Original articles

Imaging of the posterior descending coronary artery. The last frontier in echocardiography

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Key words:
Adenosine; Coronary flow reserve; Doppler echocardiography; Posterior descending coronary artery.

Background. **Non-invasive color Doppler imaging of the left anterior descending coronary artery has been described, but imaging of the posterior descending coronary artery (PD) has never been reported. The aim of this paper was to describe color Doppler imaging and flow reserve of the PD, regardless of its origin from the right or circumflex coronary artery, in different settings such as acute myocardial infarction or coronary stenting.**

Methods. **A C256 Acuson Sequoia ultrasound system connected to a standard 3.5 MHz transducer was used. Neither a contrast agent nor harmonic or power Doppler imaging was used. However, the Nyquist limit of color Doppler was reduced to 12 cm/s. Patients were examined in the apical 2-chamber view, with the coronary sinus ostium imaged in the short axis until a diastolic flow signal close to the epicardial layer was detected. Pulsed Doppler confirmed an anterograde, doming systolic and monophasic decrescendo diastolic flow. Adenosine was intravenously infused at the standard dose of 140 μg/kg/min over 90 s in order to elicit maximal microcirculatory dilation. The resting and hyperemic peak diastolic flow velocities were measured and the coronary flow reserve was calculated as the ratio between hyperemic and resting peak diastolic flow velocities.**

Results. **This simple bedside technique provided crucial information about several important issues: 1) arterial patency after thrombolysis; 2) evaluation of the physiologic impact of a coronary stenosis, with implications on the detection of a critical stenosis; 3) reperfusion imaging of perforating branches after myocardial infarction; 4) post-stent assessment of coronary flow reserve.**

Conclusions. **This paper shows, for the first time, that non-invasive imaging of the PD by non-contrast transthoracic Doppler is feasible and that the coronary flow reserve is measurable even in critical conditions. More studies are needed to assess the feasibility of PD imaging in different clinical settings and the potential benefit of contrast agents in improving the evaluation of coronary flow.**

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Introduction

Recent advances in color Doppler technology have allowed imaging of vessels with a small and slow flow such as the peripheral retinal branches[1], the anterior spinal artery[2] as well as the distal left anterior descending coronary artery (LAD)[3-5] and grafts[6,7].

Imaging of the distal LAD flow is of particular interest in cardiology. It permits direct assessment of the reestablishment of flow in acute myocardial infarction, of arterial patency[7], of myocardial reperfusion[8] and of changes in coronary flow reserve (CFR) after stenting[6,9,10]. Pending the use of appropriate probes and imaging modality, the technique is equally effective (95% success rate) with or without a contrast agent. With contrast, a 3.5 MHz probe and harmonic imaging are recommended[11,12]. On the other hand, if a contrast agent is not employed a 7 MHz probe and fundamental imaging are mandatory[3-8] for the evaluation of LAD flow.

The major criticism to this technique is that "only" the LAD can be imaged, while the circumflex and right coronary arteries cannot. In order to challenge this pre-concept, we have recently attempted imaging of the posterior descending coronary artery (PD) by transthoracic color Doppler echocardiography. The aim of this paper was to describe color Doppler imaging and flow reserve of the PD, regardless of its origin from the right or circumflex coronary artery, in different settings such as acute myocardial infarction or coronary stenting.

Methods

A C256 Acuson Sequoia (Mountain View, CA, USA) ultrasound system con-

nected to a standard 3.5 MHz (2 MHz in color Doppler) transthoracic transducer was used for PD imaging. Neither a contrast agent nor harmonic or power Doppler imaging was used. However, the Nyquist limit of color Doppler was reduced to 12 cm/s. Patients were examined in the left lateral decubitus from the apical 2-chamber view, with the coronary sinus ostium imaged in the short axis (Fig. 1). Color Doppler was focused on the proximal and mid thirds of the posterior interventricular sulcus and the transducer was slightly rotated and tilted until a diastolic flow signal close to the epicardial layer was detected. Pulsed Doppler interrogation confirmed an anterograde, doming systolic as well as a monophasic decrescendo diastolic flow. Care was taken to avoid inclusion in the sample volume of the right ventricular inflow, which is characterized by a biphasic anterograde diastolic flow, and of the retrograde coronary venous flow. Patients were studied in the fasting state and, whenever possible, all vasoactive drugs were withdrawn. A venous cannula was inserted into a cubital vein and, in order to elicit maximal microcirculatory dilation, which results in a maximal increase in the coronary flow velocity, adenosine was infused at the standard dose of 140 μg/kg/min over 90 s. The resting and hyperemic peak diastolic flow velocities (PFV) were measured and CFR was calculated as the ratio between the hyperemic and resting PFV.

Results

Case 1. A 68-year-old male patient (DSA, weight 62 kg, height 161 cm) with several risk factors for coronary artery disease (familiarity, hypertension, dyslipidemia, cigarette smoking and type II diabetes mellitus) and with a history including a previous anterior myocardial infarction, was admitted to our coronary care unit with acute inferior myocardial infarction and treated within 2 hours with intravenous rt-PA. Echocardiography showed a depressed global left ventricular function (ejection fraction 35%), akinesia of the mid anteroseptal wall and of the mid inferior wall and dyskinesia of the apex. Non-invasive coronary Doppler imaging, performed 4 hours after thrombolysis, showed a patent PD and perforating branches in the mid inferior wall. Intravenous adenosine showed a non-significant increase in PFV in the PD (CFR 1.1, Fig. 2). The total duration of the test was 12 min. Coronary angiography revealed left coronary dominance, proximal LAD occlusion with recanalization of the mid and apical tracts by means of collateral vessels and 90% stenosis in the middle tract of the circumflex coronary artery which gave rise to the PD and a large obtuse marginal branch. The right coronary artery was small and occluded in its proximal tract. Coronary surgery was successfully performed. At 3 months of follow-up, the mid inferior segment improved from akinetic to normal, and the CFR in the PD improved to 2.6.

Case 2. A 70-year-old man (BA, weight 74 kg, height 170 cm) with hypertension, dyslipidemia and familiarity for coronary artery disease and with a history of stroke and left carotid thromboendoarterectomy was admitted to our coronary care unit with constrictive chest pain and dyspnea resistant to sublingual nitroglycerin. ECG showed complete left bundle branch block. The serum levels of creatine phosphokinase and MB fraction were 1354 IU and 72 IU, respectively. Echocardiography showed a mildly dilated left ventricle, inferior wall akinesia and anteroapical hypokinesia. There was an inappropriate diastolic flow acceleration in the proximal PD at rest (53 cm/s) and a blunted CFR (1.3) in the mid-PD during adenosine infusion. The CFR was also severely impaired in the LAD (basal PFV 29 cm/s, adenosine 35 cm/s, CFR 1.2). The duration of the test was 20 min. Coronary angiography

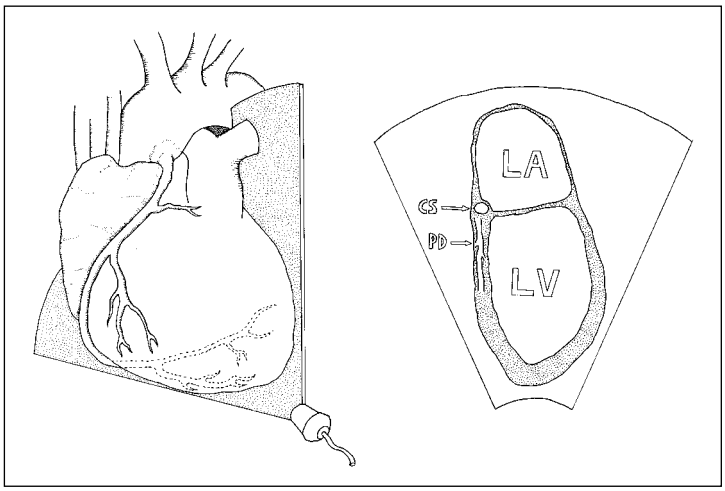

Figure 1. *Schematic depiction of the relation between the transducer and the posterior descending coronary artery (PD) in the apical 2-chamber projection* (left panel) *and corresponding echocardiographic view* (right panel). *CS = coronary sinus; LA = left atrium; LV = left ventricle.*

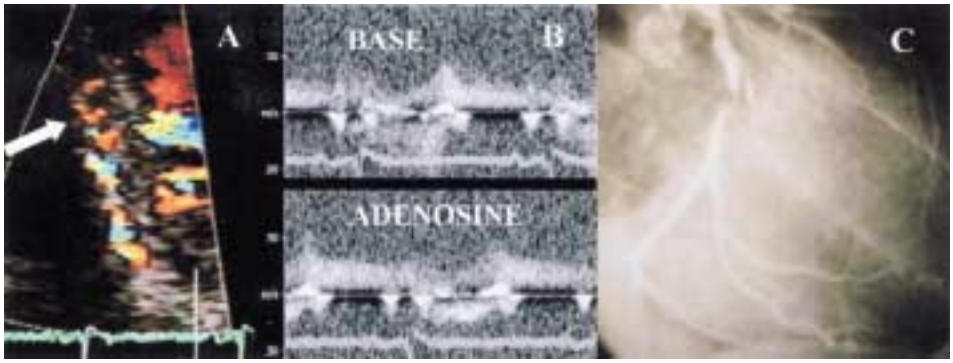

Figure 2. *Case 1 with acute inferior myocardial infarction treated by intravenous thrombolysis.* A: *transthoracic color Doppler echocardiography 4 hours after thrombolysis shows a patent posterior descending coronary artery with three perforating branches* (arrow) *perfusing the mid inferior wall.* B: *venous adenosine infusion shows blunted coronary flow reserve, suggesting a severe obstruction of the feeding artery.* C: *coronary angiography shows 90% stenosis of a dominant circumflex coronary artery.*

showed 30% stenosis of the left main coronary artery, 70% stenosis of the middle tract of the LAD, and 80% stenosis of the circumflex coronary artery. The right coronary artery presented with an 80% calcific stenosis and a 60% stenosis of its ostium and distal tracts respectively. The patient underwent triple coronary artery bypass surgery.

Case 3. A 72-year-old male patient (PP, weight 63 kg, height 158 cm) with a myocardial infarction of the lateral wall underwent in 1982 coronary surgery with inverted saphenous veins placed over the LAD, first obtuse marginal, and dominant PD. In 1997 he experienced unstable angina. ECG revealed resting T wave inversion in the anterior leads. Emergency coronary angiography showed occlusion of all grafts, subocclusion of the LAD, occlusion of the first obtuse marginal branch, and non-significant middle right coronary artery stenosis. LAD stenting was successfully performed and symptoms disappeared completely. Six months later, he again experienced unstable angina and ECG revealed abnormalities in the inferior leads. Emergency coronary angiography showed a patent LAD stent and subocclusion of the middle tract of the right coronary artery, successfully treated by multiple (34 mm) stenting. Two months later a new episode of unstable angina due to focal right coronary artery stent subocclusion was successfully treated by balloon dilation. He was asymptomatic until November 2000 when he experienced effort angina. ECG showed T wave inversion in the V_4-V_6, D1 and aVL leads. Echocardiography showed good global left ventricular function, mid lateral wall akinesia and apical hypokinesia. The non-invasive CFR was normal in the LAD (PFV from 13 to 38 cm/s, CFR 3) but blunted in the PD (PFV from 39 to 44 cm/s, CFR 1.1). Coronary angiography showed absence of LAD stenosis and full patency of the right coronary artery stent. However, there was a bifurcation lesion at the crux, with subocclusion of the posterolateral branch and 90% stenosis of the PD. The lesion was treated by stenting of the distal right coronary artery and of the proximal posterolateral branch. The PD was treated by balloon dilation. The results were optimized by the kissing balloon technique. One day after the procedure, non-invasive evaluation revealed that the CFR in the PD was fully reestablished (PFV from 19 to 57 cm/s, CFR 3).

Case 4. A 42-year-old male smoker (FD, weight 64 kg, height 169 cm) with dyslipidemia, hypertension and familiarity for coronary artery disease was admitted with recurrent symptoms and signs of inferior ischemia. Coronary angiography showed two non-significant LAD stenoses and a 95% right coronary artery stenosis that was treated by stenting. One week later, he was readmitted due to effort chest pain radiated to the neck, associated with mild dyspnea and lasting 10-15 min. Resting ECG showed aspecific changes in the inferior leads. The ECG stress test was interrupted owing to frequent ventricular ectopic beats and bigeminism, and at recovery showed ST changes in the DII-DIII-aVF-V_4-V_6 leads. The adenosine test was normal in the PD (PFV from 21 to 56 cm/s, CFR 2.7, Fig. 3) as well as in the LAD (PFV from 23 to 70 cm/s, CFR 3). The duration of the test was 15 min. Myocardial thallium-201 scintigraphy showed a mild posteroinferior perfusion defect. Coronary angiography showed full patency of the right coronary artery stent.

Discussion

While color Doppler imaging of the LAD is becoming an established and validated tool for the assessment of LAD patency and flow reserve, imaging of the PD has never been described before. This report demonstrates that imaging and measurement of flow reserve of the PD is feasible and can be performed by the bedside even in critical patients with acute myocardial infarction. In our preliminary experience, the PD, being more distal from the chest wall than the LAD, can be best imaged using a conventional 3.5 MHz (or alternatively a 5.0 MHz) rather than the dedicated 7 MHz transducer.

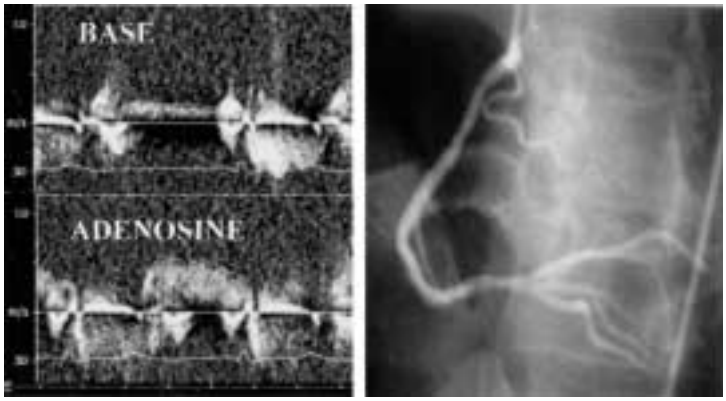

Figure 3. *Case 4 treated with stent implantation in the right coronary artery. Symptoms and signs were suggestive of in-stent stenosis. The non-invasive coronary flow reserve was normal and angiography confirmed absence of luminal stenosis.*

The first case best describes the applications of the technique in acute myocardial infarction. It provided crucial information about three important issues: 1) arterial patency after thrombolysis; 2) detection of a critical stenosis; 3) reperfusion imaging. The bedside detection of arterial patency and of critical stenosis, predicted by a damped flow reserve during adenosine infusion[10], might have significant therapeutic and prognostic implications. The blunted flow reserve prompted coronary angiography that confirmed the presence of a critical stenosis of the circumflex coronary artery. Imaging of perforating branches deserves a special comment. In our experience, perforators are reliable markers of myocardial viability[8]. Compared to the non-standardized, qualitative and subjective assessment provided by myocardial contrast echocardiography[13], the presence of flow with a given velocity in a perforator is an objective, quantitative and continuous variable, reflecting true myocardial perfusion[14] and predicting functional recovery at follow-up[8].

The second case refers to another patient with inferior myocardial infarction but with a slightly reduced reserve, who in fact had a less significant stenosis. The inappropriate flow acceleration at rest (> 50 cm/s) is due to the coronary stenosis and is necessary to maintain a constant flow. It is a potential sign of atherosclerotic disease[4].

The third case describes post-stent assessment in a patient with good CFR. This case confirms our recent observation that CFR is reestablished early after stenting[10].

The fourth case describes the usefulness of non-invasive assessment of CFR after stenting, when symptoms and signs of in-stent stenosis are often non-specific or misleading, and when other non-invasive tests may produce an excess of false positive results. Therefore, CFR may be a useful parameter for the follow-up of patients with stent implantation.

Heterogeneity of coronary flow. There might be some differences between the flow in the right coronary artery and that in the LAD. The right coronary artery also perfuses the right ventricular free wall, which, compared to the left ventricular myocardium, is subject to less intramural stress during systole. Therefore, the right coronary artery has a more pronounced systolic flow compared to the LAD. However, this difference is lost in the PD, which mainly perfuses the left ventricular myocardium. In addition, CFR is measured during diastole, making the systolic component of flow negligible.

Why adenosine? Coronary flow is the product of velocity and the area of the vessel. Adenosine is a pure microvascular dilator having little or no effect on the diameter of the epicardial artery. Therefore, any increase in flow should translate in an increase in velocity. Adenosine is a very versatile drug since its action and side effects regress within 5 s of the end of the infusion. Therefore the test can be repeated in a very short time frame when, as in the case of excessive hyperventilation, the first test has been inconclusive.

Why Doppler? Compared to other emerging techniques for non-invasive coronary imaging such as magnetic resonance imaging or multislice computed tomography, Doppler is an inexpensive, bedside technique which provides functional, rather than anatomical information. In addition, it is less affected by heart rate while magnetic resonance imaging and computed tomography require a heart rate < 60 b/min to avoid motion artifacts. This is achieved by means of pre-treatment with beta-blockers. Unlike contrast echocardiography, that after 30 years[15-18] is still being developed, non-invasive coronary Doppler became a validated technique only 3 years after its introduction in clinical practice[4].

In conclusion, this paper shows for the first time that non-invasive imaging of the PD by non-contrast transthoracic Doppler is feasible and that CFR is measurable even in critical conditions. This new improvement, together with the already established technique of distal LAD imaging, promotes Doppler echocardiography as an emerging tool for the study of coronary flow pathophysiology by the bedside and to guide our daily

practice in acute and chronic coronary syndromes. As for the state-of-the-art technology, the feasibility of PD imaging seems to be around 50%, but in any case it is still far from that of LAD imaging (95%)[10]. More studies regarding this important issue are needed in order to ascertain the potential benefit of contrast agents in improving the evaluation of coronary flow.

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