

Reconsideration of a mathematical model for post-stenting fractional flow reserve in a tandem lesion with a side branch



Naritatsu Saito*, MD

Department of Cardiovascular Medicine, Graduate School of Medicine, Kyoto University, Kyoto, Japan

I read with interest the paper by Kweon and colleagues¹ in which they proposed a prediction model for post-stenting fractional flow reserve (FFR) in a tandem lesion with a side branch. The authors derived the following two equations that predicted the FFR after treatment of distal (Equation 1) or proximal stenosis (Equation 2):

$$FFR'_{d,pred} = FFR_p - \frac{\Delta FFR_p}{1 - wk\Delta FFR_d} = FFR_p - \frac{\Delta FFR_p}{1 - 1.33 \times k\Delta FFR_d} \quad (1)$$

$$FFR'_{d,pred} = FFR_p - \frac{\Delta FFR_d}{1 - w\Delta FFR_p} = FFR_p - \frac{\Delta FFR_d}{1 - 1.33\Delta FFR_p}, \quad (2)$$

where $w = P_a / (P_a - P_w) = 1.33$ and $k = Q_1 / Q_0$. Their efforts are praiseworthy; however, they committed a serious error in their calculation. The authors calculated the hyperaemic coronary flow to each branch by using the $P = QR$ equation. The problem is that the authors always calculated perfusion pressure as the difference between the distal coronary pressure and the wedge pressure (i.e., $P_d - P_w$). However, the perfusion driving pressure should be the difference between the distal coronary pressure and the central venous pressure (i.e., $P_d - P_v$), and P_v is usually considered zero when calculating the FFR². The authors committed the same error in all their calculations. It seems that the bifurcation model described in the present study did not include the collateral supply. Thus, $w = P_a / (P_a - P_v) = 1$ is correct and should be applied in Equations 1 and 2.

$$FFR'_{d,pred} = FFR_p - \frac{\Delta FFR_p}{1 - wk\Delta FFR_d} = FFR_p - \frac{\Delta FFR_p}{1 - k\Delta FFR_d} \quad (1')$$

$$FFR'_{d,pred} = FFR_p - \frac{\Delta FFR_d}{1 - w\Delta FFR_p} = FFR_p - \frac{\Delta FFR_d}{1 - \Delta FFR_p} \quad (2')$$

Equations 1' and 2' are the correct equations.

We have already described the same equation in our previous study that analysed the true FFR of the left main coronary lesion with a downstream stenosis³. The equation is as follows:

$$FFR_{pred-m} = \frac{nFFR_1 + FFR_m}{1 + n(1 - [FFR_m - FFR_1])}, \quad (3)$$

where n is defined as the ratio of the microcirculatory resistance of the side branch to that of the main branch, and $FFR_m = P_m / P_a$, and $FFR_1 = P_d / P_a$. The relationship of $n = k / (1 - k)$, $\Delta FFR_p = 1 - FFR_m$, and $\Delta FFR_d = FFR_m - FFR_1$ is true; thus, Equation 3 can be transformed to Equation 1 as follows:

$$\begin{aligned} FFR_{pred-m} &= \frac{\frac{k}{1-k}(1 - \Delta FFR_p - \Delta FFR_d) + (1 - \Delta FFR_p)}{1 + \frac{k}{1-k}(1 - \Delta FFR_d)} \\ &= 1 - \frac{\Delta FFR_p}{1 - k\Delta FFR_d} \\ &= FFR_p - \frac{\Delta FFR_p}{1 - k\Delta FFR_d} \end{aligned}$$

Note that FFR_p is always equal to 1.

I recommend that the authors reanalyse their data by using Equations 1 and 2, which will certainly bring more correct results and improve the quality of the paper.

Conflict of interest statement

The author has no conflicts of interest to declare.

References

1. Kweon J, Kim YH, Yang DH, Lee JG, Roh JH, Mintz GS, Lee SW, Park SW. In vivo validation of mathematically derived fractional flow reserve for assessing haemodynamics of coronary tandem lesions. *EuroIntervention*. 2016;12:e1375-84.
2. Pijls NH, van Son JA, Kirkeeide RL, De Bruyne B, Gould KL. Experimental basis of determining maximum coronary, myocardial, and collateral blood flow by pressure measurements for assessing functional stenosis severity before and after percutaneous transluminal coronary angioplasty. *Circulation*. 1993;87:1354-67.
3. Yamamoto E, Saito N, Matsuo H, Kawase Y, Watanabe S, Bao B, Watanabe H, Higami H, Nakatsuma K, Kimura T. Prediction of the true fractional flow reserve of left main coronary artery stenosis with concomitant downstream stenoses: in vitro and in vivo experiments. *EuroIntervention*. 2016;11:e1249-56.

*Corresponding author: Department of Cardiovascular Medicine, Graduate School of Medicine, Kyoto University, 54 Shogoin Kawahara-cho, Sakyo-ku, Kyoto, 606-8507, Japan. E-mail: naritatu@kuhp.kyoto-u.ac.jp