

A Novel Technique to Detect Total Occlusion in the Right Coronary Artery Using Retrograde Flow by Transthoracic Doppler Echocardiography

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Background: We hypothesized that detection of reverse flow in the distal right coronary artery (d-RCA) and the inferior septal branches (ISB) by transthoracic Doppler echocardiography (TTDE) would be useful for noninvasive diagnosis of the occluded right coronary artery (RCA).

Methods: Coronary angiography and TTDE were performed on 129 patients. Antegrade flows in the d-RCA and the ISB were defined as directions from the base to the apex in the posterior sulcus and from anterior to inferior in the inferior septum, respec-

tively. Retrograde flow was defined as an inverse direction.

Results: Retrograde flow was obtained by TTDE in 14 patients (d-RCA:11, ISB:3) of 18 patients with occluded RCA. The sensitivity and the specificity for identification of occluded RCA were 100% and 97.8%, respectively.

Conclusion: Detection of reverse flow in the d-RCA and the ISB using TTDE is a useful method for the noninvasive diagnosis of occluded RCA. (J Am Soc Echocardiogr 2005;18:704–709.)

Recent studies have demonstrated the significance of early diagnosis of chronic total occlusion (CTO) in the treatment of ischemic heart disease.^{1–10} And these studies showed that the prognosis with CTO was improved by surgical treatment or percutaneous coronary intervention (PCI). However, CTO can be diagnosed only by coronary angiography, which is invasive and available only in the determinate laboratory, such as an angiography room.

Transthoracic Doppler echocardiography (TTDE) is a noninvasive, inexpensive, and widely available tool for clinical practice. Recently, TTDE has been used for noninvasive detection of coronary occlusion in the left anterior descending coronary artery (LAD),^{11,12} in addition to its potential in diagnosing coronary narrowing in the LAD.^{13–21} TTDE has also been used to evaluate coronary flow in the right coronary artery (RCA).^{22–26} However, little published data exist on the detection of total occlusion in the RCA by TTDE.

Most collateral flow distal to the occluded region of the RCA comes through the epicardial pathway, which grows from the peripheral vessels of the nonoccluded epicardial coronary artery, or the intramyocardial pathway, which runs mainly in the septum of the left ventricle.²⁷ We have hypothesized that when the collateral flow comes through the epicardial pathway, the reverse flow can be detected in the distal RCA (d-RCA), and when the collateral flow comes through the intramyocardial pathway, the reverse flow can be detected in the septal branches. Thus, the purpose of the present study was to evaluate TTDE's ability to detect CTO of the RCA by detecting these 2 collateral pathways.

PATIENTS AND METHODS

Study Patients

We prospectively examined 129 consecutive patients (99 male; mean age, 66 ± 9 years) in whom coronary angiography was planned for the evaluation of coronary artery disease (CAD). Patients with acute myocardial infarction, atrial fibrillation, and previous coronary artery bypass graft surgery were not enrolled in this study. The underlying diseases were old myocardial infarction in 29 patients, stable angina in 75 patients, and unstable angina in 25 patients. A coronary occlusion was defined as an interruption of the contrast medium without antegrade filling of

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the distal part of the coronary artery. The study patients were classified according to coronary angiography findings into group A (with total occlusion at the proximal or mid-portion RCA) and group B (without total occlusion). All patients gave informed consent to the protocol, which was approved by the Committee for the Protection of Human Subjects in Research at Osaka City University Medical School.

Collateral Vessel Classification

We used the following classification of collateral vessels proposed by Levin²⁷: type A, from the LAD through the septal branches; type B, from the distal left circumflex artery (LCX) to the distal RCA; type C, from the LCX to the distal RCA through the obtuse marginal branch; type D, from the proximal RCA to the distal RCA; type E, Kugel's collateral; type F, from the LAD through the apex of the heart; type G, from the LCX to the distal RCA through the atrioventricular branch; type H, from the proximal to distal RCA between the low acute marginal branch and the posterior descending artery (PDA); type I, from the proximal to distal RCA between the right atrial branch and the posterior lateral artery (PLA); and type J, from the LAD through the right ventricular branch of the LAD to the acute marginal branch of the RCA.

Recording of RCA and Septal Branch Flow by TTDE

All TTDE examinations were performed before coronary angiography by an investigator who had no knowledge of the other patient data. A commercially available digital ultrasound system (Sequoia 512; Acuson, Mountain View, Calif) with a broadband transducer (3V2C) was used for coronary flow recordings. B-mode, color Doppler, and spectral Doppler imaging were recorded in fundamental imaging with a Doppler frequency of 2.5 MHz. For color Doppler flow mapping, the velocity range was set at ± 12 to ± 25 cm/s. The color gain was adjusted to provide optimal imaging.

To record coronary flow velocity waveform in the d-RCA, the acoustic window was around the mid-clavicular line in the fourth and the fifth intercostal spaces in the left lateral decubitus position. The imaging plane was a modified apical 2-chamber view including the posterior interventricular sulcus, which was searched carefully by rotating the transducer in a counterclockwise manner from the apical 4-chamber view to the apical 2-chamber view (Figure 1). The ultrasound beam was angled posteriorly to obtain the best long axis of the coronary flow signals. The blood flow in the PDA was identified as the linear color signal persisting during the diastolic phase (Figure 1). The coronary artery can be distinguished from the coronary vein using their flow velocity waveform recorded by the pulsed wave Doppler method. The coronary artery wave form appears as a complex of a small wave in systole and a large trapezoidal wave in diastole.¹⁶ In contrast, the coronary vein wave form appears as a prominent systolic flow wave.^{28,29} The direction of the Doppler beam was carefully adjusted to minimize the

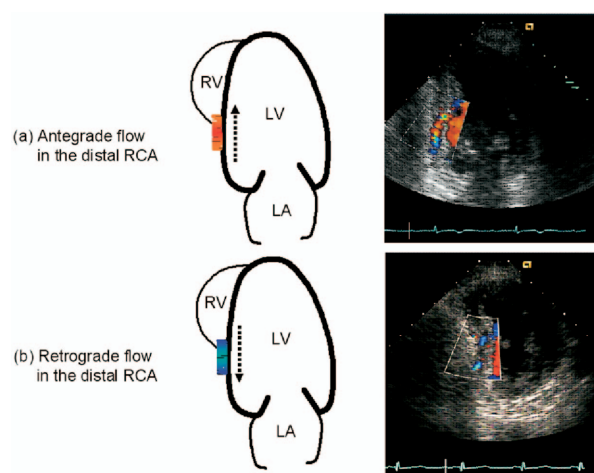


Figure 1 Examples of Doppler color flow mapping of antegrade (A) and retrograde (B) coronary flow in the d-RCA.

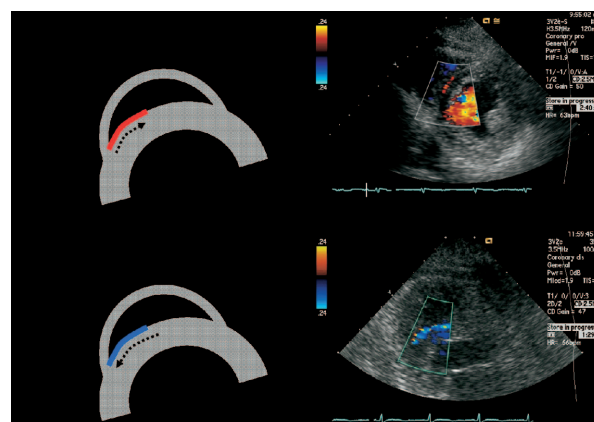


Figure 2 Examples of Doppler color flow mapping of antegrade (A) and retrograde (B) coronary flow in the inferior septal branch.

angle between the Doppler beam and the long axis of the PDA flow imaging, and to ensure that a sample volume was located on the color signal for as much of the cardiac cycle as possible. To distinguish the RCA flow from the distal LAD and LCX flow, the color signal runs from the middle of the posterior sulcus were carefully confirmed.

To record the coronary flow velocity waveform in the inferior septal branches, the imaging plane was located at the parasternal short-axis view. The flow signals on the inferior septal branches were searched as the linear color Doppler signals persisting during the diastolic phase on the inferior interventricular septum (Figure 2). With a sample volume positioned on the color Doppler signals, Doppler spectral tracing of the flow velocity on PDA and the inferior septal branches were recorded by fast Fourier transformation analysis. The direction of the flow was determined by flow velocity recordings. Retrograde d-RCA flow was defined by a Doppler waveform below zero,

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