

# Retrograde perfusion of coronary circulation

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(Ital Heart J 2000; 1 (Suppl 3): S37-S39)

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## History and present

At the end of 1800 Pratt<sup>1</sup> tested the efficacy of the perfusion of oxygenated blood in isolated cat s coronary sinus demonstrating the maintenance of mechanical function for more than 90 min. Another attempt was made in 1943 by Roberts with an autologous graft interposed between the descending aorta and coronary sinus. In 1959 Shumway stated some words which are still a real truth: The attractive of retrograde perfusion is that coronary circulation is not interrupted, also if it is inverted. A big quantity of arterious blood is wasted in the right atrium. Another disadvantage is the evidence of little backflow blood in the right coronary ostium, to indicate that left ventricle is perfused but not the right one. Some other important steps must be remembered:

Lillehei et al.<sup>2</sup> used retrograde perfusion in 1956 during aortic valve replacement in man, with direct cannulation of the coronary sinus;

Lolley et al.<sup>3</sup> in 1974 showed a complete recovery of cardiac function in the dog after hypothermic ischemic arrest with retrograde perfusion of glucose, insulin and potassium;

Menasche et al.<sup>4</sup>, in 1982, clinically reconsidered retrograde perfusion and/or cardioplegia to avoid coronary ostia lesions due to direct antegrade cannulation;

Buckberg<sup>5</sup> with various studies on myocardial perfusion showed the inefficacy of the antegrade route alone to protect the myocardium in the presence of diffuse coronary artery stenosis, suggesting the retrograde or the combined route for the infusion of cardioplegia.

During this long and slow phase of confirmation of retrograde perfusion in every-

day clinical practice, two problems have always been evident and are still present: the limitation of retroperfusion in protecting the right ventricle<sup>6-8</sup> and the presence of venovenous shunts (through the Thebesian system), which increase the non-nutritive flow<sup>9</sup>. Another technical problem is the rupture of the coronary sinus but this can be avoided in the majority of cases with a gentle technique if and whenever insertion is possible under direct vision.

At present the indications to the retrograde protection of the heart are the following: valve replacement or repair operations; severe coronary lesions or occlusions; left main disease; aortic valve incompetence; coronary reoperations; risk of embolization from coronary vessels or grafts; pediatric surgery.

## The venous system of the heart

The coronary sinus is the terminal collector of most of the cardiac veins: about 3 cm long and 10-15 mm wide, has a muscular longitudinal wall and ends in the right atrium. This orifice is usually surrounded by myocardial fibers and is valved (semilunar incompetent valve of Thebesius). It has various and variable tributary vessels:

vena cardiaca magna, drains the apex, anterolateral segments and interventricular septum; from the apex to the coronary sulcus;

left ventricular posterior vein: on the posterior aspect of the left ventricle, to the coronary sinus or to the vena cardiaca magna;

left atrial oblique vein: Marshall vein, drains the left atrium;

vena cardiaca media: posterior interventricular, satellite vein of the posterior descending artery;

vena cardiaca parva: along the acute margin of the heart;  
anterior cardiac veins: group of small veins which pass along the anterior wall of the right ventricle and flow into the right atrium; the bigger one is called Galeno's vein;

Thebesius veins: very small venous vessels which flow into the right atrium, the right ventricle and also into the left ventricle (sinusoids) from the thickness of the muscular wall.

### Embryology

In a study on quail hearts<sup>10</sup>, all the coronary vessels are endothelial-lined tubes. The vascular network is connected to the sinus venosus on the dorsal side of the heart from which it receives its blood. These connections will develop into the future coronary veins, connected to the coronary sinus. At the ventricular-arterial transition, a peritruncal ring of vessels is present around the great arteries. In a more advanced phase, two lumenized connections appear between the peritruncal ring and the two semilunar aortic sinuses facing the pulmonary artery. These two connecting vessels are the proximal stems of coronary arteries. From this stage onward this network will be supplied through the aorta. Other lumenized connections appear between the peritruncal ring and the ventral aspect of the right atrium. These vessels are the first stems of those veins that have a separate connection to the right atrium.

Thus the vascular network is supplied by the aorta and is drained via the sinus venosus and right atrium, allowing for direct artero-venous shunting via the peritruncal ring.

Due to this evolution, mainly anteriorly located coronary venous stems will be in contact with the right atrial lumen, while dorsally located coronary venous stems will flow into the coronary sinus, a sort of posterior extension of the right atrium.

The smooth muscle cells of the coronary arterial media derive from the subepicardial layer, whereas the subepicardially located cardiac veins recruit atrial myocardium.

### Flow distribution during retrograde cardiac perfusion

The anatomy of venous drainage of the heart consists in a major system (drainage to large and medium cardiac veins) and a minor system (sinusoids and Thebesius veins) which communicate with each other via a non-capillary network. The distribution of flow in both these networks is very variable and difficult to study. Various methods of visualization have been tested: resin-casting, angiography, staining, magnetic resonance<sup>11</sup> and contrast echocardiography<sup>12</sup>.

Regarding the problem of reduced perfusion of the ventricle, during retrograde cardiac perfusion the fact is that the major cardiac veins tributaries of the right ventricular flow are near the coronary sinus ostium: they are so excluded from retrograde perfusion because of the necessity to cannulate the sinus much deeper than the ostium level.

Buckberg<sup>5</sup> has shown that retroperfusion is influenced by vascular coronary resistances exactly like antegrade perfusion. The nutritive flow in the portion distal to an occluded left anterior descending artery is rather less than the one present if the artery is open. Nevertheless, the cooling is still present and also more effective. In coronary artery disease a higher number of artero-venous shunts is present in the myocardium, a fact that can lower the nutritive flow to the capillary bed even more.

The problem of myocardial edema seems to be due more to the composition than to the perfusion route of cardioplegia. Blood cardioplegia is surely more physiological, due to its rheological and biochemical characteristics which are closer to the normal ones<sup>13</sup>.

### Perfusion catheters

Many different types of perfusion cannulae have been produced until now, to cope with the variability of the anatomy of the coronary sinus, in order to better fit it in an atraumatic way. All these catheters are provided with a coaxial pressure line to monitor the infusion pressure, which should not exceed 50 mmHg. The insertion and positioning of the catheter can be made by an open or closed technique, depending whether the right atrium has an opening or not. In each case the cannulation of the coronary sinus is expected. The only technique to infuse cardioplegia without cannulation of the coronary sinus is the Fabiani technique, with the occlusion of caval veins and the infusion in the right atrium.

### Future lines

Some studies have presented an interesting point of view on the validity of venous coronary retroperfusion. Hochberg et al.<sup>14</sup> performed an *in vivo* revascularization of the satellite vein of the anterior descending artery, previously occluded. After some months, they demonstrated, first angiographically and then histologically, the normal perfusion of every layer of the myocardium, including the subendocardial one. Chiu and Mulder<sup>15</sup>, Park et al.<sup>16</sup> and Florian et al.<sup>17</sup> confirmed that the greatest selectivity for the protection of an ischemic myocardium by venous perfusion is when the venous anastomosis is performed on the satellite vein of the occluded artery, that is the closest vein to the occluded artery.

Other experiences<sup>5,18,19</sup> clearly indicate the positive effect of the continuous rather than intermittent infusion on myocardial protection.

All the studies suggest that retrograde coronary perfusion is a valid route to perfuse the myocardium, with a good distribution to all the myocardial layers.

To standardize this route two problems should be solved: the best way of infusion (intermittent or continuous) and the perfusion of the right ventricle (possibility of global perfusion of the coronary venous circulation).

In our opinion the future of this method of myocardial protection is strictly connected to innovative technical solutions capable of overcoming the present limitations.

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