

# Retrograde Coronary Sinus Versus Antegrade Cardioplegic Perfusion: A Review

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## Abstract

Retrograde coronary sinus perfusion may provide equal if not better myocardial protection than antegrade cardioplegia during certain heart surgeries.

The coronary venous system can be divided into the greater and lesser systems and veno-venous and arterio-venous anastomoses. Venous drainage varies greatly and retrograde coronary sinus perfusion depends on this variation.

Antegrade cardioplegia is effective in some severely obstructed vasculature due to collaterals but generally these are insufficient and areas of the heart remain unprotected.

The coronary venous system is a low pressure system unaffected by atherosclerosis. Great care must be taken to avoid overpressurization. Because direct cannulation can be difficult, Fabiani created a technique whereby the right heart is pressurized causing backflow into the sinus. Diehl combined this right heart approach with a dose of antegrade cardioplegia to stop the heart quickly.

Investigators have compared retrograde coronary sinus perfusion to antegrade cardioplegia using infrared myocardial thermography, microsphere injection, and crystalloid and perfluorocarbon cardioplegia.

Retrograde coronary sinus perfusion remains a viable alternative to antegrade cardioplegia for various cardiac conditions and its application may increase as investigators improve and simplify the technique.

## Introduction

Myocardial preservation during cardiac surgery is essential for the success of the procedure. While delivery of cold cardioplegia via the aortic root may be the best method of myocardial protection in normal coronary vasculature (1), retrograde coronary sinus perfusion (RCSP) may provide equal if not superior protection (1,2,3,4) during surgery for aortic valves, severe coronary artery disease, and "redo" coronary artery bypass grafts (CABG).

### I. Anatomy

The coronary venous system can be divided into three systems

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(5). The greater system (Figure 1) is composed of those vessels that drain into the coronary sinus:

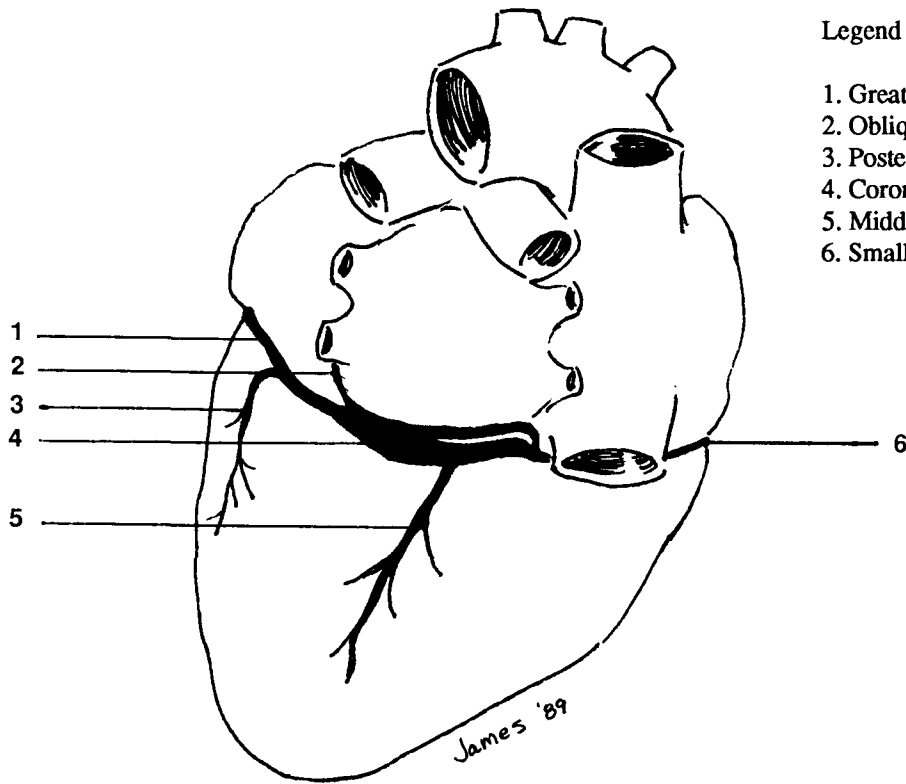
1. Anterior descending coronary vein
2. Posterior left ventricular vein
3. The oblique vein of Marshall
4. Middle cardiac vein
5. Small cardiac vein

All of these veins form the great cardiac vein which becomes the coronary sinus. The great and middle cardiac veins along with the posterior left ventricular veins have unicuspid or bicuspid valves whereas the oblique vein of Marshall does not (6). The lesser system is composed of those vessels that drain directly into the right atrium. Included is a small but important venous system called the Thebesian veins that drain into the lumens of the heart and tend to be dense in the right atrium (5). The third venous system consists of all the veno-venous and arterio-venous anastomoses that interconnect these systems. Myocardial venous drainage is extremely variant to the extent that only 21% of studied coronary sinuses follow the described drainage patterns (5). RCSP is dependent on this variation of the coronary venous system and the extent of veno-venous and arterio-venous conduits to protect the right heart because of the lack of drainage into the coronary sinus from that area.

### II. History

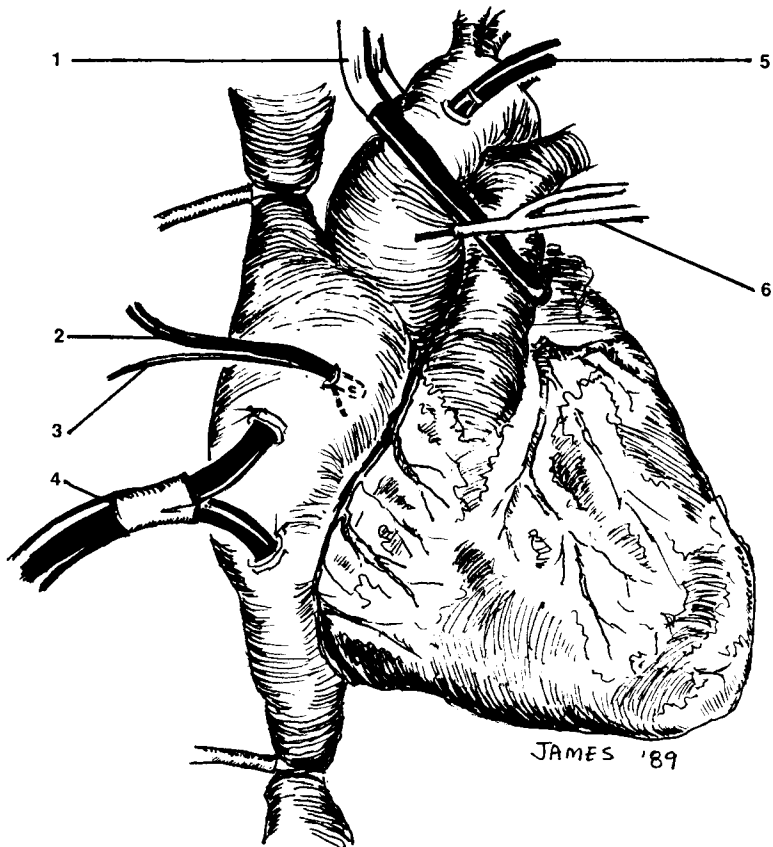
As early as 1898 Pratt (7) believed that the heart could be nourished by the Thebesian and coronary veins. Beck followed in the 1940's with an attempt to arterialize the coronary sinus of patients with coronary artery disease (8). The degree of difficulty of the two-stage procedure and a high mortality rate caused the technique to be abandoned. Eckstein (9) in 1953 and others (10, 11, 12) demonstrated that the coronary sinus was unable to deliver the normal oxygen demand requirements of the beating myocardium but could sustain a beating heart for short periods. The interest in RCSP declined as antegrade cardioplegia (AC) evolved into a simple and effective means of delivering cardioplegia.

With the success of cardiac surgery, the population of cardiac patients with diffuse coronary disease grew. A new generation of "redo" (second and third operation) patients also appeared. The inadequacy of regional myocardial protection by antegrade



Legend For Figure 1

1. Great Cardiac Vein
2. Oblique Vein of Marshall
3. Posterior Vein of Left Ventricle
4. Coronary Sinus
5. Middle Cardiac Vein
6. Small Cardiac Vein



Legend For Figure 2

1. Cross Clamp for Aorta and Pulmonary Artery
2. Cardioplegia Catheter
3. Pressure Monitoring Line
4. Venous Cannula
5. Arterial Cannula
6. Cardioplegia Needle

cardioplegia became apparent. Blanco (11) and Lillehei (12) had shown clinically and experimentally the success of RCSP for aortic valves. Now, researchers began re-evaluating RCSP as an alternative to AC on those patients whose cardiac anatomy was incompatible with the antegrade approach.

### III. Antegrade vs. Retrograde

The use of cold cardioplegia through the aortic root for rapid arrest as well as global cooling of the myocardium is currently the widely used technique for myocardial protection (1, 13). On aortic valve procedures or where the aortic valve is incompetent, direct ostial cannulation may be used (14). Certainly antegrade cardioplegia has added to the success of cardiac surgery. The drawback to AC is seen in patients with severe coronary obstruction or diffuse disease. AC is effective in some severely obstructed cases probably due to collaterals and the distal location of blockages allowing infiltrate into the first septal perforator, conus, and obtuse marginal branches (15). However, in most cases collaterals are insufficient (15, 16) so that there is a nonhomogenous distribution of solutions distal to stenosis that may be damaging (17). These areas of ischemia that would benefit most from revascularization are the least protected (13). This inadequacy of protection may be a factor in perioperative infarction and left ventricular dysfunction (16, 18). A list of the limitations of antegrade cardioplegia include:

1. Trauma to ostia by direct cannulation and possible late ostial stenosis (2, 3).
2. Uneven distribution of cardioplegia due to:
  - a. obstruction or constriction
  - b. a patent internal mammary artery graft (19,20)
3. Interruption during the procedure to administer cardioplegia through ostial cannulation.
4. Non-coronary collateral wash-out (bronchial flow) of cardioplegia causing premature rewarming (2).

Unlike the arterial system, the coronary venous system is not affected by atherosclerosis (3, 18, 21). The normal pressure range in the coronary veins is 0-6 mm Hg. Because this is a low pressure system, great care must be taken to keep perfusion pressure below 40 mm Hg as sinus injury may result (2, 5, 17). Schaper (22) has reported microvascular damage and edema even with pressure held to 30 mm Hg although some edema may be due to continuous crystalloid infusion. Menasche (2) suggests using a low flow of 30 to 50 ml per minute without monitoring the sinus pressure although he reports two cases of venous injury where the pressure was not monitored. A cardioplegia catheter with an isolated distal tip pressure port or a separate pressure line to display the pressure occurring in the coronary sinus is recommended. Measuring only the cardioplegia infusion pressure as with a Foley catheter shows a higher pressure due to the resistance to flow in the catheter. A sudden rise in pressure due to a crimp in the catheter is indistinguishable from a high sinus pressure due to an obstruction.

A general description of the technique of RCSP involves the selective cannulation and snaring of the superior and inferior

vena cava. A short right atriotomy is performed exposing the coronary sinus orifice at the acute margin. A cardioplegia catheter is inserted in the coronary sinus orifice and the balloon is inflated. The left ventricle should be vented. Once the aorta is cross-clamped, infusion is initiated while monitoring the sinus pressure. It should be noted that besides the spherical shape, there are also disc and pear-shaped balloons available that are designed to prevent occlusion of any proximal vein tributaries in the coronary sinus (5).

Direct cannulation of the coronary sinus can be difficult and has been associated with A-V block (19). Besides possible injury to the sinus, there is also concern that the right heart is not adequately protected with RCSP (18) since most of the venous drainage of the right heart is into the right atrium and ventricle by the Thebesian veins. Fabiani (23) created a new technique for the retrograde approach, which is supposed to obviate these problems of RCSP. Both cavae are cannulated and snared. The pulmonary artery is also snared. A cardioplegia catheter is inserted through a purse string into the right atrium. With cavae and pulmonary artery snared down the aorta is cross-clamped and cardioplegia is administered (5). Although there is no strong evidence of ventricular dysfunction (19, 24), the technique does "violate one of the basic principles of myocardial protection by inducing right ventricular distention in the arrested heart" (19). This technique cannot be used if a patent foramen ovale or other atrial septal defects exist (16) and has the risk of possible air embolism if attempted with an ASD present.

Another problem associated with RCSP is the length of time before cardiac arrest occurs (20, 25). In order to alleviate the problem, Diehl (19) combined antegrade and retrograde cardioplegia (Figure 2). First, a dose of cardioplegia is administered through the aortic root for rapid arrest. Then, a dose is given by the right atrial coronary sinus technique. The aortic root cannula can then be used to vent the left heart. Diehl and Bloom (24) compared this method to straight aortic root cardioplegia (ARC) and found no significant difference in ventricular recovery. Buckberg (20) believes the good recovery of the right heart using this approach may be due to a combination of coronary sinus and Thebesian vein perfusion as well as use of topical cooling of the myocardium (3, 14). Gundry (26) however, found RCSP to be superior to either right atrial cardioplegia or ARC when dealing with coronary artery obstruction.

Investigators (15, 27) have compared AC to RCSP by infrared myocardial thermography. The results show RCSP to provide more uniform hypothermia of the myocardium where stenotic or occluded arteries exist. Although a thermal picture can only reflect the surface temperature, it is still a positive indicator for RCSP.

Chiu (14) compared the flow paths of RCSP to ARC in normal canine hearts by injecting microspheres mixed with autologous blood. The results show very little injectate reaching the capillary level with RCSP as opposed to ARC. The major run-off was into the ventricular cavities with most of the microfil going to the left ventricle. In spite of this, when comparing the two techniques in hearts with occluded coronaries and in hypertrophic hearts, Chiu

found RCSP to provide more efficient cooling than ARC. Also, the thinner right myocardial wall can receive supplemental protection with topical cooling as previously mentioned.

Menasche (2) confirmed what his predecessors (10, 11, 12) had shown about the success of RCSP in aortic surgery. He compared RCSP to ARC by looking at functional recovery (serial right sided pressures, cardiac output, stroke volume index, and left and right ventricular systolic stroke work indexes) and found no statistical significance between the two techniques in aortic procedures.

The type of cardioplegic solution that is most beneficial for RCSP has also been examined. Schaper (22) compared ARC to RCSP using asanguinous crystalloid solution by looking at the ultrastructure of cardiac tissue with electron microscopy. Although they did find more extra-cellular edema and microvascular injury, there was better preservation of myocardial cells with RCSP. The edema may be associated with the lack of colloid-osmotic carrier in the solution as well as a prolonged delivery time of this fluid. Menasche suggests a hyperosmolar perfusate given at low pressure to prevent edema. He also suggests blood cardioplegia as a vehicle for increasing oxygen delivery to ischemic areas. But hemoglobin releases very little oxygen when cold according to the oxyhemoglobin dissociation curve (28). Most of the benefit from blood cardioplegia would be from the oxygen dissolved in the plasma and the oncotic and buffering properties of the blood.

Using a porcine model, Horneffer (29) compared ARC to RCSP using oxygenated and unoxygenated crystalloid and oxygenated perfluorocarbon cardioplegia. There was no significant difference between oxygenated crystalloid and oxygenated perfluorocarbon when given by continuous RCSP. The major finding was that continuous oxygenated RCSP was superior to either oxygenated or unoxygenated ARC by improving the salvage of ischemic myocardium.

### Summary

RCSP is not a replacement for AC but an alternative approach to myocardial preservation. And just as there are disadvantages associated with ARC so there are problems with RCSP:

1. Possible barotrauma and coronary sinus rupture.
2. Myocardial edema and hemorrhage with excessive pressure.
3. Difficulty of right heart isolation.
4. Delayed cardiac arrest.
5. Possible A-V block.

In patients with advanced coronary artery disease and/or aortic valvular disease and in "redo" CABG patients, these drawbacks of RCSP may be outweighed by the benefits (30):

1. More uniform cooling of the myocardium.
2. Surgical field unobstructed by cannula.
3. Avoids possible ostial stenosis.
4. Continuous infusion without surgical interruption.

The future of RCSP may be in combining the best of both RCSP and ARC to derive maximum benefit. Okike and

associates (31) have explored pulsatile RCSP that may help decrease damage to microvasculature. More research is necessary to improve and simplify today's techniques. Perhaps as RCSP gains acceptance through necessity, the technique will become a standard and functional alternative for myocardial protection.

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