

Aortic and Mitral Valve Surgery on the Beating Heart is Lowering Cardiopulmonary Bypass and Aortic Cross Clamp Time

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Borut Gersak¹, MD, PhD, Zeljko Sutlic², MD, PhD

¹Department of Cardiovascular Surgery, University Medical Center, Ljubljana, Slovenia

²Department of Cardiovascular Surgery, University Medical Center, Zagreb, Croatia

ABSTRACT

Objective: The concept of cardiac surgery on the beating heart is acceptable rationale for the cardiac surgery in the next millennium. Beating heart (off-pump) coronary artery bypass grafting (CABG) techniques have led us to consider the possibility for performing the aortic and mitral valve surgery (mitral valve repairs and replacements - with or without CABG) on the beating heart with the technique of retrograde oxygenated coronary sinus perfusion.

Methods: We used the technique of retrograde oxygenated blood coronary sinus perfusion in 78 patients (Group All) - (36 patients were with extremely low ejection fraction (Group X) - 62% of whom were in New York Heart Association (NYHA) class 4 and 34% of whom were in NYHA class 3). The procedures for the patients were: aortic, mitral and tricuspid valve surgery, in combination with CABG in ischemic patients. CABG was done in all the cases off-pump. In addition, we performed a case match study for 37 patients with good ejection fraction (51.65 ± 11.88) (Beating Heart Group) operated on the beating heart with most appropriate group of patients (No. 37) operated in our institutions on arrested heart (ejection fraction 51.07 ± 12.93) (Arrested Heart Group). The case match selection criteria were: gender, left ventricular ejection fraction, atrial fibrillation, hypertension, pulmonary hypertension, and diabetes. The selected beating heart group and selected arrested heart groups were without statistically significant differences for the mentioned criteria.

Results: There were statistically significant differences between Beating Heart Group and Arrested Heart Group in the duration of Cardiopulmonary Bypass Time (69.35 ± 13.52 min. versus 93.59 ± 28.54 min.), $p < 0.001$, and statistically significant differences in Aortic Cross Clamp Time (46.5 ± 8.95 min. versus 61.5 ± 18.34 min.), $p < 0.001$. The values for Creatinin Kinase (CK) and LDH were not statistically different, however the absolute values for Beating Heart Group were lower. There was no statistical difference in

complication rate for both the groups for: sternal infection, bleeding, death, atrial fibrillation, AV block and neurological complications.

The total early mortality for all the patients was 5.1% (4 out of 78) - for the group X 8.3 % (3 of 36 patients). Two were in-hospital deaths. One patient with triple-vessel disease and acute mitral insufficiency on intra aortic balloon pump (IABP) had been operated on 6 days after acute myocardial infarction (AMI). The cause of the death was systemic meti-cillin resistant staphylococcus aureus (MRSA) infection - (eight days prior to our operation, arthrodesis of the talocrural joint was performed by an orthopedic surgeon). The other death was a female patient who was operated on after previous multiple cerebrovascular infarctions (CVI) (cause of the death was CVD). In addition, one patient died one month after the operation because of prosthetic valve endocarditis (PVE) on aortic and mitral valves (silver-coated silzone aortic and mitral valves were implanted because of chronic latent asymptomatic tibial osteitis). None of these deaths were cardiac related.

Conclusions: We conclude that beating heart valve surgery (any combination) with or without CABG significantly lower the cardiopulmonary bypass and aortic cross clamp time.

In addition, the advantages of beating-heart surgery are 1) the perfused myocardial muscle, 2) the heart is not doing any work, 3) no reperfusion injury, 4) the possibility for ablation of atrial fibrillation on the beating heart, and 5) testing of the mitral valve repair is done in real physiologic conditions in the state of left ventricle beating tonus. The procedure could be the procedure of choice for the valve operation or combined operations (valve operation and CABG) in high-risk patients with low ejection fractions.

There is no doubt that at present day in cardiac surgery exist at least two major factors for mortality and morbidity after cardiac surgery, which are operation - related, namely cardiopulmonary bypass time and its duration and aortic cross clamp time (ischemic time of myocardium). In the last few years a number of different techniques emerged in the field of cardiac surgery, which were directed toward better results in the selected high risk patients or to minimize the deleterious effects of cardiopulmonary bypass (CPB) on the overall postoperative performance [Calafiore 1996, Tasdemir 1998]. Due to the fact, that the cardiac muscle should be protected at most during the cardiac arrest, retrograde blood

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Address reprint requests to Dr. Borut Gersak, Department of Cardiovascular Surgery, University Medical Center, Zaloska 7, 1000 Ljubljana, Slovenia, Phone + Fax.: + 386 1 4334 162, E-mail: borut.gersak@maat.sj.

cardioplegia was successfully introduced [Buckberg 1990], and more – the warm cardioplegia is being used recently [Kawasuji 1997]. The natural status of the human heart is the beating status, so it is reasonable to try to perform the operations on the beating heart. This has been done recently with the MID – CAB and OP – CAB (off-pump CABG) operations [Tasdemir 1998]. The retrograde warm blood cardioplegia has therefore led us to the premise, that with retrograde oxygenated blood perfusion it would be possible to achieve the operations on the beating heart even in the open heart surgery, such as aortic and/or mitral valve surgery. All will agree that the most damaging effect of the cardioplegia is the reperfusion injury [Allen 1997], and it is obvious that with the technique of retrograde continuous oxygenated blood perfusion this effect will be canceled. In this article, we would like to show the how-to technique for the operations on the beating heart in the case of operations on the aortic valve replacement (AVR) with mitral valve repair (MVR) or replacement MVR and with/without concomitant coronary artery bypass (CABG) surgery.

The tricuspid valve repair (PTV) is normally done on the beating heart and there it is realized what problems or technical difficulties may arise during procedures on the mitral valve: the walls of the ventricles are not flattened and the exposure of the mitral valve is challenging task. Furthermore, the free walls of the ventricles with interventricular septum are in the state of the tonus, so every force applied to better expose the aortic or mitral valve is not acceptable.

MATERIAL AND METHODS

Technique

In all the operations normothermic (37° C) cardiopulmonary bypass (CPB) is used with warm (37° C) oxygenated retrograde blood coronary perfusion.

Valve procedures with CABG

The first step is the normal CPB connection (double J-cannula and the cannulation is bi-caval as for the cardiac transplantation).

First all the distal anastomoses of the diseased coronary arteries are performed on the beating heart [Tasdemir 1998] (regional stabilization is used if necessary). The CPB is not started till all the distal anastomoses for CABG are performed. The LIMA to LAD is performed first, then the LCX region, and RCA region is done last. After each of the venous distal anastomoses the graft is connected with the oxygenated blood perfusion, so that the arterialized blood enters the coronary circulation. The caution is paid to the pressure in these grafts, not too much on the flow, where the mean pressures over 60 mm Hg are avoided.

When all the distal anastomoses are performed, vent in aorta is placed and CPB is started.

Valves

Once CPB has started, the patient is placed in the Trendelenburg position during the placement of the vent into the left ventricle through the right superior pulmonary vein.

With this vent in place, the patient will be placed in the horizontal position again.

Total CPB is obtained, enabling the empty right atrium (RA). The RA is dissected as much as possible from the left atrium (LA) in-between the interatrial sulcus. The 1 cm cut from the atrioventricular sulcus, parallel to it, is performed, opening the RA and exposing the coronary sinus (CS) opening. From outside the RA the 4/0 polypropylene purse suture around the CS ostium is made, retrograde cannula is inserted, tourniquet applied, and catheter connected with the retrograde oxygenated blood perfusion line.

Both the vents (aortic and left ventricular) are maximally draining the heart while simultaneously the aorta is clamped and retrograde CS perfusion is started around 300 ml/min, giving retrograde mean pressure of 50 – 60 mm Hg [Eke 1997].

The incision parallel to the interatrial septum is made in the LA, exposing the LA where the good visualization of the interatrial septum is obtained from both sides. The vertical cut, starting from the mid-part of the RA to the septum and through the fossa ovalis is made, [Brawley 1980], but our incision goes 45 degrees toward the CS, preserving the CS and retrograde perfusion, giving the typical H-V appearance (Figure 1, ●). The hooks are applied with ease giving excellent exposure of the mitral valve. The mitral valve procedure is then performed, and if the PMV is made, the testing on the beating heart is done. The left ventricle is filled with saline, the aortic pressure is registered through the aortic vent, and the necessary corrections of the mitral valve are finalized. The aortic vent is then opened, the heart is emptied in full, and a vent is inserted in the left ventricle through the mitral valve or if necessary through the apex (if the MVR was done the AVR will be done next). The excision of the left auricle is performed with two layered 4/0 continuous suture if the LA is enlarged or the patient is in AF. The continuous 3/0 polypropylene suture starts at the fossa ovalis, closing the interatrial septum. Left atrium is sutured from the cranial part toward the end of the atrial cut, reducing the LA. Next the RA is closed, and if the patient is in AF the right auricle is removed with two layered 4/0 continuous suture.

Aorta

At this time the aorta is opened 1 cm above the right coronary artery ostium in a L-fashion, going down to the mid of the non-coronary sinus. This type of incision is important because the right ventricle otherwise blocks the view of the aortic valve. Then the operation is proceeding as in any of the aortic valve operations. If the CABG was performed, the aorta is still clamped when the proximal anastomoses are performed one by one, the retrograde perfusion is not stopped and also the CABG grafts which are not sutured to the aorta still receive the oxygenated blood antegrade. Then the proximal parts of the grafts are clamped with bulldog clamps, the heart is de-aired through the aortic vent (the procedure is quick, because the left ventricle is not fully empty), the retrograde perfusion is stopped and aorta is declamped. At this time the grafts are freed from the bulldog clamps after deairing with insulin needle. The anastomotic sites are examined for bleeding and at the end retrograde sinus catheter is removed.

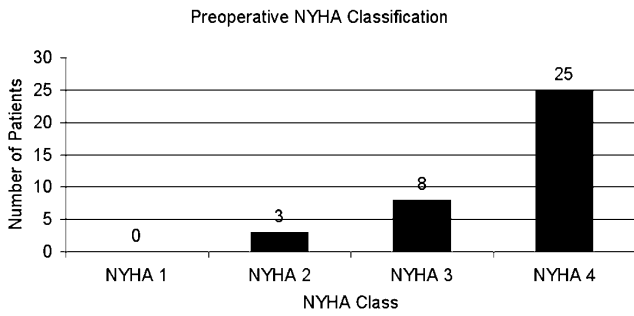


Figure 2. Preoperative NYHA classification of the patients in high risk group (Group X) where aortic and mitral valve surgery was done on a beating heart.

The CPB is shut off after cardiac performance is restored to give reasonable systemic pressures and the cannulas are removed in standard fashion.

Patients

We used the technique of retrograde coronary sinus perfusion in 78 patients (Group All). Thirty-six patients had low ejection fraction and high NYHA class, and they were additionally analyzed separately as Group X. Their characteristics are shown in Figure 2; 69% were in NYHA class 4 and 22% in NYHA class 3.

In addition, we performed a case match study for 37 patients with good ejection fraction (51.65 ± 11.88) (Beating Heart Group) operated on the beating heart with most appropriate group of patients (No. 37) operated in our institutions on arrested heart (ejection fraction 51.07 ± 12.93) (Arrested Heart Group). The case match selection criteria were: gender, left ventricular ejection fraction, atrial fibrillation, hypertension, pulmonary hypertension, and diabetes. The selected beating heart group and selected arrested heart group was without statistically significant differences for the mentioned criteria (Table 1).

Procedures for high-risk group

The procedures for Group X were: aortic valve (and CABG) – 6 patients, double and triple valves (and CABG) – 17 patients, mitral and tricuspid (and CABG) – 13 patients (Figure 3).

Mean age of the patients was 61.14 ± 11.12 years (mean \pm standard deviation).

RESULTS

Case Match Study

Perioperative data for the Beating and Arrested Heart Group are shown in Table 2. There was statistically significant difference in the duration of cardiopulmonary bypass and aortic cross clamp time ($p < 0.001$) in favor of Beating Heart Group.

Complication rate for both the case matched groups are shown in Table 3. There was no statistically significant difference for any of the studied parameters.

High-risk group

Mean Cardiopulmonary Bypass Time (CPBT) was 91.12 ± 29.19 minutes, mean Aortic Crossclamp Time (AXT) was 60.20 ± 22.52 minutes, mean Creatin Kinase (CK) on the day 1 was 11 ± 8.4 , mean CK – MB fraction of CK (MB) on the day 1 was 0.05 ± 0.03 and the mean flow through the coronary sinus was 415.25 ± 101.34 ml/minute or 26810 ± 14740 liters for the whole procedure.

We had three deaths out of the 36 patients operated. Two were hospital deaths: one in the patient operated 6 days after acute myocardial infarction (8 days prior to our operation arthrodesis of the talocrural joint was performed by orthopedic surgeon), with triple vessel disease and acute mitral insufficiency on IABP (cause of the death was systemic meticillin resistant Staphylococcus Aureus infection); second was a lady with previous multiple cerebrovascular infarctions (CVIs) (cause of the death was CVI at the date of discharge). In addition, we lost one patient one month after the operation because of Prosthetic Valve Endocarditis (PVE) on aortic and mitral valve (silver coated Silzone aortic and mitral valves were implanted because of chronic latent asymptomatic tibial osteitis). None of these deaths was cardiac related.

Total mortality for all the patients was 4 out of 78 (5.1 %).

DISCUSSION

The vital part of the procedure is the good exposure of the aortic and mitral valve as a whole, because only with good visualization the testing of the mitral valve on the beating heart can be done after repair. This is the reason that the venae cavae are cannulated with two J-cannulas for the cardiac transplantation, because with this type of cannulation the exposure is excellent, and the reduction of the left and RA, or even modified Maze III procedure, can be done with ease to prevent AF.

The 3D visualization of the mitral valve under physiologic conditions (beating heart, appropriate tonus, left ventricle contractions optimized with intracavitary saline and resulting aortic blood pressure monitoring) gives the surgeon excellent possibility to determine the cause of mitral valve problems and reconstruction of the mitral valve is optimal.

Table 1. Selection criteria for case matched study (values are mean \pm sd).

| | Beating Heart Group | Arrested Heart Group | p value |
|------------------------|---------------------|----------------------|---------|
| Number | 37 | 37 | 0.953 |
| Male | 21 | 21 | 1 |
| Female | 16 | 16 | 1 |
| Ejection fraction | 51.65 ± 11.88 % | 51.07 ± 12.93 % | 0.855 |
| Atrial fibrillation | 11 | 10 | 0.797 |
| Arterial hypertension | 15 | 13 | 0.632 |
| Pulmonary hypertension | 17 | 15 | 0.639 |
| Diabetes | 4 | 4 | 1 |
| CVI | 3 | 2 | 0.643 |

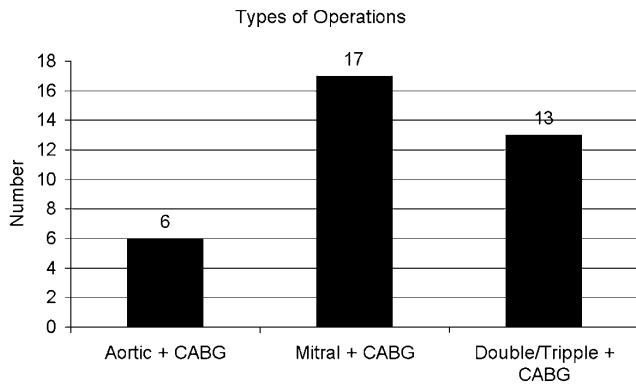


Figure 3. Types of procedures where beating heart valve surgery was done with the oxygenated blood coronary sinus perfusion in high-risk group (Group X).

In all the patients, the EKG signal is under careful observation during the retrograde oxygenated CS perfusion – normally the regular rhythm mimicking the sinus rhythm (50–80 beats per minute) is present during the retrograde perfusion with the clamped aorta, if the patient was in sinus rhythm prior to operation. In the patients with AF prior to operation, the same but irregular frequency (50–80) can be observed. We have not faced any serious ventricular arrhythmia (VF, VT), except of occasional PVC – the vital part to prevent ventricular arrhythmia is adequate CS perfusion. The retrograde CS perfusion should always be above 300 ml/min, giving the mean pressure around 50–60 mmHg. Lowering of the blood pressure after the operation is often necessary with vasodilator agents in continuous infusion.

Retrograde cardioplegia through the coronary sinus is routine today and it is generally accepted that the coronary sinus (vein system) can safely accept pressures between 50 and 60 mm Hg [Eke 1997]. The values have been observed experimentally on a beating heart, which functioned with ligation of the coronary sinus and blood flow to both coronary arteries and veins.

In experiments on an unburdened and still heart (which does not function), with pressures between 40 to 120 mmHg in the coronary sinus, presence of extra vascular bleeding on serial slices of the right and left ventricle has not been noticed. Under microscopic analysis, the slices have shown a normal presence and preservation of the structure of the heart [Gill 1977]. These studies show that the coronary sinus can withstand a somewhat higher pressure quite well during retrograde cardioplegia and, hence, during retrograde heart perfusion as well.

In approximately 50% of the patients we need to monitor the blood pressure postoperatively through the femoral artery catheter, because the values from the radial artery catheter were not in agreement with the noninvasive pressure measurements (radial arterial pressure measurements 20–50 mm Hg lower). The reason is perhaps in all the patients the continuous nor – adrenaline infusion (around 0.01 microg/kg/min) during CPB was used to obtain the mean radial pressure 60–70 mm

Hg, because the CPB is pure normothermic all the time, giving vasodilation throughout the body.

We believe that warm cardiopulmonary bypass with warm oxygenated blood coronary sinus perfusion and aortic cross clamping is a good choice for the repair of the mitral valve, aortic valve replacements and complex operations such as concomitant CABG. With this technique, there is practically no risk of air embolization. Furthermore, if the patients are in AF, beside surgical treatment also intraoperative ablation and testing can be performed, giving the ablative procedure more chance to be really effective.

The study of coronary blood flow in patients undergoing the CABG operation obtained after a period of global myocardial ischemia with blood cardioplegia shows the steady fall of the coronary artery blood flow for the first 8 to 10 minutes of the reperfusion as the coronary resistance rose [Digerness 1988]. In this study the coronary blood flow dropped from 300 ml/min to the very low 50 ml/min after controlled reperfusion.

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 [Djavakhshvili 1997].

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. What was not present in our minds is that 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 wall contains endothelium as well as basal membrane. Our technique of cardiac surgery on the beating heart for the procedures on valves is pure normothermic, oxygenated blood with the constant retrograde coronary sinus perfusion. By giving the oxygenated blood retrograde, via coronary sinus, we are in fact giving blood to the most important reservoir of the damaged myocardium.

However, not only is this the advantage of the beating heart – the three dimensional architecture of the beating heart is giving direct opportunity to examine the mitral valve under physiologic conditions before, during and after completion of the repair. The commonly employed techniques permit inspection of the valve in flaccid, arrested state, which may not accurately reflect its function in the contractile heart.

The study of our patients, operated with the beating heart technique shows that in overall population the car-

Table 2. Perioperative data for the Beating and Arrested Heart Group (values are mean ± sd, in brackets minimal – maximal value).

| | Beating Heart Group | Arrested Heart Group | p value |
|------|---------------------|----------------------|---------|
| CPBT | 69.35 ±13.52 min. | 93.59 ± 28.54 min. | < 0.001 |
| AXT | 46.5 ± 8.95 min. | 61.5 ± 18.34 min. | < 0.001 |
| LDH | 424.88 ± 147.02 | 425.89 ± 132.53 | 0.977 |
| CK | 69 (14 – 754) | 115 (18 – 1035) | 0.153 |

Table 3. Complication rate for both the case matched groups.

| | Beating Heart Group | Arrested Heart Group | p value |
|----------------------------|---------------------|----------------------|---------|
| Superficial Infection | 4 | 4 | 1 |
| Bleeding | 1 | 4 | 0.165 |
| Atrial Fibrillation | 4 | 4 | 1 |
| AV block | 1 | 0 | 0.314 |
| Neurological complications | 1 | 1 | 1 |
| Death | 1 | 2 | 0.555 |

diopulmonary bypass and aortic cross clamp time are shorter. In fact, when we speak of aortic cross clamp time this in fact is not ischemic time of myocardium – because the heart is perfused with blood, it is the time of coronary sinus perfusion. It can be postulated that this technique will be of great value in those cases, where long extra corporeal perfusion time with long ischemic time is expected – valve cases in combination with CABG. In those cases CABG can be done off-pump (no cardiopulmonary bypass and arrest at this time) and on valves of the beating heart (no cardiac arrest, shorter cardiopulmonary bypass time).

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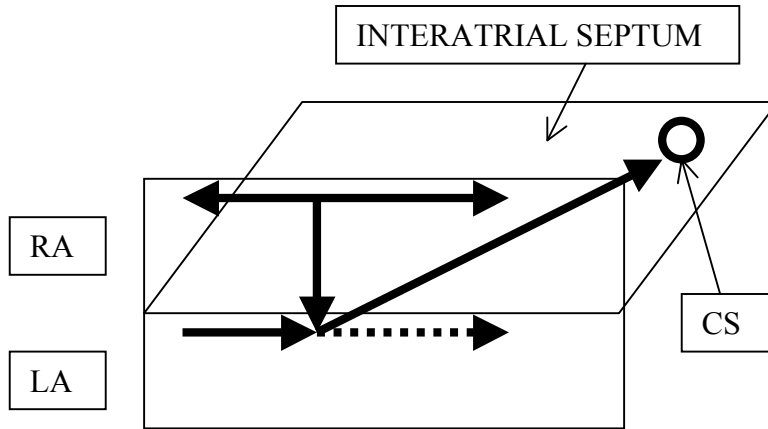


Figure 1. Incisions in the right (RA) and left atrium (LA), and through interatrial septum toward coronary sinus (CS). Arrows are giving the direction of incisions, incision represented with dashed line is used if the exposure is still not good or if antiarrhythmic operation is performed, opening the LA in full.