Original Article

Antegrade versus Retrograde Cardioplegia for Uncomplicated Coronary Artery Disease: A Comparative Study

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ABSTRACT

Since the introduction of the retrograde administration of cardioplegic solutions in cardiac surgery in the mid-1980's, the technique has been widely adopted for routine use in high risk patients with impaired ventricular function, based on favorable results demonstrated in clinical series. However, we sought to evaluate the benefits of routine use of this method in low risk patients by means of a retrospective review of 34 consecutive non-repeat, isolated coronary artery bypass grafting patients with left ventricular ejection fractions >35%. Seventeen patients received intermittent antegrade cardioplegia exclusively and 17 received antegrade induction followed by intermittent retrograde cardioplegia maintenance. No significant baseline differences were found between the two groups. There were no deaths or major complications in either group. Retrograde cardioplegia patients had significantly lower pulmonary artery diastolic pressures in the first 24 hours postoperatively, accompanied by a non-significant trend toward higher cardiac indices during this same period. Phenylephrine infusions were used more frequently during the postoperative period in the retrograde group ($p = 0.021$). Fewer pulmonary complications were seen in the retrograde cardioplegia group ($p=0.042$), in addition to non-significant trends toward less atrial arrhythmias and less hospital days. No adverse effects or increased operative time could be attributed to the retrograde administration of cardioplegic solution in this study population.

Based on the results from this small clinical series, retrograde cardioplegia administration offers distinct advantages for myocardial protection in low risk coronary bypass patients, as manifested by improved postoperative hemodynamic performance, with no significant adverse effects. A prospective, randomized trial of this technique in a larger, similar patient population is likely to show even more compelling positive results favoring the routine use of retrograde administration of cardioplegic solutions.

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INTRODUCTION

The benefits and limitations of retrograde cardioplegia have been well documented in in various research studies over the years involving both animal models and humans (1-4). In 1898, Pratt first postulated the presence of Thebesian circulation in the heart, which in part makes possible the concept of retrograde flow in the coronary vessels (1). In the 1940's, Beck attempted to make the coronary sinus carry arterial blood, but failed due to the difficulty of the surgical technique and high mortality (1). Eckstein, in the early 1950's, demonstrated that the coronary sinus could sustain a resting, beating heart for a short time, but in no way could it supply the oxygen needs of the actively working heart (1). Blanco, Lillihei, and Gott began to use retrograde cardioplegia clinically for aortic valve procedures in the mid and late 1950's with good success (1,2). However, antegrade cardioplegia became quite popular as it improved surgical results, and interest in retrograde techniques waned (1,2). As the 1970's arrived so did a new patient population; those patients needing a second or third open heart procedure (1,2). It was this patient population which pointed out the need for an adjunct to the antegrade myocardial protection strategy.

The response to this need was the development of retrograde cardioplegia administered through the coronary sinus or the right atrium (2,3,5). In the mid and late 1980's, Diehl and associates began using antegrade induction with subsequent doses of retrograde cardioplegia (2).This technique is used today at many centers with excellent results. Nevertheless, almost all clinical studies demonstrating distinct advantages and improved results with retrograde cardioplegia focus on higher risk patients, such as those with poor ventricular function, in reoperative cases, or combination procedures. Therefore, we sought to examine the potential salutory effects of employing retrograde cardioplegic delivery techniques in a consecutive series of low risk coronary bypass patients to see if routine use of this method might offer advantages over standard antegrade techniques.

MATERIALS AND METHODS

PATIENT POPULATION

In the 15 month period between December 1, 1990 and February 28, 1992, forty consecutive low-risk patients undergoing elective first-time coronary artery bypass grafting were studied by retrospective review of their hospital charts. However, complete physiologic data was available for 34 patients and only this group is analyzed. Patients included in this study were those having ejection fractions greater than 35% calculated by contrast ventriculography during cardiac catheterization and those undergoing isolated coronary artery bypass grafting to two or more vessels. Patients excluded from study were reoperative or emergency cases and cases with associated procedures, such as valve replacement, internal cardioverter defibrillator implantation or aneurysmectomy. Also excluded were cases where technical problems precluded passage of a retrograde coronary perfusion cannula or where the cannula became dislodged during the procedure. In 17 patients (Group A), cardioplegic solutions were delivered intermittently antegrade exclusively through the coronary arteries. The other 17 (Group B) underwent antegrade cardioplegic induction followed by intermittent retrograde cardioplegia maintenance. Group A patients underwent surgery during the first portion of this study period, and Group B patients were operated on during the more recent portion of the study period, following a change to routine retrograde use by one of the authors (LAR).

SURGICAL TECHNIQUE

A standard anesthetic technique was used for all cases, consisting of intravenous pancuronium for muscle relaxation, fentanyl citrate for anesthesia and midazolam for amnesia.All patients were monitored with a pulmonary artery catheter[a] introduced through the internal jugular vein and a catheter in the radial artery. All surgical procedures in both groups were performed by the same surgeon (LAR). Standard perfusion techniques were used employing a membrane oxygenator with integral heat exchanger[b] and a centrifugal pump[c], with moderate hemodilution and with the systemic temperature lowered to moderate hypothermia of 28°-32°C. A single period of cross-clamping was used for all distal anasthomoses and proximal anastomoses were performed with a partial occluding clamp on the aorta. Myocardial protection was accomplished using an oxygenated, hyperkalemic, cold blood cardioplegic solution (hematocrit approximately 20%). The same cardioplegic solution was used for both patient groups. Initially, asystole was generated by an antegrade coronary infusion of 400ml/m^2 body surface area of cardioplegic solution, and was maintained by a reinfusion of 100ml/m^2 after every distal anastomosis. In Group A, the initial and subsequent cardioplegia were delivered through an aortic root cannula[d] at approximately 100mmHg pressure. In Group B, the initial arresting dose of cardioplegic solution 300ml/m^2 was instilled antegrade through the aortic root cannula immediately followed by 100ml/ retrograde through a cannula placed into the coronary sinus. Techniques used in Group B patients were similar to those described previously (4). The manually-inflated retrograde cannula[d] was inserted transatrially into the coronary sinus and was positioned by digital palpation. Infusion pressure was measured directly in the coronary sinus using the pressure monitoring part of the cannula and was never allowed to exceed 50mmHg. Left ventricular venting was accomplished during the crossclamp period in all patients using the side-arm on the aortic root cardioplegia cannula. Continuous cold saline was instilled into the pericardium during the ischemic period for topical cardiac hypothermia. Myocardial septal temperatures were not

a Baxter Healthcare Corp. Irvine, CA
b Bard, Inc., Murray Hill, NJ
c Bio-Medicus Inc., Eden Prairie, MN
d DLP, Inc. Grand Rapids, MI

measured. Patients were rewarmed to 35°C bladder temperature prior to weaning from cardiopulmonary bypass. All pump blood was slowly returned to the patient's circulation after discontinuing bypass prior to decannulation. Appropriate intravenous fluids were given to achieve optimal preload as determined by frequent determination of pulmonary artery filling pressures and cardiac output. Intravenous infusions of nitroglycerine, dobutamine, or phenylephrine were utilized as deemed necessary to assist in optimizing myocardial performance. Temporary epicardial atrial and ventricular pacing wires were placed in all cases. The need for temporary pacemaker use was determined by cardiac conduction at the termination of cardiopulmonary bypass.

PATIENT EVALUATION

Demographic factors examined include: age, sex, height, weight, body surface area, preoperative medications, prior myocardial infarctions, preoperative congestive heart failure, left ventricular end diastolic pressure (LVEDP), ejection fraction, and the extent of coronary artery disease. Operative factors compared include: total bypass time, cross clamp time, internal mammary artery usage, presence of left main coronary artery disease, number of bypass grafts, intra-aortic balloon pump usage, need for defibrillation prior to discontinuing bypass, and pacemaker utilization following bypass. Postoperative factors reviewed include: development of atrial or ventricular arrhythmias, graft occlusion, myocardial infarction, return to operating room for postoperative bleeding, stroke, pulmonary infection or insufficiency, need for cardioversion, wound infection, postoperative days in the intensive care unit, and postoperative days in the hospital. Hemodynamic data analyzed include: pulmonary artery diastolic pressure (PAD), cardiac index (CI), mean arterial pressure (MAP), and systemic vascular resistance (SVR), all of which were measured in the operating room at the end of bypass, then six hours, twelve hours and twenty-four hours postoperatively. Postoperative vasopressor drug use and medications on hospital discharge were also examined.

STATISTICAL ANALYSIS

Quantitative data were analyzed and compared between the two groups using a computer program for data analysis (6). The Student's t-test was used for parametric data and a ratio proportion comparison was used for non-parametric data. Data were expressed as the mean ± standard deviation. Differences were considered significant when $p < 0.05$.

Table 1: Preoperative Patient Data

	Group A (n=17)	Group B (n=17)	P Value
Demographics			
Gender	10M/ 7F	15M/ 2F	0.139
Age (years)	64.6 ± 11.55	64.7 ± 9.2	0.972
Height (cm)	171.3 ± 11.5	170.8 ± 8.6	0.889
Weight (kg)	83.4 ± 22.0	80.6 ± 9.8	0.645
Body Surface area (m^2)	1.96 ± 0.30	1.94 ± 0.15	0.812
Prior myocardial infarction (% of patients)	58.8%	56.3%	0.838
Congestive heart failure (% of patients)	17.6%	31.3%	0.614
No. of total coronary occlusions/patient	0.6 ± 0.6	0.6 ± 0.7	0.941
Left main coronary stenosis (% of patients)	29.4%	25.0%	0.767
LVEDP (mmHg)	14.3 ± 7.9	17.7 ± 3.6	0.146
Ejection fraction (%)	49.6 ± 10.0	53.5 ± 12.4	0.379
Preoperatve Medications (% of people using)			
Nitrates	64.7%	50%	0.616
Calcium channel entry blocker	41.2%	43.8%	0.839
Beta adrenergic blocking agent	52.9%	25.0%	0.199
Cardiac glycosides	5.9%	12.5%	0.956
Antiarrhythmic agents	0%	6.3%	0.975
Diuretics	17.6%	12.5%	0.942
ACE inhibitors	11.8%	6.3%	0.956
Steroids	0%	6.3%	0.975
Aspirin	58.8%	50.0%	0.874
Dipyridamole	0%	0%	----

Table 2: Perioperative patient data

	Group A (n=17)	Group B (n=17)	P Value
Intraoperative			
Bypass time (min)	146.7 ± 37.2	139.5 ± 27.9	0.536
Cross clamp time (min)	70.9 ± 12.7	73.7 ± 12.5	0.527
Number of grafts	3.5 ± 0.7	3.6 ± 0.9	0.437
Internal mammary artery used (% of cases)	100%	94%	0.975
Defibrillation prior to ending bypass (%)	0%	5.9%	0.975
Intra-aortic balloon pump used (%)	5.9%	0%	0.975
Temporary pacemaker required (%)	29.4%	18.8%	0.767
Postoperative			
ICU days	2.4 ± 1.2	2.3 ± 0.8	0.661
Hospital days	9.2 ± 4.4	7.3 ± 1.9	0.093

RESULTS

The demographic patient data and preoperative medications are displayed in Table 1 and no significant differences were seen between the two groups. Table 2 shows the intraoperative patient data and postoperative hospital days, and likewise there were no significant differences between the two groups. However, there was a non-significant trend toward less total postoperative days in the retrograde cardioplegia group.

The perioperative hemodynamic data is shown in Table 3. These data points were collected in the operative room at the end of the surgical procedure and at 6, 12, and 24 hours postoperatively. The most interesting differences among the two groups were seen in the pulmonary artery diastolic pressures (PAD) and cardiac indices (CI), which are graphically displayed in Figures 1 and 2, respectively. The consistently lower left ventricular filling pressures (as approximated by PAD) and the trend toward increased CI in the retrograde cardioplegia group strongly suggest superior myocardial protection with resultant improved cardiac function was accomplished with this technique.

Postoperative complications are shown in Table 4, and are typical of what might be expected in a low

Table 3: Perioperative hemodynamic data

	Group A (n=17)	Group B (n=17)	P Value
End of Operation			
PAD	16.8 ±4.9	18.0 ±3.5	0.411
CI	2.7 ±0.6	2.9 ±0.8	0.402
MAP	78.4 ±6.9	78.1 ±6.5	0.902
SVR	1026.5 ±315.1	1028.2 ±274.7	0.987
6 Hours Postoperative			
PAD	16.8 ±3.3	14.0 ±2.9	0.016
CI	3.2 ±0.6	3.3 ±0.7	0.611
MAP	76.5 ±6.6	73.9 ±8.9	0.349
SVR	893.3 ±346.9	815.2 ±254.8	0.469
12 Hours Postoperative			
PAD	16.2 ±2.8	14.9 ±2.9	0.201
CI	3.1 ±0.6	3.5 ±0.5	0.070
MAP	74.8 ±5.9	72.4 ±5.4	0.247
SVR	1016.9 ±784.8	734.0 ±111.8	0.164
24 Hours Postoperative			
PAD	17.3 ±2.9	14.9 ±3.5	0.052
CI	3.0 ±0.4	3.2 ±0.5	0.293
MAP	81.5 ±8.5	82.2 ±10.7	0.850
SVR	974.9 ±221.9	948.1 ±281.6	0.777

Abbreviations: CI: cardiac index (L/min/m^2); MAP: mean arterial pressure (mmHg); PAD: pulmonary artery diastolic pressure (mmHg); SVR: systemic vascular resistance (dyne/sec/cm^{-5})

Table 4: Postoperative Complications

	Group A (n=17)	Group B (n=17)	P Value
Atrial fibrillation or flutter	59.0%	37.5%	0.221
Ventricular arrhythmias requiring treatment	5.9%	18.7%	0.549
Perioperative infarction or graft occlusion	5.9%	6.2%	0.382
Pulmonary complications	35.3%	6.3%	0.042
Need for cardioversion	0%	0%	----
Reoperation for bleeding	0%	0%	----
Wound infections	0%	0%	----
Stroke	0%	0%	----
Deaths	0%	0%	----

Table 5: Postoperative medications

	Group A (n=17)	Group B (n=17)	P Value
Perioperative (% of patients)			
Dopamine	11.8	25.0	0.593
Dobutamine	52.9	68.7	0.567
Phenylephrine	35.3	81.2	0.021
Epinephrine	0	12.5	0.439
Discharge medications (% of patients)			
Nitrates	0	12.5	0.493
Calcium channel blocking agent	29.4	43.7	0.621
Beta adrenergic blocking agent	29.4	25.0	0.915
Cardiac glycosides	58.8	41.1	0.605
Antiarrhythmic agent	47.1	25.5	0.340
Diuretics	11.8	6.3	0.956
ACE inhibitor	11.8	0	0.493
Steroids	5.9	0	0.975
Aspirin	76.7	81.2	0.928
Dipyridamole	11.8	0	0.493
Anticoagulants	5.9	6.2	0.493
Theophylline	5.9	6.2	0.493

risk coronary artery bypass grafting population. However, pulmonary complications (pulmonary insufficiency or infection) were significantly reduced in the retrograde cardioplegia group, as well as a non-significant trend to decreased atrial arrhythmias also in the retrograde group. The decrease in pulmonary complications may well be related to the reduced pulmonary artery pressures (and possibly decreased interstitial pulmonary edema) seen postoperatively in the retrograde cardioplegia group. Generally, patients in both groups did well, since there were no deaths or major complications in either cardioplegia group.

Perioperative vasopressor medications used are shown in Table 5. The only significant difference was the increased number of patients in the retrograde cardioplegia group who required use of the alpha adrenergic agonist phenylephrine in the early postoperative period. However, there was no difference in mean arterial pressure or systemic vascular resistance among groups, although the use of phenylephrine may have precluded finding measurable differences. Also shown in Table 5 were discharge medications, and there were no significant differences between groups.

DISCUSSION

Demonstrating the absolute benefits, safety, and indications, as well as the limitations of any new surgical technique, such as the use of retrograde administration of cardioplegic solution, is often quite challenging and awaits confirmation by multiple clinical series from various centers. The need for further clinical investigation of this technique is apparent after reviewing the various disparate reports published thus far about retrograde cardioplegia, which recount both its advantages and disadvantages; these are listed in part in Tables 6 and 7.

In order to understand the potential benefits and liabilities of this new cardioplegia delivery technique, it is important to have some basic understanding of the venous drainage of the heart. With the exception of the Thebesian valve, no valves are present in the coronary venous system, thereby allowing cardioplegic solution to be delivered in a retrograde manner. In addition, this system is not appreciably affected by atherosclerosis, so it is free of obstruction even when the coronary arteries are significantly diseased (1,10,14). Two key venous drainage systems exist. The dominant system provides 60% to 85% of myocardial drainage and empties the arterioles into the capillaries then into the cardiac venous system to the middle great cardiac vein, and finally into the coronary sinus and right atrium (1,9,14-17). The lesser drainage system provides the remainder of myocardial drainage allowing coronary artery blood to flow into the deep myocardial venous circulation which then drains directly into the cardiac chambers (14-17). Thebesian veins and arterio-sinusoids are two of the principal structures of the lesser drainage system. Thebesian veins empty into the right ventricle, and arterio-sinusoidal structures drain into the left ventricle (14-17). As with the coronary arteries, considerable individual variation exists in the myocardial venous distribution (16). This would suggest that the potential quality of myocardial protection provided by retrograde cardioplegia delivered through the coronary sinus may be directly related to the amount of venous return that

Figure 1: Postoperative pulmonary artery diastolic pressure

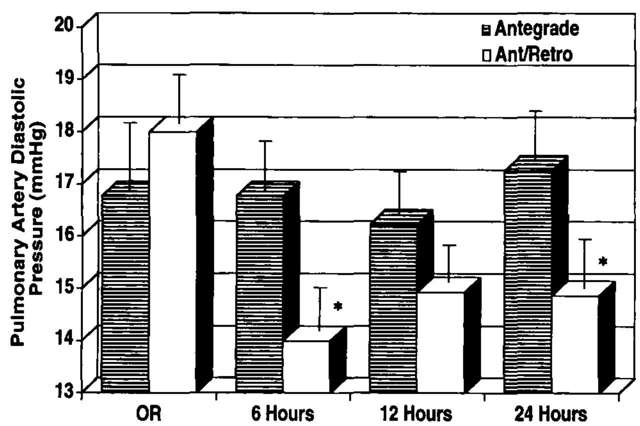
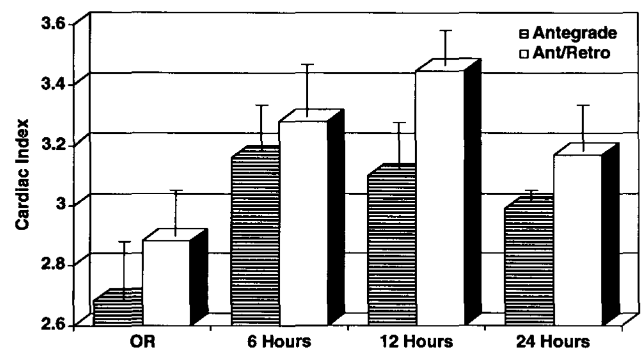


Figure 2: Postoperative cardiac index



actually drains into the dominant system which in turn drains into the coronary sinus.

Fabiani and associates in 1986 described a technique of direct right atrial retrograde cardioplegia delivery with a cannula placed just into the atrium itself which they claimed would provide better perfusion of the non-coronary sinus drainage system in addition to the dominant system (13). However, this technique has a major drawback in the myocardial protection strategy; it causes significant right ventricle distention (increased myocardial wall tension), which results in increased myocardial oxygen demands (1,3,5), possibly causing actual physical damage to the myocardium.

Many of the earlier experimental studies using animal models relied on acute occlusion of healthy coronary arteries by snaring (1). While this technique occludes the vessel flow, this type of acute blockage of a normal coronary artery rarely occurs *in vivo* in humans. Collateral channels often develop in the atherosclerotic heart over a period of years, only with an acute occlusion and possible infarction as late events. For this reason as well as the basic differences in coronary anatomy between animal and human hearts, clinical studies of the efficacy of retrograde cardioplegia protection have proven to be the most important in assessing the utility of this technique in protecting myocardium, especially that distal to total coronary occlusions. As summarized by James (1), most clinical trials have shown retrograde cardioplegia to have distinct advantages in the higher risk patients, such as with reoperative surgery, combination coronary surgery plus other procedures, and in the patient with poor ventricular function. However, others suggest that this technique adds little to improve elective coronary surgery results (7,12).

The current series, with its improved albeit modest results in the retrograde group, would tend to argue in favor of routinely using combination antegrade/retrograde cardioplegia delivery in elective, low-risk coronary surgery patients. Improved postoperative hemodynamics, decreased pulmonary complications, and trends toward less atrial arrhythmias and decreased hospital stays in the retrograde cardioplegia patients in the present small clinical series strongly suggest that this technique would be of benefit in all coronary patients. A significant limitation in this study is its retrospective, non-randomized design as well as relatively small sample size. Of all the parameters compared, most numerically favor the retrograde patient group, and would be significally different if the same trends were seen in a slightly larger patient population. For this reason, we feel that a larger prospective randomized trial of retrograde cardioplegia administration in low-risk elective coronary artery patients would result in even stronger data supporting this new technique of administering cardioplegic solution.

Other possible reasons to explain why only modest differences were found between the two groups in this series include the exclusion of more complex combination coronary/valvular surgery, emergent or failed angioplasty procedures, and reoperative coronary surgery, all of which have been found previously to benefit from retrograde cardioplegia use (4,7,9,11). Only about half of the patients in each group had one or two total occlusions with no one having more than two. This too may limit the benefits realized by receiving retrograde cardioplegia, since this method has been shown to provide superior perfusion to areas distal to total occlusions (4,7). Finally, the use of blood cardioplegia, systemic cooling and topical myocardial cooling in this series as adjuncts to the overall myocardial protection strategy have been reported to give the best possible results (18), and their use in this study population may also have tended to limit the additional benefits afforded by retrograde cardioplegia administration.

One interesting finding in this study not described previously is the increased use of phenylephrine use in the retrograde group. It is possible that pressure receptors in the transverse aortic arch may have been injured during cardiac manipulation causing the receptors to falsely perceive that the postoperative systemic blood pressure was elevated. The resulting response

Table 1. Reported benefits of retrograde

- Superior protection distal to tight lesions (7)
- Right ventriclular function is maintained well postoperatively (8,9)
- No aortic incision or coronary ostial cannulation is needed. Prevents ostial stenosis and coronary artery trauma (3,7,9)
- Better global distribution of cardioplegia with a more homogenous myocardial temperature, especially in the hypertrophied ventricle (3,4,7,9,10)
- Improved myocardial compliance, resulting in a better ejection fraction, cardiac output and survival rate (2,9,10)
- Can use retrograde cardioplegia flow to flush out debris, air or other emboli from coronary arteries; especially important in reoperative coronary surgery (4,7,9,11)
- Continuous cardioplegia infusion is possible without interrupting surgery; this prevents premature warming from collateral or bronchial circulation (1,7,11)
- Improved sub-endomyocardium perfusion occurs with decreased tissue acidosis and necrosis (7,9)
- Ideal for acute events like failed coronary angioplasty (8)
- Can cool the myocardium adequately even with an intact internal mammary graft during reoperative coronary surgery (11)
- Provides good left ventricular free wall cooling with adequate septal cooling which is unaffected by an acute occlusion (12)
- Atherosclerosis does not affect the coronary venous system and impair cardioplegia delivery (1,10)

Table 2. Reported disadvantages of retrograde

- Possible rupture of the coronary sinus (1,3,4)
- Possible myocardial edema if pressure is>50mmHg (1,3)
- The technique is more cumbersome, requiring more equipment and insertion time (1,3)
- May develop A-V block on ECG (1,2, 3,11)
- Slow to arrest heart with retrograde induction (1,2,8,13)
- Requires large fluid volumes, resulting in hemodilution (continuous retrograde (1,3,8,13)
- Ventricular septal cooling not optimal with retrograde (4,12)
- Theoretical poor right ventriculare protection because of anatomic venous drainage patterns and decreased right ventricular capillary perfusion (1, 3,4)
- Short pump runs and elective coronary artery bypass surgery show no clear benefit (7,12)
- A definite learning curve exists for retrograde cannula insertion (11)
- There is an additional cost for a retrograde cannula (1,3)
- Antegrade protects adequately until stenosis exceeds 90% (13)

might be systemic vasodilatation requiring administration of an alpha adrenergic agonist such as phenylephrine to maintain a normal arterial pressure. However, this effect, if present, should have been seen relatively evenly in both groups, since administration of retrograde cardioplegia does not technically involve aortic arch manipulation.

Another more plausible explanation for the increased need for an alpha agonist may be linked to the endogenous release of atrial natriuretic peptide or atriopeptin. Atriopeptin is a peptide hormone found in the atrial muscle cell and is released in response to atrial stretching or distention (19-21). Release of this peptide would be expected with fluid overload such as in congestive heart failure and possibly with atrial manipulation during placement of the retrograde cannula or with the actual infusion of retrograde cardioplegia. When released, atriopeptin has marked transient effects on fluid and electrolyte balance and arterial pressure. Glomerular filtration is increased with corresponding loss of electrolytes (especially sodium) and water. Arterial pressure is reduced as high levels of renin are suppressed and blood vessels are dilated directly (19-21). Atriopeptin is most effective as a direct vasodilator when a released in a hypertensive environment (19). Whatever the cause of the vasodilatation requiring increased phenylephrine use in retrograde cardioplegia patients, no adverse effects could be attributed to this pharmacological intervention.

Based on the favorable results in this retrospective review of our early experience with the use of intermittent retrograde cardioplegia administration in low-risk elective coronary artery bypass patients, we support the routine use of this technique in all open heart surgical procedures, as do other authors in this field (4,11). Prospective randomized trials with larger populations of low-risk coronary patients would likely support this recommendation and quite possibly make the use of retrograde cardioplegia the standard of care for myocardial protection. However, the cardiac surgical community appears to have already strongly embraced ths technique. In a large survey of the myocardial protection practices of 1413 U.S. board certified thoracic surgeons in 1992, a remarkable 64% report that they commonly use combination antegrade/retrograde cardioplegia administration in their cardiac surgical patients, and almost one-third of them use this technique on over 50% of their cases (21).

REFERENCES

1. James DA . Retrograde coronary sinus versus antegrade cardioplegia perfusion: A review. J Extra-Corpor Technol. 1989; 21(4): 13-17.
2. Diehl JT, Eichorn EJ, Konstam MA, et. al. Efficiency of retrograde coronary sinus cardioplegia in patients undergoing myocardial revascularization: A prospective randomized trial. Ann Thorac Surg. 1988;45:589-590.
3. Buckberg GD . Antegrade cardioplegia, retrograde cardioplegia, or both? Ann Thorac Surg. 1988:45:589-590.
4. Buckberg GD . Antegrade/retrograde blood cardioplegia to ensure cardioplegia distribution: Operative techniques and objectives. J Cardiac Surg. 1989;4:216-238.
5. Fabiani JN, Deloche A, Swanson J, et al. Retrograde cardioplegia through the right atrium. Ann Thorac Surg. 1986;41:101-102.

6. Glantz S. Primer of biostatistics. Macintosh Version 3.0. New York: McGraw Hill; 1992.

7. Haan C, Lazar HL, Bernard S, et al. Superiority of retrograde cardioplegia after acute coronary occlusion. Ann Thorac Surg. 1991;51:508-412.

8. Fiore AC, Naunheim KS, Kaiser , et. al. Coronary sinus versus aortic root perfusion with blood cardioplegia in elective myocardial revascularization. Ann Thorac Surg. 1989;47:684-688.

9. Douville EC, Kratz JM, Spinale FG, et al. Retrograde versus antegrade cardioplegia: Impact on right ventricular function. Ann Thorac Surg. 1992;54:56-61.

10. Gundry SR, Kirsh MM . A comparison of retrograde cardioplegia versus antegrade cardioplegia in the presence of coronary artery obstruction. Ann Thorac Surg. 1984;38:124-127.

11. Gundry SK, Sequiera A, Razzouk AM, et al. Facile retrograde cardioplegia: Transatrial cannulation of the coronary sinus. Ann Thorac Surg. 1990;50:882-887.

12. Aronson S, Lee BK, Liddicoat JR, et al. Assessment of retrograde cardioplegia distribution using contrast echocardiography. Ann Thorac Surg. 1991:52:810-814.

13. Menasché P, Subayi JB, Veyssié L, et al. Efficiency of coronary sinus cardioplegia in patients with complete coronary artery occlusion. Ann Thorac Surg. 1991; 51:418-423.

14. Reed CC, Stafford TB. Cardiopulmonary Bypass, 3rd ed. Houston: Texas Medical Press;1988;15-17.

15. Engelman RM . Retrograde continuous warm blood cardioplegia. Ann Thorac Surg. 1991;51:80-81.

16. Ratajczyk-Pakalska E,Kolff WJ. Anatomical basis for the coronary venous outflow. In: Mohl W, Wolner E, Glogar D, eds. The Coronary Sinus: Proceedings of the First International Symposium on Myocardial Protection via the Coronary Sinus. New York: Springer-Verlag; 1984; 40-46.

17. Schlant RC, Alexander RW. The Heart Arteries and Veins,8th ed. New York: McGraw Hill Inc;1994; 91.

18. Buckberg GD, Rosenkranz ER. Principles of cardioplegic myocardial protection. In: Roberts AJ, ed. Myocar dial protection in cardiac surgery. New York: Marcel Dekker; 1987:71-94.

19. Needleman P, Greenwald JE. Atriopeptin: A cardiac hormone intimately involved in fluid, electrolyte and blood pressure homeostasis. N Engl J Med. 1986; 314:828-834.

20. Raine EG, Phil D, Erne P, et al. Atrial natriuretic peptide and atrial pressure in patients with congestive heart failure.N Engl J Med. 1986;315:533-537.

21. Rodeheffer RJ, Tanaka I, Imada T, Hollister AS, Robertson D, Inagami T. Atrial pressure and secretion of atrial natriuretic factor into the human central circulation. J Am Coll Cardiol. 1986;8:18-26.

22. Robinson LA, Schwarz GD, Goddard DB, Fleming WH, Galbraith TA. Myocardial protection for acquired heart disease surgery:Results of a national survey. Ann Thorac Surg in press.