The role of the nurse anesthetist during a cadaver kidney harvest

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The majority of kidneys used for transplantation in the United States come from cadaveric sources. In this article, a case study of a bilateral donor nephrectomy from a brain-dead donor is reviewed. Criteria for the establishment of brain death and procedures for the attainment of legal permission for kidney harvest are delineated. The anesthetist's role in the management of hypotension and prevention of renal ischemia for the successful harvesting of viable kidneys is discussed.

Introduction

Estimates indicate that more than 55,000 patients will require dialysis for end-stage renal disease by the end of 1984. More than 5,200 of these patients are likely to receive transplants.1 Approximately two-thirds of the kidneys for transplantation in the United States now come from cadaveric sources rather than living donors.2 The reluctance of transplant teams to use a kidney from a living, related donor, unless graft success can be reasonably assured, has resulted in an increasing need for cadaver kidneys.

With an increasing physician awareness for recognizing potential kidney donors, improved surgical techniques for removing and storing organs, and increasing public empathy for the patient on long-term renal dialysis, the number of bilateral donor nephrectomies will increase yearly. The nurse anesthetist, as a vital member of the surgical team, must possess the scientific knowledge and technical skills in order to aid in the retrieval of viable kidneys for subsequent transplant.

Case study

Synopsis of history and physical. On September 7, 1983, a 44-year-old, white male was admitted to the emergency room of Hurley Medical Center located in Flint, Michigan. The patient suffered from an apparent gunshot wound to the right temple, where an entry wound was observed, with no evidence of an exit wound or other injuries noted. The circumstances surrounding the shooting were unknown. The patient's past history was unknown.

The patient's vital signs initially showed a blood pressure reading of 220/110, heart rate of 75-80 beats per minute and respiratory rate of 16-18 breaths per minute by Ambu bagging, with no spontaneous respirations noted. His pupils were dilated and nonreactive, with no corneal reflexes noted. Minimal responses were noted in reaction to deep pain, however, deep tendon reflexes and Babinski signs could not be elicited. His lungs were clear and his heart was regular with no audible murmurs.

The admitting impression was a gunshot wound to the head with possible brain death. The patient was admitted for resuscitation and stabilization as a possible kidney donor.

Hospital course. The patient's initial laboratory studies included a complete blood count...
(CBC), electrolytes, urinalysis, and a chemical profile, all of which were within normal limits. The patient was placed upon ventilatory support, and a request for consultation with renal services was initiated. After obtaining the proper authorization from the patient's family and after acquiring two flat EEG's, the patient was pronounced dead and scheduled for a donor nephrectomy on September 9, 1983.

Operative procedure. The patient was placed on the operating room table in the supine position at 3:50 a.m. The patient's endotracheal tube was connected to a ventilator at an oxygen concentration of 100%, flow rate of 6 L/min and tidal volume of 800 cc. A dopamine infusion (400 mg/250 cc) was administered to the patient via the left arm for maintenance of blood pressure. A crystalloid solution consisting of 5% dextrose in lactated Ringer’s alternated with lactated Ringer’s was infused in the patient’s right arm for maintenance of hydration. A urinary catheter connected to a gravity drainage bag was used to monitor urine output.

A cruciate incision was administered at 4:26 a.m., at which time 12.5 gm of mannitol was administered intravenously by the anesthetist. An exploratory laparotomy was conducted with no evidence of intra-abdominal malignancy or sepsis noted. Both kidneys were of normal size and each exhibited single renal arteries, veins and ureters. Each kidney, along with renal artery, vein, aorta and vena cava were exposed and mobilized.

At that time, the anesthetist administered 20,000 units of heparin intravenously at the surgeon’s request. Approximately 20 minutes later, the suprarenal aorta and vena cava were ligated, divided, and the kidneys were removed en bloc. The kidneys were perfused with a cold electrolyte solution and subsequently placed upon a perfusion machine for continual washout. The warm ischemia time was five minutes.

During the operative procedure, the dopamine drip was titrated by the anesthetist between 20-40 μg/kg/min to maintain an average blood pressure of approximately 110/60 mm of mercury. The patient’s urine output during the procedure was approximately 2,500 ml (1250 ml/hr), and he received 5,900 ml of crystalloids. After the kidneys were removed, the respirator, dopamine infusion, and intravenous fluids were turned off.

Renal anatomy and hormonal control of renal blood flow

A brief review of renal anatomy and factors which control renal blood flow is necessary in order to understand the relationship between hypotension and concomitant ischemic damage during a cadaver harvest.

Anatomy. Each kidney weighs approximately 150 gm and is composed of 1-1.25 million individual units called nephrons. Each nephron consists of a glomerular capillary tuft which invaginates Bowman’s capsule to form a renal corpuscle, a proximal convoluted tubule, loop of Henle, and distal convoluted tubule. Many nephrons empty into collecting ducts which drain urine into the renal pelvis.

Glomerular filtration. Urine formation begins with the ultrafiltration of plasma by glomerular capillaries. Approximately 20% of the plasma flowing through the glomeruli enters the Bowman’s capsule. The glomerular filtration rate (GFR) normally is 125 ml/min or 180 L/day. This large volume of filtrate is then modified by the process of tubular reabsorption and secretion to produce a relatively small amount of urine.

The major factor in regulating the GFR is capillary blood pressure. Capillary hydrostatic pressure is controlled by the variable resistance produced by afferent and efferent arterioles adjacent to each nephron and the driving pressure from the left ventricle. Afferent arteriolar constriction or efferent arteriolar dilation tend to decrease capillary pressure, filtration fraction and GFR. The opposite is true with arteriolar constriction.

Hormonal control of renal blood flow. Renal blood flow and concomitantly the GFR are controlled through the renin-angiotensin hormonal feedback mechanism involving the macula densa. The macula densa consists of modified cellular elements located adjacent to the afferent arteriole. When the renal perfusion pressure increases, the concentration of sodium reaching the macula densa also increases. In response to this stimulus, the macula densa activates the release of renin which in turn leads to the local formation of angiotensin II. Angiotensin II causes the constriction of the afferent arteriole, with the result being a fall in renal blood flow, glomerular filtration, and distal sodium delivery toward their normal levels. Various pharmacologic agents employed by the anesthetist can agonize or antagonize the effects of the renin-angiotensin system, thereby causing an increase or decrease in renal blood flow.

Hypoxemia and renal blood flow. Studies have demonstrated that a direct relationship between arterial oxygen saturation and renal cortical blood flow exists. With an acute reduction in arterial oxygen, a linear reduction in renal cortical blood flow has been observed. Renal histological changes,
seen as patchy tubular lesions, occur with reduced cortical blood supply. Therefore, it is imperative for the anesthetist to ventilate the patient with 100% oxygen in order to prevent hypoxemia with concomitant decreased blood supply to the renal cortex.

Donor selection

*Brain death.* Every brain-dead patient with normal renal function should be regarded as a potential donor. However, kidneys from patients under 10 and over 60 years of age have a higher incidence of nonfunctioning grafts. Contraindications to kidney donation are generalized infection, extracerebral malignancy, hypertension, primary renal disease, diabetes, and wide spread atheroma.

Brain death is diagnosed when all activity above the foramen magnum is shown to be absent by a series of simple bedside tests in conjunction with an isoelectric EEG. When a hospital's brain death criteria have been met, and the physician has documented the declaration of death on the patient's chart, the procedure for donor nephrectomy can be initiated.

*Legal criteria.* In kidney donation, as in all operative procedures, permission must be obtained. Written permission by the legal next of kin is requested regardless of whether the patient carried a signed uniform donor card or a driver's license sticker. The order of relatives from which permission can be obtained is spouse, adult children, parents, siblings, grandparents, uncles or aunts, and cousins. The anesthetist should review the patient's chart for a signed consent form prior to the start of the nephrectomy.

Anesthetic management

*Management of hypotension.* The majority of kidneys that never function after transplantation are probably damaged by ischemia and a prolonged period of hypotension in the donor. Cadaver kidneys that undergo more than 60 minutes of severe hypotension frequently develop acute tubular necrosis immediately after transplantation. Hypotension is defined as the donor systolic blood pressure below 90 mm/Hg and the diastolic pressure below 60 mmHg during the donor operation for a minimal period of one hour.

If a low blood pressure is accompanied by a urine output of greater than 100 ml/hr, no treatment is necessary. In all other cases, efforts must be made to raise the blood pressure and to restore urine production. Initial attempts at restoring pressure should begin with intravenous infusions of blood, plasma, or crystalloid solutions. Normally, 1-2 L of Ringer's lactate are required each hour the abdomen is open during the nephrectomy.

If hypotension persists despite intravenous fluid administration, pharmacologic agents are frequently employed to improve the viability of the kidneys. Dopamine, in low doses, affects the vasculature by decreasing peripheral resistance. It also causes mesenteric and renal vasodilation while increasing renal perfusion, glomerular filtration and urinary output. However, exceeding an infusion rate of 50 µg/min may result in decreased urine production because of alpha adrenergic induced renal vasoconstriction.

Administration of vaso pressin 5-10 units intramuscularly increases reabsorption of water from the kidney tubule and may help conserve fluid losses.

*Management of ischemia.* Ischemia secondary to hypotension produces vascular spasm, endothelial edema, and platelet aggregation. As aerobic metabolism decreases, the cellular sodium pump begins to fail and the pH falls. If the ischemia is severe, the lysozomal membranes may rupture. Methylprednisolone (50 mg/kg), administered at the beginning of the operation, helps stabilize the lysozomal membrane, thus inhibiting the release of intracellular components and toxic lysozomal enzymes. Renal vascular spasm can be mitigated with phenoxybenzamine, an alpha adrenergic blocker. Phenoxybenzamine at doses of 0.75-1.5 mg/kg is given 30-60 minutes prior to kidney removal.

*Management of urine output.* The urine output is the single most reliable criterion of renal function. The achievement of an ample diuresis by the donor is most important. A minimal urine output of 100 ml/hour should be maintained throughout the surgical procedure. Mannitol 12.5-50.0 gm is frequently given at the start of the nephrectomy. As aerobic metabolism decreases, the cellular sodium pump begins to fail and the pH falls. If the ischemia is severe, the lysozomal membranes may rupture. Methylprednisolone (50 mg/kg) is given 30-60 minutes prior to kidney removal.

If oliguria persists despite adequate hydration and mannitol administration, then furosemide 10-80 mg, a powerful loop diuretic, should be administered. On rare occasions, oliguria persists despite the measures described, in which case organ donation must be abandoned.

*Harvesting technique.* Limitation of warm ischemia time is important in maintaining the viability of the harvested kidney. The total period of warm ischemia is probably the major factor causing post-transplant acute renal failure. The period of warm ischemia is defined as the time lapse be-
tween cessation of the circulation in the harvested kidneys following the clamping of the arterial system prior to the complete perfusion with cold preservation fluid. When kidneys are harvested from heart-beating cadaveric donors, the warm ischemia time may not exceed five minutes.\(^\text{12}\)

The en bloc removal of the kidneys includes the donor’s aorta and vena cava which preserves the complete length of the renal vessels. Ten minutes prior to the clamping of the aorta, the surgeon will ask the anesthetist to administer 20,000 units of heparin to ensure complete perfusion of the kidneys. It is important that heparin be given in every cadaver donor nephrectomy. If it is not given, the kidneys will develop poor perfusion due to clotted blood in the peripheral microcirculation and will not be suitable for transplant.\(^\text{1}\)

After removal, the kidneys are immediately immersed in a pan of ice cold electrolyte solution, and flushed through the aorta or renal arteries with an ice cold electrolyte solution. Many teams employ modified Ringer’s lactate solution or an intracellular electrolyte solution. The initial objectives of flushing kidneys with cold solution after removal are to achieve rapid cooling to reduce cellular metabolic requirements and to wash out the blood’s formed elements. After the kidneys are removed, the anesthetist is dismissed from the case by the surgeon. The ventilator and intravenous fluids are discontinued.

The packaged kidney is placed within an isolated container filled with ice chips. The container is then sent to the appropriate transplant center via the most urgent transportation.\(^\text{10}\)

**Conclusion**

Due to the growing number of patients on hemodialysis, kidney harvesting will become a routine procedure in many hospitals in the future. Successful human cadaver kidney harvesting depends upon the reliable skills and expertise of the surgical team.

The anesthetist, as a vital team member, assists the surgeon by preventing hypotension, maintaining a diuresis and minimizing warm ischemia time. The anesthetist’s diligent efforts will abet the surgeon in the removal of viable kidneys which have a minimal potential for post-transplant renal failure.

**REFERENCES**


**ADDITIONAL READING**


**AUTHOR**

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