

A Technique for Aortic Valve Replacement on the Beating Heart With Continuous Retrograde Coronary Sinus Perfusion With Warm Oxygenated Blood

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The protection of ventricular myocardium in aortic valve operations is always an issue because those hearts do not tolerate global ischemia well. A technique of aortic valve replacement is described involving continuous retrograde coronary sinus perfusion with warm oxygenated

blood used in 34 patients to date without any complications. This technique maintains a beating heart throughout the procedure.

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The classic technique of aortic valve replacement consists of cardiopulmonary bypass (CPB), aortic cross-clamping, and use of cardioplegia. The type of incision, complete or partial sternotomy, small thoracotomy, and use of vacuum-assisted venous drainage has added some variety to the procedure; however, in reality the basics of the procedure have not changed. The use of continuous antegrade coronary artery perfusion in the patients after previous coronary revascularization with patent left internal mammary artery graft [1] despite the fact that enables beating heart surgery in reality has not changed the basic concept. We describe the alternative technique that can be used in all the patients including patients in whom the cardioplegic cardiac arrest may not protect all regions of the heart adequately. Furthermore, this technique can be used in combined cases, in which coronary artery revascularization is also necessary.

Technique

In all the operations normothermic (37°C) CPB with aortic and double venous cannulation is used. A vent is placed in the ascending aorta, close to the aortic cannulation site.

Two minutes after CPB has started, another vent is placed into the left ventricle through the right superior pulmonary vein [2] and caval tourniquets are applied. The 1 cm cut from the atrioventricular sulcus, close to the inferior vena cava, parallel to it, is performed, opening the right atrium and exposing the coronary sinus (CS)

opening. From outside the right atrium the 4-0 polypropylene purse suture around the CS ostium is made, a retrograde cannula is inserted, a tourniquet is applied, and a catheter is connected with retrograde oxygenated blood perfusion line. The cut made previously is held back with 3-0 polypropylene suture.

While aortic and left ventricular vents are draining the heart maximally, the aorta is clamped and retrograde CS perfusion is started simultaneously (for the first 30 seconds from 0 to 100 mL/min, then increased to around 300 to 500 mL/min), giving a retrograde mean pressure of 50 to 60 mm Hg [3].

When the situation is stable (empty beating heart, usually after 1 minute), the aorta is opened 1 cm above the right coronary artery ostium in an "L" fashion, going down to the middle of the noncoronary sinus.

Then the operation proceeds as in any aortic valve operations. The backflow coming from the left and right coronary ostia flows into the left ventricle where the vent empties the heart. When suturing around the coronary ostia, a small soft vent is placed into the corresponding coronary artery returning blood back to the CPB pump.

At the end of the operation, air is removed from the heart through the aortic vent (the procedure is quick, because the left ventricle is not fully empty), the retrograde perfusion is stopped, and the aorta is declamped. The CPB is shut off after cardiac performance is restored to give reasonable systemic pressures and the cannulas are removed in standard fashion.

Comment

For all patients, the electrocardiogram (ECG) signal is under careful observation during the retrograde oxygenated CS perfusion—normally the regular rhythm mimicking the sinus rhythm (50 to 80 beats per minute) is present during the retrograde perfusion with the

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clamped aorta, if the patient was in sinus rhythm before operation.

In patients with atrial fibrillation before operation, the same but irregular frequency (50 to 80 beats per minute) can be observed. We have not observed any serious ventricular arrhythmias (ventricular fibrillation, ventricular tachycardia) except an occasional premature ventricular contraction. Adequate CS perfusion is vital to prevent ventricular arrhythmia. The retrograde CS perfusion rate should always be more than 300 mL/min, yielding a mean pressure of around 50 to 60 mm Hg.

The retrospective analyses of ECG, comparing preoperative with postoperative ECG on day 1, as well as before discharge, did not show any signs of myocardial infarction. Some studies even showed [3] that the coronary sinus can withstand a somewhat higher pressure well during retrograde cardioplegia and, hence, during retrograde heart perfusion as well.

The use of retrograde coronary sinus perfusion with warm oxygenated blood is a completely new concept, which is changing the basis of myocardial protection, and may help to finally solve the problem of inadequate right ventricular protection during retrograde cardioplegia. It was not our intention to demonstrate the superiority of this procedure over other cardioplegic techniques in this report with our limited number of cases, but to show certain advantages over conventional methods.

The direct coronary artery perfusion [1] has potential dangers and limitations: in calcified aortas the ostia of the coronaries may be compromised, and this technique cannot be used with ease in combined cases (with coronary pathology) without a limited amount of potential ischemia.

We can see in the myocardium in cardiosclerosis, as well as during experimental ischemia and hypoxia, that there exists a paradox: the inflow diminishes while the backflow increases [4]. In reality the expansion of the venous channel compensates for the deficiency of the arterial vascularization of the blood supply, bringing nutrients to the myocardium by retrograde blood flow. With age capillary net of the myocardium becomes sparser and sinusoids become wider and more prominent. Venous system of myocardium begins in the sinusoids, and their walls contain endothelium as well as basal membrane. Our technique of cardiac surgery on the beating heart is giving the oxygenated blood retrograde, through the coronary sinus, in fact to the most important reservoir of the damaged myocardium.

The problem of right ventricular protection, either during the retrograde cardioplegia or during the retrograde coronary sinus perfusion with warm oxygenated blood, is a defined problem in the literature [1]. However, in comparison with other techniques, our technique has important differences that minimize this risk. First, we use the purse string cannulation technique of the coronary sinus, where the catheter is positioned at the ostium of the coronary sinus, giving blood to both right and left venous systems. Second, we are always inspecting the adequate filling of the veins of the right ventricle and when the aorta is opened, the backflow from both the

ostia can be seen clearly. Furthermore, the warm blood vasodilates the venous system of the heart, so the flow can and must be increased to obtain the mean pressure of 50 mm Hg. In hypertrophied ventricles the adequate flow can be as much as 500 mL/min. The studies of vascular arrangements and relationships comparing arrested and beating heart [4] have shown that during a heartbeat the contractions of the ventricular musculature in fact are distending the vascular bed and further reduce the flow resistance, enabling better myocardial perfusion.

We have used this technique of aortic valve replacement with retrograde coronary sinus perfusion in 34 patients to date without any complications (no mortality, no cardiovascular incidents). It should be emphasized that retrograde return of blood to coronary orifices did not impair the operative view during our surgery. It was important to have a vent in the left ventricle taking the blood coming from the ostia away.

The aorta was cross-clamped between 25 and 48 minutes, with the total bypass time of 32 and 55 minutes. The aortic cross-clamp time is not the ischemic time, because the heart was receiving the blood all the time.

We have compared the blood samples going into the coronary sinus catheter (arterial blood) with samples coming from the coronary ostia in limited number of cases. The difference of lactate production was compared in patients operated on in cardioplegic arrest. Preliminary data suggest smaller difference in the beating heart group; however, the absolute values of lactate production are higher (which is reasonable, because the heart is beating). The CPB times are in fact extremely short, due to a fast weaning from the CPB in this group of patients, in whom the performance of the ventricles is not in question.

In all the cases we were able to stop CBP 5 to 8 minutes after cross-clamp removal. Perhaps one of the advantages of this technique is the ease of weaning patients from CBP and use in patients with impaired left ventricular function [5]. We have shown previously that this technique in other types of operations reduces the aortic cross-clamp time and duration of CPB [5].

The coronary sinus perfusion flow was usually between 300 and 500 mL/min (600 mL/min in 1 patient). In 2 patients (when we started to use this technique) we had to defibrillate the heart (because of inadequate retrograde coronary sinus flow—after defibrillation and increase of blood flow, the heart restored the normal rhythm). In 1 patient with extremely narrow aortic annulus an annular enlargement has been done without any intra- or postoperative complications.

In conclusion, we believe that continuous retrograde coronary sinus perfusion with warm oxygenated blood and aortic cross-clamping is a safe, effective method of aortic valve replacement and if performed with care a technically nondemanding and simple operation.

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