Do internal mammary artery side-branches have the potential for haemodynamically significant flow steal?

Mario Gaudino*, Michele Serricchio, Paolo Tondi, Franco Glieca, Piergiorgio Bruno, Gianfederico Possati, Paolo Pola

Department of Cardiac Surgery and Angiology, Catholic University, Rome, Italy

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Abstract

Objective: To evaluate the potential for flow steal of the internal mammary artery (IMA) side-branches at rest and in case of dilatation of their vascular bed (as probably occurs during physical exercise). Methods: Transthoracic echo-Doppler evaluation of IMA flow was performed preoperatively in 40 patients undergoing myocardial revascularization. IMA flow was measured at rest and in condition of peripheral vasodilatation (obtained using forced ventilation for 2 min, dypiridamole 0.84 mg/kg endovenous (e.v.), xantinole nicotinate 500 mg e.v., nifedipine 20 mg sublingual (s.l.)). Results: IMA mean peak systolic velocity increased 23% after forced ventilation (from 67 to 83 cm/s), 6% after dypiridamole (from 75 to 80 cm/s), 30% after xantinole infusion (from 62 to 81 cm/s) and 23% after nifedipine administration (from 60 to 74 cm/s). IMA flow increased 17.7% after forced ventilation (from 39.5 to 46.5 ml/min), 4.8% after dypiridamole (from 39.2 to 41.1 ml/min), 20.2% after xantinole infusion (from 41.4 to 49.8 ml/min) and 16.5% after nifedipine administration (from 41.6 to 48.5 ml/min). Conclusions: The limited functional flow reserve of the in situ IMA, even after pure muscular vasodilatation, seems to minimize the possibility of significant flow steal from patent IMA graft collaterals. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Mammary artery; Collaterals; Flow steal

1. Introduction

Although cases of flow steal from patent internal mammary artery graft side branches (IMASB) have been anecdotally reported (and careful identification and legation of all the IMASB recommended [1–5], to date the haemodynamic importance of IMASB at rest and after pharmacological or exercise-induced dilatation has received only limited attention, so that the effective potential of these vessels to induce a clinically significant flow steal in patients submitted to coronary bypass procedures is still controversial.

The volume capacity of IMASB and, more notably, its variations in the different physiological situations is the major determinant of this potentiality as, if only limited amount of blood can be diverted in the mammary side branches, flow steal from the larger coronary bed would seem unlikely.

This report was conceived to provide an estimation of the IMASB haemodynamic importance at rest and after pharmacological or exercise-induced vasodilatation by using a transthoracic echo-Doppler method.

2. Methods

2.1. Patients population

This study protocol involved 40 patients selected among the 361 coronary artery bypass cases referred at the Department of Cardiac Surgery of the Catholic University of Rome between September 1997 and February 1998.
The main preoperative clinical characteristics of these patients are summarized in Table 1. Selection was based on the willingness of the patients to undergo the echo-Doppler investigation. The evaluation was performed in the preoperative period (at a mean interval of 1.5 – 2.0 days before surgery) and informed consent to the procedure was provided by all patients.

2.2. Evaluation of mammary artery flow reserve

Evaluation of mammary artery flow reserve was performed following a described protocol [6]. The left IMA was usually detected in the third intercostal space in parasternal position. Colour-Doppler imaging was obtained using a constant angle of 60° between the ultrasound beam and the long axis of the vessel. UnderColour-Doppler guidance, a pulsed Doppler evaluation of the flow velocity in the IMA using a sample volume of 1 mm³, and taking into consideration the angle between the ultrasound beam and the axis of the vessel, was performed.

The following parameters were calculated: peak systolic velocity (m/s) (PSV); end diastolic velocity (m/s) (EDV); time average mean velocity (m/s) (TAMV) and resistance index (RI). The TAMV was defined as the area between the line traced on the Doppler wave and the base line. The diameter of the IMA was calculated using internal electronic callipers on frozen frame images from the B-mode recording.

Flow (F) was obtained using the formula: 
\[ F = \text{TAMV (cm/s)} \times \left( \pi r^2 \times 60 \right) \]
where \( r \) is half the internal diameter of the IMA expressed in centimetres.

2.3. Vasodilatory protocol

Left IMA flow was evaluated at rest and after (in progressive order).

1. Forced ventilation for two min (which was supposed to increase the flow in the intercostal muscles served by the mammary artery) (40 patients).
2. Administration (e.v.) of dypiridamole 0.84 mg/kg (Persantin, Boehringer Mannheim, Germany) (40 patients).
3. Administration (e.v.) of 500 mg of xantinole nicotinate (Complamin, Italchimici, Italy) (an almost selective peripheral vasodilator) [7] (32 patients).
4. Administration of nifedipine 20 mg s.l. (Adalat, Bayer, Germany) (29 patients).

Flow evaluation was started immediately after administration of the vasodilator stimulus and continued without interruption for 15 min; measurements were made when the vasodilator effect was judged maximal by the operator. In order to minimize the possible overlapping effects of the various stimuli, a minimal interval of 30 min was allowed between the different tests and the nifedipine administration was performed at last.

2.4. Statistical analysis

Data are expressed as mean ± standard deviation, minimum and maximum (in parenthesis). The paired Student t-test was used to compare the haemodynamic characteristics of IMA flow at rest and after vasodilatation. A P-value < 0.05 was considered significant. Statistical analysis was not applied to flow, as this is a derived measure (as described above).

3. Results

Detailed results of the echo-Doppler measurement in the different conditions are shown in Tables 2, 3, 4 and 5. Muscular vasodilatation (achieved either by xantinole nicotinate, forced ventilation or nifedipine) led to a more sustained increase in IMA PSV (+30, +23 and +23%, res-
Table 3
Internal mammary artery flow characteristics at rest and after dypiridamole infusion

<table>
<thead>
<tr>
<th></th>
<th>PSV (m/s)</th>
<th>EDV (m/s)</th>
<th>TAMV (m/s)</th>
<th>RI</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>0.74 ± 0.19</td>
<td>0.8 ± 0.06</td>
<td>0.21 ± 0.05</td>
<td>0.94 ± 0.07</td>
<td>2.25 ± 0.37</td>
</tr>
<tr>
<td>Dypiridamole</td>
<td>0.80 ± 0.02</td>
<td>0.11 ± 0.04</td>
<td>0.22 ± 0.10</td>
<td>0.87 ± 0.06</td>
<td>2.25 ± 0.37</td>
</tr>
<tr>
<td></td>
<td>(0.74–0.84)</td>
<td>(0.05–0.18)</td>
<td>(0.03–0.46)</td>
<td>(0.61–0.94)</td>
<td>(1.55–3.16)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.07</td>
<td>0.003</td>
<td>0.13</td>
<td>0.00002</td>
<td>0.97</td>
</tr>
</tbody>
</table>

EDV, end diastolic velocity; PSV, peak systolic velocity; TAMV, time average mean velocity; RI, resistance index.

Table 4
Internal mammary artery flow characteristics at rest and after xantinole nicotinate infusion

<table>
<thead>
<tr>
<th></th>
<th>PSV (m/s)</th>
<th>EDV (m/s)</th>
<th>TAMV (m/s)</th>
<th>RI</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>0.62 ± 0.10</td>
<td>0.9 ± 0.01</td>
<td>0.22 ± 0.01</td>
<td>0.91 ± 0.04</td>
<td>2.0 ± 0.58</td>
</tr>
<tr>
<td>Xantinole nicotinate</td>
<td>0.81 ± 0.25</td>
<td>0.10 ± 0.04</td>
<td>0.28 ± 0.07</td>
<td>0.93 ± 0.04</td>
<td>2.12 ± 0.60</td>
</tr>
<tr>
<td></td>
<td>(0.46–0.80)</td>
<td>(0.07–0.12)</td>
<td>(0.19–0.25)</td>
<td>(0.82–0.98)</td>
<td>(1.05–2.98)</td>
</tr>
<tr>
<td></td>
<td>(0.23–0.98)</td>
<td>(0.04–0.17)</td>
<td>(0.13–0.38)</td>
<td>(0.82–0.98)</td>
<td>(0.74–3.14)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0002</td>
<td>0.01</td>
<td>0.00006</td>
<td>0.27</td>
<td>0.50</td>
</tr>
</tbody>
</table>

EDV, end diastolic velocity; PSV, peak systolic velocity; RI, resistance index; TAMV, time average mean velocity.
flow from the coronary system to the smaller IMASB bed is a remote possibility; the difference in flow pattern between the two districts (diastolic in the coronaries, systolic in the IMASB) makes this diversion even more unlikely.

On the contrary, if technical imperfections (anastomotic stenosis) or anatomic factors (small quality and diameter of the mammary artery or the target vessel) reduce the mammary run-off, flow can probably be diverted to large collaterals with lower resistance.

However, due to the wide inter-individual variability of IMASB anatomy and distribution, extension of our observations to the totality of cardiac surgery patients can be difficult; it is possible that particular anatomic variations of IMASB exist in whom the haemodynamic importance of mammary side-branches is superior to what we have observed.

Despite that, the large number of patients involved in our study and the notable concordance of the echo-Doppler results among the different patients allow us to believe that our observations can be applied to at least the great majority of coronary artery bypass patients.

In conclusion, our investigation testifies that in the majority of patients, the haemodynamic importance of IMASB is small either at rest and in condition of peripheral vasodilatation; this finding minimizes the potential for flow steal of IMASB and underlines the need for further investigation on this controversial subject.

### References


Table 5

Internal mammary artery flow characteristics at rest and after nifedipine administration

<table>
<thead>
<tr>
<th></th>
<th>PSV (m/s)</th>
<th>EDV (m/s)</th>
<th>TAMV (m/s)</th>
<th>RI</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>0.60 ± 0.10</td>
<td>0.10 ± 0.03</td>
<td>0.21 ± 0.02</td>
<td>0.96 ± 0.04</td>
<td>2.0 ± 0.42</td>
</tr>
<tr>
<td></td>
<td>(0.39–0.76)</td>
<td>(0.07–0.12)</td>
<td>(0.18–0.25)</td>
<td>(0.85–0.99)</td>
<td>(0.92–2.8)</td>
</tr>
<tr>
<td>Nifedipine</td>
<td>0.74 ± 0.15</td>
<td>0.09 ± 0.04</td>
<td>0.30 ± 0.03</td>
<td>0.93 ± 0.02</td>
<td>2.20 ± 0.61</td>
</tr>
<tr>
<td></td>
<td>(0.44–0.97)</td>
<td>(0.88–0.96)</td>
<td>(0.26–0.35)</td>
<td>(0.88–0.96)</td>
<td>(0.70–3.0)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0002</td>
<td>0.59</td>
<td>0.000</td>
<td>0.0001</td>
<td>0.16</td>
</tr>
</tbody>
</table>

EDV, end diastolic velocity; PSV, peak systolic velocity; RI, resistance index; TAMV, time average mean velocity.