

PROCUREMENT, PRESERVATION, AND TRANSPORT OF CADAVER KIDNEYS

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Cadaveric renal transplantation requires an extensive network of health care individuals to facilitate the recognition, procurement, preservation, and transport of kidney grafts. The responsibility of identifying potential organ donors lies with all health care workers involved in the care of neurologically injured patients. For those who do not experience the enormous benefit of organ transplantation, obtaining consent from grieving families can be difficult. It is estimated that more than 25% of families of potential organ donors are not approached for donation. Much has already been accomplished, but clearly more can be done to provide kidneys for a steadily increasing waiting list, which has grown to nearly 35,000 while only 8559 cadaveric kidney transplants were performed in 1996.

BRAIN DEATH DETERMINATION

In July 1981, the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research submitted guidelines for the determination of brain death, which led to the "Uniform Determination of Death Act." These guidelines outline neurologic criteria (Table 1) that define the diagnosis of brain death in patients whose cardiopulmonary function is being artificially maintained.³

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SURGICAL CLINICS OF NORTH AMERICA

Table 1. CRITERIA FOR BRAIN DEATH**Prerequisite**

All appropriate diagnostic and therapeutic procedures have been performed and the patient's condition is irreversible.

Criteria (to be present for 30 minutes at least 6 hours after the onset of coma and apnea)

1. Coma
2. Apnea (no spontaneous respirations)
3. Absent cephalic reflexes (pupillary, corneal, oculoauditory, oculovestibular, oculocephalic, cough, pharyngeal, and swallowing)

Confirmatory test

Absence of cerebral blood flow by radionuclide brain scan

Brain death occurs when complete and irreversible loss of brain and brain stem function occurs, which presents clinically as complete apnea, brain stem areflexia, and cerebral unresponsiveness. In order to evaluate a patient clinically for brain death, several preconditions must be met. The patient must be on a ventilator in a coma and have a cause for underlying brain damage. Most cases are caused by trauma, subarachnoid hemorrhage, cerebral abscess or tumor, meningitis, encephalitis, or cerebral hypoxia. Reversible causes of brain stem depression such as hypothermia and drug intoxication must first be excluded. Trauma patients are often intoxicated with alcohol. Thus, 8 hours should be allowed to pass if alcohol use is suspected before a diagnosis of clinical brain death can be made. Patients in intensive care units may also be under the influence of sedative or paralytic agents.

Clinical testing is relatively straightforward and examines the presence of brain stem reflexes and the presence of total apnea. Five brain stem reflexes should all be absent in order to diagnose brain stem death: pupillary response to light, corneal reflex to touch, vestibulo-ocular reflex using the cold caloric test, the gag reflex, and the apnea test. The apnea test demonstrates the absence of respiratory drive to PCO_2 greater than 50 mm Hg. During apnea, the PCO_2 rises by about 2 mm Hg/min; thus, if the starting PCO_2 is over 30, the PCO_2 will rise to over 50 mm Hg in about 10 minutes.²² To prevent hypoxia during these 10 minutes, the patient should be preoxygenated prior to the test. Confirmatory studies, although not necessary, include serial electroencephalography and radionuclide scan to assess cerebral perfusion.

DONOR EVALUATION

The evaluation of a cadaveric donor begins at the time of initial referral. It is essential that the transplant coordinator obtain a detailed and systematic history in order to avoid mistakes that may compromise the donor organs. Often physicians or nurses outside the field of transplantation mistakenly apply more strict criteria for organ donation than

the organ procurement team does. For example, patients with prolonged hypotension, an episode of respiratory arrest in the field, or a primary brain tumor may still become successful multiorgan donors. Basically, any patient who has been declared brain dead or is to be withdrawn from life support should be considered as a potential multiorgan donor.

The consent for organ donation is obtained from the next of kin by either the local hospital or the procurement coordinator. A review of the history should focus on such details as the mechanism of death, length of time during cardiac and/or pulmonary arrest, periods of hypotension, vasoactive drugs, arrhythmias, alcohol use, fevers, donor's social and medical history, previous operations, and foreign travel. Laboratory evaluation of the cadaveric kidney donor includes serum creatinine, blood urea nitrogen (BUN), serum electrolytes, hemoglobin, white blood cell count, arterial blood gas, urinalysis, serum glucose, prothrombin time/partial thromboplastin time, hepatitis screen including hepatitis B surface antigen and anti-hepatitis C virus (HCV), Venereal Disease Research Laboratory/rapid plasma reagin, human immunodeficiency virus (HIV) antibody screen, and human T-cell lymphotropic virus (HTLV)-1, anti-HIV-1 anti-HIV-2, anti-HTLV-1, anti-cytomegalovirus, ABO typing, and cultures of blood and urine if hospitalized for more than 72 hours. Additional tests are needed for multiorgan donors. For kidney donors, the final serum creatinine, BUN, and urinalysis after resuscitation are also important indicators of renal function.

MARGINAL DONOR

As waiting lists for cadaveric renal transplantation become progressively longer, the list of absolute contraindications to cadaveric donation is becoming shorter. Table 2 lists the current absolute and relative contraindications to cadaveric renal donation. Experience with marginal donors has demonstrated that although they may lead to higher rates of acute tubular necrosis (ATN), they ultimately provide excellent long-term function.

Rarely are donors excluded because of age. In patients older than

Table 2. ABSOLUTE AND RELATIVE CONTRAINDICATIONS TO CADAVERIC KIDNEY DONATION

Absolute	Relative
Malignancy outside central nervous system	Age >60
Prolonged warm ischemia	Age <6
Long-standing hypertension	Mild hypertension
Hepatitis B surface antigen	Hepatitis C virus
Sepsis	Prolonged cold ischemia
Intravenous drug abuse	Acute tubular necrosis
Human immunodeficiency virus	Donor diabetes

60, a biopsy of the donor kidney may provide useful information about the degree of glomerulosclerosis. If glomerulosclerosis is greater than 20%, a double kidney implant can be considered.¹⁵ An alternative approach used at the University of Wisconsin has been to match the donor and recipient ages, that is, to use older kidneys for older (and smaller) recipients because they have lower muscle mass and shorter potential longevity. This has been shown by Cecka and Terasaki⁴ to be the best way to use kidneys from older donors. A baseline biopsy of the donor kidney may also help in the interpretation of subsequent biopsies, especially in relation to the degree of fibrosis. Kidneys from pediatric donors less than 5 years old may still be used by transplanting both kidneys en bloc with the donor aorta and vena cava intact.

Even donors with serum creatinine over 2.5 mg/dL may have kidneys adequate for transplantation. Often donor kidneys experience transient ATN secondary to hypovolemia and improve with rehydration. As long as the creatinine is falling after rehydration, the kidneys may be used. Young, healthy donors with elevated serum creatinine up to 2.5 mg/dL from ATN secondary to cardiac arrest or hypotension can still donate their kidneys. In general, to err on the side of retrieval benefits the greatest number of patients.

Recently there has been renewed interest in expanding the donor pool by using non-heart-beating donors (NHBD). The majority of the organ procurement organizations have NHBD protocols for procuring kidney grafts. It has been estimated that the donor pool could be increased by 20% with widespread use of NHBD.¹⁹ NHBD was the sole method of organ retrieval prior to the establishment of brain death criteria. Although the ATN rate and the discharge creatinine are slightly higher for NHBD, the 10-year graft survival of 52% for NHBD was similar to the graft survival of 45% for heart-beating donors.⁷ This remains a relatively untapped source of donors for both renal and extrarenal organs.

The use of kidneys from donors who have died of toxic exposure has been reported, with excellent immediate (97%) and 1-year (74%) graft survival.¹⁸ Such toxins include ethanol, cocaine, carbon monoxide, barbiturates, and lead.

For many years HCV seropositivity was an absolute contraindication to organ donation. The risk of seroconversion after transplantation of a HCV-positive kidney approaches 100% when assayed by polymerase chain reaction techniques, and up to 50% of recipients develop clinical manifestations of hepatitis.¹⁷ However, recipients who are HCV-positive prior to transplantation can benefit by bypassing the waiting list and being transplanted within a few weeks to months. These patients should be fully informed and give consent because of the potential risk of transmitting a more virulent form of HCV. HCV-negative recipients with limited life expectancy due to their age, medical condition, or severe vascular access difficulties may benefit from immediate transplantation with HCV-positive kidneys.

DONOR MANAGEMENT

Following the declaration of brain death and obtaining of consent from the next of kin, the management of the patient changes to maximize the function of the donor organs for the benefit of the recipient. All expenses are then transferred to the organ procurement organization. The care of the patient is coordinated between the surgical, intensive care, anesthesia, and organ procurement teams.

An understanding of the physiologic responses that occur after the brain and brain stem become necrotic is helpful in caring for the brain-dead patient. Increased intracranial pressure secondary to trauma or a cerebrovascular accident leads to a massive catecholamine release as the body attempts to prevent cerebral ischemia by increasing systemic pressure.⁵ Once the brain becomes necrotic, the catecholamine levels drop to less than 10% of normal within several hours.²⁰ This leads to marked vasodilatation and hemodynamic instability. This problem is further compounded by the strategy of fluid management for patients with brain edema, which is to achieve relative dehydration by maintaining maximum diuresis with furosemide and mannitol. Therefore, patients usually require massive fluid resuscitation after brain death is declared. In addition, as the posterior pituitary gland becomes necrotic, the antidiuretic hormone vasopressin is no longer secreted, and more than 75% of brain-dead patients develop diabetes insipidus, leading to further hypovolemia. The maintenance of adequate intravascular volume is particularly important to prevent ATN of the kidneys.

The control of body temperature by the hypothalamus is lost in up to 86% of donors.¹² Also, the large amount of fluid required to maintain adequate intravascular volume may further exacerbate the donor's hypothermia. Hypothermia has many detrimental effects on the donor organs, including a shift in the oxygen dissociation curve to the left, direct effects on the renal tubules leading to more diuresis, detrimental effects on hepatic and cardiac function, coagulopathy secondary to platelet dysfunction, and ventricular fibrillation at temperatures below 28°C. Coagulopathy is also caused by the release of plasminogen activating factors and fibrinolytic agents, leading to disseminated intravascular coagulation.

Rapid response time from the organ procurement team is the best method to avoid the physiologic sequelae of brain and brain stem necrosis. At the University of Wisconsin, the average time from declaration of brain death to organ procurement is 6 hours. During this 6-hour response time, the donor is volume resuscitated, usually with 2 to 4 L of crystalloid initially. Systolic blood pressures are maintained above 100 mm Hg, with central venous pressure (CVP) monitoring if necessary to evaluate volume status. Patients should be transfused to a hematocrit of 25% to 30%. If the CVP is above 10 and the blood pressure is still less than 100 mm Hg, dopamine in doses less than 10 $\mu\text{g/kg/min}$ may be helpful. Other agents that may be helpful include dobutamine, norepinephrine, phenylephrine, and epinephrine. Once brain death has oc-

curred, bradyarrhythmias do not respond to atropine. Isoproterenol or epinephrine is more effective.

Diabetes insipidus is treated by replacing urine output volume for volume with hypotonic fluids and following electrolytes frequently. When urinary losses exceed 200 mL/hr, vasopressin (Pitressin) is given at a dose of 40 units/L at 125 mL/hr for 15 minutes and repeated every 4 hours. Another antidiuretic agent is desmopressin (desamino-Cys-D-arginine-vasopressin, DDAVP) at a dose of 1 to 2 μ g every 8 hours. Overall, a good rule of thumb is a systolic blood pressure greater than 100 mm Hg, PaO_2 greater than 100 mm Hg, and hourly urine output greater than 100 mL/hr.

DONOR NEPHRECTOMY

Isolated Renal Procurement

The anesthetic management is a continuation of the pre-procurement care, with maintenance of intravascular volume, tissue oxygenation, and prevention of hypothermia. The patient is brought to the operating room, and appropriate hemodynamic monitors are placed. Muscle relaxation is achieved with vecuronium or pancuronium. Spinal reflexes may still be present after brain death, which may be disconcerting for operating room personnel. The stomach is decompressed with a nasogastric tube. Generous exposure is obtained with a midline incision and an abdominal retractor. Supraceliac aortic control is achieved by dividing the left triangular ligament to retract the left lateral lobe of the liver, dividing the diaphragmatic crura overlying the aorta, and placing an umbilical tape loosely around the aorta immediately below the diaphragm. Next, the right colon and distal small bowel are mobilized and eviscerated onto the chest wall by dividing their peritoneal attachments. The third and fourth portions of the duodenum are mobilized to expose the left renal vein, which lies just caudal to the superior mesenteric artery (SMA). Occasionally the left renal vein may pass behind the aorta. The adrenal and gonadal branches of the left renal vein are ligated. The distal aorta is exposed, and the inferior mesenteric artery is ligated. Two umbilical tapes are placed loosely around the aorta, one just above the iliac bifurcation and the second one several centimeters proximally. After blood is drawn for crossmatching, 20,000 units of heparin and 10 mg of phentolamine (Regitine) are infused prior to cross-clamping the aorta. A 20 F chest tube is beveled and passed into the aorta just above the iliac bifurcation and secured with umbilical tapes. A no-touch technique prior to the flushout helps prevent renal artery vasospasm. A large clamp is placed around the supraceliac aorta, aided by the previously placed umbilical tape. Supraceliac clamping avoids injuring the left renal artery, which is often only a few millimeters below the SMA and occasionally may be above the SMA. The vena cava is divided and 1 L of cold University of Wisconsin (UW)

solution is infused. The organs are bathed in iced saline. Following the aortic flush, the left renal vein is divided at the vena cava. The aorta is opened anteriorly, allowing identification of orifices for multiple renal arteries. All renal arteries should be procured with an aortic Carrel patch if possible. Next, the ureters are divided distally, and care should be taken to avoid skeletonizing the ureter, which may compromise the ureteral blood supply. The kidneys are mobilized separately and dissected out of the retroperitoneum. The posterior attachments of the aorta are divided, and generous Carrel patches are maintained on the arterial vessels. The kidneys are transferred to a separate back table, where they are flushed again until clear with UW solution, usually 250 to 500 mL each. The perinephric fat should be excised in order to visualize the surface of the kidneys to rule out renal tumors. If the kidneys are going to be machine perfused, plastic renal artery cannulas are secured in place for later attachment to the machine. The kidneys are packaged in plastic bags and placed on ice at 4°C. Before closing the abdominal cavity, lymph nodes are taken from the small bowel mesentery and a piece of spleen is removed for tissue typing and crossmatching.

Part of Multivisceral Procurement

The technique for isolated renal procurement can be easily incorporated into multivisceral procurement (Fig. 1). Supraceliac aortic control, infrarenal placement of cannulas for perfusion, and dissection of the left renal vein with ligation of its branches are similar. Dissection near the kidneys should be avoided because this may provoke vasospasm. The pancreas and liver are dissected as previously reported.^{9, 24} The aorta and portal vein are each flushed with 1 L of UW solution. After the flush, the left renal vein is divided near the vena cava. The aorta is divided between the SMA and the left renal artery by first incising the aorta anteriorly to locate the orifice of the left renal artery. It is better to leave a Carrel patch on the left renal artery than on the SMA because the SMA is always shortened before reconstructing with an iliac Y graft for pancreas transplantation. Care should be taken to avoid damaging the left kidney and its vessels when developing the plane between the lower margin of the liver and the adrenal gland. Also, the right renal vein need not be injured when dividing the vena cava because there is always plenty of length on the inferior vena cava for the liver, especially if the piggyback technique is being used. The kidneys are usually removed after the en bloc resection of the liver and pancreas.

Non-Heart-Beating Donor

For renal procurement alone, the following method is used. Ventilatory support may be withdrawn in the intensive care unit or in the operating room, depending on the family's wishes. While the patient is

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Figure 1. Mr. Robert M. Hoffmann (*left*) and the late Dr. Folkert O. Belzer (*right*) with an early model of their preservation machine at the University of California, San Francisco in 1965. (From Hoffmann RM, Southard JH, Belzer FO: Organ preservation. In Phillips MG (ed): UNOS: Organ Procurement, Preservation and Distribution in Transplantation. Richmond, United Network for Organ Sharing, 1996, p 167; with permission.)

fully supported, he or she is given heparin and phentolamine. A physician not associated with the transplant team extubates the patient and declares death after complete cessation of cardiac and pulmonary function. An additional 4 to 5 minutes elapses before infusing cold solutions and starting the organ retrieval. Once the surgery starts, a midline incision is made and the kidneys are quickly removed and flushed with cold UW solution on the back table. The kidneys are then placed on continuous machine perfusion or packed in ice. In extrarenal procurement from NHBDs, the placement of femoral arterial and venous catheters expedites the aortic flush. From January 1985 to December 1993, 239 kidneys were transplanted at the University of Wisconsin from 125 NHBDs. The average warm ischemia time of the right kidney was 15.8 ± 7.7 minutes and that of the left kidney was 18.2 ± 7.3 minutes. The

mean preservation time was 30.2 hours. The need for dialysis for all causes was 22% following transplant. The 1-month and 1-year patient and graft survivals were 99.1% and 94.3%, and 94.6% and 83.4%, respectively.⁷

If procurement is to include the extrarenal organs from an NHBD, consent is obtained for femoral catheter placement prior to declaration of death, and to date support has been withdrawn only in the operating room. Heparin and phentolamine are administered before withdrawal of support. All abdominal organs are removed en bloc after cooling via the femoral artery catheter and returned to our center for separation. Briefly, a manubrium-to-pubis midline incision is made for exposure. The thoracic aorta is cross-clamped proximal to the diaphragm, and the femoral artery opposite the cannula is clamped. The esophagus and sigmoid colon are divided between staple lines. The ureters are divided at the bladder. The entire abdominal viscera are then excised from the abdominal cavity by retracting them anteriorly and caudally. On the back table, the celiac trunk, SMA, and renal arteries are flushed with cold UW solution. The mean warm ischemia time is 15.4 ± 10.7 minutes. Our experience has shown that the kidneys, liver, and pancreas can be safely procured from NHBDs and transplanted with excellent results.⁸

PRESERVATION

Historical Perspective

The ultimate goal of cadaveric renal transplantation is to preserve the function of the kidneys while allowing adequate time to find a suitably matched recipient. A period of 24 to 48 hours allows enough time for tissue matching, selection of the recipient, sharing of organs around the country, crossmatching, and preparation of the recipient for transplant. Good preservation with immediate function of the kidneys after transplant reduces patient morbidity, reduces hospital stay, lowers cost, and may lead to improved long-term graft survival.^{25, 26}

The field of organ preservation has progressed as our understanding of preservation injury has improved. The ionic environment of the renal cortex is highly dependent on oxygen for aerobic metabolism to generate ATP. ATP maintains ionic gradients of potassium, sodium, magnesium, and calcium. The cell experiencing warm ischemia becomes edematous, and calcium leakage activates phospholipase, an enzyme that lyses cellular membranes. Increased levels of lactic acid generated by anaerobic glycolysis lower pH and affect the activity of other cellular enzymes. Hypothermia may also destabilize cell membranes by causing a phase change in cell membrane lipids from a liquid state to a more crystalline state.¹⁰ This phase transition appears to be fully reversible for organs preserved for 10 hours or less because they usually have immediate function. Oxygen free radicals may also play a role in reperfusion injury,

although strategies utilizing free radical scavengers have met with limited success.¹¹

In 1967, Belzer et al² demonstrated that kidneys could be stored for 3 days by continuous machine perfusion using cryoprecipitated plasma as the perfusate (Fig. 2). The machine perfusion technique has been used successfully for 30 years. However, the perfusion solution has evolved from cryoprecipitated plasma to an albumin-based perfusate and now to a hydroxyethyl starch-based perfusate. In 1969, Collins et al⁶ showed that kidneys could be stored by a simple method consisting of washout with what became known as Collins solution, followed by cold storage on ice. The Collins solution consists of high concentrations of potassium (110 mM), magnesium sulfate (30 mM), and phosphate (57.5 mM), which maintains the ionic gradients; and glucose (140 mM), which makes the solution hypertonic and prevents cell swelling within the kidney. Although the Collins solution was associated with a higher rate of delayed

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Figure 2. Cadaver donor multiple organ retrieval. A, Heart-beating. (From Sollinger HW, Odorico JS, D'Alessandro AM, et al: Transplantation. In Schwartz S (ed): Principles of Surgery, ed 7. New York, McGraw-Hill, 1997, in press; with permission.) B, Non-heart-beating donors. (From D'Alessandro AM, Hoffmann RM, Knechtle SJ, et al: Successful extrarenal transplantation from non-heart-beating donors. Transplantation 59:977, 1995; with permission.)

graft function, its simplicity allowed easier sharing of organs. During the 1970s, cold storage with Collins solution became the most popular method of kidney graft preservation. A modified Collins solution was developed in Europe (Euro-Collins) which lacked magnesium and added mannitol in place of glucose.

UW Solution

With the development of cyclosporine in the early 1980s, the need for better preservation of extrarenal organs, including the heart, liver, and pancreas, was even greater. In the late 1980s, Belzer and Southard at the University of Wisconsin developed the UW solution (ViaSpan, Dupont Pharma, Wilmington, DE), which has become the standard cold storage preservation solution for kidney,²¹ pancreas,²¹ liver,¹⁶ heart,¹⁴ and lung preservation. Like Collins solution, the UW preservation solution has a high concentration of potassium, which maintains physiologic ionic gradients. Additionally, the UW solution contains agents to suppress hypothermic cell swelling (lactobionic acid, raffinose, and hydroxyethyl starch), a hydrogen ion buffer (phosphate), and other beneficial agents (glutathione, adenosine, allopurinol, and magnesium) (Table 3). The use of UW solution extended preservation times up to 3 days for kidneys, 72 hours for the pancreas, 48 hours for livers, and 12 hours for hearts.²³

Cold Storage versus Machine Perfusion

Preservation of cadaveric kidney grafts by machine perfusion has several theoretical benefits that have translated into lower rates of delayed graft function. Machine perfusion allows the kidney to function

Table 3. COMPOSITION OF UNIVERSITY OF WISCONSIN SOLUTION

Component	Concentration
K lactobionate	100 mmol/L
Raffinose	30 mmol/L
Pentafraction (hydroxyethyl starch)	50 g/L
KH ₂ PO ₄	25 mmol/L
Glutathione (GSH)	3 mmol/L
Adenosine	5 mmol/L
Allopurinol	1 mmol/L
MgSO ₄	5 mmol/L
Penicillin	200,000 U/L
Insulin	16 mg/L
Dexamethasone	16 mg/L
Na	25 mmol/L
K	125 mmol/L

aerobically because of the constant supply of substrate and oxygen as well as the removal of metabolic end products. The supply of ATP is better maintained, which is crucial during the period of warm ischemia and at the time of reperfusion. At the University of Wisconsin and other transplant programs, the delayed graft function rate is less than 10% for machine-perfused grafts,^{1, 13} versus 20% to 30% for cold-stored grafts.²¹ Lower rates of delayed graft function are associated with shorter hospital stays and may improve long-term graft survival. From 1987 to 1994, we transplanted 720 kidneys (629 primary and 91 nonprimary) using machine perfusion for preservation, with an average preservation time of 32 hours. The need for acute dialysis was 8.4% (primary transplant) and 9.9% (nonprimary transplant). The mean serum creatinine at the time of discharge was 1.7 ± 0.9 mg/dL. The 1-month, 1-year, and 5-year patient (and graft) survivals were 98.3% (94.5%), 94.6% (84.6%), and 82.3% (69.2%).

The technique of machine perfusion has simplified over the years. The kidneys are initially cold stored at the donor hospital after being flushed with UW solution. Upon return to the University of Wisconsin, the kidneys are placed on the perfusion machine until the time of transplant. The perfusion solution is similar to the UW solution for cold storage except for replacement of lactobionate with gluconate, a high sodium:potassium ratio, and adenine and ribose for ATP regeneration.

TRANSPORT

The transportation of cadaveric kidneys is an essential component of successful sharing of organs between transplant centers around the country. Organs are routinely transported within an organ procurement organization's territory to the corresponding transplant center. When no suitable match is found locally, the kidneys are shared regionally or nationally. Also, all HLA six-antigen matches are shared on a national level according to the United Network for Organ Sharing (UNOS) regulations. The recipient transplant center is then responsible for sending a comparable kidney back through UNOS.

To expedite the handling of organs during transportation, to facilitate the transfer of information to the recipient transplant center, and to ensure quality control, UNOS has standardized the packaging, labeling, and handling of all organs. The kidney graft must be placed in sterile plastic bags containing preservation solution and then placed in a strong plastic container and an additional plastic bag. The proper insulation, ice, and/or refrigeration must be arranged to maintain the organs below 4°C. Transplant coordinators should be familiar with the packaging requirements as well as proper labeling to prevent delays during transportation.

The development of UW solution has permitted the safe transport of kidneys, livers, and pancreata by commercial airlines rather than requiring custom hiring of private planes and jets for organ transport.

This has translated into cost savings for the transport of organs and ultimately a savings in health care costs.

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