Cardiac Operation Without Hypothermia for the Patient With Cold Agglutinin

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Recently, a new technique for myocardial protection that does not rely on hypothermia has been reported. In this method, the heart is continuously perfused with normothermic hyperkalemic blood cardioplegia during the crossclamp period. Cardiac arrest is achieved and maintained using high levels of potassium. Hypothermia is not part of this technique; thus, the danger of hypothermia can be avoided in the patient with cold agglutinin disease without compromising myocardial protection. This communication reports our experience using retrograde continuous normothermic blood cardioplegia in one patient with potent cold agglutinins and severe coronary artery occlusive disease. This patient experienced an uneventful operative and postoperative course and remains asymptomatic, now more than two years after operation. (Chest 1993; 104:1627-29)

Most current techniques of myocardial protection rely on moderate systemic hypothermia (22° to 30°C) and profound cardiac hypothermia (15° to 20°C). These temperatures are well below the critical temperature and within the range of thermal amplitudes exhibited by most cold hemagglutinins. Patients with cold agglutinin disease are therefore at risk for acute vascular thrombosis and hemolysis using standard techniques of myocardial protection. Alternative procedures, usually involving some compromise of myocardial protection, have been tried in the past for these patients. This condition is unusual enough that there is yet no consensus for the optimum conduct of bypass and myocardial protection.

The question of the necessity of hypothermia for myocardial protection has been raised recently and the successful use of continuous normothermic hyperkalemia blood cardioplegia, a new technique based on this concept, has been reported. Theoretically, this technique has several attractive aspects, including the avoidance of cold injury to blood elements and avoidance of periods of myocardial ischemia. As reported initially, cardioplegia was administered in an antegrade fashion. We have employed a modification of this technique with the retrograde administration of continuous normothermic blood cardioplegia since April 1990. When presented with a patient with potent cold agglutinins, we thought this technique would be ideal to provide appropriate myocardial protection.

Case Report

A 76-year-old man was referred to our practice for myocardial revascularization. He has been known to have idiopathic cold hemagglutinin disease since 1975 but was in generally good health. At the time of hospital admission, he was noted to have a mild anemia (hemoglobin, 9.1 g/dl; hematocrit, 26.3 percent). The cold agglutinin titer was 1:8,192 and the critical temperature of his cold reactive autoantibodies was 28° to 30°C. Serum protein electrophoresis showed an abnormal protein (paraprotein) band measuring 0.6 g/dl. To avoid cold stress, the patient had moved to southern Mexico more than 10 years ago.

The patient developed exertional angina in 1983, and was successfully treated medically until 1990. Coronary angiography was performed in October 1990 and revealed significant left main disease, severe triple-vessel disease, and normal left ventricular function. The patient was seen at two hospitals in southern California with tertiary cardiac surgery programs, but was turned down for operation because of the high thermal amplitude and severity of his cold hemagglutinin disease. He was subsequently referred to our service and underwent operation on November 8, 1990.

Surgical Technique and Intraoperative Course

After the induction of general anesthesia, standard median sternotomy was performed. The arterial cannula was inserted in the ascending aorta. Venous return was through a single, two-stage cannula placed in the right atrial appendage and directed to the inferior vena cava. A retrograde coronary sinus cannula was inserted blindly from the right atrium. The position of this cannula was checked by palpation. With crystalloid prime, cardiopulmonary bypass was initiated at normothermia. Normothermia was maintained throughout the procedure. The ascending aorta was cross-clamped and normothermic blood cardioplegia with a final potassium concentration of 20 mEq using a 4:1 blood cardiopulmonary delivery system was given in an antegrade fashion at 300 ml/min. Complete cardiac arrest was achieved without ventricular fibrillation within 2 min. Maintenance normothermic blood cardioplegia, identical to the induction blood cardioplegia except for a final potassium concentration of 6 mEq/L, was then delivered continuously via the retrograde catheter throughout the remainder of the operation.
cross-clamp period at a rate of 100 ml/min. The hematocrit on bypass was never lower than 19 percent. Coronary sinus pressure was monitored and maintained at a mean of 30 mm Hg. Catheter position was intermittently confirmed by observation of the middle cardiac vein. Electrical and mechanical arrest was maintained throughout the cross-clamp period.

Aortocoronary reversed saphenous vein grafts were constructed to the lateral circumflex coronary artery and main right coronary artery; the left internal mammary artery was anastomosed to the left anterior descending artery. All distal and proximal anastomoses were performed during a single period of aortic cross-clamping lasting 126 min.

Approximately 1 min after removal of the aortic cross-clamp, the heart began to beat spontaneously. Junctional rhythm was followed by sinus rhythm within 3 min as the electrocardiogram normalized. Cardiopulmonary bypass was terminated without difficulty 21 min after the removal of the aortic cross-clamp. No inotropic agents were used.

Cerebral function was monitored throughout the procedure using a processed electroencephalogram. No abnormalities were seen. Urine output during cardiopulmonary bypass was 0.9 ml/min without the use of diuretics. There was no evidence of hemoglobinuria. The patient was given two units packed red blood cells on cardiopulmonary bypass when the hematocrit dropped to 19 percent due to hemodilution.

Postoperative Course

The postoperative course was unremarkable. The endotracheal tube was removed 12 h after operation. The chest tube was removed 24 h after operation. Diuretics were not required and there was no evidence of hemoglobinuria. The hematocrit was stable and stayed above 30 percent. The patient was discharged home in good condition on the 7th day after operation. Four months following operation, the patient remained asymptomatic. An exercise stress test (7 METZ) showed normal blood pressure and heart rate response without significant ST changes or symptoms. Late postoperative echocardiography revealed a normal left ventricle without segmental wall motion abnormality. The patient remains asymptomatic at two years after operation.

Discussion

Cold agglutinin disease is an autoimmune disease. In most cases, the autoantibody is directed against antigen-I or antigen-i on the red blood cells that are precursors for the ABO glycoproteins and are found on the red blood cells of most individuals. The etiology for these antibodies is obscure. In addition to their idiopathic occurrence, there is correlation with various neoplasms, viral and Mycoplasma pneumonia, and other infections. These antibodies have a certain range of thermally mediated immunologic activity referred to as the thermal amplitude. In addition, there is a maximum temperature, above which their activity ceases, known as the critical temperature.\(^{11-12}\) Although cold hemagglutinin disease is not primarily a hemolytic process because of the relative sluggishness of complement at lower temperature, a chronic hemolytic state usually develops over time. Cold stress can precipitate severe problems such as extremity ischemia or renal shutdown due to acute hemolytic anemia.\(^{14}\)

These dangers preclude routine hypothermic cardiopulmonary bypass techniques for individuals with this disorder. To overcome this condition, several techniques have been used.\(^{14}\) Williams\(^{4}\) used anoxic arrest with normothermic cardiopulmonary bypass. Plasmaphresis had been used for temporary removal of antibodies and relief of cold agglutinin symptoms.\(^{19}\) Klein et al\(^{5}\) reported the use of plasma exchange prior the cardiac operation in 1980. Berreklouw et al\(^{4}\) and Blumberg et al\(^{6}\) used warm crystalloid cardioplegia to wash out the blood from the heart followed by cold crystalloid cardioplegia for protection. Prior to reintroduction of blood to the heart, the heart was rewarmed with warm crystalloid cardioplegia. Normothermic cardiopulmonary bypass was used by these authors. Dake et al\(^{7}\) used local coronary occlusion with electrical fibrillation and ischemic arrest for coronary bypass grafting. Díaz et al\(^{8}\) reviewed this problem in 1984 and concluded that rapid determination of critical temperature, total coronary washout with cardioplectic solution, cardiac isolation by aortic cross-clamping, and maintenance of moderate hypothermia above the critical temperature of the cold reactive autoantibodies was the best combination for systemic protection and myocardial preservation.

Each report includes only one or two cases and there remain questions as to the effectiveness and safety of each technique. It is generally accepted that normothermic fibrillation or ischemic arrest does not offer optimal myocardial protection. Certainly cold crystalloid cardioplegia provides effective myocardial protection in most cases, but the successful washout of all red blood cells from the coronary circulation may be difficult to achieve initially and will certainly be difficult to maintain. In addition, the temperature gradient between the relatively normothermic perfusate and the heart will compromise myocardial protection.

Virtually all modern techniques share the premise that hypothermia is indispensable for myocardial protection during the aortic cross-clamp period. Our experience indicates otherwise. Continuous normothermic blood cardioplegia makes it possible to protect the heart without hypothermia, eliminating the concerns in patients with cold agglutinins.\(^{7-10}\)

This is a new application of an old technique. Continuous coronary artery infusion is one of the original techniques of myocardial protection. As originally applied, the coronary arteries were perfused and the heart allowed to beat. This technique did not provide adequate myocardial protection because the energy requirements of the beating heart were not met by the supplied coronary blood flow. By inducing hyperkalemic diastolic arrest, however, myocardial energy demands are dramatically decreased. The nonbeating normothermic heart requires only 1.10 ml O\(_2\)/min/100 g while the empty beating heart has an oxygen consumption of 5.6 ml O\(_2\)/min/100 g. Hypothermia decreases oxygen consumption very little once diastolic arrest is accomplished. If diastolic arrest is maintained, hypothermia is dispensable because myocardial oxygen demands can be met by the continuous infusion of normothermic blood. Reports\(^{8,10}\) suggest a flow rate of 80 ml/min and higher will meet the oxygen requirement of nonhypertrophied hearts. We use flows of 100 to 200 ml/min in all cases.

We have used the technique of continuous normothermic blood cardioplegia as originally described by the Toronto Group\(^{5,8,10}\) with one modification. The Toronto Group initially described delivery of the continuous normothermic blood infusion in an antegrade fashion; our routine technique is to use antegrade then retrograde cardioplegia as described in the "Methods" section. Subsequent to discussions with us, the Toronto Group began using retrograde as well as...
antegrade cardioplegia delivery. The effectiveness and safety of continuous warm blood cardioplegia has been reported.\textsuperscript{[1]}\textsuperscript{[2]} \textsuperscript{[3]}\textsuperscript{[4]}\textsuperscript{[5]}\textsuperscript{[6]}\textsuperscript{[7]}\textsuperscript{[8]}\textsuperscript{[9]}\textsuperscript{[10]} We have applied this technique in more than 500 patients in our institution. In our hands, myocardial preservation using this technique has been equal to or superior to techniques requiring hypothermia. For the patient with cold hemagglutinin disease, it allows us to perform the operation in a routine fashion.

This patient's excellent postoperative course and early hospital discharge speak to the utility of this technique. This outcome is routine in our hands with this technique. Although the technique of warm blood continuous cardioplegia has only a short history and further study of the technique is necessary, we believe that normothermic systemic perfusion and normothermic continuous blood cardioplegia during the aortic cross-clamp period offers the surgeon excellent cardiac protection.

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**Dynamic Left Ventricular Outflow Tract Obstruction**

**Diagnosis by Transesophageal Echocardiography in a Critically Ill Patient**

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Dynamic left ventricular outflow tract obstruction (DLVOTO) can be present in critically ill patients with congestive heart failure. Diagnosis by transthoracic two-dimensional echocardiography may be technically difficult in the critically ill patient or patients who are obese. This report describes the diagnosis of DLVOTO by transesophageal echocardiography and subsequent management.

(Chest 1993; 104:1629-31)

**CHF** = congestive heart failure; **DLVOTO** = dynamic left ventricular outflow tract obstruction; **LVOT** = left ventricular outflow tract; **TEE** = transesophageal echocardiography

Hypotension and oliguria are common problems in critically ill adult patients and frequently are caused by hemorrhage, sepsis, or congestive heart failure (CHF). However, some patients may have unrecognized dynamic left ventricular outflow tract obstruction (DLVOTO) as an etiology. An appreciation of the physiologic mechanism by which DLVOTO causes CHF is necessary to ensure proper therapy and avoidance of inappropriate pharmacologic intervention. Drugs usually contraindicated for the therapy of CHF such as β-blockers and α-adrenergic drugs may improve hemodynamic function and relieve symptoms of CHF. In this report, we present the course of a patient who had DLVOTO and describe the diagnosis by transesophageal echocardiography (TEE).

**Case Report**

A 62-year-old obese woman with a history of atrial fibrillation, episodic dyspnea, and poorly controlled hypertension was hospitalized for transient ischemic attacks. Admission blood pressure was 204/100 mm Hg and respirations were labored at 22 breaths per minute. A grade 3/6 systolic ejection murmur was present over the left sternal border with radiation to the axilla. Auscultation of the lungs revealed diffuse wheezes and bibasilar rales. Her ECG demonstrated atrial fibrillation and left ventricular hypertrophy. Cardiomegaly and pulmonary interstitial edema were noted on the chest roentgenogram. Two-dimensional echocardiography demonstrated a normally functioning, but markedly hypertrophied, left ventricle, mild to moderate mitral regurgitation, and biatrial enlargement. However, the study was compromised because of her obesity. Treatment with digoxin and furosemide resulted in oliguria, hypotension, and increasing respiratory distress. She was transferred to the medical intensive care unit where a pulmonary artery catheter was placed to help assess intravascular volume and cardiac function. Initial values were a pulmonary arterial pressure of 89/42 mm Hg, pulmonary artery occlusion pressure of 42 mm Hg, right

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