Collateral flow reserve and right coronary occlusion: evaluation during off-pump revascularization

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Abstract

The aim of this study was the determination of the pressure-derived collateral fractional flow reserve (FFRcoll) in patients with three vessel disease and chronic occlusion of the right coronary artery undergoing surgical complete revascularization with the off-pump technique. The angiograms of eight patients were preoperatively analysed to quantify collaterality. FFRcoll was determined before any revascularization (FFRcoll 0), and after revascularization of the left coronary arteries, (FFRcoll 1). FFRcoll 0 was compared to the Rentrop grade, to the left ventricular ejection fraction (LVEF), and to FFRcoll 1. No correlation was demonstrated between preoperative Rentrop grade and FFRcoll 0. There was a linear statistically significant correlation between FFRcoll 0 and LVEF (P=0.001). No significant variation of the FFRcoll index was observed after performing left coronary artery bypass grafts. Collaterality observed on the coronary angiogram cannot be used as an estimation of the functional collaterality, which can be better appreciated with the LVEF. The absence of variation of FFRcoll before and after left coronary artery revascularization suggests that grafting of the occluded right coronary artery remains justified.

Keywords: Angiography; Coronary artery bypass surgery; Off-pump

1. Introduction

A well-developed coronary collateral circulation can protect the myocardium during a phase of ischaemia, decrease impairment of left ventricular function secondary to acute coronary occlusion, and decrease the risk of formation of a left ventricular aneurysm [1,2].

To more precisely assess the collateral flow able to protect the myocardium during coronary occlusion, Pijls et al. [3,4] proposed determination of the maximum recruitable collateral flow reserve during coronary occlusion (Qc) compared to maximum myocardial perfusion (Qm). During acute coronary occlusion, the mean arterial pressure (Pm), central venous pressure (Pc), and distal coronary pressure at the coronary artery occlusion (wedge pressure) (Pw) can be used to calculate the $Qc/Qm = (Pm - Pc) / (Pw - Pm)$. This index, the pressure-derived collateral fractional flow reserve (FFRcoll), reflects the collateral flow to a temporarily occluded artery. However, in patients with chronic coronary artery occlusion, FFRcoll cannot be calculated, as Pw cannot be measured.

The presence of chronic occlusion is not exceptional in patients undergoing surgical revascularization and usually corresponds to occlusion of the right coronary artery. The potential value of determining FFRcoll in this particular pathological setting would be to establish the functional nature of the collateral flow observed on preoperative coronary angiography. Off-pump coronary surgery, with a direct access to the distal runoffs of an occluded vessel, allows Pw measurement and the FFRcoll index can therefore be calculated. The objective of this study was to estimate collateral flow in the presence of chronic coronary artery occlusion via the determination of FFRcoll, in comparison with angiographic collateral flow and to analyze its relationship with left ventricular ejection fraction (LVEF). FFRcoll was calculated before then after left coronary artery bypass graft, in order to evaluate the variation of left-right collateral flow induced by these bypass grafts.

2. Patients and methods

2.1. Patients

The inclusion criteria were patients with three vessel diseases and chronic right coronary artery occlusion (segment 1 or 2), with no history of anterior or lateral myocardial infarction, in candidates for surgical coronary revascularization. Patients with occlusion of the circumflex artery or left anterior descending artery were excluded. Patients with a right coronary artery are considered to be unsuitable for revascularization, or patients with nonviable myocardium in the territory of the right coronary artery were excluded. Eight patients were finally included in this
Pressure measurements before left coronary arteries revascularization

Pressure measurements after left coronary arteries revascularization

Distal anastomosis of the vein graft onto the right coronary artery

Distal anastomosis of R and L anterior mammary arteries onto left coronary arteries

Proximal anastomosis of the vein graft onto the right coronary artery

Pₐ, Pᵥ and Pₜ measurements

(FFR₉₀)

(FFR₁₀₀)

Fig. 1. Protocol of the study.

study. Informed and signed consent was obtained in all patients before the study. The right coronary artery collateral flow was evaluated according to Rentrop’s classification [5] by two independent observers. In the case of discordance, two operators reviewed coronary angiography. Classification of right coronary artery filling from collateral flow was as follows: 0, no filling; 1, filling of the distal branches of the right coronary artery via the collaterals without visualization of its epicardial segment; 2, partial filling of the epicardial segment via the collaterals; 3, complete filling of the epicardial segment via the collaterals.

2.2. Operative methods and determination of the FFR₉₀ index

A Swan–Ganz catheter was used for measurement of pressures in the right cardiac cavities. A radial artery catheter monitored systemic blood pressure. The surgical technique has been previously described [6]. After midline sternotomy and opening of the pericardium, the coronary network, particularly the distal runoff of target vessels, was explored in order to confirm the revascularization strategy. The two left and right internal mammary arteries as well as saphenous vein grafts were then harvested. Pericardial traction sutures performed exposure of the various walls of the heart. The anastomotic site was immobilized by an Octopus tissue stabilizer (Medtronic Inc, Minneapolis, MN, USA). The first step of coronary revascularization consisted of distal anastomosis of the vein graft onto the right coronary artery. A first series of measurements (Pₐ, Pᵥ, Pₜ) allowed calculation of baseline FFR₉₀ (FFR₉₀). Pₜ was determined by direct catheterization of the vein graft as far as the anastomosis via a radial catheter. Left coronary arteries were then revascularized by both internal thoracic arteries. A second series of measurements was then performed; allowing calculation of FFR₁₀₀ with only the left network revascularized (FFR₁₀₀). All measurements were performed on the heart placed in its anatomical site after stabilization of haemodynamic parameters (cardiac index >2 L/min/m² and systolic aortic pressure >80 mmHg). Complete revascularization was performed in all patients (3.1 ± 0.35 distal anastomosis per patient). The protocol is presented in Fig. 1.

2.3. Statistical analysis

Data were analysed by SPSS software and are expressed as the mean ± standard deviation. Three analyses were performed. The comparison between FFR₉₀ and Rentrop grade was analysed by a Student t test. The relationship between FFR₉₀ and LVEF was analysed by linear regression. The variation of FFR₉₀ before and after left coronary artery bypass grafts (FFR₉₀–FFR₁₀₀) was analysed by a Student t test for paired series. An associated probability <0.05 was considered to be statistically significant.

3. Results

Five patients had a history of inferior myocardial infarction. The mean ejection fraction was 52 ± 12%. Two patients were classified as Rentrop grade two, and six patients were classified as Rentrop grade three. Measurements were performed in all patients included and the data recorded are presented in Table 1. No correlation was demonstrated between preoperative Rentrop grade and FFR₉₀ index (mean FFR₉₀ 0: 0.46 ± 0.09 for the Rentrop two group and 0.45 ± 0.16 for the Rentrop three group). Linear regression analysis of the FFR₉₀ index as a function of LVEF demonstrated a statistically significant correlation between these two parameters (P=0.001, r=0.92, Fig. 2). The FFR₉₀

Table 1

<table>
<thead>
<tr>
<th>Patient</th>
<th>Preoperative data</th>
<th>Pressure measurements before left coronary arteries revascularization</th>
<th>Pressure measurements after left coronary arteries revascularization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior Inf MI</td>
<td>LVEF</td>
<td>Rentrop</td>
</tr>
<tr>
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<td>60</td>
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<td>8</td>
<td>1</td>
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<td>3</td>
</tr>
<tr>
<td>All</td>
<td>52 ± 12</td>
<td>81</td>
<td>3</td>
</tr>
</tbody>
</table>

Inf MI: inferior myocardial infarction; LVEF: left ventricular ejection fraction; Pₐ: aortic pressure; Pᵥ: central venous pressure; Pₜ: wedge pressure in occluded right coronary artery.
index was significantly lower in patients with a history of inferior myocardial infarction (0.58 vs 0.38, \(P=0.04\)). No significant variation of the \(F_{\text{FR}_{\text{coll}}}\) index was observed after performing left coronary artery bypass grafts (mean \(F_{\text{FR}_{\text{coll}}}\) 0–4 difference \(-0.006, P=0.83\)).

4. Comment

The concept of Fractional Flow Reserve, proposed by Pijls et al. [3] in 1993, allows estimation of collateral flow by determination of the maximum collateral flow compared to maximum myocardial perfusion. In case of chronic arterial occlusion, this quantification of collateral flow is not possible as the distal runoff of the occluded artery is no longer accessible. Our findings therefore confirm that angiographic data are poorly predictive of collateral flow [1, 4–7–9], while collateral flow and its functional nature are more accurately predicted by haemodynamic data. Conversely, it therefore demonstrates a correlation between Fractional Collateral Flow Reserve and the severity of ischaemic sequelae deduced from measurement of the ejection fraction. The superiority of haemodynamic assessment of collateral flow compared to angiographic studies has already been reported [8–10, 11]. However, our results indicate that this concept of a limit of protection against ischaemia must be interpreted cautiously. Although all patients with a history of inferior myocardial infarction had an \(F_{\text{FR}_{\text{coll}}} <0.55\), the impact and extension of the infarct very clearly depend on the quality of the collateral flow, as analysis of \(F_{\text{FR}_{\text{coll}}}\) and LVEF clearly demonstrates a linear relationship between these two parameters. This relationship between LVEF and collateral flow has already been demonstrated by Whan Lee et al. [1], who showed that in patients with acute myocardial infarction, a high \(F_{\text{FR}_{\text{coll}}}\) index was associated with less severe deterioration of LVEF. Bruyne et al. [12] reported a correlation between LVEF and \(P_{\text{w}}\) in patients with single-vessel disease. These results are in line with those presented by Matsuo et al. [13], who demonstrated, during acute coronary artery occlusion by an intracoronary balloon, a linear relationship between \(F_{\text{FR}_{\text{coll}}}\) and the extent and severity of the ischemic defect. The absence of increase of \(F_{\text{FR}_{\text{coll}}}\) after revascularization of left coronary arteries suggests that the collateral flow toward the occluded right coronary artery is not significantly modified. This implies the necessity of revascularization of the occluded right coronary artery especially in the case of impaired inferior wall kinetics. In that way, that absence of variation of the \(F_{\text{FR}_{\text{coll}}}\) index could also suggest that the majority of the collateral flow to the right coronary artery originates proximal to the stenotic lesions of the left coronary arteries.

4.1. Study limitations and clinical implications

It is clear that this study needs more patients to confirm those results and to draw any conclusion about the requirement of a bypass graft on a chronic occluded artery. At the present time, a new series of patients is now being evaluated. The Rentrop grade was chosen in this work because of its long-term utilization, and also because our patients showed old chronic occlusions without possibility of recanalization to perform invasive measurements such as described by Werner et al. [14]. It would also be interesting to monitor the long-term course of left ventricular function after revascularization.

4.2. Conclusions

We did not demonstrate any relationship between collateral flow observed on coronary angiography and its functional nature evaluated by the \(F_{\text{FR}_{\text{coll}}}\) index in patients with three-vessel disease and chronic right coronary artery occlusion. However, this collateral flow can be estimated preoperatively on the basis of the strong linear relationship between \(F_{\text{FR}_{\text{coll}}}\) and LVEF. The absence of variation of \(F_{\text{FR}_{\text{coll}}}\) before and after left coronary artery revascularization suggests that grafting of the occluded right coronary artery is justified, but a definitive answer to this question would only be provided by direct measurement of coronary perfusion.

References


