FULL TEXT ARTICLE

The Influence of Hydrostatic Pressure on Physiological Indexes

Valeria Paradies and Pieter Cornelis Smits

Cardiovascular Revascularization Medicine, 2023-07-01, Volume 52, Pages 106-107, Copyright © 2023 Elsevier Inc.

Highlights

- The height difference between the coronary ostium and the pressure wire sensor during FFR measurement can lead to under- or overestimated functional severity of a stenosis.
- The hydrostatic pressure phenomenon may affect the interpretation of physiological indexes.
- Future research is needed to understand the clinical relevance of hydrostatic error in guiding functional assessment of lesion severity.

"Gravity is one variable in a lot of scientific processes. If you can remove gravity or minimize its effect, then you can understand the other processes that are going on." Laurel Clark; NASA astronaut and medical doctor

Fractional flow reserve (FFR) is the gold standard for invasive assessment of hemodynamic severity of a coronary stenosis and it has been shown to improve clinical outcomes in randomized clinical trials [1] . Acknowledged pitfalls of FFR may originate from calibration, equalization, submaximal hyperemia, drifting, whipping, and wedging.

Hydrostatic pressure is also a factor contributing to FFR imprecision, but relies instead on a physical principle of coronary anatomy. Normal coronary arteries lie in different vertical planes. The position of the pressure wire sensor during FFR measurement is rarely at the same level as the coronary ostium where equalization is performed. As a consequence, FFR values may under- or overestimate the functional severity of a stenosis depending on the coronary artery examined and its anatomical course.

The concept of hydrostatic error has been poorly investigated so far, and is not recognized in clinical practice.

Al-Janabi, et al. used computed tomography angiography (CTA) to measure height differences between the coronary ostia and varying points in the coronary tree, demonstrating a statistically significant height variation between the proximal and distal vessel [2] . However, CTA may fail to identify the most distal parts of the coronary vessels, resulting in an underestimation of height differences [2] .

In vitro measurements, performed by Härle, et al., using a dynamic pressure simulator, showed a significant correlation between absolute pressure differences and height differences ($r = 0.993$; $p < 0.0001$) with a slope of 0.77 mmHg/cm [3] .

Resting Pd/Pa and FFR values from in vivo measurements in supine and prone positions, were found by Kawaguchi, et al., to differ significantly between anterior and posterior coronary territories. FFR values, corrected by adding the hydrostatic pressure factor, showed good correlation between measurements in both positions (R^2 : 0.948 in the left anterior descending [LAD]; R^2 : 0.942 in the left circumflex [LCx]; and R^2 : 0.928 in the right coronary artery [RCA]) [4] .

Üveges et al. investigated the effect of hydrostatic pressure on 41 measurements of FFR between 0.7 and 0.9, using a 3D reconstruction model. Correction of hemodynamic indexes by the hydrostatic pressure factor led to a reclassification of FFR and resting Pd/Pa values in 5 (12 %) and 11 (27 %) measurements, respectively [5] . Limitations of in vivo studies using computer simulation and 3D reconstruction to investigate hydrostatic pressure, are related to assumptions of standard mass density, motion of coronary arteries during the cardiac cycle and accuracy of frame selection, and influence on artery heights of comorbidities (obesity, emphysema, aortic stenosis).

Wirecath® (Cavis Technologies AB, Uppsala, Sweden) overcomes the hydrostatic error by using “open wire technology”, with a water-filled interior and an external pressure transducer for hemodynamic measurements. We performed simultaneous measurements of stenosis severity with a conventional sensor-tipped FFR wire and Wirecath technology, in a patient presenting with chronic coronary syndrome and multivessel disease. (Figure) Given the dichotomous interpretation of FFR measurements, the use of Wirecath determined the reclassification of the RCA stenosis from non-ischemic to ischemic.

The hydrostatic error has a greater impact on resting indices as compared to FFR [4] (Fig. 1). In clinical practice, hydrostatic pressure accounts for hemodynamic index values >1.00 most commonly in posterior territories and values lower than 1.00 in anterior territories.

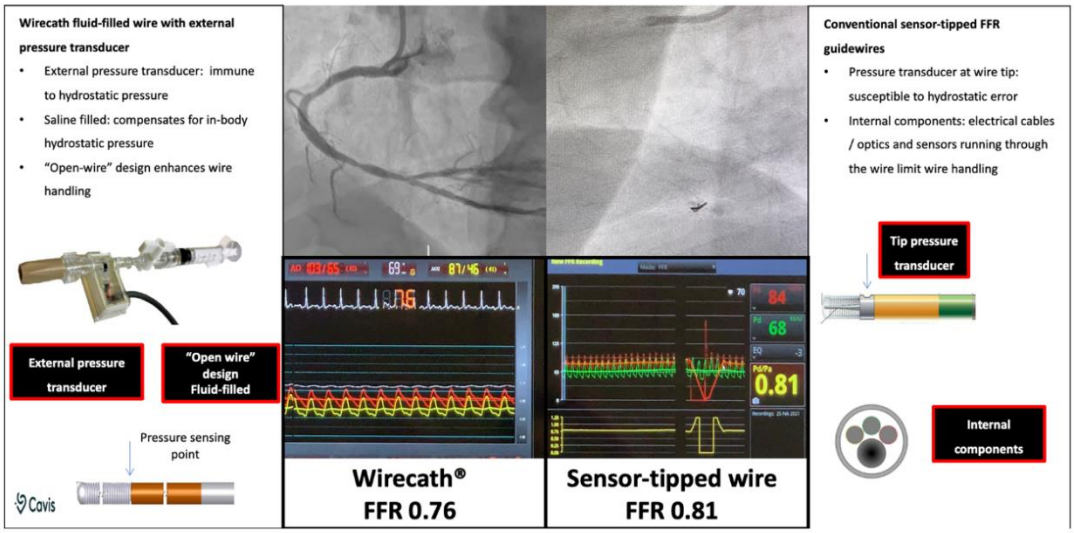

Fig. 1

Central figure upper panel. RCA coronary angiography from an LAO 40° (left) and an LAO 67° (right) view. Lower panel. FFR value with Wirecath 0.76 (left) and a sensor-tipped wire 0.81 (right) in the RCA.

Right panel CAVIS Wirecath.

Left panel Sensor-tipped wire.

The hydrostatic pressure phenomenon may affect the interpretation of physiological indexes. When a binary cut-off for hemodynamic assessment is used, a small change in FFR values may reclassify the stenosis from ischemic to non-ischemic, or steer the indication from coronary artery bypass grafting (CABG) to percutaneous coronary intervention (PCI), and vice versa. Future research is needed to understand the clinical relevance of hydrostatic error in guiding functional assessment of lesion severity.

The authors declare that no funding, grants or other form of financial support have been provided.
The authors declare no conflict of interests related to the content of this paper.

References

1. Pijls N.H.J., Fearon W.F., Tonino P.A.L., et. al.: Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel coronary artery disease: 2-year follow-up of the FAME (Fractional Flow Reserve Versus Angiography for Multivessel Evaluation) study. J Am Coll Cardiol 2010; 56: pp. 177-184.

View In Article Cross Ref

2. Al-Janabi F., Karamasis G., Cook C.M., et. al.: Coronary artery height differences and their effect on fractional flow reserve. Cardiol J 2021; 28: pp. 41-48.

View In Article Cross Ref

3. Härle T., Luz M., Meyer S., et. al.: Effect of coronary anatomy and hydrostatic pressure on intracoronary indices of stenosis severity. JACC Cardiovasc Interv 2017; 10: pp. 764-773.

View In Article

4. Kawaguchi Y., Ito K., Kin H., et. al.: Impact of hydrostatic pressure variations caused by height differences in supine and prone positions on fractional flow reserve values in the coronary circulation. J Interv Cardiol 2019; 2019: pp. 4532862.

View In Article

5. Üveges Á., Tar B., Jenei C., et. al.: The impact of hydrostatic pressure on the result of physiological measurements in various coronary segments. Int J Cardiovasc Imaging 2021; 37: pp. 5-14.