Improving Feasibility of Posterior Descending Coronary Artery Flow Recording by Transthoracic Doppler Echocardiography

A. Auriti¹, C. Cianfrocca¹, C. Pristipino², S. Greco¹, M. Galeazzi¹, V. Guido¹ and M. Santini¹

¹Department of Cardiovascular Disease, Echo-Lab, S. Filippo Neri Hospital, Rome, Italy; and
²Department of Cardiovascular Disease, Cath-Lab, S. Filippo Neri Hospital, Rome, Italy

Aims: Recording coronary arteries’ flow by transthoracic Doppler echocardiography (TTDE) is a new task. Despite several studies concerning the left anterior descending artery (LAD) exist, the same for posterior descending coronary artery (PD) do not. Reported feasibility is not more than 76%. The aim of the study was to try to improve feasibility by using an additional two-dimensional view as a guide.

Methods and Results: PD flow recording was performed in 35 consecutive unselected patients under the guidance of the usual two-dimensional modified view [a two-chamber view (2-C)], and with a new four-chamber modified view (4-C). A semi-quantitative growing-quality score (from 0 to 3 points) to the trace was given. Contrast enhancement was used if PD was not visualized without it. The overall feasibility was 80%. A good or very good velocity signal (TTDE score ≥2) was observed in 48% of patients without contrast enhancement. Time for first visualization of PD was short and significantly lower in 2-C than in 4-C (66 ± 39 vs 90 ± 70 s, respectively, \( P < 0.05 \)).

Conclusions: TTDE recording of PD flow gained better feasibility being guided by two views. Maximal time for first visualization of PD was less than 3 min.

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Key Words: coronary flow; echocardiography; Doppler.

Introduction

The echocardiographic imaging of coronary arterial flow by means of transthoracic Doppler echocardiography (TTDE) is a new and promising diagnostic tool aimed at obtaining valuable information about coronary circulation and coronary reserve. Other techniques can give such information, but TTDE has the unique advantage of being performed noninvasively at bedside. The initial attempts in recording the coronary flow and reserve were performed by trans-esophageal echocardiography²⁴. However, no information about the presence of mid and distal coronary stenosis can be harvested with this latter semi-invasive approach. On the contrary, by TTDE, it became possible to investigate the flow in mid or distal segments of coronary arteries and to have information about the presence of significant stenoses in more proximal portions of the vessels. The topic is of great clinical relevance for the evaluation of the conditions of the coronary vessels and of the microcirculation after reperfusion for myocardial infarction without the need of invasive procedures.

Almost the totality of the recently published papers concerning this new application relates to the imaging of the left anterior descending coronary artery (LAD) flow, with a reported feasibility rate above 90%, regardless the use of contrast enhancement⁵–¹². The possibility to record the posterior descending coronary artery (PD) flow by means of TTDE is also described in few selected patients¹³–¹⁷ and, to our knowledge, in only one recent report concerning a systematic approach on a large series of unselected patients¹⁸.
However, the reported feasibility rate (ranging from 50 to 76%) is still disappointing and is a burden on the clinical application of the technique. Nonetheless, this low feasibility might be related to the current use of only a single echocardiographic two-dimensional view adopted [a modified two-chamber view (2-C)] for guiding TTDE recording. After having assessed that PD flow can also be recorded by using a modified four-chamber view (4-C) as a guide, the aim of the present study was to test whether feasibility could be improved by using this additional echocardiographic view also as a guide, considering the difficulties in recording the PD flow due to the distance of the vessel from the probe and to its anatomical position on the inferior surface of the heart.

**Methods**

**Patients Population**

Thirty-five consecutive in-patients undergoing standard or stress exam in the echo-lab were enrolled (28 men, age 40–86 years). Echocardiography was scheduled for the evaluation of cardiac status, as requested by the caring physician. The only inclusion criterion was the availability of a recent coronary arteriography (≤3 months or scheduled). No ‘technically difficult’ patient was excluded. The echo operator was blinded to the results of the coronary arteriography. Concerning the underlying cardiac disease, 24 patients had coronary artery disease, four patients had dilated cardiomyopathy, two patients had valvular aortic stenosis, one had hypertrophic cardiomyopathy, one had corrected Tetralogy of Fallot, one had syndrome X, one had atrial myxoma, and one with atypical chest pain resulting to be normal.

Patients were informed about the aim of prolongating the exam and gave informed consent for the eventual use of ultrasonographic contrast.

**Doppler Recording**

Echocardiography was performed with the standard technique by a single operator trained in recording coronary artery and coronary graft flows by TTDE (A.A.) and with the patient lying as usually on the left side. A commercially available echocardiographic system was used (Sequoia-Imagegate C256, Acuson-Siemens, Mountain View, CA) connected to a standard 3.5 MHz 3V2c harmonic probe. PD flow recording was performed using two different two-dimensional views as a guide: a usual 2-C obtained from the standard apical position by twisting the probe to intercept the inferior interventricular groove as previously described [14–16], and a 4-C obtained from the standard apical position shifting the probe superiorly towards the fourth intercostal space and twisting and tilting the probe obtaining the beam sectioning of the inferior wall of the ventricles (Fig. 1). This latter view, along with a careful tilting of the probe on the horizontal and axial planes, allows the visualization of the arteries and veins running on the inferior surface of the heart (Fig. 2). To obtain a TTDE trace, a careful search of the best angulation of the probe must be carried out considering that the diastolic signal of the coronary artery is reduced to few pixels sometimes. However, along with a proper magnification of the region of interest, the two-dimensional color-Doppler mapping and the TTDE typical velocity trace of coronary artery flow can be recorded.

![Figure 1. Planes of section of 2-C and 4-C views for PD flow recording. 2-C, modified two-chamber view; 4-C, modified four-chamber view.](image1)

![Figure 2. Color Doppler of PD flow. 4-C view. The view crosses the inferior cardiac wall at the epicardial level and crosses the first portion of PD (forward coronary diastolic flow coded in red). PD, posterior descending coronary artery; 4-C, modified four-chamber view.](image2)
Investigation of PD was begun with 2-C (Fig. 3) or 4-C views alternatively. Doppler interrogation was performed, depending on circumstances, either using conventional color mapping set at low Nyquist limit (15–30 cm/s) with adjusted filtration as necessary, or by the implemented dedicated nondirectional color Doppler software for coronary flow recording (‘coronary’ application) which is set at low velocities (24 cm/s) and adjusted filtering for default (Fig. 4). In order to analyze practical feasibility of PD flow recording, attempts were stopped if a Doppler trace was not obtained after 5 min. If a PD flow trace was obtained in at least one view, contrast enhancement was not employed. On the contrary, if PD was not visualized with the described method, i.v. ‘Levovist’ (Shering, Berlin, Germany) 300 mg/ml solution was given at the infusion rate of 0.5–1 ml/min [6].

Quality of TTDE velocity signal was quantified by a four-level semi-quantitative growing score (from 0 to 3 points) in use in our lab, which is as follows: score 0 = signal not recordable (in either 2-C or 4-C) even with contrast enhancement; score 1 = low intensity but recordable signal, hardly reproducible, with poor delineation of the diastolic contour (Fig. 5); score 2 = good intensity signal, easily reproducible, with good delineation of the only diastolic contour (Fig. 6); score 3 = very sharp and intense signal, highly reproducible, with good delineation of diastolic and systolic contours and almost resembling (Shering, Berlin, Germany) 300 mg/ml solution was given at the infusion rate of 0.5–1 ml/min [6].

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intracoronary signal (Figs. 4, 7 and 8). Score was evaluated separately both in 2-C and in 4-C views. Time for first color-Doppler visualization of PD and mean TTDE velocities were measured in each patient and for each view. Angle correction was not used for recording.

**Coronary Arteriography**

Angiography was performed following the usual standards. In the case TTDE had been performed previously, the operator was blinded to its results. TIMI flow grade and semi-quantitative visual severity of stenosis in PD-related coronary artery were evaluated.

**Statistical Analysis**

Data are expressed as mean ± SD. Student t-test was used for comparison between continuous variables. Comparison among proportions was performed by χ² test and by contingency coefficient C. Correlation between qualitative and quantitative variables was calculated by correlation ratio test (Eta coefficient) and by Pearson coefficient. A level of significativity ≤0.05 was accepted. Statistical package SPSS/PC+ was used for computing.

**Results**

In our study, overall feasibility in recording PD flow by TTDE was 80% (28/35 patients). PD was recorded in a similar proportion of patients in 2-C and in 4-C (71 and 66%, respectively; P = NS). In 23% of cases (8/35 patients), the coronary flow could be recorded in only one view, most with a TTDE score 1. A good or very good signal (TTDE score ≥2) in at least one view could be obtained in 48% of patients, a percentage achieved without contrast enhancement. Contrast enhancement did not improve any TTDE score 0 in either 2-C or in 4-C. 2-C and 4-C views did not show any statistically significant differences in the distribution of TTDE score yielded (Table 1) or in mean TTDE velocity recorded (0.40 ± 0.16 vs 0.38 ± 0.13 m/s, respectively).

Mean time for first visualization of PD, on the contrary, resulted slightly but significantly less in 2-C than in 4-C (66 ± 39 vs 90 ± 70 s, respectively; P < 0.05).

**TIMI Flow Grade in PD and TTDE**

Ninety-four percent of patients had angiographic TIMI 3 flow grade in PD, 30% of them had TTDE score 3 and 21% had TTDE score 2 in PD, in one

**Table 1. Distribution of TTDE scores in 2-C and 4-C in 35 patients.**

<table>
<thead>
<tr>
<th>TTDE score</th>
<th>2-C (n)</th>
<th>4-C (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10*</td>
<td>12**</td>
</tr>
<tr>
<td>1</td>
<td>10*</td>
<td>8**</td>
</tr>
<tr>
<td>2</td>
<td>9*</td>
<td>7**</td>
</tr>
<tr>
<td>3</td>
<td>6*</td>
<td>8**</td>
</tr>
</tbody>
</table>

n = number of patients; *P = NS; **P = NS. TTDE, transthoracic Doppler echocardiography; PD, posterior descending coronary artery; 2-C, modified two-chamber view; 4-C, modified four-chamber view.
view at least. One patient had TIMI 2 flow grade in PD with a TTDE score 3 in both 2-C and 4-C. One patient had TIMI 1 flow grade in PD with a TTDE score 1 in 4-C and TTDE score 0 in 2-C. No patient had TIMI flow grade 0 in PD. Concerning patients with TTDE score 0 in both 2-C and 4-C, all of them had TIMI 3 flow in PD. No correlation was found in our series either between TIMI flow grade and TTDE score or between TIMI flow grade and TTDE velocity in both 2-C and 4-C.

**Stenosis Severity of PD-Related Artery and TTDE**

Right dominance of coronary circulation was found in 91% of cases.

Twenty-three percent of patients had ≥70% diameter narrowing in PD-related artery. No correlation was found between semi-quantitative angiographic severity of stenosis and TTDE score in both 2-C and 4-C. One patient had occlusion of right coronary artery with TIMI flow 1 in PD due to collaterals from LAD, and had TTDE score 0 in 2-C and score 1 in 4-C. Another patient, with 95% diameter narrowing in PD and TIMI flow grade 2, had TTDE score 3 in both 2-C and 4-C. None of the seven patients with both 2-C and 4-C TTDE score 0 had angiographically significant stenoses.

No correlation was found between severity of stenosis of PD-related coronary artery and TTDE velocity.

**Discussion**

**Feasibility**

Our study reports, to our knowledge, the highest feasibility (80%) of TTDE for PD flow imaging in a series of unselected consecutive patients. A good or very good quality of the signal (TTDE score ≥2) was obtainable in 48% of patients without the use of contrast enhancement. Data from other authors report a feasibility in PD recording ranging from 50 to 76% by using a single only view for guidance (2-C) and without contrast enhancement. Our results in each single view seem to parallel such results (71% in 2-C and 66% in 4-C). However, in our study, the combined use of two different two-dimensional views for guidance improved the feasibility in recording PD flow to 80%, thus almost to the levels reported for LAD. Therefore, our results strongly suggest that the two views should be used in a combined fashion in PD flow recording, especially when considering that PD flow, in our study, could be recorded in 23% of patients in one view only.

Some authors report a higher feasibility of LAD flow recording with the use of contrast enhancement but others reported similar feasibility even without contrast. In our study, we did not observe improvements in feasibility by using contrast enhancement in patients with TTDE score 0. A possible explanation for this failure could be that only a low frequency probe may be used for recording PD flow (due to the distance from the probe to the vessel to be recorded), while LAD flow, lying on a closer field, is usually recorded by high frequency probes.

In patients with TTDE score 1, a Doppler coronary signal, although of poor quality, could be recorded. In such patients, we did not use contrast enhancement because it was beyond the aims of our study. Therefore, the efficacy of contrast enhancement in recording PD flow by improving TTDE score 1, thus facilitating the use of adenosine or dipyridamole for coronary flow reserve assessment, cannot be excluded and needs further investigations.

In former studies, 2-C was reported to allow recording of perforating branches of PD. Recording perforating branches of PD seems to have a special interest after reperfusion in order to foresee recovery of contractile function. As a fact, a preserved presence of perforating branches seems to predict the presence of viable myocardium after such interventions. In 4-C it is not possible to visualize perforating branches in a long axis, however, it is possible to check the direction of the main artery and to differentiate the posterolateral branches of right coronary artery or left circumflex coronary artery from PD. Moreover, marginal branches of the left circumflex coronary artery and even cardiac veins can be viewed too, in 4-C.

Concerning the practical feasibility of recording basal coronary artery flow by TTDE, the time for first visualization of PD by color Doppler mapping was rather short in the present study and it was slightly less in 2-C than in 4-C views. However, in all cases, it was less than 3 min indicating that coronary flow recording is not much time-consuming, provided an accomplished learning curve. Different task, however, is the study of coronary flow reserve which involves additional preparation of the patient and additional costs.

**TTDE Velocities and Coronary Correlations**

TTDE velocities did not differ between the two views in the present study. However, talking about velocities, because the main target of a coronary flow recording is not to demonstrate a flow but, rather, to gain the possibility to assess coronary flow reserve (calculated as a ratio), the importance of the absolute value of the velocity itself becomes negligible. Besides, the absence of angle correction use can partially explain the lack of correlation between severity of coronary stenosis and TTDE velocity, even though 77% of our patients did not show angiographically significant stenoses in the PD-related coronary artery,
conditioning a scarce possibility to find statistical correlations.

**Scoring TTDE Coronary Flow Recording**

Intensity of the TTDE signal and TTDE score system are of some interest. At present, intensity of TTDE signal can be graded only semi-quantitatively. Intensity of Doppler signal is related, in the absence of contrast, to the quantity of red cells flowing in the time-unit in the vessel and crossing the sample volume. Therefore, the higher the flow, the more intense ought to be the signal in terms of gray scale (which could be graded in decibels by a software). However, in our study, we did not find a correlation between TTDE score and TIMI flow grade or with severity of coronary narrowing which is expected to be related to the intensity of the flow. One reason could be that the pressure manually deployed during coronary injection for angiography is high enough to force the flow through the coronary stenosis, while by TTDE, only ‘really natural’ flow is recorded. Nonetheless, attenuation due to surrounding tissues and air plays a major role (see Fig. 4 in which intensity of the signal changes with respiration and movements of the chest). Forthcoming improvements in technology might clarify these issues.

Unlike other authors, who already used a ‘3-point’ TTDE score (starting from score 1 in case of no recording) we used a ‘4-point’ scoring system (starting from 0 in case of no recording) because it is less sensitive to misunderstandings and allows a better grading, considering the variability of the trace usually observed, and moreover it can match better with other scorings used in cardiology (e.g. TIMI flow grade).

**Limits**

Although this study was not pointed on calculating the coronary flow reserve but on ‘how-to’ improve recording of PD flow by TTDE, the latter is a very new task and comprehensive works are lacking. Pointing out a method is crucial for next developments and for achieving valid clinical results afterward, when calculating the coronary flow reserve.

Grading of the coronary stenosis was made only in a semi-quantitative way in the present study. However, while in studies on coronary flow reserve the quantitative assessment of coronary stenosis is crucial, in studies on the basal flow its importance is expected to be less.

At the time when the study was performed, the only contrast available was ‘Leovist’, which, however, proved to be effective in enhancing feasibility of LAD flow recordings. Although this contrast agent did not improve PD flow score 0 in our work, it cannot be excluded since it could be useful in improving score 1 traces. Moreover, by using a next generation contrast, feasibility might be further improved.

Clinical application of TTDE is related also to the learning curve necessary to gain expertise in order to reduce the time of the exam and to achieve high feasibility. In coronary artery or graft flow detection we experienced that a learning curve of about 100 exams might suffice. PD is a little bit more difficult to record and needs additional effort when using two views for guiding. However, the little time interval required in our study for the first visualization of the color mapping signal of the vessel indicates that the method is clinically applicable.

**Conclusions**

Feasibility of PD flow recording by TTDE was improved by using two complementary two-dimensional views for guidance. Together with the possibility of recording LAD flow, it means that the largest part of the coronary circulation can be studied in a non-invasive way. Further investigations are needed to ascertain whether the use of contrast might facilitate recording PD flow improving TTDE scoring.

**Acknowledgement**

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**References**


