85 and the epicardial FFR (FFRepi) is ≤0.45, then FFRtrue is ≤0.80 in some cases.

However, these conclusions are not surprising. These conclusions can be proven mathematically. Bruyne et al. (2) previously described theoretical equations that calculate the true FFR of individual stenosis in a tandem lesion. Based on their study, an equation that calculates FFRtrue in a bifurcation lesion can be derived. When the downstream stenosis is located in the LAD, and n is defined as the ratio of microcirculatory resistances of the LCX to the LAD, FFRtrue is calculated as per the following Equation 1.

\[ FFR_{true} = \frac{nFFR_{epi} + FFR_{app}}{1 + n(1 - (FFR_{app} - FFR_{epi}))} \]

(1)

The partial differentiation of FFRtrue with respect to FFR_{epi} is calculated as follows:

\[ \frac{\partial FFR_{true}}{\partial FFR_{epi}} = \frac{n(n + 1)(1 - FFR_{app})}{1 + n(1 - (FFR_{app} - FFR_{epi}))^2} > 0 \]

(2)

The above inequality in Equation 2 indicates that the FFRtrue monotonically increases when FFR_{epi} is larger. Similarly, the partial differentiation of FFRtrue with respect to FFR_{app} and n are calculated as follows:

\[ \frac{\partial FFR_{true}}{\partial FFR_{app}} = \frac{(n + 1)(nFFR_{epi} + 1)}{1 + n(1 - (FFR_{app} - FFR_{epi}))^2} > 0 \]

(3)

\[ \frac{\partial FFR_{true}}{\partial n} = \frac{(1 - FFR_{app})(FFR_{epi} - FFR_{app})}{1 + n(1 - (FFR_{app} - FFR_{epi}))^2} < 0 \]

(4)

The inequalities in Equations 2, 3, and 4 suggest that FFRtrue increases with FFR_{epi} and FFR_{app}, but that it decreases with an increase in n. n is the ratio of microcirculatory resistances of the LCX to the LAD, which is usually considered approximately 2. Thus, FFRtrue > 0.80 is always true when FFR_{app} is >0.85, FFR_{epi} is >0.45, and n = 2. Similarly, Equation 1 suggests that when FFR_{app} is between 0.81 and 0.85 and the epicardial FFR (FFR_{epi}) is ≤0.45, then FFRtrue can be either larger or smaller than 0.80. These calculations are completely in accordance with the study results of Fearon et al. (1). Their study was well designed and the results were reasonable, but it lacked the understandings of the background mechanism. Another important limitation of their study is that they only assessed the LMCA plus 1 downstream stenosis and lacked the assessment of the LMCA plus 2 downstream stenoses both in the LAD and LCX, which is also frequently encountered in clinical practice. In the case of the LMCA plus 2 downstream stenoses, FFRtrue is calculated as per Equation 5 when the epicardial FFR of the LAD and LCX are defined as FFR_{LAD} and FFR_{LCX}.

\[ FFR_{true} = \frac{nFFR_{LAD} + FFR_{LCX}}{1 - (FFR_{app} - FFR_{LCX}) + n(1 - (FFR_{app} - FFR_{LAD}))} \]

(5)

I hope that the legitimacy of Equation 5 will be assessed in the future clinical study.

*Naratatsu Saito, MD
*Department of Cardiovascular Medicine
Graduate School of Medicine
Kyoto University
54 Shogoin Kawahara-cho
Sakyo-ku
Kyoto 606-8507
Japan
E-mail: naritatsu@kuhp.kyoto-u.ac.jp
http://dx.doi.org/10.1016/j.jcin.2015.06.011

Please note: Dr. Saito has reported that he has no relationships relevant to the contents of this paper to disclose.
REFERENCES


REPLY: True Fractional Flow Reserve of Left Main Coronary Artery Stenosis in the Presence of Downstream Coronary Stenoses

We would like to thank Dr. Saito for his interest in our study (1) evaluating the influence of a downstream epicardial stenosis on the fractional flow reserve measurement of an intermediate left main stenosis with the pressure wire positioned in the nondiseased contralateral vessel. We agree with Dr. Saito that the findings are in accordance with mathematical equations like the one he proposes and the one we have previously published, which demonstrated our understanding of the background mechanism (2). Unfortunately, these equations and the even more complex one proposed for the case in which both downstream vessels are diseased suffer from the major limitation that they assume the microvascular resistance in each downstream vessel. Moreover, as was the case with the equations proposed for evaluating the individual fractional flow reserve values of serial stenoses (3,4), their complexity makes it unlikely that a practicing interventional cardiologist will apply them clinically. We are pleased that Dr. Saito’s letter highlights the practical message of our paper, that the effect of downstream epicardial disease on the functional assessment of intermediate left main disease with the pressure wire in the non-diseased downstream epicardial vessel is small and clinically irrelevant, unless the downstream disease is severe.

*William F. Fearon, MD
Andy S. Yong, MBBS, PhD
Guy Lenders, MD
Gabor G. Toth, MD
Catherine Dao, MD
David V. Daniels, MD
Nico H.J. Pijls, MD, PhD
Bernard De Bruyne, MD, PhD

*Stanford University Medical Center
300 Pasteur Drive, H2103
Stanford, California 94305
E-mail: wfearon@stanford.edu
http://dx.doi.org/10.1016/j.jcin.2015.06.012

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Please note: This study was supported in part by a research grant from St. Jude Medical. Dr. Fearon has received research support from St. Jude Medical. Drs. De Bruyne and Pijls are consultants for St. Jude Medical. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

REFERENCES


The Role of Drug-Eluting Balloons in Bifurcations

The Remaining Variable to Fit the Perfect Equation

We have read with great interest and satisfaction the elegant paper written by Kim et al. (1) and the editorial by Abdel-Latif et al. (2); we want to congratulate the authors on the original design of these 2 trials. As occurs with chronic total occlusions and left main disease, bifurcation lesions represent a constantly debated issue in all the meetings of Interventional Cardiology, and despite the large number of trials and the different techniques tested, there still exist unresolved aspects in the treatment of this subset of patients. To date, none of the dedicated stent platforms has shown relevant advantages over the conventional drug-eluting stents (DES) because of their higher profile, the complexity of utilization, or the need for additional stents, and although there is a general agreement supported by previous trials that provisional stenting is the best choice, there is still significant heterogeneity, and different techniques are widely used, such as crush, T-stenting, modified T-stenting, culotte, and a large list of the mentioned dedicated stents and techniques. The data provided by these 2 trials with 54% of second-generation DES in the CROSS (Choice Of Optimal Strategy For Bifurcation Lesions With Normal Side Branch) and 37% in the PERFECT (Optimal Stenting Strategy For True Bifurcation Lesions) trials show us the best paths to face against these challenging lesions in the following years. Second-generation stents have