Transthoracic Doppler coronary flow reserve at the right coronary artery stenosis

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for European Congress of Cardiology, 2010, Stockholm
Coronary flow reserve (CFR) is defined as the ratio of coronary flow under maximal coronary vasodilatation to coronary flow under resting conditions.


Intracoronary Doppler is the reference standard for the assessment of coronary flow reserve in vivo.

Proximally measured coronary flow reserve has not been predictive of blood flow distal to coronary stenoses. Distal flow velocity is measure providing an accurate assessment of lesional hemodynamics.

Peterson RJ et al., J Am Call Cardiol, 1987;10:253-60
Transthoracic echocardiography is a good noninvasive method for assessment of left anterior descending coronary artery (LAD) pathology, because with advent of harmonic imaging, contrast agents and high-frequency transducers, it permits visualization of the LAD in 90-100% of patients, detection of LAD stenosis using assessment of ratio of stenotic to prestenotic velocities and analysis of distal coronary flow reserve, and evaluation of effect of therapeutic coronary interventions

- Fusejima K. J Am Coll Cardiol 1987;10:1024-31
- Ross JJ Jr et al., J Am Coll Cardiol 1990;15:373-7
- Lambertz H. et al., Herz 1998;23:516-25
- Voci P. et al., Am J Cardiol 2002;90:988-91; Am J Cardiol 2003;92(11):1320-4
- Watanabe N. et al., J Am Coll Cardiol 2001;38:1329-32
- etc............>50 papers

Visualization of the distal right coronary artery (RCA) and assessment of distal coronary flow reserve are totally possible in 33-76% of patients — Tries HP et al., 2002; Voci P et al., 2002; Ueno Y. et al, 2002; Krzanowski M et al., 2000; Krzanowski M et al., 2003; Auriti A et al., 2003

Certain transthoracic ultrasound markers of stenosis of the RCA were determined — Krzanowski M et al., 2003; Saraste M et al., 2005
Relationship between intracoronary Doppler CFR and transthoracic Doppler CFR in the right coronary artery

CFR, intracoronary Doppler

CFR, TTE

Distal RCA (PDA) $r=0.97$, $y=0.87x+0.56$

Transthoracic CFR in the PDA with echocontrast enhancement can be useful for detecting:

- of myocardial ischemia in the left ventricular inferior regions — Tokai K et al., 2003
- of RCA stenosis - Watanabe H et al., 2004
Main coronary arteries: transthoracic Doppler visualization without echocontrast enhancement (n=150)

<table>
<thead>
<tr>
<th>Artery</th>
<th>proximal part</th>
<th>mean part</th>
<th>distal part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left main coronary artery</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left anterior descending coronary artery (LAD)</td>
<td>85</td>
<td>87</td>
<td>93</td>
</tr>
<tr>
<td>Circumflex artery</td>
<td>37</td>
<td>8</td>
<td>31</td>
</tr>
<tr>
<td>Right coronary artery (RCA)</td>
<td>22</td>
<td>35</td>
<td>91</td>
</tr>
</tbody>
</table>

Boshchenko A, Vrublevsky A., Karpov R. Ultrasound diagnostics, 2008 (6)
The aim of our study was a Doppler assessment of coronary flow reserve in the right coronary artery in CAD patients with single-vessel RCA stenosis and patients without RCA stenosis using transthoracic echocardiography without echocontrast enhancement.

**Inclusion criteria:**
- CAD patients with coronary artery stenosis;
- sinus rhythm;
- normal wall thickness and function of the left and right ventricles;
- normal right ventricular systolic pressure;
- mitral and tricuspid valvular regurgitation less than grade 2;
- arterial normotension (blood pressure <140/90 mm Hg)

**Exclusion criteria:**
- contraindications to dipyridamole infusion;
- valvular disease;
- cardiomyopathy;
- diabetes mellitus;
- esophageal, gastric or severe pulmonary diseases;
- mental disorders;
- diseases of the musculoskeletal system or nervous system, which prevent left decubitus position of the patient
STUDY PROTOCOL

Quantitative coronary angiography

Coronary artery disease

1-7 days

Assessment of study inclusion criteria
Detection of possible exclusion criteria

71 patients (mean age 49±12 years, 58 men and 13 women)

Transthoracic Doppler assessment of coronary flow reserve in the right coronary artery
### Study groups

**Patients with single-vessel RCA stenosis > 50%**

- N = 23

**Patients without RCA stenosis**

- N = 48

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group 1 (M/F)</th>
<th>Group 2 (M/F)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>19/4</td>
<td>39/9</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Obesity, % in the group</td>
<td>25</td>
<td>16</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Smoking, %</td>
<td>47</td>
<td>36</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Hyperlipidemia, %</td>
<td>73</td>
<td>67</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total cholesterol, mg/ml</td>
<td>245 ±53</td>
<td>228±42</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>CH-LDL, mg/ml</td>
<td>163±42</td>
<td>151±45</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
Transthoracic echocardiography

Technical issues:
- ultrasound diagnostic system Vivid 7 GE Healthcare;
- M3S, narrow-band sector transducer, 1.7-3.5 MHz;
- second tissue harmonics imaging;
- the Nyquist limit set 13-27 cm/s;
- absence of echocontrast enhancement

Reference coronary artery:
- posterior descending artery (PDA) as the distal right coronary artery (dRCA)

Stress-agent:
- dipyridamole 0.56 mg/kg;
- if HR increase <10% from basal level - extra-injection of dipyridamole, 28 mg/kg is used
Color Doppler images of the distal right coronary artery presented by posterior descending artery and Doppler velocity pattern in the PDA.
Assessment of absolute coronary flow reserve

**basal level**

- basal $V_p = 20$ cm/s

**dipyridamole**

- hyperemic $V_p = 54$ cm/s

**Absolute coronary flow reserve (CFR)**

$$\text{CFR} = \frac{\text{hyperemic } V_p}{\text{basal } V_p}$$

- $V_p$, cm/s – peak diastolic coronary flow velocity

**Normal absolute CFR > 2.0**

A good color Doppler mapping and Doppler velocity patterns in the posterior descending artery

Patients with single-vessel RCA stenosis $>50\%$ (n=23)

- Yes: 4 (17%)
- No: 19 (83%)

Patients without RCA stenosis (n=48)

- Yes: 6 (13%)
- No: 42 (87%)
## Main haemodynamic parameters

**Patients with single-vessel RCA stenosis >50%**

- N=23

**Patients without RCA stenosis**

- N=48

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patients with single-vessel RCA stenosis &gt;50%</th>
<th>Patients without RCA stenosis</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR, b/min</td>
<td>62 ± 9</td>
<td>64 ± 11</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>129 ± 19</td>
<td>125 ± 17</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>78 ± 11</td>
<td>77 ± 15</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>EF, %</td>
<td>63 ± 4</td>
<td>63 ± 5</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>SV, ml</td>
<td>73 ± 15</td>
<td>72 ± 13</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>CO, l/min</td>
<td>4.57 ± 0.84</td>
<td>4.32 ± 1.26</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>CI, l/min*m²</td>
<td>2.32 ± 0.66</td>
<td>2.15 ± 0.36</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>IMM LV, g/m²</td>
<td>114 ± 33</td>
<td>108 ± 21</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
Peak diastolic coronary flow velocity in the RCA: basal level and hyperemia

**Basal Level**

- RCA stenosis > 50%
  - 26 ± 11
- No RCA stenosis
  - 18 ± 5

**Dipyridamole**

- RCA stenosis > 50%
  - 53 ± 25
- No RCA stenosis
  - 65 ± 17

p < 0.001
Absolute CFR in the RCA:
group analysis and correlation with percent of area stenosis

CFR = $2.8889 - 0.0160 \times \%$ of area stenosis
\( r = -0.61 \)

![Graph showing CFR vs. maximal percent of RCA stenosis](image)

- 95% confidence interval
- p < 0.001
- RCA stenosis > 50%
- no RCA stenosis

1.47 ± 0.81
2.76 ± 0.86
Absolute CFR in the PDA: individual analysis

- **Absolute CFR <2.0** in the distal RCA is a predictor of RCA stenosis >50% with 84% sensitivity and 86% specificity.

Note: * - p<0.001 – in comparison with patients without RCA stenosis.
Examples of Doppler coronary flow reserve in the distal RCA

Patient B. without RCA stenosis

\[
\text{CFR} = \frac{53}{20} = 2.65
\]

Patient N. with 75% proximal RCA stenosis

\[
\text{CFR} = \frac{42}{38} = 1.02
\]
Conclusion:

- Stenosis of the RCA >50% is a cause of reduced CFR distal to the stenosis.
- The decrease of the CFR depends on RCA stenosis area.
- The CFR <2.0 in the distal RCA is a predictor of RCA stenosis >50% with 84% sensitivity and 86% specificity.
Study limitations:

- Study patients were highly selected.
- False-positive results of CFR assessment in patients with high hyperlipidemia or heavy smoking patients without RCA stenosis.
- False-negative results of CFR assessment in patients with strongly dominant left coronary artery in which the PDA is a branch of the left and not the right coronary artery.
- An operator-dependent factor, i.e. the necessity of a well-trained specialist.