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Improved Cardiac Function Using Cardioplegia During Procurement and Transplantation

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CARDIAC transplantation was resumed as a therapeutic procedure at the University of Pittsburgh in June of 1980. Distant procurement and a simple preservation technique can be used to preserve donor hearts for 3–4 hr with satisfactory function of the graft.[1] In this report, we describe a technique using cardioplegia, which improves preservation during implantation.

MATERIALS AND METHODS

Our use of cardioplegia during cardiectomy and implantation has varied. In 10 instances, none was used during excision nor during implantation, in 3 it was infused only during cardiectomy, and in 16, both during excision and implantation. "Stanford solution"[1] (Table 1) has been used during cardiectomy and "Buckberg blood cardioplegia"[2] (Table 2) during implantation.

Heart, liver, and kidneys, all functionally satisfactory for grafting, have been obtained from 10 donors. The donor's temperature ambiently cools to 33–34°C and in situ cooling of the liver, achieved by infusing lactated Ringer's solution (4°C) into the portal vein, further cools the heart. An initial sternotomy and celiotomy provide access for a rapid cardiectomy should the hepatectomy and nephrectomy compromise cardiac function, but this has never occurred. In situ cooling of kidneys is preferred, and the infusion is begun immediately after occlusion of the ascending aorta initiates cardiectomy. The liver and kidneys are excised subsequent to removal of the heart. Ex vivo cooling of kidneys necessitates interruption of venous return and results in hemodynamic instability. Although not preferable, it has been accomplished in order to comply with the hosting institution's wishes.

The superior vena cava is stapled, the inferior cava occluded and divided, the aorta occluded and cardioplegia infused, the pulmonary veins and pulmonary arteries transected, and lastly the aorta divided. Cardioplegia is infused into the aorta through a 12-gauge catheter at a maximal pressure of 150 mm Hg. The infusion is facilitated by promptly transecting a pulmonary vein and eliminating return to the left atrium and ventricle.

A novel technique of stapling the divided aorta of the donor heart with the Ravitch TIA 30 stapler (3.5 mm or V staples) (American Surgical Instruments, Inc.) enables cardioplegia to be infused into the donor heart during implantation (Fig. 1). The 12-gauge catheter used during cardiectomy is affixed to the donor's aorta with a purse-string suture at that time and left in place. During infusion, air is evacuated by placing an 18-gauge needle into the segment of aorta between the aortic valve and staple line. The solution is infused every 20 min at a pressure of 120 mm Hg by employing a constant pressure-variable flow pump. External cooling every 20 min (4°C crystalloid solution) and internal cooling upon completion of the atrial anastomoses via the left atrial appendage was employed in every transplantation.

The need for inotropic drugs (dopamine and/or dobutamine) was ascertained retrospectively according to the number of days (>12 hr = 1 day) dopamine and/or dobutamine was used in excess of 10 μg/kg/min to maintain a normal mean arterial pressure (60–80 mm Hg) and urinary output (>30 cc/hr).

RESULTS

When no cardioplegia (10 patients) was used during cardiectomy or implantation, dopamine and/or dobutamine were used for 2.8 days, whereas when cardioplegia was used during cardiectomy and also during implantation (16 patients), these drugs were used for 0.1 days—a difference that is statistically significant ($p < 0.001$). The total ischemic times were not statistically different ($p > 0.05$) (Fig. 2). The times of transportation and implantation are detailed in Fig. 3.

DISCUSSION

Our initial concept was that rapid excision of the donor heart and immersion in a crystalloid solution at 4°C was simpler and would quickly cool and arrest the heart so that the fundamental principles of preservation would be met.[3] The postoperative need for inotropic support in these patients suggested that this was not correct, and subsequent laboratory

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0041-1345/83/1501-0302$01.00/0

Table 1. Stanford Cardioplegic Solution

Component	Concentration
Potassium	30 meq/liter
Sodium	25 meq/liter
Chloride	30 meq/liter
Bicarbonate	25 meq/liter
Dextrose	50 g/liter
Mannitol	12.5 g/liter
Osmolality	440 mosmole/liter
pH (at 4° C)	8.1–8.4

Table 2. Buckberg Blood Cardioplegia

Component	Concentration
Ionic calcium	0.6 meq/liter
KC1	30 meq/liter
Osmolarity	355 mOsmole
Hct	20
pH	7.7

evidence contradicted this concept. In dogs, the septal temperature decreased more rapidly and arrest occurred sooner (Fig. 4) when cardioplegia was used during the cardiectomy. Not compared in this report were three transplants in which cardioplegia was used during excision of the donor heart but not during implantation. The lesser need for inotropic support was readily evident (retrospectively 0.5 days of dopamine and/or dobutamine at >10 μg/kg/min compared to 2.8 days without it). Concurrently, the idea of stapling the donor aorta in order to facilitate the use of cardioplegia during implantation originated and was combined with the latter. The benefits to the donor heart include maintenance of arrest and hypothermia and washout of metabolites. The early benefit to

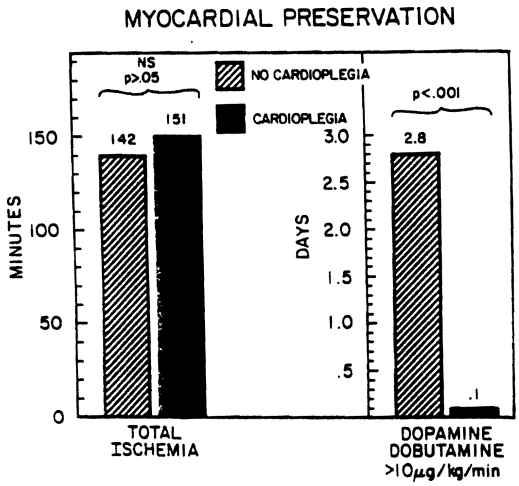

Fig. 2. When no cardioplegia (10 patients) was used during cardiectomy or implantation, dopamine and/or dobutamine were used for 2.8 days, whereas when cardioplegia was used during cardiectomy and also during implantation (16 patients), these drugs were used for 0.1 days—a difference that is statistically significant ($p < 0.001$). The total ischemic times were not statistically different ($p > 0.05$).

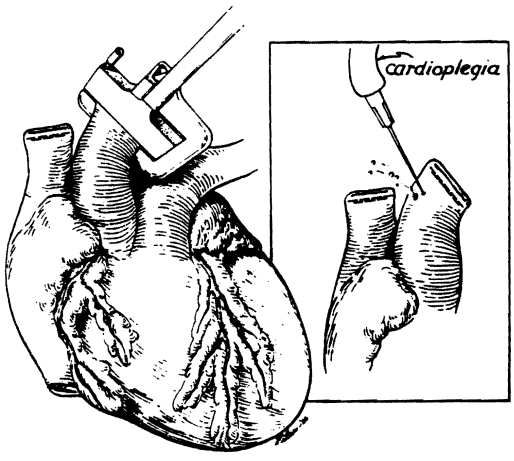

Fig. 1. Technique of infusing cardioplegia into the donor heart during implantation.

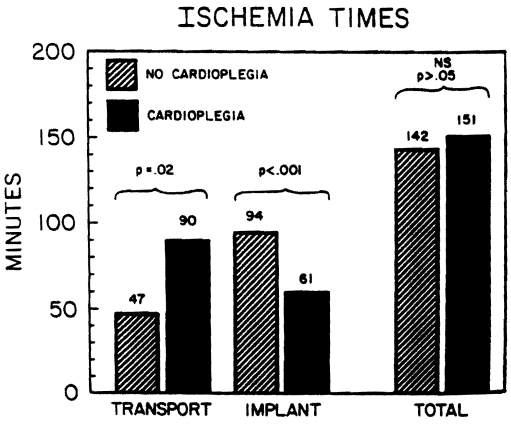

Fig. 3. The total ischemic times were not statistically different. The times of transportation and implantation are statistically significantly different.

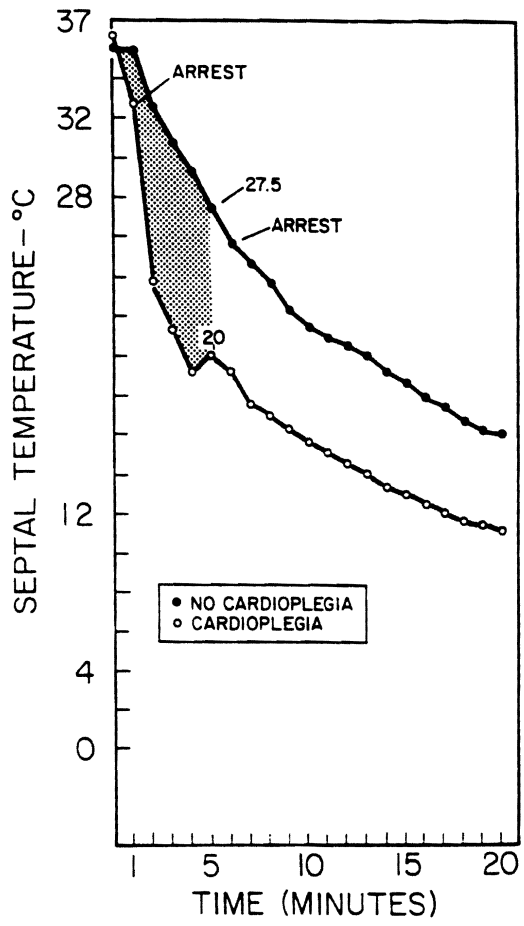

Fig. 4. In six dogs, the septal temperature decreased more rapidly and arrest occurred sooner when cardioplegia was used during the cardiectomy.

the recipient is a lesser need for cardiotonic support postoperatively.

SUMMARY

More rapid cooling and early arrest of a donor heart can be achieved with the use of cardioplegia during cardiectomy. Stapling the divided aorta of the donor heart facilitates the infusion of cardioplegia during implantation. Combining the use of cardioplegia during excision and implantation lessens the need for inotropic drugs following transplantation.

REFERENCES

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