Noninvasive Fractional Flow Reserve for the Diagnosis of Lesion-specific Ischemia: A Case Example

Jesper Møller Jensen, Lars Christian Gormsen1, Henning Mølgaard, Bjarne Linde Nørgaard
Departments of Cardiology and 1Nuclear Medicine, Aarhus University Hospital, Aarhus, Denmark

ABSTRACT
A physically active 52-year-old male with atypical chest pain was referred to our department. A coronary computed tomography angiography (CCTA) showed a stenotic plaque in the mid left anterior descending coronary artery (LAD). A rest–stress Rubidium-82 myocardial perfusion was normal. One year later the patient sustained a cardiac arrest and percutaneous coronary intervention of the mid-LAD was successfully performed. The original CCTA data were submitted for noninvasive determination of fractional flow reserve (FFRCT) revealing an ischemia-producing lesion in the mid-LAD. This case demonstrates the inherent limitations of assessing lesion-specific ischemia. FFRCT shows promise as a new method for future selection of patients for coronary angiography.

Key words: Coronary artery disease, fractional flow reserve, nuclear medicine

INTRODUCTION
Recently, a new method for assessing the functional significance of coronary computed tomography angiography (CCTA) has become available.1-4 This method uses patient-specific anatomic data from CCTA, mathematic modeling of coronary physiology, and computation of coronary pressure and blood flow utilizing computational fluid dynamics5 to provide a noninvasive measure of fractional flow reserve (FFRCT), which can identify ischemia-producing stenoses.1-4 The present case demonstrates the potential role of this new method as a gatekeeper to the catheterization laboratory.

CASE REPORT
A 52-year-old male was referred for evaluation of atypical chest discomfort after strenuous exercise and occasional stabbing pain in the left thorax not associated with physical activity. The patient exercised daily and he had competed in 39 marathons without any chest symptoms. He had familial hypercholesterolemia but no history of diabetes, hypertension, or smoking. The patient had discontinued cholesterol-lowering medication. The patient's blood pressure, electrocardiogram, and echocardiogram were normal. Total cholesterol and low
density lipoprotein were 7.1 and 5.5 mmol/L, respectively. Due to the uncharacteristic nature of the patient’s symptoms, a CCTA was performed. The calcium score was 140 and CCTA revealed calcified and noncalcified coronary atherosclerosis with a mixed, stenotic plaque in the mid left anterior descending coronary artery (LAD) [Figure 1]. Functional testing was scheduled with a rest–stress Rubidium-82 myocardial perfusion scan. Myocardial perfusion and coronary flow reserve were normal during adequate stress response to adenosine (140 µg/kg/min) [Figure 2]. Atorvastatin was prescribed and the patient continued his high level of daily physical activity.

One year later, following strenuous running, the patient sustained a cardiac arrest. Cardiopulmonary resuscitation was started immediately with successful electrical cardioversion of ventricular fibrillation and return of spontaneous circulation 6 min after the alarm. The electrocardiogram showed ST-elevation [Figure 3]. Acute invasive angiography revealed occlusion of the mid-LAD. Normal coronary flow was restored after recanalization and stenting [Figure 4]. Ten days later, transthoracic echocardiography showed left ventricular ejection fraction of 40–45% with apical hypokinesis. The patient was advised cardiac rehabilitation.

As a blind study, we submitted the patient’s CCTA data, which had been obtained one year earlier and had revealed a highly significant ischemia-producing lesion in the mid-LAD, for FFR$_{CT}$ analysis [Figure 5]. FFR$_{CT}$ analysis was performed at HeartFlow (Redwood City, CA, USA) utilizing updated proprietary software. Computation of noninvasive FFR$_{CT}$ from CCTA image data requires a physiologic model of coronary blood flow. The physiologic model is based on three underlying principles as described in detail by Taylor et al.,:

(i) The total resting coronary blood flow can be quantified relative to the myocardial mass, (ii) The

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**Figure 1:** 52-year-old male with atypical chest pain. Coronary computed tomography angiography curved planar reformation image of the mid left anterior descending coronary artery. The white arrow marks an area suspicious for significant stenosis (>70%).

**Figure 2:** 52-year-old male with atypical chest pain. Static rubidium-82 perfusion images (17 segment polar maps) demonstrates no difference between stress (top) and rest perfusion (bottom). Images were acquired 150 s after injection of 1110 MBq Rb82. Total acquisition time was 270 s.

**Figure 3:** 53-year-old male presenting with severe chest pain and cardiac arrest, which was successfully treated with resuscitation and cardioversion. 12-lead electrocardiogram shows massive ST-elevation consistent with anterior ST-elevation myocardial infarction.

**Figure 4:** 53-year-old male presenting with severe chest pain and cardiac arrest, which was successfully treated with resuscitation and cardioversion. Invasive angiography shows pre-stent image of left anterior descending coronary artery occlusion marked by the white arrow (left side, angiography projection: 4° right anterior oblique and 24° cranial) and post-stent image of re-perfused left anterior descending coronary artery with the white arrow marking the point of previous occlusion (right side, angiography projection: 6° right anterior oblique and 30° cranial).
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CT shows promise as a new method to identify lesion-specific ischemia noninvasively and, thus, $FFR_{CT}$ may play a role in the selection of patients for coronary angiography.

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