

---

# Technique: Continuous Retrograde Cardioplegia Followed by Warm Blood Antegrade Infusion

---

John M. Ingram BS, CCP, Ernest A. Traad, MD, PA

Miami Heart Institute  
Miami, Florida

**Key words:** Cardioplegia, coronary sinus, retrograde, warm blood

## Abstract

The optimum myocardial preservation technique during cardiopulmonary bypass procedures remains widely debated. It is believed that the efficacy of the myocardial preservation technique is largely responsible for post-operative myocardial function and recovery.

At the Miami Heart Institute, a recently developed technique has been under investigation. It is the purpose of this report to reveal the latest research findings on what we believe to be a superior form of myocardial preservation.

Fifty patients who underwent cardiac operations were randomly selected for this study. In each patient, the technique of retrograde cardioplegia was employed. The cardioplegia was administered continuously in retrograde fashion in order to maintain a myocardial temperature range of 6° - 12°C throughout the ischemic period. Shortly before aortic cross clamp removal, warm pump blood was administered antegrade fashion through the aortic root. Aortic root pressure was strictly maintained between 75 - 85 mmHg to insure adequate infusion into the coronary arteries.

The result of the retrograde technique has been strict maintenance of myocardial hypothermia throughout the ischemic period. The antegrade warm blood infusion permits adequate myocardial reperfusion and rewarming. The result of this warm blood infusion has been a spontaneous reinstatement of the patient's cardiac rhythm without a fibrillation period. Of patients undergoing this technique, 94% experienced no cardiac fibrillation at any time during the operation. While marked improvement in post-operative myocardial function has been observed and is currently under data accumulation, it is our conclusion that this technique is a significant advancement in the field of myocardial preservation (J. Extra-Corporal Technol, 21(2): 56-60, 1989, 15 Ref).

## Introduction

Myocardial hypothermia is an important modality for myocardial preservation during cardiac operations. Numerous methods of attaining myocardial hypothermia have been employed. Generally, most techniques involve a two fold approach consisting of pouring saline slush or ice chips into the pericardial well combined with a cold cardioplegia solution

---

*Address Communications to: Ernest A. Traad, M.D., P.A., 1150 N.W. 14th St., Suite 207, Miami, FL 33136 or John M. Ingram, BS, CCP, 14120 Harpers Ferry St., Davie, FL 33325*

delivered via the aortic root or coronary sinus. Most commonly employed is an intermittent antegrade administration of cardioplegia<sup>4, 12</sup>.

In this report we assess the effectiveness of a two phase technique. In phase I, cold blood cardioplegia is administered via the coronary sinus on a continual basis throughout the ischemic period. Through this means, myocardial hypothermic temperatures are strictly maintained.<sup>7, 9</sup> Slight adjustments in the cardioplegia administration rate permits one to maintain any myocardial temperature range desired. Phase II consists of warm oxygenated pump blood being administered antegrade fashion into the aortic root for 15 - 25 minutes prior to cross clamp removal. The significance of phase II is the elimination of haphazard myocardial reperfusion and rewarming.

Improvement in myocardial preservation must be of concern to all those employing cardiac surgery today. With the numbers of critically ill patients being treated with cardiac surgery quickly on the rise, the need for optimal myocardial preservation has become imperative for patient survival<sup>8</sup>. Preliminary results of this two phase technique have been very favorable and are discussed in this report.

## Method

Fifty randomly selected patients undergoing cardiac surgery were used for this study. In each patient, a routine skin incision and median sternotomy was performed. Aortic cannulation and single atrial cannulation was performed except in patients undergoing a mitral valve procedure in which bicaval cannulation was used. Cardiopulmonary bypass was instituted and systemic core cooling initiated in the routine manner. All patients were systemically cooled to an esophageal temperature of 25°C. The Gundry Retrograde Coronary Sinus Perfusion Cannula (DLP Inc., Grand Rapids, MI) was inserted through a small incision in the right atrial wall and into the coronary sinus (see figure 1). Next, the aortic cross clamp was applied. The coronary sinus cannula was fixed into place by injecting 3cc of normal saline into the balloon located at the tip of cannula. An obturator may be used to facilitate cannula insertion into the coronary sinus. In the case of bicaval cannulation, direct visualization of the coronary sinus was obtained by making a small incision in the right atrium and directly inserting the cannula into the coronary sinus. Purse string sutures were used to secure the cannula at the site of insertion. The cannula was then connected to the Gish Blood Cardioplegic Solution Delivery System (Gish Biomedical Inc., Santa Ana CA). A pressure

monitoring port was flushed and connected to the cannula in order to monitor coronary sinus pressure. Cold blood cardioplegia (3-5° C) consisting of 4 parts Plegisol (Abbott Laboratories, Chicago, IL) to 1 part pump blood was administered into the coronary sinus. Upon infusion an ice slush of normal saline was poured into the pericardial well. Twelve mEq of sodium bicarbonate and ten mEq of potassium chloride was added to each 1000 cc bag of Plegisol solution. The cardioplegia delivery rate for the initial 1000 cc was 250 - 300 cc/min. All subsequent infusions were delivered at 50 -150 cc/min. At all times, the maximum coronary sinus pressure was carefully maintained below 40 mm Hg. Infusion flow rates were adjusted in accordance with the coronary sinus pressure.

Myocardial septal monitoring was employed throughout, and was consistently maintained between 6° - 12°C (see figure 2). The cardioplegia infusion rate was increased once myocardial septal temperatures reached 12°C. Conversely, the infusion rate was greatly decreased, or temporarily discontinued, if the septal temperature dropped below 6°C. Cardioplegia infusion was never suspended for greater than 12 minutes on any of the 50 patients studied.

The second phase of the technique consists of an antegrade infusion of warm arterial pump blood. This phase is initiated during the systemic rewarming period 15-25 minutes prior to aortic cross clamp removal. A 14 gauge aortic root cannula (DLP Inc., Grand Rapids, MI) with an integrated monitoring port was inserted into the aortic root. Purse string sutures were necessary to secure the cannula in place. The initial 500 cc bolus of warm arterial pump blood was combined with 20

mEq of potassium chloride and then delivered at a rate of 250-1000 cc/min. The delivery rate was adjusted so that the aortic root pressure was maintained between 75-85 mm Hg at all times. Following the 500 cc hyperkalemic bolus, bulldog clamps placed on the internal mammary graphs were released and straight arterial pump blood maintained between 37°-38° was continuously delivered into the aortic root. our established lower limit for the warm blood infusion rate is 150 cc/min x BSA (body surface area). At no time was the infusion rate permitted to drop below this lower limit. In the event that the lower limit rate was being administered and the aortic root pressure exceeded 85 mm Hg, intracoronary nitroglycerin (NTG) was given through the aortic root cannula. Subsequent doses of NTG (2000-3000 micrograms) were given as necessary. Continuous warm blood infusion is administered for 25 minutes or until the heart is contracting vigorously. As shown in figure 3, the electrocardiographic development begins with asystole, and progresses naturally with reperfusion time. If sinus rhythm did not return after 25 minutes, some form of cardiac pacing was instituted. Subsequently, the aortic cross clamp was removed and the patient was soon weaned from cardiopulmonary bypass.

## Results

The preliminary results of this two phase technique has shown great promise. In phase I, the continuous retrograde infusion of blood cardioplegia, the hypothermic temperature regulation of the myocardium is easily controlled and maintained. Figure 2 is a cumulative average of all fifty patients whose myocardial temperatures were recorded every 10 minutes.

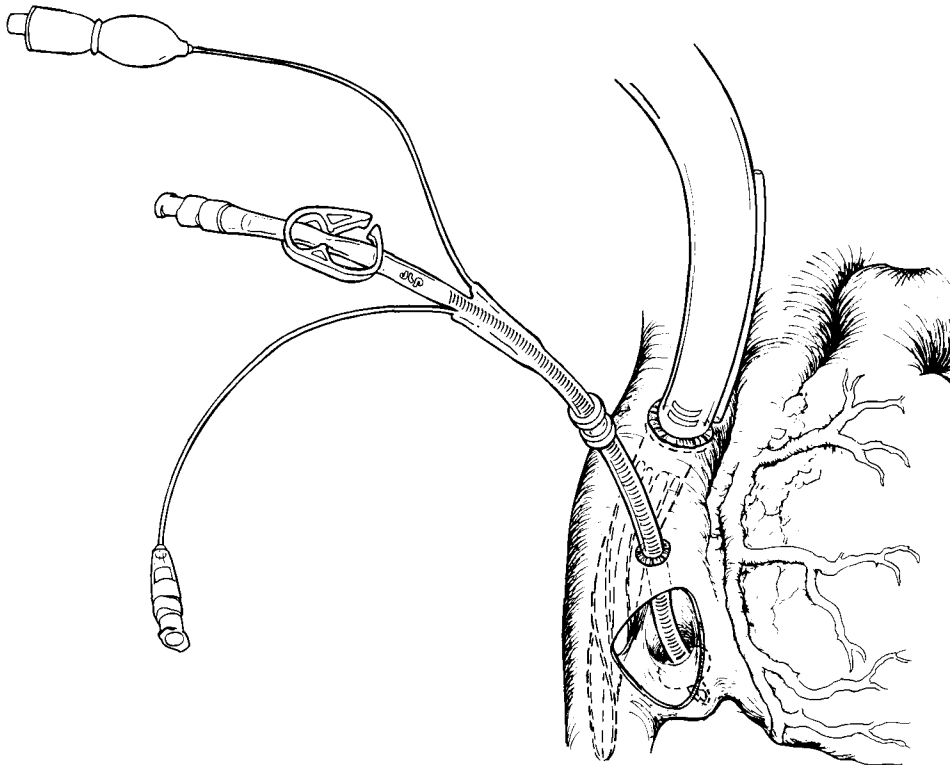


Figure 1

The myocardial temperature is controlled by increasing or decreasing the cardioplegia infusion rate until the desired temperature is reached. The benefits realized by this technique are three-fold. First, undesired myocardial rewarming due to the patient's systemic temperature and overhead surgical lighting, is eliminated. Secondly, the myocardial temperature is unaffected by the core rewarming period. Thirdly, myocardial capillary beds malperfused or unperfused due to arterial blockage via an antegrade infusion, are completely accessible via the retrograde pathway. This results in a global infusion of cardioplegia throughout the myocardium<sup>11, 13</sup>.

The purpose of phase II, the antegrade warm blood infusion, is to insure adequate reperfusion of the myocardium. In addition, the myocardium is rewarmed more evenly and completely. The initial infusion of hyperkalemic blood suspends the heart in a state of diastole so that a reperfusion period may be achieved without cardiac fibrillation. As is shown in figure 3, the heart is in a complete state of diastole following the initial hyperkalemic bolus. Subsequent continuous blood infusion results in a spontaneous reinstatement of the patient's rhythm. Of the fifty patients studied, 94% experienced no cardiac fibrillation period at any time during the operation. Of the 6% who did experience fibrillation, all responded immediately to cardiac defibrillation. Undue fibrillation is felt to be due to the presence of a large noncoronary collateral blood flow prematurely washing out the initial hyperkalemic infusion<sup>2, 3</sup>.

### Discussion

With the increasing numbers of double procedures and re-operations in cardiac surgery, there is a great need for optimal myocardial preservation<sup>6</sup>. Most commonly, a technique of intermittent antegrade cardioplegia is employed. While success has been realized with this technique, myocardial preservation for the critically ill cardiac patient may be inadequate.

Undue myocardial rewarming during ischemic periods due to the surgical surroundings may lead to areas of poor myocardial preservation<sup>12, 13</sup>. In addition, excessive ischemic periods during re-operations and double procedures has made successful outcomes less likely. The necessity for better myocardial preservation for longer periods of time is strongly indicated for the future of cardiac surgery<sup>14</sup>.

In cases of coronary artery bypass grafts, distal anastomoses were achieved in the routine surgical manner. However, the grafts bypassing complete or high grade lesions were anastomosed distally to the coronary artery as expected, and then anastomosed proximally to the aorta prior to the hyperkalemic blood infusion. The purpose was to adequately reperfuse areas distal to high grade obstructions in order to optimize myocardial reperfusion. Grafts anastomosed to coronary arteries with noncritical blockages were not anastomosed proximally to the aorta before the warm blood infusion. Adequate reperfusion of these areas was satisfactorily obtained through the normal antegrade flow through the coronary arteries. Subsequent to cross clamp removal, a partial aortic clamp was applied and the proximal anastomoses were made in the usual

manner.

Further investigation is necessary for complete verification of post-operative improvement in myocardial performance. Although this technique may be used in routine cardiac surgery, its indications include: aortic insufficiency, re-operations, double procedures, severely compromised ventricle (E.F. less than 25%), and procedures requiring an extended ischemic time.

While we have noted a significant improvement in myocardial function post-operatively and are currently collecting data, it is our conclusion that this two phase technique is a significant advancement in myocardial preservation.

### References

1. Utley JR: Pathophysiology and Techniques of Cardiopulmonary Bypass, Vol. 2, Maryland, 1983, Williams and Wilkins Inc., p. 138 - 163
2. Reed CC, Stafford TB: Cardiopulmonary Bypass, 2nd ed., Texas, 1985, Texas Medical Press Inc., p. 416-426
3. Netter FA: Heart, 2nd ed., New Jersey, 1980, CIBA, p. 16-17
4. Buckberg GD: A proposed "solution" to the Cardioplegia Controversy. *J Thorac Cardiovasc Surg* 77:6, 1979
5. Kaijser L, Jansson E, Schmidt W, Bomfin V: Myocardial Energy Depletion During Profound Hypothermic Cardioplegia for Cardiac Operations. *J Thorac Cardiovasc Surg* 90:896-900, 1985
6. Balderman SC, Binette J, Chan AWK, Gage AA: The Optimal Temperature for Preservation of the Myocardium during Global Ischemia. *Ann Thorac Surg* 35:605-614, 1983
7. Bolling SF, Flaherty JT, Bulkley BH, Gott VL, Gardner TJ: Improved Myocardial Preservation during Global Ischemia by Continuous Retrograde Coronary Sinus Perfusion. *J Thorac Cardiovasc Surg* 86:659-666, 1983
8. Rosenfeldt FL: The Relationship between Myocardial Temperature and Recovery after Experimental Cardioplegic Arrest. *J Thorac Cardiovasc Surg* 84:656-666, 1982
9. Chiu RCJ, Blundell PE, Scott HJ, Cain S: The Importance of Monitoring Intramyocardial Temperature During Hypothermic Myocardial Protection. *Ann Thorac Surg* 28:317-322, 1979
10. Wittnich C, Chiu RCJ: The Significance of Persistent Myocardial Perfusion during Aortic Cross-clamping in Myocardial Protection. *J Thorac Cardiovasc Surg* 85:612-617, 1983
11. Fisk RL, Ghaswalla D, Guilbeau EJ: Asymmetrical Myocardial Hypothermia during Hypothermic Cardioplegia. *Ann Thorac Surg* 34:318-323, 1982
12. Guiraudon GM, Campbell CS, McLellan DG, et al: Retrograde Coronary Sinus versus Aortic Root Perfusion with Cold Cardioplegia: randomized study of levels of cardiac enzymes in 40 patients. *Circulation* 74 (suppl III): 105-115, 1986
13. Lazar HL: Coronary Sinus Interventions during Cardiac Surgery. *Ann Thorac Surg* 46:475-482, 1988
14. Snyder HE, Smithwick W, Wingard T, Agnew RC: Retrograde Coronary Sinus Perfusion. *Ann Thorac Surg* 46:389-390, 1988

15. Gore JM, Weiner BH, Benotti JR, et al: Preliminary Experience with Synchronized Coronary Sinus Retroperfusion in Humans. *Circulation* 74(2):381-388, 1986

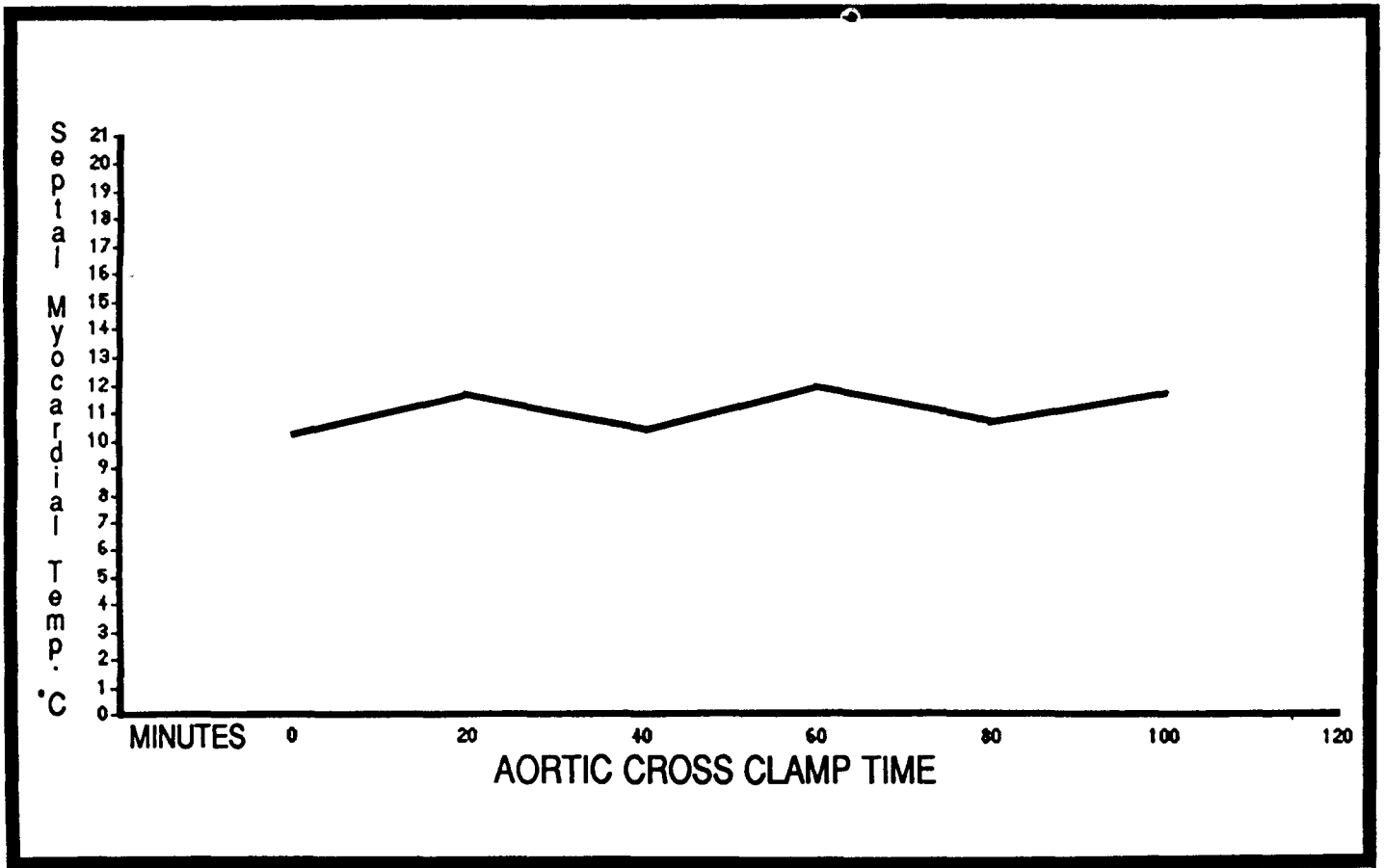


Figure 2  
Cumulative average of all fifty patients whose myocardial septal temperatures were recorded every ten minutes during retrograde cardioplegia infusion. All patients were maintained between 6°-12°C.

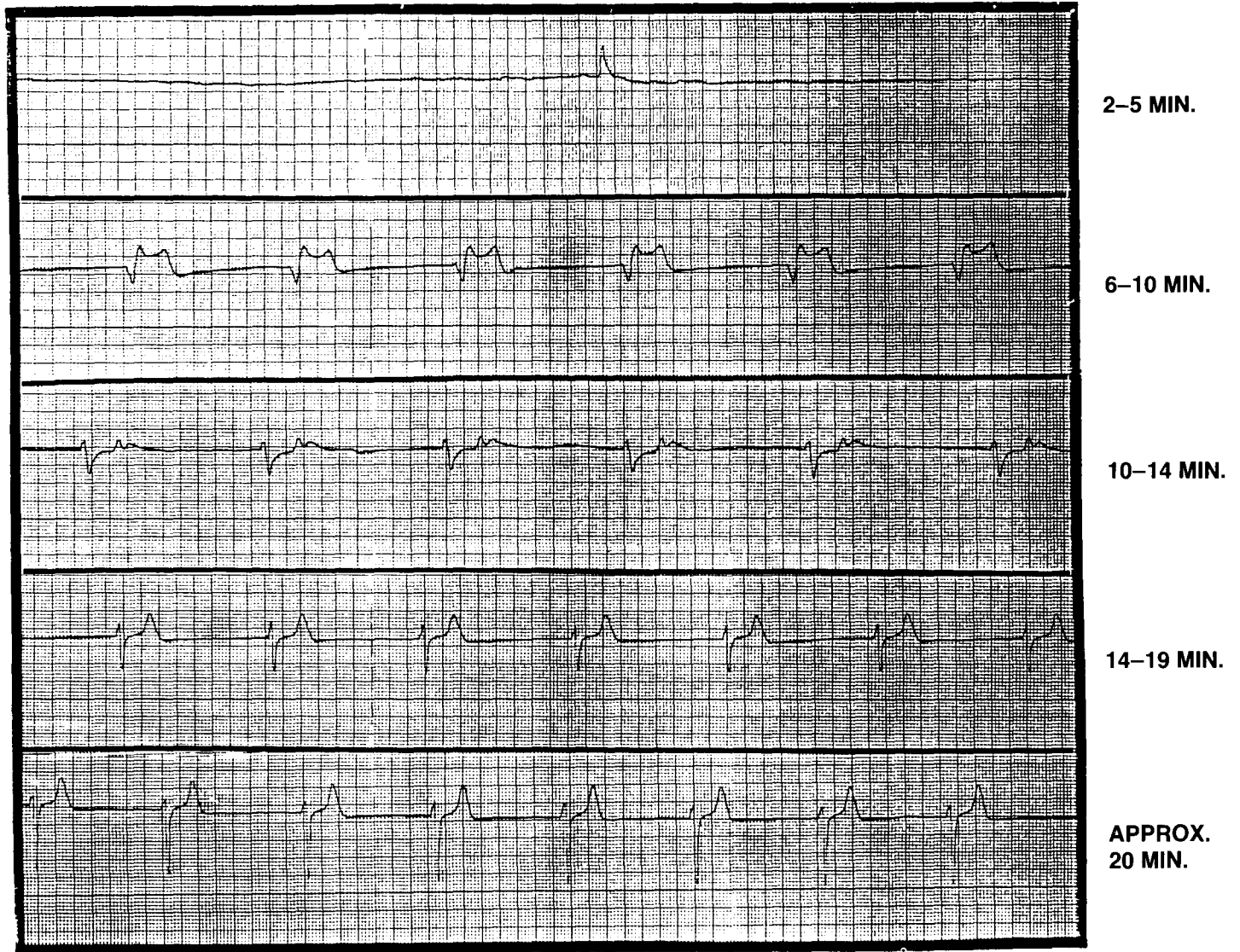


Figure 3

Continuous antegrade warm blood infusion results in a gradual reinstatement of the patient's rhythm. Of the fifty patients studied, 94% experienced no cardiac fibrillation.