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TECHNIQUES FOR COMBINED PROCUREMENT OF HEARTS AND KIDNEYS WITH SATISFACTORY EARLY FUNCTION OF RENAL ALLOGRAFTS

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IMPROVED SURVIVAL RATES following cardiac transplantation have stimulated renewed interest in this mode of therapy for otherwise intractable heart failure, according to Oyer and associates (1), Starzl and colleagues (2) and Merkel and coworkers (3). As the demand for heart donors has increased, the techniques of combined donor nephrectomy and cardiectomy have required wider application. Because of the regional nature of kidney procurement centers compared with the rather centralized phenomenon of cardiac transplantation, the optimal use of available organs will require increasing co-operation between institutions during organ procurement procedures.

The standard techniques of donor nephrectomy require only minor modifications to satisfy the concerns of the cardiac surgeons over the quality of their grafts. At the same time, these modifications should, in no way, jeopardize the immediate functional quality of the kidneys obtained. The method of combined procurement of kidneys and hearts from 18 donors by the University of Pittsburgh team is described; the results of transplantation of 34 kidneys obtained using these techniques are reviewed.

METHODS

The technique of cardiectomy in this series has gone through several modifications, differing in the use of cardioplegic solution. Despite these changes, the method of nephrectomy has remained standardized. In all instances, in situ cooling of the kidneys, with arterial infusion of cold preservation solution through an aortic cannula, was used. However, any standard method of donor nephrectomy is compatible with all of the techniques of cardiectomy that were used, provided that several critical steps are followed.

Preliminary Steps

A midline sternotomy and celiotomy are used. The electrocautery is used liberally to minimize blood loss. The sternum is split and opened widely at the same time as the abdomen. This not only provides excellent exposure for the nephrectomies but also, more importantly, allows for rapid cardiectomy, should it become necessary. Donor core temperature, arterial pressure, serum electrolytes, hemoglobin and blood oxygen content must be monitored to prevent premature development of cardiac arrythmias and, thus, to help assure satisfactory organs for grafting. Urinary output is maintained by forced diuresis using mannitol, and filling pressures are aggressively supported with intravenous infusion of crystalloid and, if needed, red blood cells. A central venous or pulmonary artery catheter has often facilitated these measures.

If in situ kidney cooling is not desired, the left kidney can be excised at this time and infused ex vivo. Because a segment of vena cava is usually taken with the right kidney to provide for extra length of the vein, removal of it is delayed until after cardiectomy. As long as venous return to the heart is preserved, however, the right kidney could be removed at the outset as well. These techniques were not used in the present investigation.

The preliminary dissection for in situ infusion involves encircling the aorta just below the diaphragm, ligating the celiac axis and the superior and inferior mesenteric arteries and placing a

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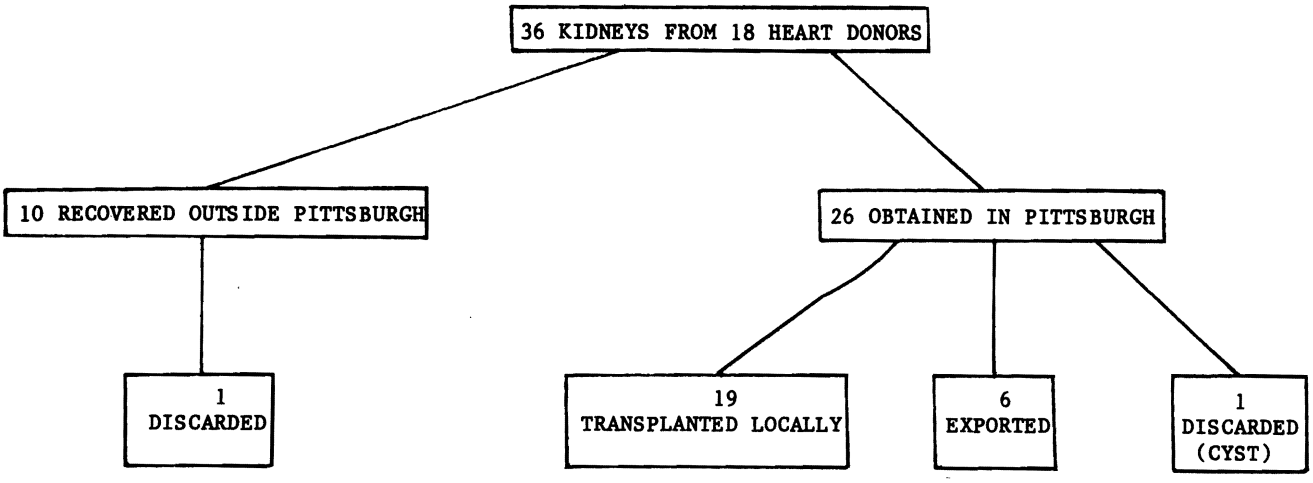

FIG. 1. Origin and distribution of kidneys procured with hearts.

cannula into the distal part of the aorta. Both kidneys are mobilized completely to facilitate the speed of removal later. A clamp is positioned around the abdominal aorta just below the diaphragm and made ready for occlusion at the appropriate time. The ureters are divided close to the bladder and dissected free from the retroperitoneal space. Individual cultures are taken of urine from each ureter.

Organ Removal

Cardiectomy is performed first. In all instances, the proximal part of the abdominal aorta is not clamped, and the arterial infusion is not begun until: 1, the aorta is clamped or transected in the chest by the cardiac surgeon and 2, the venous return to the heart has been interrupted. These provisos are important to avoid left ventricular strain and contamination of coronary artery flow with renal preservation solution.

The previously divided sternum provides for quick access to the heart by way of a pericardiotomy. The organ is inspected for gross suitability. Just proximal to the innominate artery, the aorta is freed from the pulmonary artery and encircled. When infusion of a cold (4 degrees C.) solution, containing potassium (20 milliequivalents per liter), is to be used to achieve sudden cardiac arrest, a 14 gauge polyethylene catheter is inserted into the ascending aorta.

Before proceeding, anticoagulation of the donor is achieved with heparin (3 milligrams per kilogram), and a vasolytic agent (chlorpromazine, tolazoline hydrochloride or phentolamine) can be given at the discretion of the kidney procurement team. In this series, 25 milligrams of chlorpromazine were given to all donors, except those in whom cardiovascular instability developed.

Cardiectomy begins with transection of the superior and inferior vena cava at the pericardial reflections. Several beats are permitted to decompress the heart, and the aorta is clamped just proximal to the innominate artery. When a cardioplegic solution is used, 500 to 750 milliliters are infused through the 14 gauge catheter at a rate of 150 to 200 milliliters per minute. During this infusion period, cardiectomy is completed with sequential division of the pulmonary artery at its bifurcation, the pulmonary veins as they enter the pericardium and, finally, the aorta just proximal to the occluding clamp. The heart is taken from the field and further cooled in two successive ice baths (4 degrees C.)

Staple closure of the divided ends of the superior vena cava and aorta is done during this time. This measure facilitates intermittent delivery of additional cold cardioplegic solution later during the recipient procedure. The heart is placed in a polyethylene bag and immersed in an ice-slush solution for transportation.

The surgeon doing the nephectomy clamps the proximal abdominal aorta and begins infusion of cold preservation solution immediately after the aorta is clamped in the chest. In this series, modified Collins solution at 4 degrees C, was used in the 13 procurements done locally and the solution of choice of the hosting institution used in the other five. The infrarenal vena cava is divided and the aorta elevated and dissected free posteriorly by ligating and dividing the lumbar vessels, as reported by Squifflet and co-authors (4).

Once 1,000 milliliters of infusion have been completed, the kidneys are excised en bloc. They are taken to a back table, separated and either preserved in cold storage or placed on pump perfusion, using a colloid solution at 5 to 7 degrees C.

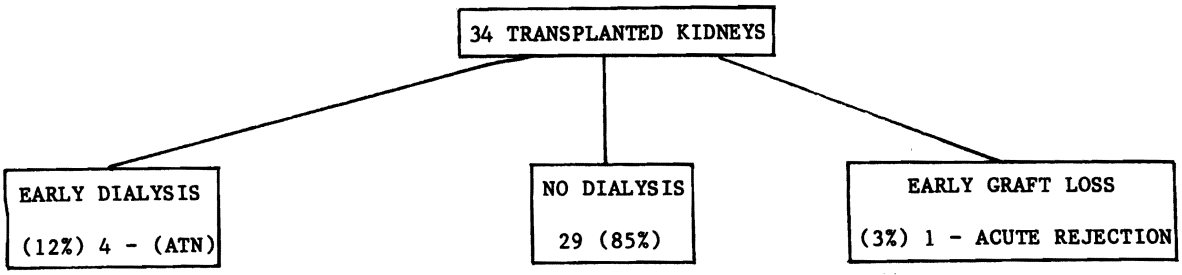

FIG. 2. Results following transplantation of kidneys procured with hearts.

with an MOX-100 pump (Waters Instrument Corporation). The time added by the cardiectomy to that for nephrectomy is usually no more than 30 minutes, including the initial sternotomy.

RESULTS

From 1 June 1980 until 31 December 1981, 18 cardiac donors yielded 36 potential kidney grafts. In Figure 1, the fates of the kidneys harvested are summarized. Two organs were discarded—one because of a suspected donor infection, the other because of a cyst, involving one-third of the kidney. Twenty-seven organs were preserved by pump perfusion, with a mean preservation time of 24.7±8.5 hours (± S.D.). The other seven were kept in ice storage for a mean of 20.0±4.8 hours before engraftment. The preservation times on each method are not different when subjected to Student's t test ($0.1>p>0.05$).

Of the 26 kidneys harvested in Pittsburgh, 19 were transplanted there, one was discarded and the other six were exported. On the other hand, none of the ten kidneys harvested outside of the geographic area normally assigned to the University of Pittsburgh's Transplant Organ Procurement Foundation were imported to Pittsburgh.

The results of transplantation of the remaining 34 kidneys are shown in Figure 2. One graft was removed after nine days because of severe acute rejection. Four other recipients required acute dialysis before kidney function became adequate. Satisfactory early function of the contralateral mate to each of the kidneys received by these patients was obtained. The mean total pump preservation time of the grafts that did not exhibit adequate early function (25.2±9.2 hours) was not different from that of the grafts that did (24.8±8.4 hours) $p>0.50$. None of the seven recipients of the grafts preserved in ice storage were among those requiring early dialysis.

DISCUSSION

Surgeons responsible for the procurement of renal allografts are naturally wary of any changes in their techniques which might jeopardize the quality of those grafts. The addition of a donor cardiectomy to their normal routine may be viewed as an imposition on that responsibility. Yet, to meet the increasing demand for heart transplants, combined donor cardiectomy and nephrectomy will require wiser acceptance, particularly among transplant centers not directly involved in cardiac transplantation. All standard methods of nephrectomy are adaptable to combination with the method of cardiectomy reported herein without the need for extensive modification and without increased hazard to the kidneys. The additional time required for cardiectomy is nominal.

The results reported upon herein demonstrate satisfactory early function of 29 of 34 transplanted kidneys of a total of 36 that were harvested in combination with cardiac allografts. None of the kidneys were discarded because of the technical errors during procurement.

Four kidney recipients required early dialysis and a fifth lost a graft because of acute rejection. This incidence of early dialysis is less than that cited by Squifflet and collaborators (4), Feduska and co-authors (5), Cho and associates (6) and Anderson and colleagues (7). Vaughn and coworkers (8) reported an early dialysis incidence of 40.5 per cent for cold stored and 32.8 per cent for perfused kidneys in a compilation of data from the collected institutions of the Southeastern Organ Procurement Foundation.

The four recipients requiring early dialysis eventually obtained satisfactory function. The fifth patient lost a graft to acute rejection. The cause of inadequate early graft function in these four other instances was not documented but was presumed secondary to acute tubular necrosis (ATN).

Of the five donor pairs from which the four kidneys with ATN and the one with acute rejection were obtained, none of the contralateral mates failed to exhibit adequate early function. In view of this, the procurement procedure itself

cannot be indicted as the cause for the instances of ATN.

Because of the time interval between aortic clamping and removal of the heart, in situ kidney cooling is preferred. This affords the nephrectomy team the luxury to stand back and allow the cardiac surgeons adequate room and time to cool and excise the heart. Kidney warm ischemia time is eliminated since in situ cooling of the organs can be done simultaneously.

Three donor hearts experienced arrhythmias prematurely and required rapid excision before kidney dissection had been completed. In two of these instances, the sternum had been opened widely at the beginning of the procedure. Satisfactory hearts for transplantation were obtained because of the speed with which cardiectomy could be performed. The third instance of arrythmia was ventricular asystole, occurring shortly after the skin incision had been made. In retrospect, the donor core temperature had been inadequately maintained, and a hyperkalemia of 6.4 milliequivalents per liter was exacerbated by acidosis. Although the heart from this donor was excised, it was not transplanted. Both kidneys experienced approximately 25 minutes of relatively warm ischemia but were successfully transplanted after more than 24 hours each of ice storage, with neither recipient requiring early dialysis.

Careful assessment of donor condition and maintenance of fluid and electrolyte balance and blood acid-base status are all important to the prevention of these terminal stage cardiac arrhythmias. Blood loss must be minimized, and if necessary, donors should be transfused to maintain coronary arterial blood oxygen content. The use of a heating blanket to keep the cadaver core temperature above 33 to 35 degrees C. has become routine.

SUMMARY

Methods for combination of donor nephrectomy with donor cardiectomy are outlined. The satisfactory early function of 29 of 34 transplanted kidneys harvested with these techniques supports their wider application and should encourage their wider acceptance.

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