Diagnostics of Main Coronary Artery Stenoses and Occlusions: Multiplane Transoesophageal Doppler Echocardiographic Assessment

A. V. Vrublevsky*, A. A. Boshchenko and R. S. Karpov

Cardiology Research Institute, Tomsk, Russian Academy of Medical Sciences, Siberian Branch, Russia

Aim and Methods: The possibility of using multiplane transoesophageal echocardiography (TEE) and quantitative coronary angiography (QCA) in the diagnostics of stenotic atherosclerosis of the main coronary arteries in a comparative aspect were studied in 94 patients with coronary artery disease (men, mean age 52 ± 7 years). Coronary arteries stenoses were calculated with Doppler echocardiography using a modified continuity equation:

\[ \text{stenosis} \, (\%) = 100 \times (1 - \text{prestenotic VTI} / \text{stenotic VTI}) \]

where prestenotic VTI, (cm)=diastolic velocity integral in the prestenotic zone, and stenotic VTI, (cm)=in the trans-stenotic zone.

Results: High sensitivity and specificity of TEE in the diagnostics of stenotic and occlusive atherosclerosis of coronary arteries were revealed. They measured 88% and 98% for the left main coronary artery (LMCA), 97% and 67% for the left descending artery (LDA), 95% and 92% for the circumflex artery (CX), 83% and 97% for the right coronary artery (RCA), respectively. A high correlation was found between the results of TEE and QCA in the diagnostics of coronary stenoses which were made for the LMCA (r=0.82, P<0.001), LDA (r=0.84, P<0.001), CX (r=0.85, P<0.001), and RCA (r=0.84, P<0.001). We developed Doppler echocardiography criteria for haemodynamically significant stenoses of coronary arteries (>50%) according to a peak diastolic velocity of the coronary blood flow, calculated as 1-4 m.s\(^{-1}\) for the LMCA, 0.9 m.s\(^{-1}\) for the LDA, and 1.1 m.s\(^{-1}\) for the CX. We determined Doppler echocardiography criteria of coronary arteries occlusions such as a ‘break’ of colour mapping, absence of Doppler spectrum and retrograde blood flow during late diastole.

Conclusion: Transoesophageal Doppler evaluation of coronary blood flow with application of a modified continuity equation is an accurate, non-invasive method of coronary arteries stenoses diagnostics.

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Key Words: transoesophageal Doppler echocardiography; coronary blood flow; coronary artery disease.

Introduction

At present, roentgenocontrast quantitative coronary angiography (QCA) remains the ‘gold standard’ in the diagnostics of coronary atherosclerosis. However, the demand for non-invasive visualization of the coronary vascular tree is great in clinical practice, as QCA can not be performed in all patients. Over the last decade progress in the sphere of non-invasive ultrasound technologies has allowed them to compete with the direct methods of diagnostics of coronary vascular tree pathology. Thus, multiplane transoesophageal echocardiography (TEE) permits us, on the one hand, to overcome the generally known limitations of a transthoracic approach, and, on the other hand, significantly widens the diagnostic range of the method, providing a good visualization of the proximal and in some cases, mid segments of coronary arteries by recording the Doppler spectrum of the coronary blood flow.

During the last 5 years the reports on Doppler echocardiography evaluation of the coronary blood flow with a transoesophageal approach have been...
n numerous\textsuperscript{[1–8]}. Some authors have focused on the methodical aspects of transoesophageal ultrasound location of coronary arteries and the parameters of laminar coronary blood flow\textsuperscript{[1,6]}, while others, taking into account the ultrasound physics, studied the Doppler echocardiography criteria of coronary blood flow turbulence in haemodynamically significant coronary stenoses\textsuperscript{[2,4–6]}. Certain researchers attempted Doppler echocardiography assessment of stenosis severity in the left main coronary artery and the proximal third of the left descending artery with a transoesophageal approach\textsuperscript{[5,6]}. Summarizing the data obtained by a number of authors, it should be noted that in current literature there is no well-developed technology and criteria of transoesophageal Doppler echocardiography diagnostics of coronary stenoses.

The aim of our study was a comparative analysis of diagnostic possibilities of multiplane TEE and QCA in revealing main coronary artery atherosclerosis and the development of Doppler echocardiography criteria for stenoses.

**Methods**

**Study Group**

Ninety-four patients (men: mean age 52 ± 7 years) with stable angina and angiographically documented coronary artery disease were selected to participate in this study. Exclusion criteria were as follows: acute myocardial infarction, unstable angina, atrial fibrillation, more than first-degree atrioventricular block, heart failure of III-IV NYHA functional classes, cardiomyopathy, bronchospasm. Transoesophageal measurements were performed blinded to angiographic stenosis localization and severity. The interval between TEE and QCA did not exceed 1 month. All drugs with a cardiovascular effect were withdrawn 1 or 2 days before the echocardiographic study. Written informed consent for TEE examination was obtained in all patients.

**Quantitative Coronary Angiography**

QCA was performed via the femoral approach according to Judkins’ standard method (1967) with the use of Cardoskop U angiographic complex (Siemens, Germany). Coronary injections were performed using multiple views, and images were recorded on Kodak CFE 746 film at a framing rate of 25 frames.m.s\textsuperscript{−1}. Film images were converted into digital format using a video camera and a video-digital converter interfaced with a computer-assisted automated edge-detection system (DIGITRON 3 VAC, Siemens, Germany). Two to three end-diastolic images were analysed to obtain the percentage luminal area reduction of the stenosis, and the highest stenosis, grade was included for further analysis.

**Transoesophageal Echocardiography**

Assessment of coronary arteries with a transoesophageal approach was performed using ultrasound diagnostic systems — Ultramark 9 HDI (ATL, USA), multiplane probe 7-4 MHz and Aloka SSD 2200 Vario View (Japan), rotational probe 5-0 MHz. The course of evaluation was recorded on videocassettes. Oesophageal intubation was made in the left lateral decubitus position after premedication (Cerucal 2%, 2 ml, Relanium 0.5%, 1 ml) and oropharyngeal local anaesthesia (Dicain 3%, 3 ml). On obtaining a good visualization of the ascending aorta cross-section at the level of the aortic valve leaflets using a duplex scanning and changing the probe position in the oesophagus (moving it upward to the level of the Valsalva sinuses and rotating the piezoelement from 0° to 50°), we got a good image of the left main coronary artery (LMCA) all over its length and its bifurcation, of the left descending artery (LDA), the circumflex artery (CX) and the right coronary artery (RCA) proximal segments (Fig. 1). A good visualization of the RCA anatomically branching off a little superior to the LMCA was technically more difficult, which is why — in order to obtain a excellent view — both transverse and longitudinal axes were used where the RCA branches off the aorta practically perpendicularly and the sample volume is parallel to the flow.

**Recording of Coronary Blood Flow**

Search of coronary artery stenotic zones was performed with colour scanning guided by the appearance of ‘aliasing’ phenomenon, that is evidence of turbulence. At low velocities of coronary blood flow the colour scale was changed to obtain an optimum image. The coronary blood flow spectrum was registered simultaneously with ECG, slowly moving the sample volume of pulse-wave Doppler from the prestenotic zone of the vessel with laminar flow into the turbulence zone. The insonation angle between the longitudinal axis of coronary artery and ultrasonic beam did not exceed 60°. At high velocities in the trans-stenotic zone a regime of pulse repetition frequency was used.

**Coronary Blood Flow Analysis**

We determined the peak and average velocities of coronary blood flow during systole (Vp, Vms, cm.s\textsuperscript{−1}) and diastole (Vd, Vmd, cm.s\textsuperscript{−1}), velocity integral (VTI\textsubscript{p}, VTI\textsubscript{d}, cm), velocity integral ratio (VTI\textsubscript{p}/VTI\textsubscript{d}), blood flow acceleration time (AT\textsubscript{p}, AT\textsubscript{d}, ms) and blood flow acceleration (Ac\textsubscript{p}, Ac\textsubscript{d}, cm.s\textsuperscript{−2}) (Fig. 2). The severity of coronary artery stenosis was calculated with a modified continuity equation according to the formula:

\[ \text{stenosis} \% = 100 \times \left(1 - \frac{\text{prestenotic VTI}_d / \text{stenotic VTI}_d}{1} \right) \]

where prestenotic VTI\textsubscript{d}, (cm)=velocity integral during diastole in the prestenotic zone, and stenotic VTI\textsubscript{d},
The analysis of images from the videocassette was made with a video processing plato frame grubber built into the ultrasound systems. Indexes were calculated in not less than three cardiocycles by two independent investigators.

**Statistical Analysis**

The findings were statistically analysed with a package of applied programmes STATISTICA, ver. 5.0 (StatSoft Inc., USA). The data are presented as mean (m) ± SD. To estimate the intragroup differences, a pair Student t-criterion was used. Correlation between TEE and QCA findings was evaluated with correlation and correlation-regression analyses.

**Results**

**Visualization of Coronary Arteries using TEE**

Coronary arteries were visualized in the grey scale in the majority of patients: 94 (100%) for the LMCA, 90 (96%) for LDA mouth, 72 (77%) for whole proximal third and initial segments of the LDA mid third, 72 (77%) for CX proximal third and 67 (72%) for RCA proximal third.
The Doppler recordings were successful in 91 (97%), 90 (96%), 65 (69%), 45 (48%) of patients for the LMCA, LDA, CX and RCA in the entire study cohort.

**Coronary Artery Stenoses and Occlusions**

Doppler echocardiographic assessments of the main coronary arteries stenoses with a continuity equation allowed us to adequately identify seven of eight (88%) LMCA stenoses, 54 of 56 (96%) LDA stenoses, 18 of 19 (95%) CX stenoses, 24 of 29 (83%) RCA stenoses and 10 of 10 (100%), two of two (100%), 16 of 19 (84%) LDA, CX, RCA occlusions, respectively (Table 1). ‘Aliasing’, phenomenon in colour scanning, as an initial search criterion of turbulence, was revealed in 100%, 66%, 86%, 19% of cases in the LMCA, LDA, CX, RCA stenoses, respectively, and as a rule was an evidence of 50% and more of vessel stenosis. In coronary artery occlusion a ‘break’ of colour mapping and absence of Doppler spectrum were observed. Distal to the occlusion a flow of retrograde filling during late diastole with the mean velocity of 53 ± 25 cm.s⁻¹ was registered in 10 cases of occlusions (Fig. 3). Sensitivity and specificity of multi-plane TEE in the diagnostics of stenotic atherosclerosis were for the LMCA 88% and 98%, the LDA 97% and 67%, the CX 95% and 92%, and for the RCA were 83% and 97%, respectively.

Coronary artery stenoses percentage in TEE, calculated according to a continuity equation, accurately reflected the stenosis percentage determined by QCA in all coronary arteries (Table 2). Additional evidence was a statistically significant correlation coefficient between the stenosis percentage of coronary arteries in TEE and QCA: for the LMCA these were \( r=0.82, R^2=0.67, P<0.001 \); LDA \( r=0.84, R^2=0.71, P<0.001 \); CA \( r=0.85, R^2=0.72, P<0.001 \); RCA \( r=0.84, R^2=0.71, P<0.001 \).

**Doppler Criteria of Coronary Arteries Stenoses**

In all coronary arteries and the trans-stenotic zone the indexes of the coronary blood flow were, as expected, higher than in the prestenotic area (Table 3; Fig. 4). We found a highly significant correlation between the values...

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**Table 1.** Comparative assessment of the transoesophageal echocardiography and quantitative coronary angiography in diagnostics of main coronary arteries stenoses and occlusions.

<table>
<thead>
<tr>
<th>Coronary vessel</th>
<th>QCA Stenoses (n)</th>
<th>QCA Occlusions (n)</th>
<th>TEE Stenoses Diagnosed (n)</th>
<th>TEE False-negative (n)</th>
<th>TEE False-positive (n)</th>
<th>TEE Occlusions Diagnosed (n)</th>
<th>TEE False-negative (n)</th>
<th>TEE False-positive (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMCA</td>
<td>8</td>
<td>—</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>LDA</td>
<td>56</td>
<td>10</td>
<td>74</td>
<td>2</td>
<td>20</td>
<td>10</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>CX</td>
<td>19</td>
<td>2</td>
<td>26</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>RCA</td>
<td>29</td>
<td>16</td>
<td>26</td>
<td>5</td>
<td>2</td>
<td>19</td>
<td>—</td>
<td>3</td>
</tr>
</tbody>
</table>

**Figure 3.** Left panel) Occlusion in the proximal third of the left descending artery with retrograde filling, the velocity=33 cm.s⁻¹. (Right panel) Occlusion in the proximal third of the right coronary artery with retrograde filling, the velocity=42 cm.s⁻¹.

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Table 2. Main coronary artery stenosis percentage according to data from transoesophageal echocardiography and quantitative coronary angiography.

<table>
<thead>
<tr>
<th>Method</th>
<th>LMCA (n=7)</th>
<th>LDA (n=54)</th>
<th>CX (n=18)</th>
<th>RCA (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEE</td>
<td>54.6 ± 13.8</td>
<td>65.0 ± 20.5</td>
<td>60.2 ± 22.2</td>
<td>83.7 ± 24.8</td>
</tr>
<tr>
<td>QCA</td>
<td>47.5 ± 15.4</td>
<td>66.4 ± 24.2</td>
<td>66.4 ± 18.1</td>
<td>83.2 ± 23.3</td>
</tr>
</tbody>
</table>

Table 3. Blood flow indexes in the prestenotic and trans-stenotic zones of the main coronary arteries.

<table>
<thead>
<tr>
<th>Indexes of coronary blood flow</th>
<th>LMCA (n=7)</th>
<th>LDA (n=54)</th>
<th>CX (n=18)</th>
<th>RCA (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prestenosis</td>
<td>Stenosis</td>
<td>Prestenosis</td>
<td>Stenosis</td>
</tr>
<tr>
<td>Vp_d, (cm.s⁻¹)</td>
<td>42 ± 16</td>
<td>80 ± 21†</td>
<td>20 ± 7</td>
<td>37 ± 28‡</td>
</tr>
<tr>
<td>Vm_d, (cm.s⁻¹)</td>
<td>31 ± 12</td>
<td>62 ± 22‡</td>
<td>14 ± 6</td>
<td>27 ± 21‡</td>
</tr>
<tr>
<td>VTI_d (cm)</td>
<td>5 ± 2</td>
<td>10 ± 3‡</td>
<td>3 ± 2</td>
<td>5 ± 4‡</td>
</tr>
<tr>
<td>AT_d, (ms)</td>
<td>61 ± 21</td>
<td>54 ± 14</td>
<td>63 ± 20</td>
<td>68 ± 20</td>
</tr>
<tr>
<td>Ac_d, (cm.s⁻²)</td>
<td>769 ± 393</td>
<td>153 ± 566‡</td>
<td>360 ± 176</td>
<td>580 ± 479‡</td>
</tr>
<tr>
<td>Vp_d, (cm.s⁻¹)</td>
<td>72 ± 25</td>
<td>206 ± 60‡</td>
<td>38 ± 12</td>
<td>91 ± 61‡</td>
</tr>
<tr>
<td>Vm_d, (cm.s⁻¹)</td>
<td>56 ± 20</td>
<td>158 ± 45†</td>
<td>30 ± 12</td>
<td>69 ± 47‡</td>
</tr>
<tr>
<td>VTI_d (cm)</td>
<td>24 ± 11</td>
<td>71 ± 29†</td>
<td>12 ± 6</td>
<td>32 ± 23‡</td>
</tr>
<tr>
<td>AT_d, (ms)</td>
<td>131 ± 44</td>
<td>172 ± 49*</td>
<td>113 ± 41</td>
<td>138 ± 51†</td>
</tr>
<tr>
<td>Ac_d, (cm.s⁻²)</td>
<td>617 ± 298</td>
<td>1522 ± 375‡</td>
<td>381 ± 196</td>
<td>744 ± 487†</td>
</tr>
<tr>
<td>VTI_d/VTI_d</td>
<td>6 ± 3</td>
<td>8 ± 2*</td>
<td>6 ± 3</td>
<td>8 ± 5†</td>
</tr>
</tbody>
</table>

Note: *P<0.05, †P<0.01, ‡P<0.001 in comparison with the prestenotic zone indexes.

Figure 4. The Doppler spectrum of coronary blood flow in the proximal third of the left descending artery at 80% stenosis. (Left panel) prestenotic zone, peak diastolic velocity (V_d)=74 cm.s⁻¹, velocity time integral (VTI_d)=19 cm. (Right panel) stenotic zone, peak diastolic velocity (V_d)=257 cm.s⁻¹, velocity time integral (VTI_d)=97 cm.

of peak diastolic velocity of coronary blood flow in the trans-stenotic zone and the severity of vascular stenoses according to QCA data which for the LMCA were r=0.78, P<0.001, for the LDA r=0.33, P<0.01, and for the CX r=0.40, P=0.001. All these allowed us to range the peak diastolic velocity of coronary blood flow in the trans-stenotic zone of each artery with a pace of 5 cm.s⁻¹ and calculate Doppler criteria of more than 50% stenosis according to the highest coefficient of correlation with the QCA data. These values were...
made for the LMCA at 1.4 m.s⁻¹ (r=0.66,  P<0.001, sensitivity=80%, specificity=97%), the LDA at 0.9 m.s⁻¹ (r=0.31,  P<0.01, sensitivity=32%, specificity=92%), and the CX at 1.1 m.s⁻¹ (r=0.48,  P<0.001, sensitivity=50%, specificity=92%). Doppler echocardiography criteria for the RCA stenoses were not developed because of occlusion prevalence.

Discussion

The clinical application of TEE provides the possibility of studying ultrasound anatomy of coronary arteries and the non-invasive assessment of coronary blood flow through the visualization of coronary artery proximal segments. Unlike biplane TEE, multiplane technology allows us to obtain the optimum image of coronary arteries due to the numerous step-by-step ultrasound sections[9,10]. Thus, Tardif et al[1] using multiplane TEE in 45 patients, achieved a satisfactory visualization of the LMCA full length, LDA, CX, RCA proximal segments in 100%, 69%, 80% and 84% of cases, respectively, and the LDA, CX, RCA mid portion in 31%, 51% and 16% of cases. Kasprzak et al.,[8] having performed 210 transoesophageal ultrasound evaluations, obtained an optimum location of the LMCA, LDA, CX, RCA proximal third in 100%, 97%, 99% and 95% of cases, respectively. The results of our study confirm a high percentage of qualitative grey-scale visualization of the LMCA bifurcation and the LDA, CX and RCA proximal segments with a transoesophageal approach, while a satisfactory location of the mid segments was obtained only in the LDA; this is apparently associated with the peculiarities of CX and RCA localization and the difficulty in fitting these vessel mid portions into the ultrasound section plane. Most difficulties were encountered when attempting to visualize the coronary arteries of people with a hypersthenic constitution, because of the horizontal position of the heart and the limited number of ultrasound sections. In these cases the only good image obtained was that of the LMCA.

The appearance of ‘aliasing’ a phenomenon in the colour scanning of coronary arteries was found to be a marker of blood flow turbulence in the zone of haemodynamically significant stenosis[2,4,5,7]. The results of our study demonstrated that the presence of ‘aliasing’ phenomenon allowed us to adequately localize more than 50% and even more accurately more than 75% stenosis in the LMCA, LDA and CX proximal third, while in the RCA ‘aliasing’ phenomenon was observed very rarely, even in high-grade stenoses. The appearance of blood flow turbulence is known to be determined by Reynolds high number[11], however, the mean coronary blood flow velocity during diastole in the RCA prestenotic zone averaged 1.5–2 times lower than in the LDA (18 ± 8 cm.s⁻¹ and 30 ± 12 cm.s⁻¹, respectively,  P<0.05) in the vessels of comparable diameters, and three to four times lower than in the LMCA and CX (18 ± 8 cm.s⁻¹, 56 ± 17 cm.s⁻¹ and 53 ± 18 cm.s⁻¹, respectively,  P<0.001). Even a two- to threefold increase of blood flow velocity in the RCA trans-stenotic zone did not result in an increase of Reynolds number to threshold values and, consequently, in the appearance of ‘aliasing’ phenomenon.

According to the laws of haemodynamics, a vessel lumen stenosis increases the blood flow velocity in the narrowed segment[13]. Invasive assessment of coronary haemodynamics performed by Nakatani et al[13] and Zehetgruber et al.[15] with intracoronary Doppler flowmeters confirmed that coronary blood flow velocity was increased in the stenotic zone. Caiati et al.[3] and Isaaz et al.[5], extrapolating the findings of invasive studies and using transoesophageal ultrasound Doppler echocardiography of the LMCA and LDA, found a significant correlation between Doppler calculated stenoses percentage and QCA data, which by the use of ranging, allows the calculation of Doppler criteria for haemodynamically significant stenosis in the LMCA, LDA and CX.

The laws of haemodynamics state that blood flow volume in the prestenotic segment is equivalent to that in the stenotic one[16,17]. This principle is the basis of a modified continuity equation, and, knowing the integrals of coronary blood flow diastolic velocity in the prestenotic and transstenotic segments, one can calculate the vessel stenosis percentage[5]. Johnson E et al.[18], Nakatani et al.[13] and Di Mario et al.[19] using intracoronary Doppler flowmeters, were the first to report the possibility of quantitative assessment of coronary arteries stenoses with a modified continuity equation. Isaaz et al.[5], using the experience of invasive evaluations, applied a modified continuity equation for transoesophageal Doppler echocardiography of the LMCA and LDA proximal third, and found a significant correlation between Doppler calculated stenoses and QCA findings. The results of our study show that application of a modified Gorlin equation for transoesophageal Doppler echocardiography of coronary arteries permits the accurate calculation of stenosis percentage not only in the LMCA and LDA, but also in the CX and RCA proximal segments. This is confirmed by a high correlation with the angiographic evaluation data. In comparison with the QCA data, we found no significant underestimation of stenosis in any of the

coronary arteries, this fact being reported by Isaaz et al.\[5\]. Thus, we consider it quite appropriate to apply a modified continuity equation for accurate quantitative assessment of the main coronary artery stenoses.

Application of TEE was successful in revealing less than 25% stenosis of the main coronary arteries, as the method has no geometric limitations. It may be useful in the diagnostics of minimally manifested coronary stenoses, as well as in the estimation of coronary angioplasty treating effect, where even the QCA possibilities are limited\[6,7\]. Accurate quantitative assessment of the LMCA stenosis was rather difficult, as a prestenotic segment in this zone is not easy to detect, and in the mouth a deposition of the aortic flow on the coronary blood flow Doppler spectrum occurs. Thus, the Doppler criterion of haemodynamically significant stenosis according to the peak diastolic velocity of coronary blood flow which we have provided is most informative. In addition, in the LMCA atherosclerotic lesion it is difficult to adequately calculate the LDA and CX stenosis percentage, as poststenotic turbulent high velocity blood flow is preserved in these vessels. However, the main methodical disadvantage of TEE is the impossibility of assessing atherosclerotic lesions of the distal part of the coronary tree, as it is difficult to fit these segments of the coronary arteries into the ultrasound section plane.

The possibility using multiplane TEE in the diagnostics of the main coronary artery occlusions should be particularly stressed. In the literature available there are no reports on similar investigations. According to our data the principal diagnostic criteria of coronary artery occlusions are signs such as: ‘amputation’ of colour mapping and a sudden ‘break’ of the Doppler spectrum. Moving the sample volume of pulse-wave Doppler more distally along the vessel in non-extensive occlusions, one can frequently register a flow of retrograde filling during late diastole, sometimes against the background of colour mapping inversion. It should be noted that only registration of a flow of retrograde filling is an absolute criterion of occlusion.

According to the findings of our study, transoesophageal Doppler echocardiography of coronary arteries demonstrated high sensitivity and specificity in the diagnostics of stenotic atherosclerosis consistent with data from the literature\[1,2,5–7\]. However, a lower specificity of the Doppler assessment method in the diagnostics of the LDA stenoses should be noted, since by using Doppler echocardiography we tried to calculate even minor stenoses (up to 25%) that were diagnosed as usuration by an echocardiography. We tried to calculate even minor stenoses, as well as in the estimation of coronary angioplasty treating effect, where even the QCA possibilities are limited\[6,7\]. Accurate quantitative assessment of the LMCA stenosis was rather difficult, as a prestenotic segment in this zone is not easy to detect, and in the mouth a deposition of the aortic flow on the coronary blood flow Doppler spectrum occurs. Thus, the Doppler criterion of haemodynamically significant stenosis according to the peak diastolic velocity of coronary blood flow which we have provided is most informative. In addition, in the LMCA atherosclerotic lesion it is difficult to adequately calculate the LDA and CX stenosis percentage, as poststenotic turbulent high velocity blood flow is preserved in these vessels. However, the main methodical disadvantage of TEE is the impossibility of assessing atherosclerotic lesions of the distal part of the coronary tree, as it is difficult to fit these segments of the coronary arteries into the ultrasound section plane.

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Thus, despite the fact that at present coronary angiography continues to be the leading method in the diagnostics of stenotic atherosclerosis, the transoesophageal Doppler study of coronary blood flow is a highly informative, well reproduced, and, no doubt, perspective non-invasive method of the proximal coronary arteries stenoses and occlusions screening.

**Conclusions**

- Transoesophageal Doppler assessment of coronary blood flow is a highly sensitive and specific non-invasive method in the diagnostics of stenotic and occlusive atherosclerosis of the main coronary arteries.
- A modified continuity equation is haemodynamically correct and allows with application of transoesophageal Doppler allows the accurate calculation of the coronary artery stenosis percentage.
- The peak diastolic velocity of coronary blood flow (equal to 1·4 m·s\(^{-1}\) in the LMCA, 0·9 m·s\(^{-1}\) in the LDA, and 1·1 m·s\(^{-1}\) in the CX) alongside the ‘aliasing’ phenomenon is a Doppler criterion of haemodynamically significant stenosis.
- ‘Break’ of colour mapping, absence of Doppler spectrum and registration of retrograde blood flow during late diastole are Doppler echocardiography criteria for coronary artery occlusion.

**References**


