

Isolated, Hypothermic Cardioplegia Using Aortic Root Perfusion: A Technical Description

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Management of the coronary circulation during cardiopulmonary bypass has remained a controversial issue for many years. A variety of perfusion techniques have been developed to protect the myocardium from ischemia and at the same time provide easy access to pathologic lesions requiring surgical intervention. Included in these techniques are total body hypothermia, normothermic ischemic arrest, cold cardioplegia using topical application of cold solutions, and continuous or intermittent extracorporeal coronary perfusion at normothermic or hypothermic temperatures.¹⁻⁶ These schemes have been employed to decrease the metabolic needs of the heart or maintain normal myocardial oxygenation, or both, during periods when normal coronary perfusion must be interrupted. Burdette^{7,8} demonstrated that normothermic anoxic arrest for periods of 15 minutes caused no decisive change in the myocardial ultrastructure, but at 30 minutes there was some marginal clumping of the nuclear chromatin which became pronounced at the end of 45 minutes. Stemmer, et al reported that after 60 minutes of anoxic arrest there was a regular development of marked myocardial rigor strongly suggestive of a "stone heart" as described by Cooley.^{6,9} Griepp¹⁰ stated that profound local hypothermia as a means of myocardial protection could increase the time of ischemia to one and one half hours without major myocardial damage. Ebert¹¹ concluded that the best protection of ventricular function is achieved by employing profound topical hypothermia and intermittent hypothermic coronary perfusion. However, he did not study the effects on the myocardium of continuous hypothermic coronary perfusion. Stemmer et al⁶ demonstrated experimentally that isolated hypothermic coronary perfusion resulted in the best survival and preservation of the cardiac output. Moreover, the myocardial ultrastructure remained essentially normal in contrast to the other myocardial preservation techniques studied. Most objections to coronary perfusion, however, are based not on its physiological consequences, but rather, on the possibility of mechanical injury of the coronary ostia when selective cannulation of the coronary arteries is performed. In laboratory studies reported by Stemmer et al, they utilized cannulation of the aortic root rather than the coronary arteries because of the well known difficulty in selectively cannulating canine coronary arteries. Thus, the possibility of mechanical injury of the coronary ostia was greatly reduced.

A growing interest in isolated hypothermic cardioplegia using aortic root perfusion coupled with a large series of consecutive patients in which the technique was used, suggests the need for a detailed description of the technique employed at this hospital. Aortic root perfusion has been routinely applied in 290 patients undergoing cardiac surgery. The only exceptions have been two patients undergoing repair of an atrial septal defect.

Aortic root perfusion as used at this hospital depends upon, first, an aortic cross clamp placed high on the ascending aorta and a competent aortic valve. The area thus defined ensures filling of the coronary arteries when an extracorporeal blood source is inserted. Constant perfusion flow rates maintain the aortic valve in a closed position and the aortic clamp eliminates admixture of cold root perfusion blood and normothermic systemic perfusate. The only point of egress for blood from the area defined is via the coronary arteries.

Aortic root perfusion was originally considered as a means of cooling the heart in patients with aortic stenosis and hypertrophied, hyperdynamic left ventricles. Because of the frequently associated aortic insufficiency, aortic root perfusion was only marginally effective. When applied in patients with normal aortic valves, myocardial cooling is effectively achieved.

Cardiopulmonary bypass is instituted using a disposable bubble oxygenator.* Standard cannulation technique is employed with separate drainage of the vena cavae. The femoral artery is used for arterial return to the patient. Left heart decompression is achieved via the apex of the left ventricle.

Systemic blood temperature on bypass is maintained at 36°C-37°C using a Blanketrol hypo-hyperthermia machine in conjunction with the integral heat exchanger in the oxygenator. A separate Gorman-Rupp hypo-hyperthermia machine is used with a Sarns, 65 ml prime heat exchanger for aortic root perfusion cooling.

The aortic root perfusion circuit (diagrammed below) consists entirely of 1/4" by 1/16" wall P.V.C. tubing. The 1/4 inch coronary outlet of the oxygenator is joined to the inlet of a Sarns 65 ml prime heat exchanger which is mounted vertically on the side of the pump. The inlet is located at the bottom. An eight foot piece of tubing handed off the operative field is connected to the outlet at the top of the exchanger and then passed through a 5" roller pump. At the operative field the line terminates with a 1/4" by 3/8" reducing connector with a female luer adaptor to which one end of a six foot high pressure monitoring line is fitted. The other end of the monitoring line is passed off the operative field to the pump where it is secured to an aneroid pressure manometer calibrated in mmHg. This manometer is placed at the level of the patient's heart. The circuit is now complete except for a #16 French, Bardic femoral artery cannula which is fitted to the 3/8" end of the reducing connector just prior to its insertion into the aortic root.

During recirculation the root perfusion system is cooled and purged of air by pumping into a basin on the operative field and aspirating the perfusate with the cardiectomy suction.

Once stable bypass is instituted and the left ventricle decompressed, a teflon felt reinforced purse-string is placed in the ascending aorta. The aorta is crossclamped and a small stab wound made within the purse-string. With the root perfusion pump turning slowly to ensure that no air is introduced into the aorta, the #16 arterial cannula is advanced into the aortotomy incision. Root perfusion flow is then increased until pressure recorded in the aortic root reaches 70 - 100 mmHg. Flow is thereafter regulated to maintain that range of pressure.

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Just prior to the removal of the aortic crossclamp, when the coronary anastomoses are completed, small occluding clamps are placed at the proximal ends of the vein grafts and the native coronary arteries are compressed with the digital pressure near their origin. A large bore needle is inserted superficially into the lumen of the aorta and the cross clamp is removed. When air is satisfactorily removed, the occluding clamps on the vein grafts are removed. The heart is rewarmed for approximately ten minutes after the aortic crossclamp is removed and before defibrillation is attempted. Defibrillation is usually successful on the first shock. When defibrillation is attempted earlier than ten minutes after removal of the crossclamp, spontaneous ventricular fibrillation may occur. Varying degrees of A-V dissociation are occasionally seen in the first five minutes following successful defibrillation. This A-V block resolves spontaneously and no patient has required external pacing as a result of the root perfusion techniques.

The method of isolated, hypothermic cardioplegia using aortic root perfusion described in this paper has been used in patients undergoing the repair of a variety of intercardiac lesions and cardiac revascularization procedures. Modifications of the single aortic perfusion techniques have been employed to accommodate selective coronary artery cannulation for aortic and selected mitral valve replacement.

In the past four years, hypothermic cardioplegia via root perfusion has been used in 290 patients. In this series two patients were unable to maintain adequate circulatory dynamics at the end of routine cardiopulmonary bypass. In these patients the extent of the disease precluded any definitive surgical procedure and intra-operative death ensued.

In the remaining patients, cardiopulmonary bypass was successfully terminated. Vasopressor agents were seldom necessary for the support of blood pressure. Inotropic agents were required in about 30% of the patients for brief periods following termination of cardiopulmonary bypass.

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