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Effect of Coronary Anatomy and Hydrostatic Pressure on Intracoronary Indices of Stenosis Severity

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ABSTRACT

OBJECTIVES The authors sought to analyze height differences within the coronary artery tree in patients in a supine position and to quantify the impact of hydrostatic pressure on intracoronary pressure measurements in vitro.

BACKGROUND Although pressure equalization of the pressure sensor and the systemic pressure at the catheter tip is mandatory in intracoronary pressure measurements, subsequent measurements may be influenced by hydrostatic pressure related to the coronary anatomy in the supine position. Outlining and quantifying this phenomenon is important to interpret routine and pullback pressure measurements within the coronary tree.

METHODS Coronary anatomy was analyzed in computed tomography angiographies of 70 patients to calculate height differences between the catheter tip and different coronary segments in the supine position. Using a dynamic pressure simulator, the effect of the expected hydrostatic pressure resulting from such height differences on indices stenosis severity was assessed.

RESULTS In all patients, the left anterior and right posterior descending arteries are the highest points of the coronary tree with a mean height difference of −4.9 cm (SD 1.6) and −3.8 cm (SD 1.0); whereas the circumflex artery and right posterolateral branches are the lowest points, with mean height differences of 3.9 cm (SD 0.9) and 2.6 cm (SD 1.6) compared with the according ostium. In vitro measurements demonstrated a correlation of the absolute pressure differences with height differences ($r = 0.993$; $p < 0.0001$) and the slope was 0.77 mm Hg/cm. The Pd/Pa ratio and instantaneous wave-free ratio correlated also with the height difference (fractional flow reserve $r = 0.98$; $p < 0.0001$; instantaneous wave-free ratio $r = 0.97$; $p < 0.0001$), but both were influenced by the systemic pressure level.

CONCLUSIONS Hydrostatic pressure variations resulting from normal coronary anatomy in a supine position influence intracoronary pressure measurements and may affect their interpretation during stenosis severity assessment. (J Am Coll Cardiol Intv 2017;■:■–■) © 2017 by the American College of Cardiology Foundation.

Functional assessment of coronary stenoses using intracoronary pressure guidewires constitutes a simple and clinically important diagnostic tool in the catheterization laboratory. In practice, fractional flow reserve (FFR) is calculated as the ratio of the distal trans-stenotic pressure to the proximal coronary or aortic pressure during pharmacologically induced (usually adenosine-induced) hyperemia, assuming that the effect of boundary conditions such as central venous pressure is negligible (1). The instantaneous wave-free ratio (iFR) is a new adenosine-independent index of coronary stenosis

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

CT = computed tomography

CTA = computed tomography angiography

CX = circumflex artery

DPS = dynamic pressure simulator

ECG = electrocardiogram

FFR = fractional flow reserve

iFR = instantaneous wave-free ratio

LAD = left anterior descending artery

LV = left ventricular

LVEF = left ventricular ejection fraction

Pa = mean systemic pressure

Pd = mean distal pressure

RCA = right coronary artery

RPD = right descending posterior artery

RPL = right posterolateral artery

severity. For iFR calculation, the aforesaid pressures are measured and indexed during a specific diastolic wave-free period, when coronary resistance is most stable and minimized over the cardiac cycle (2).

This simple approach facilitates physiological assessment of coronary stenosis severity in the catheterization laboratory. However, it is potentially fraught by the boundary conditions and assumptions of the model. Thus, although stenosis location should, from a theoretical perspective, not influence FFR or iFR measurements, significant differences of both iFR and FFR values between anterior and posterior coronary territories have been observed in clinical practice (3,4), with higher values of both indices in the circumflex (CX), obtuse marginal, and right coronary arteries (RCA), when compared with the left anterior descending coronary artery (LAD) and its diagonal branches. This difference was independent of the effects of potential clinical and anatomic confounders (4).

We hypothesized that variations in hydrostatic pressure, related to coronary anatomy, might be the cause of these findings. This might be important, not only for the interpretation of conventional FFR or iFR measurements, but also for intracoronary pressure mapping, an increasingly used application of both indices, and for measurements of microcirculatory resistance.

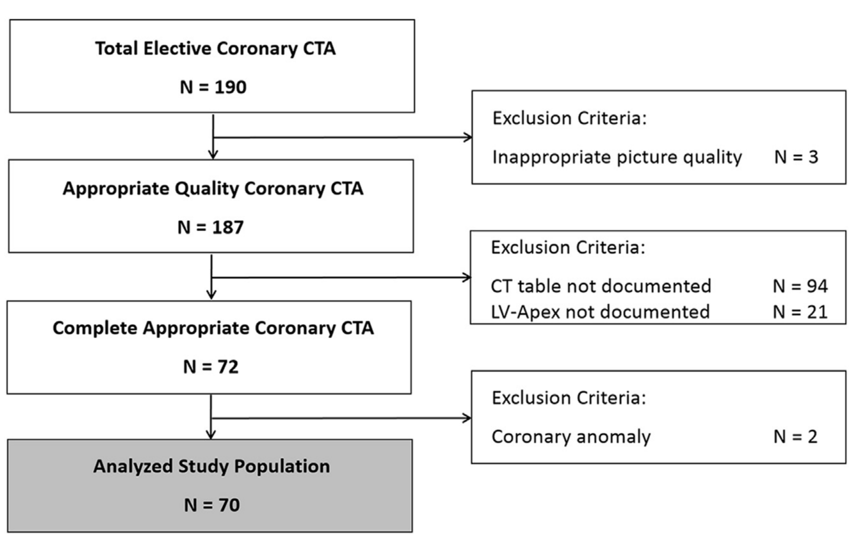
In the study presented, we sought to analyze and quantify the impact of hydrostatic pressure on the results of intracoronary pressure measurements using an in vitro model. Furthermore, we aimed to quantify the height differences between the distal coronary vessels and the corresponding coronary ostia in real patients in a supine position in order to quantify a theoretical impact of hydrostatic pressure in vivo.

METHODS

STUDY POPULATION. From May 2015 to June 2016 a total of 190 elective coronary computed tomography angiographies (CTAs) were performed in our hospital. Inclusion criteria for this analysis was any elective coronary CTA with capture of the complete heart as well as the computed tomography (CT) table. Patients with incomplete opacification of the coronary vessels (n = 2), extensive artefacts (n = 1), and coronary anomalies (n = 2) were excluded from analysis. Overall, a number of 70 CTA was identified as appropriate for the intended analysis (**Figure 1**).

ANALYSIS OF CORONARY ARTERY HEIGHT DIFFERENCES. Coronary CTA was performed according to common standards using a CT scanner with 64 detector rows. Beta-blockers were administered intravenously if necessary, targeting a heart rate below 90 beats per

FIGURE 1 Flow Chart of Patient Selection



CTA = computed tomography angiography; LV = left ventricular.