Approximately 91,000 patients with end-stage organ failure are on the US Organ Procurement and Transplantation Network waiting list for organ transplantation. Despite a 10.8% increase in the number of deceased organ donors from 2003 to 2004, the organ supply continues to fall far short of the demand; each year since 1999 more than 6000 patients have died while on the waiting list.

The number of organs transplanted per donor is an important metric that reflects the overall success of the staff members of the donor hospital, the transplant program, and the organ procurement organization (OPO) working in concert to maximize transplantation. Several efforts to increase the number of organs transplanted per donor are under way, including a major initiative sponsored by the US Department of Health and Human Services known as the Organ Transplantation Breakthrough Collaborative, which brings together expertise from OPOs, transplant programs, and the critical care community to make improvements in every aspect of the organ donation and transplantation system. The goal of this collaborative is to dramatically increase the number of transplantations performed each year to a mean of 3.75 or more organs transplanted per donor. The Joint Commission on Accreditation of Healthcare Organizations, along with other organizations, is a strong supporter of hospitals’ efforts to increase organ donation and published an excellent white paper, Health Care at the Crossroads: Strategies for Narrowing the Organ Donation Gap and Protecting Patients, in June 2004.

Because most potential organ donors are patients in the intensive care unit, critical care personnel (eg, nurses, physicians, and social workers) play an essential role in optimizing management of organ donors and maximizing the supply of organs for transplantation.

Organ donation from deceased donors is classified into 2 types according to the criteria used to declare death: donation after brain death, in which death is determined on the basis of neurological criteria, and donation after cardiac death, in which death is determined on the basis of cardiopulmonary criteria.

Another consideration in transplantation is the risk of transmission of disease, both infectious disease and malignant neoplasms, from donor to recipient. Examples of high-risk donors include those who are seropos-
itive for hepatitis C virus, those who have a behavioral risk profile for HIV infection (eg, intravenous nontherapeutic injectable drug abuse), and those who have a history of cancer. Unlike organ-specific functional impairment, which may improve with appropriate management of a potential donor, these risk factors for disease transmission are non-modifiable in the intensive care unit setting. Nonetheless, they play an important role in the determination of donor suitability and in the organ placement process, which includes both the offer of the organ by the organ procurement specialist and the acceptance of the organ by the transplanting surgeon.

Although the number of patients who donate organs after cardiac death has increased steadily during the past few years, most organ donors continue to be patients pronounced dead on the basis of neurological criteria. In 2003, 96% of deceased donors were brain-dead patients. Other articles in this issue of Critical Care Nurse and elsewhere address donation after cardiac death. In this article, we focus on intensive care management of organ donors with brain death to optimize the number and quality of organs for transplantation.

Identification and Referral of Potential Organ Donors

All patients with severe, nonsurvivable brain injury, regardless of the cause, are potential organ donors. Because exclusion criteria for organ donation may vary from region to region, identification and referral of all potential organ donors to the local OPO for further evaluation is essential. In addition, regulations of the Centers for Medicare and Medicaid Services require that all ventilator-dependent patients with severe brain injury be referred to the local OPO before termination of life-support measures. Once the local OPO has been contacted, procurement specialists are dispatched to the intensive care unit for a detailed evaluation of the potential donor, determination of his or her suitability as an organ donor and the proposed physiological management, and subsequent coordination of the donation process. These steps are all done in collaboration with intensive care unit and OPO personnel as well as transplant program staff. Current contact information for all US OPOs is available at the Web sites of the Association of Organ Procurement Organizations (http://www.aopo.org) and the United Network for Organ Sharing (UNOS) (http://wwwunos.org).

Because of the intense demand for organs for transplantation, few absolute contraindications eliminate patients from becoming organ donors. Many healthcare professionals, as well as the general public, incorrectly consider age a limiting factor for being an organ donor. However, organs have been successfully transplanted from donors who were more than 80 years old. In addition, patients with various types of severe brain injury, including, but not limited to, head trauma, spontaneous intracranial hemorrhage, primary brain tumor, and anoxic encephalopathy, can be eligible for organ donation.

Consent for Donation

Before organ donation, consent must be obtained from the patient (first-person consent), the patient’s next of kin, a person holding legal durable power of attorney for the patient, or other legal entities. Published studies suggest that certain process elements are associated with higher rates of consent; these include the amount of time spent with the family of a potential donor discussing the patient’s circumstances, the involvement of OPO staff in these discussions, and foreknowledge of the patient’s wish to be an organ donor at the time of death. Therefore, critical care staff should communicate early with their local OPO, before any discussion of organ donation with the family of a potential organ donor, and develop a collaborative plan to maximize the probability of obtaining consent for donation, with full and careful consideration of the unique circumstances of each potential donor.

Management of Organ Donors

The interval between brain death and the procurement of organs is most often characterized by unstable hemodynamic conditions. These conditions must be addressed and managed in order to maintain the viability and optimal condition of the organs. Therefore, timely hemodynamic management is the cornerstone of successful donor management. The pathophysiological processes leading to and following brain death contribute significantly to a donor’s unstable hemodynamic condition. Before brain stem herniation, elevated intracranial pressure precipitates a profound compensatory catecholamine response to sustain cerebral perfusion pressures. This catecholamine surge and attendant increase in left ventricular pressure/afterload can precipitate left ventricular ischemia and myocardial necrosis, which are associated with decreased
left ventricular function. After herniation of the spinal cord, ischemia effectively deactivates the sympathetic system, a situation that results in a state of profound vasodilatation. Thus, brain death commonly results in coincident cardiac dysfunction and vasodilatation. Figure 1 indicates the cascade of events that occur after brain death and contribute to a patient’s unstable hemodynamic condition.

The goals of hemodynamic management of potential organ donors are to ensure adequate intravascular volume, appropriate cardiac output, and consistent organ perfusion. Figure 2 gives a general approach to the hemodynamic management of potential donors. Ideally, in adults, mean arterial pressure should be maintained at or greater than 60 mm Hg, and urine output should be maintained at or greater than 1.0 mL/kg per hour with dopamine, if needed, given in a dosage of up to 10 μg/kg per minute. Appropriate donors should also undergo echocardiographic assessment to define left ventricular ejection fraction and to detect any structural abnormalities that would preclude donation.
Figure 2  Hemodynamic management of potential brain-dead organ donors.

Abbreviations: DA, dopamine; DOB, dobutamine; EPI, epinephrine; NE, norepinephrine.

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medications, and address the competing fluid requirements between the kidneys and lungs. It is crucial that hearts not be excluded on the basis of the initial echocardiogram; recovery of cardiac function over time with proper management is well documented, and decisions about the suitability of a heart for transplantation should be based on serial echocardiograms.12 However, if evidence of severe structural abnormalities is overwhelming, the heart may be ruled out for donation after consultation with OPO specialists.

Intravascular volume is often depleted in potential organ donors because dehydration is used as a medical intervention to minimize cerebral edema and elevated intracranial pressure. Thus, establishing adequate intravascular volume is crucial and may require the placement of a pulmonary artery catheter or, at the very least, central venous pressure monitoring. Of note, measurements of central venous pressure may lead to underestimations of the actual pulmonary capillary wedge pressure because brain death can reduce left ventricular compliance.13 Therefore, measurement of pulmonary capillary wedge pressure is the preferable method for direct measurement of left ventricular preload.

When appropriate, initial expansion of intravascular volume should be achieved by using a balanced crystalloid solution such as lactated Ringer’s solution or isotonic sodium chloride solution. Once intravascular volume has been replenished, as determined by invasive monitoring, hypotonic solutions such as 5% dextrose in water can be used to correct hyponatremia if present. Blood glucose levels should be monitored frequently in patients receiving 5% dextrose in water to determine the need to correct hypernatremia, and insulin infusions should be used as needed to maintain blood glucose levels at 8.3 mmol/L or less (150 mg/dL). Blood products should be transfused to achieve a minimum hematocrit of 0.30 and an international normalized ratio less than 2.0 (patient’s prothrombin time, expressed in seconds, divided by the mean of the range of the normal prothrombin time, expressed in seconds). Because potential donors lose the ability to maintain normal body temperature as a result of brain death, all intravenous fluids should be warmed and a warming blanket should be used to prevent hypothermia, thus eliminating some of the associated complications, such as exacerbation of coagulopathy.

Often, potential donors may have competing fluid requirements between the lungs and the kidneys. Higher rates of procurement of lungs are associated with less fluid replacement,13 whereas renal function and procurement of kidneys may benefit from a more aggressive fluid replacement strategy. In circumstances in which the lungs are clearly not appropriate for transplantation, a more generous fluid strategy may be used. A more generous strategy requires a focused approach to mechanical ventilation to ensure that systemic oxygen delivery is maintained. When both the lungs and the kidneys are appropriate for transplantation, fluid balance can be maintained on the basis of measurements obtained with a pulmonary artery catheter.

Hypotension that persists despite adequate intravascular volume necessitates vasoactive support. Dopamine has historically been the first-line agent for both cardiac and blood pressure support. Ideally, vasoactive therapy should be adjusted according to the specific physiological need: inotropic agents (eg, dobutamine) should be used to correct low cardiac output, and vasoconstrictors (eg, norepinephrine) should be used to correct vasodilatation. It is crucial to remember that high levels of vasoactive support do not preclude donation. Persistent hemodynamic instability, as evidenced by failure to achieve the hemodynamic goals indicated in Figure 2, or a left ventricular ejection fraction of 0.45 or less as indicated by echocardiogram, can be improved markedly by adding therapy with a thyroid hormone (ie, triiodothyronine or thyroxine), corticosteroids, vasopressin, and insulin. Dramatic improvements in hemodynamic status and cardiac function have been reported with this approach, which has enabled the procurement of organs that otherwise would have been deemed less than satisfactory or altogether unsuitable.14 Many OPOs use hormonal therapy on all donors as part of the OPO protocol.

Traditionally, only ideal lungs were recovered and transplanted into ideal recipients. However, with the current shortage of donor lungs and the increasing number of deaths among patients on the waiting list for lung transplants, this approach has been challenged. Multiple authors15,16 have reported that recipients’ outcomes with less-than-ideal or “marginal” lungs are equivalent to the outcomes with ideal lungs. In these studies,15,16 aggressive pulmonary management, including strict attention to and regulation of ventilatory settings, judicious use of positive
end-expiratory pressure, frequent suctioning, use of respiratory treatments such as inhalation albuterol, and use of bronchoscopy; avoidance of a markedly positive fluid balance; and use of antibiotics were key components that enabled the transplantation of marginal lungs with successful outcomes. The 2 most correctable causes of hypoxemia that preclude recovery of lungs for transplantation are atelectasis and excessive fluid replacement. Current recommendations for minimizing these causes of hypoxemia are given in Table 1.

Diabetes insipidus is common in potential organ donors and should be differentiated from use of mannitol or a hyperglycemic osmotic diuresis. Table 2 lists the laboratory characteristics of the differential diagnosis of polyuria in potential organ donors. In adults with diabetes insipidus and urine outputs less than 200 mL/h, urine output should be matched with administration of 5% dextrose in water on a milliliter-for-milliliter basis while monitoring for hyperglycemia. In addition, any fluid maintenance strategy should accommodate insensible fluid losses associated with perspiration, mechanical ventilation, and gastric suctioning. A higher level of urine output requires the use of arginine vasopressin or desmopressin. Arginine vasopressin produces vasoconstriction and may reduce requirements for inotropic drugs in addition to having an antidiuretic effect; desmopressin has no vasoconstrictive effects. It is also recommended that desmopressin be used in donors with vasopressin resistance. However, desmopressin can be associated with coagulation problems, especially in pancreatic grafts.17,18

### Table 1

<table>
<thead>
<tr>
<th>Mechanical ventilation</th>
<th>Bronchoscopy</th>
<th>Fluid management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume 10-12 mL/kg</td>
<td>Used to assess/assist in foreign body removal</td>
<td>Central venous pressure 6-8 mm Hg</td>
</tr>
<tr>
<td>Positive end-expiratory pressure +5 cm H$_2$O</td>
<td>Performed in all donors</td>
<td>Pulmonary capillary wedge pressure 8-12 mm Hg</td>
</tr>
<tr>
<td>Static airway pressure ≤30 cm H$_2$O</td>
<td>Used to remove secretions</td>
<td></td>
</tr>
<tr>
<td>Highest arterial oxygen pressure (PaO$_2$) with lowest fraction of inspiratory oxygen</td>
<td>Used in conjunction with pulmonary toilet to prevent atelectasis</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diabetes insipidus</th>
<th>Mannitol therapy</th>
<th>Hyperglycemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum sodium, mmol/L</td>
<td>≥150</td>
<td>≥150</td>
<td>≥150</td>
</tr>
<tr>
<td>Serum osmolality, mOsm</td>
<td>≤300</td>
<td>≥300</td>
<td>≥300</td>
</tr>
<tr>
<td>Serum osmolar gap, mOsm</td>
<td>Normal</td>
<td>&gt;10-15</td>
<td>&gt;10-15</td>
</tr>
<tr>
<td>Urine output, mL/h</td>
<td>≥300</td>
<td>≥200</td>
<td>≥200</td>
</tr>
<tr>
<td>Urine sodium, mmol/L</td>
<td>&lt;10</td>
<td>50-70</td>
<td>50-70</td>
</tr>
<tr>
<td>Urine osmolality, mOsm/L</td>
<td>&lt;200</td>
<td>≥300</td>
<td>≥300</td>
</tr>
<tr>
<td>Urine specific gravity</td>
<td>≤1.010</td>
<td>≥1.020</td>
<td>≥1.020</td>
</tr>
<tr>
<td>Urine glucose</td>
<td>Absent</td>
<td>Absent</td>
<td>Present</td>
</tr>
</tbody>
</table>

### Benefits of Increasing Transplantation

Family members of organ donors, recipients of transplanted organs, and society in general benefit from increasing transplantation. The family members of organ donors derive tremendous, lasting comfort from the knowledge that something positive results from the families’ loss and often develop close personal relationships with one or more of the recipients of their loved one’s organs. The benefits to organ transplant recipients include survival, improved quality of life, less disability, and lessened psychological burden. The benefits to society include all of those mentioned for donors’ families and for recipients plus increased productivity and life-years saved.

### Conclusion

Critical care staff play an essential role in maximizing organ donation and transplantation and thereby increasing the benefits to the family members of organ donors, recipients of organ transplants, and society in general. After brain death is declared, systematic efforts to increase organ recovery and transplantation provide an opportunity for a fundamental shift in critical care, from the care of a single patient (the donor) to the simultaneous care of many patients (the recipients). Continuing intensity of care and vigilance to hemodynamic management are integral to converting potential donors to actual donors and increasing transplantation.
References
Intensive Management of Organ Donors to Maximize Transplantation
Kevin J. O'Connor, Kenneth E. Wood and Karen Lord

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