Sapporo Med. J. **64** (1・2) 51～57 (1995)

Aortic Root Versus Coronary Sinus Perfusion with Cold Blood Cardioplegia in Isolated Aortic Valve Replacement: Randomized Study of Postoperative Hemodynamics and Cardiac Enzymatic Levels in 50 Patients

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ABSTRACT A total of 50 patients undergoing isolated aortic valve replacement received either aortic root (anterograde [AGC]: 25 patients) or coronary sinus (retrograde [RGC]: 25 patients) perfusion with cold blood cardioplegic solution and were compared. The groups were similar with respect to age, sex, preoperative NYHA Class, aortic cross-clamping time and mean dose of cardioplegic solution. There were no significant differences in low cardiac output syndrome, rhythm disturbances and surgical mortality between the two groups. There were also no significant differences in right ventricular stroke work and postoperative cardiac enzymatic levels after surgery in the groups. However, there was a significant improvement in left ventricular stroke work after RGC over that after AGC and significantly more inotropic agents were required with aortic root perfusion than with coronary sinus delivery of cardioplegic solution. These findings indicate that coronary sinus perfusion has benefits not only as a surgical technique but also better preserves the hypertrophied left ventricle more effectively than aortic root perfusion.

(Received February 9, 1995 and accepted March 22, 1995)

Key words: Myocardial protection, Aortic valve replacement, Aortic root delivery
Coronary sinus delivery, Cold blood cardioplegia

Introduction

Intermittent anterograde cold cardioplegia with systemic hypothermia is a conventional technique for myocardial protection during induced cardiac arrest[1-3]. Recently, coronary sinus retrograde perfusion with cold cardioplegic solution was introduced by Lolley and Hewitt[4] and Partington *et al.*[5] and is a popular technique in cardiac operation[6-7]. However, the optimal method of myocardial protection with cardioplegia is not established yet in open heart surgery, and few studies[7-8] have compared anterograde and retrograde delivery of cardioplegic solution in aortic valve replacement. This study was designed to evaluate the effects of these delivery methods on hemodynamics and levels of cardiac enzymes in 50 patients after isolated aortic valve replacement.

Patients and methods

Between January 1990 and December 1994, a total of 50 patients undergoing isolated aortic valve replacement (AVR) were evaluated; 25 received intermittent aortic root (anterograde) cold blood cardioplegia (AGC) and 25 received intermittent coronary sinus (retrograde) cold blood cardioplegia (RGC) with systemic mild hypothermia (30℃). Patients with other concomitant cardiac operations and previous cardiac operations were excluded in this study. Preoperative data are summarized in Table 1.

Table 1 *Preoperative data*

Parameter	AGC (N=25)	RGC (N=25)	P-value
Sex (men/women)	17/8	16/9	NS
Age (years) (mean±SD)	22~ 74 (52.7± 7.2)	18~ 76 (53.1± 8.4)	NS
NYHA Class	2~ 4 (3.1± 0.2)	2~ 4 (3.1± 0.1)	NS
AR/AS	14/11	13/12	NS
Ejection fraction (%)	38~ 76 (58.7±11.9)	34~ 79 (56.2±13.9)	NS
LV-AO pressure gradient (mmHg)	60~170 (96.7±21.4)	64~190 (101.1±39.1)	NS

Data are expressed as the mean (S. D.)(range)
Abbreviation:
AGC=anterograde cardioplegia, RGC=retrograde cardioplegia,
NYHA Class=New York Heart Association classification,
AR=aortic regurgitation, AS=aortic stenosis, LV=left ventricle, AO=aorta

Surgical procedures:

Cardiopulmonary bypass was obtained with an arterial cannulation of the ascending aorta and a bicaval cannulation was used from the right atrium for venous return. A flow rate of 2.2 L/min/m^2 was maintained with hollow-fiber membrane oxygenators (Maxima-Medtronic, Sunnheim, California USA; Cobe C. M. L.-Exel, Colorado, USA; SMO_2-Sarns, Michigan, USA), a roller pump, systemic hypothermia (rectal temperature 30℃) and moderate hemodilution. Cold (15℃) blood cardioplegia with a mixture of oxygenated blood and crystalloid Sapporo Medical Solution[1-2] (potassium chloride 20 mmol/L, sodium bicarbonate 25 mmol/L, magnesium 24 mmol/L, pH 7.8 osmorality 380.0 mOsm/L) was infused after aortic cross-clamping. The ratio of oxygenated blood and crystalloid solution was 1:1 and potassium chloride was adjusted to the level 10 to 20 (13.5±2.0) mmol/L. Anterograde cardioplegia with initial dose 8 m*l*/kg then 4 m*l*/kg was given at 20 to 30-min intervals into the aortic root[3]. Topical cooling with slushed ice was also used. During coronary sinus perfusion, cardioplegia was given at the same intervals and dosage from a transatrial coronary sinus cannula (Buckberg Cannula, Utah, USA) at pressure of 20-40 (28.4±6.3) mmHg and a flow rate of 150~250 m*l*/min during aortic cross-clamping.

Transverse aortotomy was performed in all patients; the valve prostheses used in this study were CarboMedics in 21, St. Jude Medical in 18 and Carpentier-Edwards in 11.

1) **Intraoperative parameters:**

The incidence of pharmacological and mechanical support (dopamine, dobutamine, transient pacing and intra-aortic balloon pumps (IABP)) during the operation was evaluated by two cardioplegic methods.

2) **Hemodynamics:**

Heart rate (HR), systolic (SAP), diastolic (DAP) and mean arterial (MAP), mean right atrial (MRA), mean pulmonary artery (MAP), and pulmonary capillary wedge pressure (PCWP) were monitored in all patients. Cardiac output (CO) was measured using the thermodilution technique.

Derived hemodynamic indices were calculated as follows:

Cardiac index (CI)=CO/body surface area (*l*/min/m^2), Stroke volume index (SVI)=CI/HR(m*l*/min/m^2),

Left ventricular stroke work index(LVSWI)=SVI(MAP-PCWP)×0.0136(g/min/m^2), Right ventricular stroke work index(RVSWI) = SVI(MPA−MRA) × 0.0136(g/min/m^2),

Data were obtained at three stages: stage A: after anesthesia but before skin incision; stage B: after cardiopulmonary bypass and under stable hemodynamic condition; and stage C: 12 hours after the operation, in the ICU.

3) **Cardiac enzymatic evaluations:**

The levels of creatine phosphokinase (CPK) with MB isoenzyme (CPK-MB) fractions were obtained at 12 and 24 hours after operation. Perioperative myocardial infarction was diagnosed by the presence of new Q waves and/or serum CPK maximum levels≧1000 unit/*l* and CPK-MB≧50% of total CPK within 24 hours after surgery.

Statistical analysis

Data of each group were presented as the mean (S. D.) and were analysed with the paired Student's t test or Wilcoxon signed rank test when appropriate. Significance was assumed at $P<0.05$.

Results

Intraoperative findings: There were no significant differences between the groups.

Bypass time (AGC: 113.3±22.3 (range 87-172)) min versus RGC: 119.4±23.7 (range 84-182)) min; aortic cross-clamping time (AGC: 90.5±19.4 (range 61-117)) min versus RGC: 88.7±14.8 (range 63-125)) min; total dose of cardioplegic solution (AGC: 1807±488 (range 900-2500)) m*l* versus RGC: 1755±376 (range 1100-2460) m*l* and total trials of defibrillations AGC: 1.7±1.2 (range 1-4) times versus RGC: 1.2±0.7 (range 0-3) times.

Inotropic supports and IABP;

In AGC, inotropic support (dobutamine and/or dopamine) was required by all 25 patients soon after bypass. The maximum doses were (AGC: 3.9±1.5 (0.-15)) μg/min/kg versus RGC: 1.5±0.7 (0-6) μg/min/kg ($P<0.007$) for dobutamine and (AGC: 2.3±1.2 (0-10)) μg/min/kg versus RGC: 1.4±0.8 (0-5) μg/min/kg ($P<0.02$) for dopamine. The requirement of inotropic support to maintain optimal hemodynamics was significantly greater in AGC than in RGC. Eleven patients required temporal pacing in AGC (44%) and seven in RGG (28%). An IABP was required after surgery in one patient with AGC (4%), but in no patient with RGC (0%).

Hemodynamic evaluations:

Hemodynamic data are shown in Table 2. In both groups, the mean values of HR and CI were significantly increased at stages B and C as compared with stage A. The mean value of LVSWI, RGC was significantly increased at stages B and C, but no significant increase of mean values with AGC was noted in LVSWI.

The other data, including mean values of SAP, mean RAP, PCWP and RVSWI revealed no statistically significant differences at any stage before and after surgery.

Postoperative cardiac enzymatic levels:

The peak levels of CPK within 24 hours after surgery were 754.8±177.2 unit/l in AGC and 811.2±146.4 unit/l in RGC and the corresponding peak levels of CPK-MB were 37.2±8.1 and 42.8±10.2 unit/l. New postoperative Q waves were noted in one patient in AGC, but no patient with RGC developed postoperatively. The postoperative cardiac enzymatic levels were increased more after RGC than after AGC, but these differences were not statistically significant (Table 3). All patients were discharged from the hospital.

Table 2 *Hemodynamic data*

Parameter	Stage	AGC	RGC
Heart rate (/min)	A	61.7± 6.7	63.3± 7.4
	B	86.7±16.5*	88.7±10.7*
	C	76.9±10.7*	98.6±11.7*
Systolic arterial pressure (mmHg)	A	111.5+5.7	107± 6.7
	B	107.8±4.9	113±11.8
	C	110.9±6.7	121± 7.2
Mean right atrial pressure (mmHg)	A	5.7±2.7	6.3±1.7
	B	8.4±3.2	7.6±3.1
	C	7.9±3.2	9.4±4.1
Pulmonary capillary wedge pressure (mmHg)	A	12.7±3.3	11.7±2.9
	B	9.4±2.4	8.9±1.7
	C	10.7±2.1	9.1±2.1
Cardiac index (*l*/min/m²)	A	3.23±0.61	3.37±0.54
	B	3.67±0.69*	3.84±1.21*
	C	3.96±0.70*	3.91±0.61*
LVSWI (g/min/m²)	A	39.0±10.6	33.3±7.3
	B	42.7± 6.7	43.7±7.9*
	C	41.4± 7.1	39.4±6.6*
RVSWI (g/min/m²)	A	5.3±1.8	5.8±1.4
	B	6.4±1.8	7.4±3.1
	C	6.2±1.7	6.9±2.8

LVSWI=laft ventrictular stroke work index *P<0.01
RVSWI=right ventricular stroke work index

Table 3 *Postoperative cardiac enzymatic data*

Parameter	AGC	RGC	P-value
Peak CPK (24hours (μ/L)	754.8±177.2	811.2±146.4	P=0.77
Peak GOT (24hours)	51.1± 13.3	75.6± 43.3	NS
Peak LDH (24hours)	805.6±163.3	781.1±172.3	NS
Peak CPK-MB (24hours)	37.2± 8.1	42.8± 10.2	NS

CPK=creatine phosphokinase, GOT=glutamic-oxaloacetic transaminase
LDH=lactate dehydrogenase, CPK-MB=CPK isoenzyme B type

Discussion

Excellent preservation of left ventricular function has been reported in both aortic valve replacement (AVR) and aorto-coronary bypass graft (CABG) operations using coronary sinus cardioplegic solution[6-8].

The present study in 50 patients after isolated AVR indicated better function of the left ventricle with retrograde cardioplegia in 25 patients than with anterograde in 25 patients. Partington *et al.*[5] suggested that superior left ventricular myocardial protection with retrograde cardioplegia was noted even with patients coronary arteries, and demonstrated that the retrograde infusion selectively maintained delivery flow to the subendocardial myocardium. This method may therefore have advantages in myocardium where hypertrophy has been induced by pressure or volume overloading in aortic valve stenosis or regurgitation, because these, in particular subendocardial myocardium, are more sensitive to ischemia[9].

In the present study, preservation of the left ventricular subendocardium in patients who received retrograde cardioplegia significantly improved in left ventricular stroke work as compared with 25 patients who received anterograde cardioplegia. Mangano[10] reported that biventricular function after CABG surgery using cold cardioplegia showed transient deterioration after surgery, but this deterioration improved within 12～24 hours after surgery. Inotropic and mechanical supports were also instituted according to the decision of surgeons, with routine clinical criteria to maintain left ventricular function. The requirement of inotropic support was significantly more frequent in AGC than in RGC, which suggests more myocardial depression during AGC than during RGC.

The levels of cardiac enzymes (CPK and CPK-MB) increased within 24 hours after surgery in the two groups, but the magnitude of these values was greater in RGC than in AGC, though there was no statistical significance between the groups. Partington *et al.*[11] reported that retrograde cardioplegia in experimental animals provided superior protection for the left ventricle, although right ventricular protection was less satisfactory. These findings may be related to the present results which indicated the slight increased in enzyme release with RGC. Shiki *et al.*[12] also reported in canine anatomical studies that most of the right ventricle and the posterior part of the interventricular septum were not drained by the coronary sinus. However, clinical reports[6][8] and the present study indicated no statistically significant differences of the recovery of right ventricular function after AGC or RGC.

One disadvantage of retrograde cardioplegia is thought to be a delay in getting cardiac arrest[5][11]. Fiore *et al.*[6] reported that, in patients undergoing CABG surgery, the time taken to achieve complete cardiac arrest was significantly longer in RGC than in AGC. In the present study, total dose of cardioplegia required is even greater in AGG than in RGC, and also heart beat returned to normal rhythm with fewer applications of an electric defibrillator in RGC than in AGC. Advantages of retrograde were not only a gain in time; it was also unneccessary to interrupt the surgical procedure to infuse cardioplegic solution or to dissect the right coronary artery orifice with perfusion cannula. Another advantage of retrograde delivery of cardioplegic solution in AVR is that atheromatous debris is not dislodged in the coronary arteries during infusion with AGC under high pressure[13]. Retrograde delivery of cardioplegic solution may be superior to aortic root perfusion in aortic valve replacement.

Conclusion

The present study indicated significant improvement in left ventricular function in patients after AVR with RGC as compared with AGC. AGC more frequently required the usage of inotropic supports to maintain left ventricular global and hemodynamics than RGC did, but there were no significant differences in right ventricular stroke work index before and after surgery or in levels of cardiac enzymes after surgery between the techniques. When AGC is used, attention should be focused on the dissection of atherosclerotic coronary arteries; in contrast, when RGC is used, attention should be paid to protection of the right coronary artery area by meticulous topical cooling with slushed ice.

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64 (1・2) 1995

大動脈弁置換術における冷却血液心筋保護液を用いた順行性と逆行性冠灌流法の比較検討

—術後の血行動態, 左右心室機能および心筋逸脱酵素値からみた心筋保護効果の検索—

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著者らは, 開心術中の心筋保護法について, 従来の大動脈切開両側冠状動脈からの順行性心筋保護液注入法(anterograde delivery : AGC)と, 右房切開下, 冠状静脈洞からの注入法(retrograde delivery : RGC)による心筋保護効果について, 単独大動脈弁置換手術各25症例を対象に検討した. 両群とも術後の手術死亡は認められなかった. RGCはAGCに比し, 術後のカテコールアミン使用は有意に少なく, 左室機能も良好であった. RGCによる心筋保護法は, 左心室肥大を有する大動脈弁置換手術の心筋保護法として, 手術視野を防げず手術操作を容易にし, 術後の左心機能を良好に保持することから, 右室への保護効果に留意すれば, 有用な心筋保護法であると指摘された.