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Mitral Valve Repair or Replacement on the Beating Heart

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Borut Gersak, MD, PhD

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

Dr. Gersak

ABSTRACT

Background: Beating heart (off-pump) coronary artery bypass grafting (CABG) techniques have led us to consider the possibility of performing mitral valve repairs and replacements (with or without CABG) on the beating heart.

Methods: If CABG had to be performed in addition to the valve procedure, CABG was done first on the beating heart without cardiopulmonary bypass, if possible. For the valve procedure, the aorta was cross-clamped and the beating-heart status was maintained throughout the whole procedure with continuous, warm, oxygenated blood coronary-sinus perfusion.

Results: We used this technique in 23 patients with extremely low ejection fractions, 78% of whom were in New York Heart Association (NYHA) class 4 and 17% of whom were in New York Heart Association (NYHA) class 3. The procedures were: mitral-tricuspid (11 patients), mitral-aortic (7 patients), mitral-tricuspid CABG (1 patient), and mitral-aortic CABG (4 patients). The total early mortality was 13% (3 of 23 patients). Two were in-hospital deaths. One patient with triple-vessel disease and acute mitral insufficiency (AMI) on intra aortic balloon pump had been operated on six days after AMI. The cause of death was systemic methicillin resistant staphyloccocus aureus infection. The other death was a female patient who was operated on after previous multiple cerebrovascular infarctions (CVIs) (cause of the death was CVI). In addition, one patient died one month after the operation because of prosthetic valve endocarditis 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: The main advantages of beating heart surgery are: 1) the perfused myocardial muscle, 2) the heart 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 in high-risk patients with low ejection fractions.

INTRODUCTION

Retrograde blood cardioplegia was successfully introduced [Buckberg 1990] to protect the cardiac muscle, especially during cardiac arrest, and has been used recently in cardiac surgery [Kawasuji 1997]. Also, minimally invasive direct coronary artery bypass (MIDCAB) and off-pump coronary artery bypass (OPCAB) operations on the beating heart have been performed recently [Tademir 1998]. With these successful cardiac procedures in mind, we were led to the premise that with retrograde oxygenated blood perfusion, it would be possible to perform operations on the beating heart, even in open heart surgery such as aortic or mitral valve surgery. Everyone would agree that the most damaging effect of the cardioplegia is reperfusion injury [Allen 1986]. It was obvious to us that retrograde continuous oxygenated blood perfusion would cancel this effect.

The tricuspid valve repair (PTV) is normally performed on the beating heart, and it is from an operation like PTV that we may realize what problems or technical difficulties may arise during a mitral valve procedure; the walls of the ventricles are not flattened and the exposure of the mitral valve is a challenging task.

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Address correspondence and reprint requests to: Borut Gersak, MD, PhD, Department of Cardiovascular Surgery, University Medical Center, Zaloska 7, 1000 Ljubljana, Slovenia, Phone/Fax: + 386 61 1334 162, Email: borut.gersak@maat.si

Table 1. Characteristics of patients in whom mitral valve repair or replacement was performed on the beating heart

Patient No.	NYHA Classification	Age, y	Sex	Procedure
1	4	62	M	PVM, AVR, RCA
2	4	68	F	MVR, PVT, VVI
3	4	76	F	PVM, AVR, RCA, LAD, LCX M1
4	4	72	F	PVM, AVR
5	4	65	M	MVR, AVR, RCA
6	4	66	M	PVM, AVR
7	4	67	F	PVM + resection PML
8	3	67	M	MVR, PVT
9	4	47	F	MVR, AVR
10	4	53	F	MVR
11	4	66	F	PVM, PVT
12	4	65	M	MVR, PDA, LAD, LCX M2
13	3	51	M	PVM
14	2	69	F	MVR, PVT
15	3	62	M	MVR, AVR, RCA
16	3	77	M	MVR, AVR, PVT
17	4	66	F	MVR, AVR
18	4	62	M	PVM, AVR
19	4	31	F	PVM
20	4	47	M	MVR
21	4	35	M	PVM, AVR + root enlargement
22	4	66	M	PVM + resection PML
23	4	49	M	MVR, PVT

NYHA, New York Heart Association; PVM, mitral valve repair; AVR, aortic valve replacement; RCA, right coronary artery; MVR, mitral valve replacement; PVT, tricuspid valve repair; VVI, insertion of VVI pacemaker; LAD, left anterior descending coronary artery; LCX M, marginal branch of the circumflex artery; PML, posterior mitral leaflet; PDA, posterior descending artery.

MATERIALS AND METHODS

Operation

Total cardiopulmonary bypass (CPB) is used to obtain an empty right atrium (RA). The RA is dissected as much as possible from the left atrium (LA) between the interatrial sulcus. An incision is made 1 cm from and parallel to the atrioventricular sulcus, opening the RA and exposing the coronary sinus (CS) opening. From outside the RA, the 4/0 polypropilene purse suture is made around the CS ostium and a retrograde cannula is inserted, a tourniquet is applied, and a catheter is connected with the retrograde oxygenated blood perfusion line (see Movie 1, ◎).

Both vents (aortic and left ventricular) maximally drain the heart while, simultaneously, the aorta is clamped and retrograde CS perfusion is started at a rate of approximately 300 mL/min, giving a retrograde mean pressure of 50 to 60 mm Hg [Eke 1997].

The incision parallel to the interatrial septum is made in the LA, exposing the LA and providing good visualization of the interatrial septum from both sides. The vertical cut, starting from the middle of the RA is made to the septum, toward and through the fossa ovalis, similar to that proposed earlier [Brawley 1980]. However, our incision is made in the direction of 45 degrees toward the CS, preserving the CS and the retrograde perfusion, and giving the typical H–V appearance. Hooks are then easily applied giving excellent exposure of the mitral valve. The procedure on the mitral valve is then performed and, if the mitral valve repair is made, 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 for the mitral valve are finalized. The aortic vent is then opened, the heart is emptied in full, and the vent is inserted in the left ventricle through the mitral valve or, if necessary, through the apex. At this point, if mitral valve replacement was performed, the aortic valve replacement can be done next. The excision of the left auricle is performed with two layered 4/0 continuous sutures if the LA is enlarged or if the patient is in atrial fibrillation (AF). A continuous 3/0 polypropylene suture, starting at the fossa ovalis, is used to close the interatrial septum. The left atrium is sutured from the cranial portion 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, closing with two layered 4/0 continuous sutures.

Patients

At the time of introducing the technique of beating-heart valve procedures, we performed this operation on patients with extremely low ejection fractions and high NYHA class. Their characteristics are shown in Table 1 (◎) and Figure 1 (◎). The mean age of the patients was 60.39 years.

RESULTS

Table 2 (◎) shows the operative data for the valve procedures on the beating heart; the types of procedures are shown in Figure 2 (◎).

The mean time of CPB was 100.34 minutes; mean aortic cross-clamp time was 67.39 minutes; mean creatine kinase (CK) on day 1 was 11.33; mean CK–MB (MB fraction of CK) on day 1 was 0.06; and mean flow through the coronary sinus was 414 mL/minute or 28.429 liters for the whole procedure.

Of the 23 patients who were operated on, 3 patients died. Two were in-hospital deaths. One patient (patient No. 12) with triple-vessel disease and acute mitral insufficiency on intra aortic balloon counter pulsation had been operated on six days after acute myocardial infarction. The cause of the death was systemic meticillin resistant staphylococcus aureus 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 (patient No. 11) who was operated on after previous multiple cerebrovascular infarctions (CVIs) (cause of the death was CVI. In addition, one patient (patient No. 5) died one month after the operation because of prosthetic valve endocarditis on aortic and mitral valve (silver-coated

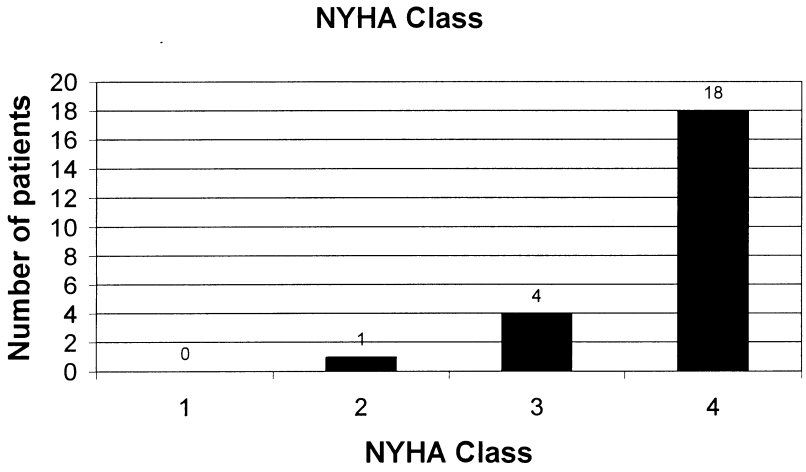

Figure 1. New York Heart Association (NYHA) class of the patients in whom mitral valve repair or replacement was performed on the beating heart.

silzone aortic and mitral valves were implanted because of chronic latent asymptomatic tibial osteitis). None of these deaths were cardiac related.

DISCUSSION

Beating-heart surgery with CPB is not a novelty; it is being used routinely in repairing atrial septal defects, in pulmonary artery procedures, and as a method for tricuspid-valve repair.The tendency toward beating-heart surgery is shown in the first of experimental emergent surgeries: in repairing post-infarction ventricular septal defect with myocardial infarction exclusion; in the use of the endocardial patch on the beating heart with normothermic CPB; and in infusion of the ultra-short beta blocker [Takahashi 1996]. Severely compromised hearts may not withstand any additional ischemic deficiency.

With these procedures, CPB also ensures a pumping function of the heart, compensating for the fact that the heart or great vessel cavity must be opened. With some procedures blood may reach the coronary arteries in a natural way. Operations such as valve replacements (aortic, mitral) have been performed on a beating heart using CPB to ensure circulation with oxygenated blood by attaching catheters directly to the ostia of the coronary arteries. Because of the many disadvantages of this technique (e.g., danger of damaged ostia, blocking the view in aortic valve replacement), we introduced the technically simpler procedure of supplying oxygenated blood retrograde through the venous system of the coronary sinus. Initiating retrograde cardioplegia, where the fluid is injected through the coronary sinus, flows through the venous system, capillaries, and then out the arterial end, requires a leap in traditional surgical thinking. Experimental studies have shown that most of the fluid escapes through the venous system (Tebez's veins) into the right atrium. Retrograde blood cardioplegia, related to antegrade blood cardioplegia, is today a method of achieving an arrested heart during heart surgery.

Just a step away from oxygenated blood flowing retrograde through the coronary sinus is retrograde cardiac perfusion. Some similarities exist between retrograde cardioplegia and retrograde cardiac perfusion (the insertion technique is the same, as is the physiologic principle), but there are two essential differences. In retrograde cardioplegia, the fluid that flows through the system is a crystalloid solution, mixed with cold or warm blood; in retrograde cardiac perfusion the fluid is warm (37°C), oxygenated blood, the same as blood that flows from the CPB to the aorta and throughout the body.

The basic requirements are:

1. The catheter in the coronary sinus must be in place throughout the entire procedure and, under all conditions, must remain in place because it provides the heart with the blood it needs.
2. The blood in the retrograde perfusion system must maintain a temperature of 37°C. At this temperature we ensure maximal vasodilatation of cardiac veins, steady retrograde distribution and blood flow, and normal pressures in the venous system, which should not exceed 60 to 80 mm Hg of mean pressure. Optimal pressure is achieved by the CPB technician regulating the degree of blood flow through the coronary sinus.
3. Throughout the procedure, the heart volume and pressure must be unburdened.

Retrograde cardioplegia through the coronary sinus is today routine. 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 ligature 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 mm Hg in the coronary sinus, presence of extravascular bleeding on serial slices of the right and left ventricle

Table 2. Duration of CPB (CPBT), aortic cross-clamp time (AXT), CK (Creatine Kinase) and CK MB (MB Fraction of CK) values day 1 after the operation

Patient No.	Procedure	CPBT, min	AXT, min	CK (day 1)	CK–MB (day 1)	CS–F, mL	CS–F, mL/min.
1	PVM, AVR, RCA	115	91	36.88	0.16	43580	478
2	MVR, PVT, VVI	94	66	9.12	0.12	19800	300
3	PVM, AVR, RCA, LAD, LCX M1	174	102	20.88	0.05	28830	282
4	PVM, AVR	100	76	10.46	0.04	49400	650
5	MVR, AVR, RCA	158	91	26.58	0.08	54580	599
6	PVM, AVR	133	103	3.55	0.12	51580	500
7	PVM + resection PML	67	48	3.78	0.04	28310	589
8	MVR, PVT	65	35	6.92	0.11	12129	346
9	MVR, AVR	98	73	8.41	0.05	25550	350
10	MVR	66	46	5.68	0.06	26800	582
11	PVM, PVT	65	41	5.03	0.04	12300	300
12	MVR, PDA, LAD, LCX M2	85	59	7.61	0.04	20600	349
13	PVM	65	44	8.08	0.04	12500	284
14	MVR, PVT	73	48	7.04	0.12	22640	471
15	MVR, AVR, RCA	144	111	10.65	0.07	59940	540
16	MVR, AVR, PVT	123	79	6.13	0.02	26070	330
17	MVR, AVR	98	73	13.6	0.03	21900	300
18	PVM, AVR	115	64	4.96	0.03	26740	417
19	PVM	63	29	8.74	0.03	9280	320
20	MVR	60	32	9.25	0.02	17600	550
21	PVM, AVR + root enlargement	175	144	30.28	0.04	50400	350
22	PVM + resection PML	67	43	10.7	0.02	14620	340
23	MVR, PVT	105	52	6.28	0.01	18720	360

PVM, mitral valve repair; AVR, aortic valve replacement; RCA, right coronary artery; MVR, mitral valve replacement; PVT, tricuspid valve repair; VVI, insertion of VVI pacemaker; LAD, left anterior descending coronary artery; LCX M, marginal branch of the circumflex artery; PML, posterior mitral leaflet; PDA, posterior descending artery

has not been noticed. Under microscopic analysis, the slices have shown a normal presence and preservation of the structure of the heart [Gill 1997]. 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.

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. In reality, the expansion of the venous channel compensates for the deficiency of arterial vascularization of the blood supply, bringing nutritients to the myocardium by retrograde blood flow [Djavakhshvili 1997]. With age, the capillary net of the myocardium becomes sparse and sinusoids become wider and more prominent. The venous system of myocardium begins in the sinusoids, which contain endothelium as well as basal membrane in their walls.

Our technique of beating heart cardiac surgery on valves involves the constant retrograde coronary sinus perfusion of pure, normothermic, oxygenated blood. By giving the oxygenated blood retrograde, via coronary sinus, we are in fact giving the blood to the most important reservoir of the damaged myocardium. However, this is not the only advantage of beating-heart surgery. The three-dimensional architecture of the beating heart gives a 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 a flaccid, arrested state that may not accurately reflect its function in the contractile heart.

Near–red spectrum spectroscopy is a useful method for constant determination of myocardial oxygenation during "warm" heart surgery. Studies made during perfusion with warm blood cardioplegia have shown that episodes of ischemia longer than 10 minutes have a consequence of less than optimal myocardial preservation (protection) and are to be avoided [Kawasuji 1997]. Encouraging results of myocardial preparation to ischemia (preconditioning) in experimental models of myocardial infarction or models with extended ischemia have revealed questions about the use of similar techniques as a support to conventional cardioplegia. Unfortunately, the connection between the combination of ischemic preconditioning and myocardial protection with "cold" blood cardioplegia, compared with using exclusively cold blood cardioplegia, did not show any better results [Cremer 1997]. Actually, it seems that this combination lowered the contractile capacity of the heart fibers.

It is important to emphasise that our early mortality was 3 of 23 patients (13%) and that none of the deaths were cardiac related. This is a good result, considering the preoperative data of the patients. It is clear that 78% were

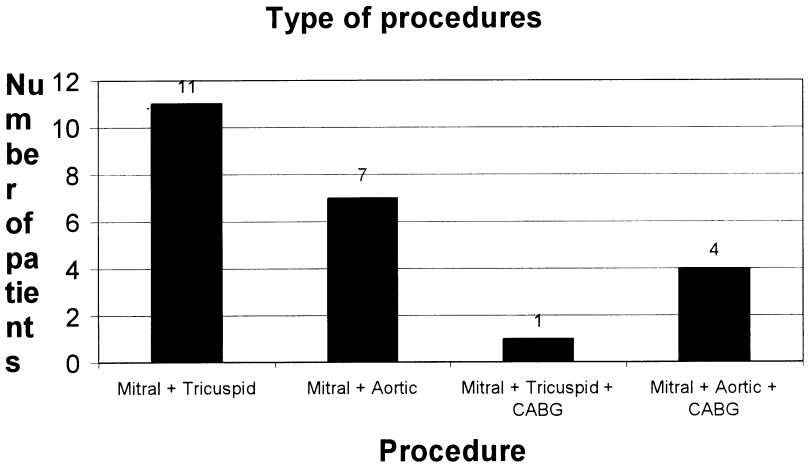

Figure 2. Type of beating-heart procedure used in the mitral valve surgery.

NYHA class 4, and 17% were NYHA class 3, totalling 95% in the high-risk group.

In the beginning we thought that only simple valve procedures were possible with this technique; however, we soon realized that this was not the case. Now we believe that this technique also enables complex mitral valve reconstruction, even such techniques as resection of the leaflets and aortic root enlargements. This is of special value because we strongly believe that it is advantageous to repair the valves of high-risk patients, thus leading to better long-term results.

It has been shown that current techniques of cardioplegia are not necessarily connected to avoiding ischemic myocardial damage in patients with high risk, such as a left ventricular ejection fraction of 0.25, arising myocardial infarction, developing and progressive myocardial ischemia, and elderliness [Perrault 1997], especially for those who are also scheduled for coronary artery bypass graft (CABG) surgery. We have two alternatives — proceeding on a beating heart without CPB or proceeding on a beating heart using CPB.

Working on a beating heart using CPB has been found to be a better alternative, compared with the classic technique (still-heart CPB). Of course this alterative adopts the weaknesses of CPB, but eliminates the consequences of global myocardial ischemia.

If we have patients who require valve procedures in connection with CABG, it is our strategy that the OPCAB technique is used (as in patients 1, 3, 5, 12, 15, which was 20% of our cases). If we have, as an additional procedure, mitral valve repair or replacement, we can still do the proximal anastomoses prior to this procedure. In the case of surgery on the aortic valve, the valve procedure is done first and, at the end, proximal anastomoses are sutured in the aorta.

MIDCAB and OPCAB techniques are still associated with acute regional ischemia in normothermic conditions at the time when the surgeon is suturing the distal anastomosis, which dictates a need for protecting the myocardial muscle under these conditions. One of the possibilities is to establish blood flowing through the coronary artery using an intraluminal shunt [Heijmen 1998], using pharmacological agents, or mechanically unburdening the ischemic heart during and after regional ischemia. With our technique of continuous coronary sinus perfusion during valve surgery in combination with CABG, we can perfuse the heart during the time of proximal anastomoses suturing.

The methods of protecting the heart muscle during intentional cardiac arrest and using CPB have approached simplicity and efficiency in the last forty years. Today cardioplegia is given antegrade and retrograde; blood cardioplegia is in use, either cold, moderate or warm. In the future we can expect efforts in initiating successful cardioprotective effects during cardiac preconditioning [Pirc 1995], preventing the destructive effects of accumulating calcium with inhibition of the sodium pump and the role of hydrogen ions in preserving the functions of the endothelium [Gersak 1996].

Coronary surgery without the use of cardioplegia or CPB, even in the presence of coronary artery disease and corresponding CABG, can present the ultimate form of protecting the heart muscle.

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