JACC: CARDIOVASCULAR IMAGING VOL. ■, NO. ■, 2018

PUBLISHED BY ELSEVIER

EDITORIAL COMMENT

Let's Join Them!*

John McB. Hodgson, MD

". . . what has been done will be done again; there is nothing new under the sun." (1)

Since Mason Sones discovered selective coronary contrast injections (October 30, 1958), the coronary angiogram has been the cornerstone for assessing coronary artery disease and guiding patient therapy. An entire subspeciality of invasive and interventional cardiology has developed around the coronary angiogram. Specific professional societies (e.g., Society for Cardiac Angiography and Interventions) were formed (first meeting June 5, 1978). Specialized fellow training (circa 1985) and board exams (1999) were developed and an era of unprecedented innovation and advancement in the treatment of coronary artery disease was born (2).

Unfortunately, the coronary angiogram is flawed. Although the x-ray imaging equipment has improved through the years, providing better resolution, the fundamental problem of imaging a complex 3-dimensional structure in 2 dimensions continues to plague accurate interpretation. It is well appreciated that visual interpretation of the angiogram is widely variable among different operators, even when proximal stenosis in large vessels are involved (3,4). To overcome this problem, and to move toward a more physiologic approach to the assessment of coronary artery stenosis, multiple techniques have been tried to measure coronary blood flow, or parameters closely related to blood flow (e.g., velocity, pressure gradients) (5).

Many of us tried to use coronary flow reserve, either by digital angiography (6,7) or by coronary velocity measurements (8). We soon learned that there were too many confounding influences to allow accurate determination of the physiologic significance of individual lesions. We also tried simple translesional pressure gradient measurements (9), but the major breakthrough came with Nico Pijl's work on fractional flow reserve (FFR) (10). Subsequent advancements have largely revolved around modifications of the FFR technique and translating the invasive measurement of FFR to noninvasive imaging. The use of cardiac computed coronary tomography with complex computer flow modeling has allowed a true noninvasive assessment of FFR suitable for routine use (11).

In the current issue, Gosling et al. (12) explore the application of computational flow dynamics (CFD) to invasive coronary angiograms. Their proof-of-concept study shows that with certain limitations, such an approach might be able to yield FFR estimates from routinely acquired angiograms. I was initially quite skeptical of this approach. A careful read of the paper will allow an understanding of the numerous assumptions (e.g., distal boundary conditions, flow behavior) and anatomic limitations (quality of the angiogram, overlap, tortuosity, branches, etc.). Undoubtedly, as has occurred with computed coronary tomography-based measures of FFR, the technique described by Gossling et al. (12) can be refined and simplified. Given sufficient computer processing power, it could provide estimates in near real time. There may be some practical advantages of this approach compared with computed coronary tomography-FFR: for example, motion artifacts, calcium blooming, and misalignment would not be encountered. Other investigators have recently reported similar techniques to assess FFR from the invasive angiogram (albeit using simpler techniques) (13).

More importantly, why do I need a complex analysis of the coronary angiogram to estimate the FFR, when I can easily pass a pressure wire and measure it directly! After all, I am already in the catheterization lab! Then it dawned on me: I am a "believer," but most invasive operators are (sadly) not. I would not hesitate to measure the FFR or to use intravascular imaging tools to better assist me in interpreting the basic angiogram. In many Asian countries, the use of FFR or intravascular imaging is common (>80%);

*Editorials published in *JACC: Cardiovascular Imaging* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Imaging* or the American College of Cardiology.

From the Case Western Reserve University, Cardiac Intensive Care Unit, MetroHealth Medical Center, Cleveland, Ohio. Dr. Hodgson has received consulting and speaking fees from Philips Volcano.

ISSN 1936-878X/$36.00 https://doi.org/10.1016/j.jcmg.2018.02.013

however, in the United States and Europe, these tools are used in ≤20% of procedures (14). Thus the need for an assessment tool that can be used by the many operators who are either uncomfortable (or uninterested) in performing measurements that enhance our ability to gauge the significance of coronary angiographic lesions.

As Gossling et al. (12) point out, use of FFR to assess and guide stenosis treatment is superior to using visual angiographic assessment alone. Their technique performs simulated stent placement; this feature will allow operators new paradigms in planning percutaneous coronary intervention. For example, for multiple lesions, being able to identify which lesion is more physiologically important might minimize unnecessary stenting.

The ability to provide an estimate of FFR in all 3 major coronary vessels in near real time becomes attractive to every angiographer from a public health perspective. An objective FFR measurement based on angiographic computational flow dynamics could provide an initial screening tool to assist in the planning of appropriate therapy for individual patients. This could also provide many new insights for patients with multivessel disease. This method might not be accurate in patients with nonideal microvascular resistance assumptions, such as patients with prior infarction or ventricular hypertrophy. Appropriate trials would need to be performed to assess this strategy; however, I personally find it hard to believe that the "more informed" strategy would not provide better patient outcomes.

Yet another analysis of the benefit of image-guided intervention has just been published (15). Although a welcome addition to the scientific publications, I have to agree with Gary Mintz that this analysis may be ignored, as have the many preceding it (16). So, if we cannot beat them, we will have to join them! By providing a tool in the catheterization lab that rapidly estimates the FFR for major epicardial arteries from routine angiograms, we may finally be able to get a majority of invasive operators "on board." Although the work of Gossling et al. (12) is not "new under the sun," it may finally penetrate the darkness of visual angiographic interpretation. Only time will tell!

ADDRESS FOR CORRESPONDENCE: Dr. John McB. Hodgson, Case Western Reserve University, Cardiac Intensive Care Unit, MetroHealth Medical Center, 2500 MetroHealth Drive, Cleveland, Ohio 44109. E-mail: jhodgson@tsg-ed.com.

REFERENCES

1. Book of Ecclesiastes 1:9 (NIV).

2. Gaspard P, Whitin H. The History of Coronary Angioplasty. Salt Lake City, UT: Europa Digital & Publishing; 2017.

3. Nallamothu BK, Spertus JA, Lansky AJ, et al. Comparison of clinical interpretation with visual assessment and quantitative coronary angiography in patients undergoing percutaneous coronary intervention in contemporary practice: the Assessing Angiography (A2) project. Circulation 2013;127:1793–800.

4. Fisher LD, Judkins MP, Lesperance J, et al. Reproducibility of coronary arteriographic reading in the Coronary Artery Surgery Study (CASS). Cathet Cardiovasc Diagn 1982;8:565–75.

5. Marcus ML. The Coronary Circulation in Health and Disease. New York: McGraw-Hill; 1983.

6. Hodgson JM, Riley RS, Most AS, Williams DO. Assessment of coronary flow reserve using digital angiography before and after successful percutaneous transluminal coronary angioplasty. Am J Cardiol 1987;60:61–5.

7. Hodgson JM, LeGrand V, Bates ER, et al. Validation in dogs of a rapid digital angiographic technique to measure relative coronary blood flow during routine cardiac catheterization. Am J Cardiol 1985;55:188–93.

8. Graham SP, Cohen MD, Hodgson JM. Estimation of coronary flow reserve by intracoronary Doppler flow probes and digital angiography. Cathet Cardiovasc Diagn 1990;19:214–21.

9. Hodgson JM, Reinert S, Most AS, Williams DO. Prediction of long-term clinical outcome with final translesional pressure gradient during coronary angioplasty. Circulation 1986;74:563–6.

10. 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;334:1703–8.

11. Min JK, Taylor CA, Achenbach S, et al. Noninvasive fractional flow reserve derived from coronary CT angiography: clinical data and scientific principles. J Am Coll Cardiol Img 2015;8:1209–22.

12. Gosling RC, Morris PD, Silva Soto DA, Lawford PV, Hose DR, Gunn JP. Virtual coronary intervention: a treatment planning tool based upon the angiogram. J Am Coll Cardiol Img 2018;11:xxx–xx.

13. Xu B, Tu S, Qiao S, et al. Diagnostic accuracy of angiography-based quantitative flow ratio measurements for online assessment of coronary stenosis. J Am Coll Cardiol 2017;70:3077–87.

14. Dattilo PB, Prasad A, Honeycutt E, Wang TY, Messenger JC. Contemporary patterns of fractional flow reserve and intravascular ultrasound use among patients undergoing percutaneous coronary intervention in the United States: insights from the National Cardiovascular Data Registry. J Am Coll Cardiol 2012;60:2337–9.

15. Buccheri S, Franchina G, Romano S, et al. Clinical outcomes following intravascular imaging-guided versus coronary angiography-guided percutaneous coronary intervention with stent implantation: a systematic review and Bayesian Network meta-analysis of 31 studies and 17,882 patients. J Am Coll Cardiol Intv 2017;10:2488–98.

16. Mintz GS. Intravascular imaging, stent implantation, and the elephant in the room. J Am Coll Cardiol Intv 2017;10:2499–501.

KEY WORDS computational fluid dynamics, coronary artery disease, coronary physiology, fractional flow reserve, percutaneous coronary intervention