Retrograde perfusion of coronary circulation

Giorgio Arpesella, Piero Maria Mikus, Marco Cirillo*, Carlo Savini, Sofia Martin Suarez, Angelo Pierangeli

Department of Cardiac Surgery, University of Bologna, Bologna, *Cardiac Surgery Division, Poliambulanza Hospital, Brescia, Italy

Address:
Prof. Giorgio Arpesella
Divisione di Cardios chirurgia
Dipartimento di Discipline Chirurgiche, Rianimazione e dei Trapianti
Università degli Studi Policlinico S. Orsola- Malpighi
Via Massarenti, 9
40138 Bologna

History and present

At the end of 1800 Pratt1 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 arterial 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.2 used retrograde perfusion in 1956 during aortic valve replacement in man, with direct cannulation of the coronary sinus; Lolley et al.3 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.4, in 1982, clinically reconsidered retrograde perfusion and/or cardioplegia to avoid coronary ostia lesions due to direct antegrade cannulation;

Buckberg5 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 everyday clinical practice, two problems have always been evident and are still present: the limitation of retroperfusion in protecting the right ventricle6-8 and the presence of venovenous shunts (through the Thesbian system), which increase the non-nutritive flow9. 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 Thesbian). 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 in
to the left ventricle (sinusoids) from the thickness of the
muscular wall.

Embryology

In a study on quail hearts\(^\text{10}\), 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 lumen-
ized 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 con-
nection to the right atrium.

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

Due to this evolution, mainly anteriorly located coro-
nary 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 ex-
tension 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 my-
ocardium.

Flow distribution during retrograde cardiac
perfusion

The anatomy of venous drainage of the heart consists
in a major system (drainage to large and medium car-
diac veins) and a minor system (sinusoids and Thebe-
sius 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. Var-
ious methods of visualization have been tested: resins-
casting, angiography, staining, magnetic resonance\(^\text{11}\)
and contrast echocardiography\(^\text{12}\).

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 ven-
tricular flow are near the coronary sinus ostium: they are
so excluded from retrograde perfusion because of the ne-
cessity to cannulate the sinus much deeper than the os-
tium level.

Buckberg\(^\text{5}\) has shown that retroperfusion is influ-
enced 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 coro-
nary 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 seems to be surely more
physiological, due to its rheological and biochemical char-
acteristics which are closer to the normal ones\(^\text{13}\).

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 pres-
sure, 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 atri-
um 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.\(^\text{14}\) performed an in vivo revascularization
of the satellite vein of the anterior descending artery, pre-
viously occluded. After some months, they demon-
strated, first angiographically and then histologically, the
normal perfusion of every layer of the myocardium,
including the subendocardial one. Chiu and Mulder\(^\text{15}\),
Park et al.\(^\text{16}\) and Florian et al.\(^\text{17}\) confirmed that the great-
est selectivity for the protection of an ischemic my-
ocardium by venous perfusion is when the venous anas-
tomosis is performed on the satellite vein of the occluded
artery, that is the closest vein to the occluded artery.

Other experiences\(^\text{5,18,19}\) 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.

References

1. Pratt FH. The nutrition of the heart through the vessels of Thebesius and the coronary veins. Am J Physiol 1898; 1: 86.