Transthoracic Doppler Echocardiography for Detection of Stenoses in the Left Coronary Artery by Use of Poststenotic Coronary Flow Profiles: A Comparison with Quantitative Coronary Angiography and Coronary Flow Reserve

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Background: The aim of this study was to determine whether poststenotic diastolic-to-systolic velocity ratio (DSVR) assessed by transthoracic Doppler echocardiography could accurately identify significant stenoses in the left coronary artery.

Methods: A total of 108 patients scheduled for coronary angiography because of chest pain or acute coronary syndromes were studied.

Results: The success rates of peak DSVR (pDSVR) measurements in the distal to mid left anterior descending coronary artery and marginal branches of the left circumflex coronary artery were 85% and 32%, respectively. With peak coronary flow velocity reserve as a reference, pDSVR was significantly higher in arteries with normal coronary flow reserve (peak coronary flow velocity reserve ≥ 2.0) compared with arteries with reduced coronary flow reserve (peak coronary flow velocity reserve < 2.0) (1.86 ± 0.32 vs 1.53 ± 0.31, *P* < .0001). In comparison with quantitative coronary angiography, pDSVR was significantly higher in lesions with diameter stenosis < 50% compared with those with diameter stenosis of 50% to 75% (1.92 ± 0.32 vs 1.53 ± 0.18, *P* < .0001) or diameter stenosis of 76% to 100% (1.43 ± 0.13, *P* < .0001). Receiver operating characteristic curves showed pDSVR < 1.68 to be the optimal cutoff value for identifying both functionally significant stenoses and diameter stenoses ≥ 50%, with sensitivity of 86% and 90%, specificity of 74% and 84%, positive predictive value of 51% and 71%, and negative predictive value of 94% and 95%, respectively.

Conclusions: Transthoracic pDSVR measurements in the distal to mid left anterior descending coronary artery and marginal branches of the left circumflex coronary artery had high accuracy for excluding functionally significant stenoses in the left coronary artery, as well as for identifying angiographic significant stenoses. (J Am Soc Echocardiogr 2013;26:77-85.)

Keyword: Transthoracic Doppler echocardiography

Quantitative coronary angiography (QCA) has traditionally been the gold standard for assessing coronary artery disease, with a significant coronary stenosis generally defined as luminal diameter reduction ≥ 50%. However, it can be difficult to determine on angiography whether a stenosis causes ischemia or not. This distinction is important, because anatomically significant but functionally nonsignificant stenoses have a good prognosis without invasive treatment.[1,2] Functionally nonsignificant stenoses are common in the borderline stenosis group (diameter stenosis, 50%–75%) and may as well be found among high-grade stenoses (diameter stenosis, 76%–100%), with a recent study showing that 65% of lesions with diameter stenosis of 50% to 70% and 20% of lesions with diameter stenosis of 71% to 90% were without functional significance.[3] Other testing options are therefore important in the selection for coronary angiography and to distinguish functionally significant from nonsignificant coronary stenoses,[3-9] with fractional flow reserve as a probable reference for the functional evaluation of a coronary stenosis.[3] Coronary flow velocity reserve (CFVR) assessed using Doppler transthoracic echocardiography (TTE) has recently been shown to be a noninvasive surrogate of fractional flow reserve, especially in the detection of a functionally nonsignificant lesion.[8] Normal coronary

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Abbreviations

CFVR = Coronary flow velocity reserve

Cx = Left circumflex coronary artery

CxMb = Marginal branches of the left circumflex coronary artery

DSVR = Diastolic-to-systolic velocity ratio

LAD = Left anterior descending coronary artery

LM = Left main coronary artery

NPV = Negative predictive value

pCFVR = peak coronary flow velocity reserve

pDSVR = peak diastolic-to-systolic velocity ratio

PDV = Peak diastolic flow velocity

PPV = Positive predictive value

PSV = Peak systolic flow velocity

QCA = Quantitative coronary angiography

RCA = Right coronary artery

ROC = Receiver operating characteristic

TTE = Transthoracic echocardiography

arteries display a predominant diastolic blood flow pattern, which is less marked in the distal right coronary artery (RCA), probably because of lower intramyocardial systolic contraction pressure in the right ventricle.[10] Several studies have shown that in the presence of a significant coronary stenosis, the ratio between the diastolic and systolic coronary blood flow velocities, diastolic-to-systolic velocity ratio (DSVR), is significantly reduced when invasively measured distally to the stenosis.[10-13] This reduction is postulated to be caused by a combined poststenotic decrease of diastolic flow and an increased systolic flow from an intramyocardial systolic contraction pump acting on the intramyocardial capacitance vessels.[14] Modern high-end echocardiographic equipment permits excellent imaging of coronary artery blood flow, allowing measurements of coronary blood flow profiles.[6,7,9,15-22] Recent reports have indicated that findings of reduced DSVR measured by TTE in the distal left anterior descending coronary artery (LAD) may be a simple, noninvasive method for the detection of high-grade coronary stenoses located more proximally in the LAD.[18,20,21] This is demonstrated for patients with or without wall motion abnormalities of the left ventricle,[20] and peak DSVR (pDSVR) values < 1.6 to 1.8 are proposed to represent high-grade LAD stenoses.[18,20,21] However, there is a paucity of studies comparing LAD pDSVR obtained by TTE with various degrees of stenosis in the LAD and the left main coronary artery (LM) as defined by QCA, and pDSVR measurements in marginal branches of the left circumflex coronary artery (CxMb) might be used for evaluating coronary disease in the left circumflex coronary artery (Cx) and LM. Furthermore, the functional significance of pDSVR requires further validation, and this parameter could be useful in the evaluation of borderline coronary stenoses. Because the normal pDSVR in the distal RCA is low and probably close to pathologic values, the potential utility of distal pDSVR measurements seems primarily to be in the evaluation of possible upstream stenoses in the LAD and Cx.

The aim of this study was to assess the feasibility and accuracy of pDSVR measurements on TTE as a simple method for diagnosing significant stenoses in the LM, LAD, and Cx, using QCA and CFVR measured by TTE as the anatomic and functional references, respectively.

METHODS

Study Population

Patients were included in the study if they fulfilled the following criteria: (1) already scheduled for coronary angiography because of documented or suspected stable or unstable coronary disease, (2) age > 18 years, and (3) met no exclusion criteria. The exclusion criteria were (1) previous aortocoronary bypass surgery, (2) presumed insufficient acoustic windows because of severe emphysema or severe overweight, (3) significant valvular disease, (4) atrial fibrillation, and (5) administrative reasons.

The study protocol was approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Data Inspectorate. All participants gave written informed consent. This study is registered at ClinicalTrials.gov under identifier NTC00281346.

A total of 108 patients were included in the study, and this patient cohort has been previously presented.[7] Clinical characteristics of the patients are presented in Table 1. All patients took their medications on the day of the echocardiographic study. Standard 12-lead electrocardiograms were recorded in all patients.

Transthoracic Coronary Flow Measurements

Patients were examined using an Acuson Sequoia C512 (Siemens Medical Solutions USA, Inc., Mountain View, CA) ultrasound system connected to standard 4V1C and 7V3C transthoracic transducers. Contrast agent was not used. TTE with CFVR measurements was not performed earlier than the day after hospital admission and only after the patients were clinically stable. The coronary arteries were investigated using color Doppler mapping with the data postprocessing mix function, which makes the colors transparent, as described previously.[16] The velocity scale of color Doppler was set to 0.24 m/sec but was actively changed to provide optimal images. With the patient in the left lateral decubitus position, the course of the mid and distal LAD could be seen from modified parasternal short-axis and long-axis views or from modified apical two-chamber and three-chamber views, focusing on the anterior interventricular sulcus (Figure 1A1). From modified left parasternal short-axis and long-axis views, the Cx could be imaged leaving the LM and further coursing caudally in the atrioventricular sulcus to the inferior margin of the sulcus.[16] However, measurements of flow velocities in the main trunk of the Cx are difficult because of cyclic cardiac motion. Marginal branches of the Cx leave the artery at various levels, and from modified apical four-chamber views focusing on different levels of the lateral wall of the left ventricle, marginal branches could be visualized coursing in the distal direction on the epicardial surface toward the transducer (Figure 1B1). Measurements of coronary flow velocities in marginal branches are less influenced by cardiac cyclic motion. Whenever possible, the most inferior marginal branch viewed was used for measurements. Echocardiographic evaluation of regional left ventricular contractility was not part of the study protocol, but regional contractility was assessed in 30 of 35 patients (86%) with and in 32 of 73 patients (44%) without unstable coronary disease.

The coronary flow velocity waveform appears as a complex of a small wave in systole and a large trapezoid wave in diastole (Figures 1A2 and 1B2). Blood flow velocities in the distal LAD and CxMb were measured using pulsed-wave Doppler at frequencies of 1.75 to 3.5 MHz in a sample volume of 1.5 to 5 mm, with the sample volume positioned on the laminar color flow Doppler signal. The sample volume was positioned distally to any visualized turbulent color