Limitations and Pitfalls of Fractional Flow Reserve Measurements and Adenosine-Induced Hyperemia

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KEYWORDS

• Fractional flow reserve • Limitations • Ischemic coronary artery disease • Coronary stenosis
• Adenosine-induced hyperemia

KEY POINTS

- Fractional flow reserve (FFR) provides a reliable lesion-specific and vessel-specific assessment of the functional significance (ischemic potential) of coronary stenoses.
- Operators must be aware of multiple technical pitfalls of measurement including wire drift, guide catheter damping, beat-to-beat variation, and wire artifacts.
- Adenosine is associated with dynamic and variable hemodynamic responses that can complicate the interpretation of FFR.
- FFR is measured clinically without regard to central venous pressure, which may become relevant in certain patient subgroups.
- Specific clinical settings that may complicate FFR measurement include multivessel disease, acute myocardial infarction, and left main stenosis.

INTRODUCTION

Coronary physiologic assessment addresses the well-known limitations of coronary angiography in determining the clinical significance of intermediate lesions. FFR is increasingly accepted as the gold standard for determining the ischemic potential of coronary lesions and guiding percutaneous coronary intervention (PCI). FFR is an index of the functional significance of coronary stenosis defined as the maximal flow in a vessel in the presence of a stenosis divided by the maximal flow in the theoretic absence of the stenosis. Assuming flow is linearly related to pressure during hyperemia, the translesional pressure ratio serves as a surrogate for the percent of normal flow. The derivation of FFR, Pd − Pv/Pa − Pv, during maximal hyperemia, describes the ischemic potential of the lesion (Pd is the pressure distal to a stenosis, measured by a pressure guide wire, and Pa is the pressure proximal, measured by the pressure transducer on the guiding catheter; the effect of central venous pressure, Pv, is assumed to be clinically negligible).[1]

BASIC PRINCIPLES AND PREREQUISITES

FFR is a technique that is simple to learn yet can be difficult to master because of several caveats that can give inaccurate pressure measurements.

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Following are the steps that are essential to collect accurate FFR measurements and minimize the risk of error:

1. Administer anticoagulant (usually intravenous [IV] heparin) and intracoronary (IC) nitroglycerin (100- to 200-μg bolus) before insertion of the guide wire.
2. Calibrate the pressure guide wire to the system's analyzer: zero to atmospheric pressure outside of the body. Tighten all pressure tubing connections.
3. Insert the pressure guide wire into the guide catheter and match the wire/guide catheter pressures in the aorta. This process requires removing the needle introducer, tightening the Y-connector (Tuohy-Borst), and flushing the catheter with saline.
4. Advance the wire across the lesion 2 to 3 cm distal to the coronary lesion. Again, this requires removing the needle introducer, tightening the Y-connector, and flushing the catheter with saline.
5. Induce maximal hyperemia with IV adenosine (140 μg/kg/min) or IC bolus of adenosine (20–30 μg for the right coronary artery [RCA] or 60–100 μg for the left coronary artery).
6. When using IC adenosine, measure FFR as the lowest Pd/Pa after hyperemia is induced (usually 15–20 seconds after injection). When using IV adenosine, measure FFR after 1.5 to 3 minutes of infusion and do not accept pressure for calculations until stable hyperemia is seen for at least several seconds.
7. Confirm the absence of signal drift with pressure wire pullback into the guide. Equal pressure readings indicate wire signal stability.

PITFALLS OF FRACTIONAL FLOW RESERVE MEASUREMENTS

Mechanical Issues: Transducers, Zeros, Connections

Measurement of aortic pressure through a fluid-filled guide catheter is subject to technical issues such as loose connections, leak in guide connections, and improper zeroing. Improper leveling of the systemic pressure transducer can overestimate or underestimate aortic pressure. Loose connections and malfunctioning pressure transducers can generate abnormal or moving systemic pressure measurements, mimicking wire drift. Most commonly, the Y-connector or Tuohy-Borst connector may be inadequately tightened, or the needle introducer left in during measurement or normalization of pressures, leading to a decrease in measured aortic pressure (Fig. 1). Finally, a saline flush before any pressure measurement clears

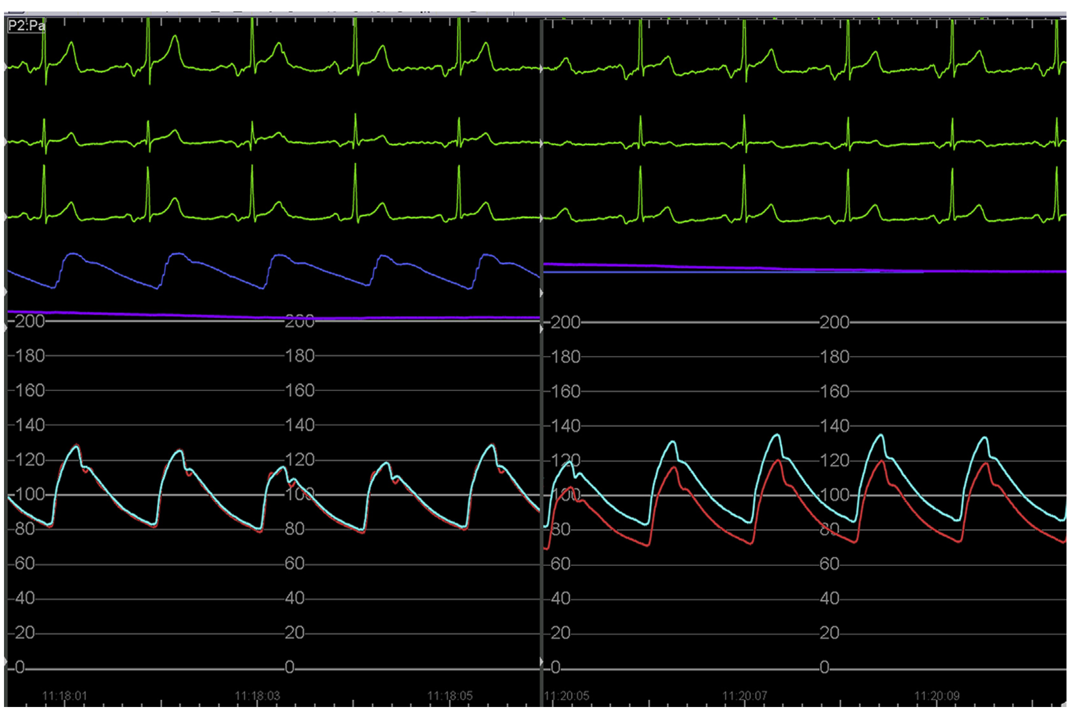

Fig. 1. Loose connections. Equalized Pa and Pd pressures (*left panel*) becomes unequal when the Tuohy-Borst introducer is not tightened (*right panel*), causing partial loss of aortic pressure. Leaving a needle introducer in place causes a similar loss of pressure.