Figure 4. Postoperative Doppler echocardiogram. At hospital discharge (left); 6 months after surgery (right).

triangular resection or leaflet plication alone may render the cusp motion restricted. Therefore, the repaired valve with restricted cusp motion may undergo undue stress. By making the valve tricuspid, the valve moves more physiologically, its opening area may become larger, and the stress on the valve may be minimized. Casselman and colleagues² reported 12 reoperations among 94 patients after repair of bicuspid aortic valve. Most of their reoperations were performed because of suture dehiscence of the triangular resection. In view of long-term durability, we anticipate that this new technique will prove superior to the conventional technique because the stress on the repaired valve is lessened. However, long-term durability after the repair remains to be determined.

References

1. Haydar HS, He GW, Hovaguimian H, McIrvin DM, King DH, Starr A. Valve repair for aortic insufficiency: surgical classification and techniques. *Eur J Cardiothorac Surg.* 1997;11:258-65.
2. Casselman FP, Gillinov AM, Akhrass R, Kasirajan V, Blackstone EH, Cosgrove DM. Intermediate-term durability of bicuspid aortic valve repair for prolapsing leaflet. *Eur J Cardiothorac Surg.* 1999;15:302-8.
3. Izumoto H, Kawazoe K, Kawase T, Kim H. Subvalvular circular annuloplasty as a component of aortic valve repair. *J Heart Valve Dis.* 2002;11:383-5.
4. Izumoto H, Kawazoe K, Ishibashi K, Kin H, Kawase T, Nakajima T, et al. Aortic valve repair in dominant aortic regurgitation. *Jpn J Thorac Cardiovasc Surg.* 2001;49:355-9.

Drowned donor lung for bilateral lung transplantation

C. J. McNamee, MD,^a D. L. Modry, MD,^b D. Lien, MD,^b and A. Alan Conlan, MD,^a
Worcester, Mass, and Edmonton, Alberta, Canada

Submersion accidents may result in three outcomes: death by drowning, secondary drowning death (rescue of a victim with vital signs who later dies of complications), or near drowning of a victim who survives after being

rescued. It is estimated that worldwide there are 140,000 to 150,000 yearly deaths by drowning, with 6000 to 8000 of these deaths occurring in the United States.^{1,2} Drowning causes global ischemia from hypoxia, and the cause of death at the scene is probably cardiac dysfunction; in secondary drowning deaths, however, the final common pathway is brain death from cerebral hypoxia.¹⁻⁴

In 10% to 15% of secondary drowning victims, dry drowning (no aspiration of water into the lungs) occurs; death in this situation is caused by acute laryngospasm leading to profound obstructive asphyxia.¹⁻³ It would seem unreasonable to consider lungs for transplantation from a victim of drowning; because of organ shortages, however, there are now efforts to consider marginal lungs for transplantation.^{5,6} In our case, we implanted both lungs from a victim of dry drowning into a patient with pulmonary hypertension related to veno-occlusive disease after all criteria for donor lung transplantation acceptability were met. An excellent result at 35 months of follow-up was achieved.

From the Department of Surgery,^a University of Massachusetts Medical School, Worcester, Mass, and the Departments of Surgery and Medicine,^b University of Alberta, Edmonton, Alberta, Canada.

Received for publication Dec 26, 2002; accepted for publication Feb 19, 2003.

Address for reprints: C. J. McNamee, MD, 67 Belmont St, Worcester, MA 01605 (E-mail: mcnameec@ummc.org).

J Thorac Cardiovasc Surg 2003;126:910-2

Copyright © 2003 by The American Association for Thoracic Surgery

0022-5223/2003 \$30.00 + 0

doi:10.1016/S0022-5223(03)00370-2

Clinical Summary

A 28-year-old man sustained hypoxic injuries when his automobile slipped on ice and then rolled over into a ditch, where the driver was submerged for approximately 10 minutes in near-freezing water. The patient was resuscitated in the hospital with ventilation because of profound neurologic injury and transient pulmonary edema. After 24 hours a diagnosis of brain death from hypoxic brain injury was established. The patient was accepted as a lung donor after meeting all the criteria for donor lung transplantation. His chest radiograph initially suggested mild acute pulmonary edema, which cleared during the subsequent 12 hours. A bronchoscopy did not demonstrate any bronchial secretions or foreign material, and the oxygen challenge test on 100% oxygen revealed a PO_2 of 347 mm Hg. A 48-year-old man with pulmonary hypertension (pulmonary arterial resistance 4.73 Wood units) was selected as the recipient for lung transplantation.

At the commencement of surgery the pulmonary arterial systolic pressure was 90 mm Hg, with a mean pulmonary arterial pressure of 60 mm Hg. Cardiopulmonary bypass support was required for recipient lung removal and sequential donor implantation. The ischemic times of the donor lungs (including transportation to the implantation center) were 6 hours for the right lung and 6 hours and 15 minutes for the left lung.

Ventilation was maintained for 4 days after the operation, after which the patient was successfully extubated. The patient was weaned to an inspired oxygen fraction of 0.21 by 11 days after bilateral lung transplantation. The total hospital stay was 31 days; the delay was caused by a need for immunoglobulin G infusion because of a cytomegalovirus mismatch. The patient's chest radiograph and bronchoscopic evaluations are clear at a follow-up of 35 months. He has an excellent quality of life without exogenous oxygen.

Discussion

The final common pathway for death from drowning or secondary drowning is brain death, which results from one of several factors: cerebral hypoxia, carbon dioxide narcosis, acute laryngospasm, or vagally mediated cardiac arrest.³ There are three stages to drowning. Stage 1 follows the aspiration of a small amount of water, which leads to laryngospasm, which can last as long as 2 minutes.⁴ In stage 2, water may be swallowed into the stomach because of hypoxia or panic. During stage 3, the patient may have severe laryngospasm (dry drowning, which occurs in 10% to 15% of patients); in the remaining patients, the laryngospasm relaxes and they aspirate further volumes of water or aspirate gastric contents.⁴

Pulmonary edema occurs in as many as 43% of submersion victims, depending on the neurologic status when first rescued and later when admitted to hospital as well as the type of water in which the victim was submerged.^{7,8} Manifestations of pulmonary edema are usually not delayed and are almost always apparent at first evaluation in the emergency department.⁷ The edema fluid may be a sequela of myocardial depression from hypoxia; Orłowski⁴ has shown that anoxia by itself is the major cause of lung dysfunction in submersion injuries. In a series of drowning experiments comparing lungs filled with fluid and those with anoxia (dry drowning), there was no major difference in the pathophysiology resulting in pulmonary dysfunction. Hypoxia in both wet and dry drowning induces an acute rise in central venous pressure and

pulmonary capillary wedge pressure matched by a depression in cardiac index and a decrease in lung compliance. Pulmonary vascular resistance shows a linear increase with time. All these observations are reversible after the administration of oxygen and ventilation with positive end-expiratory pressure.⁹ This reversibility suggests a cardiac origin for the pulmonary edema.

Arterial hypotension from myocardial depression in advanced submersion injuries probably induces coma as a result of reduced cerebral blood flow.⁸ There is a strong association between level of consciousness on admission and pulmonary edema.^{7,8} On the basis of this association and the rapid resolution of pulmonary edema in drowning victims, there is a suggestion that pulmonary edema may be of neurogenic origin.¹⁰ However, it is clear that pulmonary edema after near-drowning events may be effectively treated by ventilation with reversal of the pulmonary insult.^{1,7,8,11} Respiratory failure occurs in 15% to 20% of secondary drowning victims, but this is due to secondary pulmonary infections occurring in the presence of severe neurologic dysfunction, which usually is the ultimate determinant of overall survival.¹

Fluid aspirated into the lungs may inactivate surfactant or may induce osmotic shifts drawing plasma into the alveoli, resulting in right to left shunts.⁴ The differences in salinity between fresh and salt water drowning are now believed to be less important than the temperature and possible contamination of the water.^{1-3,12} Submersion injuries in contaminated water probably increase the risk of pneumonia, as does aspiration of particulate matter (sand, aquatic vegetation). Victims of cold water submersions have less of a tendency toward pneumonia, as evidenced by the fact that Alaska, which has the highest drowning rate of any state in the United States, has the lowest rate of drowning associated pneumonia. The basis for this cold weather natural selection phenomenon is that cold environment bacteria (psychrophilic bacteria) are unable to survive at temperatures greater than 25°C, whereas normal bacteria and fungi may not survive in cold environments.¹²

Gastric aspiration occurs in at least 25% of drowning victims,¹² and the rate may be higher if neurologic dysfunction (seizures, intoxication, trauma) precede the submersion event. Ventilation is strongly associated with the development of pneumonia in near-drowning and secondary drowning victims, either as a marker of initial respiratory insult or from nosocomial contamination.^{7,12} Pneumonia after submersion injuries carries a mortality from 27% to 60%,^{2,7} although there is probably codependence on other factors.

Since 1970 there have been several attempts to identify prognostic criteria that will distinguish near-drowning victims with meaningful survival chances from secondary drowning victims.^{2,7,11,13} However, no true consensus exists concerning this issue in the literature. There are numerous case reports in the literature demonstrating good outcomes despite early onset poor prognostic predictors. This is particularly true for near-drowning incidents in cold water (5°C).² In general with respect to prognostic outcome determinants, recent reviews have suggested that several postresuscitation factors are associated with adverse outcomes in near-drowning victims. These factors include the need for inotropes or cardiopulmonary resuscitation in the emergency department and continued global neurologic dysfunction after a 12- to 24-hour period of stabilization.^{2,7}

TABLE 1. Suggestions for consideration of donor lungs from drowning victims

Factors favoring donor lung transplantation
Drowning in cold water (<5°C)
Pulmonary edema that clears rapidly with treatment
Submersion injuries without:
Trauma preceding the submersion event
Neurologic deterioration (seizures, intoxication) before submersion
Dry drowning victims
Factors with relative contraindication
Contaminated water (as opposed to chlorinated waters)
Unusual chemical contaminants in the liquid (industrial setting)
Need for cardiopulmonary resuscitation in the emergency department
Need for inotropes in the emergency department to induce a cardiac rhythm
Pulmonary trauma before or after the submersion event
Factors with indeterminate effect on donor lungs
Use of steroids for the near-drowning victim
Use of prophylactic antibiotics
Use of artificial surfactants or nitric oxide
Absolute contraindications
Pulmonary edema that does not quickly clear with ventilation and diuretics
Evidence of pneumonia (temperature, purulent secretions, lung abscess)
Refractory hypoxia, worsening hypercapnia
Progressive deterioration on chest radiograph after ventilation and treatment
Bronchoscopic determination of foreign material (sand, vegetative material, gastric fluid)
Prolonged ventilation with nosocomial infections

Near-drowning victims may ultimately be declared to have irreversible brain injury and may be considered for donor transplantation. In such a situation standard lung donor criteria⁵ should

be satisfied, in conjunction with considerations specific to drowning injuries as listed in Table 1. Victims of dry drowning may be possible candidates for donor lung transplantation; however, vigilance must be maintained during donor assessment because of the potential for pulmonary edema and pneumonia in the donor lungs.

References

1. DeNicola LK, Falk JL, Swanson ME, Gayle MO, Kissoon N. Submersion injuries in children and adults. *Crit Care Clin.* 1997;13:477-502.
2. Falk JL, Escowitz HE. Submersion injuries in children and adults. *Semin Respir Crit Care Med.* 2002;22:47-55.
3. Levin DL, Morriss FC, Toro LO, Brink LW, Turner GR. Drowning and near-drowning. *Pediatr Clin North Am.* 1993;40:321-36.
4. Orłowski JP. Drowning, near-drowning, and ice-water submersions. *Pediatr Clin North Am.* 1987;34:75-92.
5. Sundaresan S, Semenkovich J, Ochoa L, Richardson G, Trulock EP, Cooper JD, et al. Successful outcome of lung transplantation is not compromised by the use of marginal donor lungs. *J Thorac Cardiovasc Surg.* 1995;109:1075-80.
6. Gabbay E, Williams TJ, Griffiths AP, Macfarlane LM, Kotsimbos TC, Esmore DS, et al. Maximizing the utilization of donor organs offered for lung transplantation. *Am J Respir Crit Care Med.* 1999;160:265-71.
7. van Berkel M, Bierens JJ, Lie RL, de Rooy TP, Kool LJ, van de Velde EA, et al. Pulmonary oedema, pneumonia and mortality in submersion victims; a retrospective study in 125 patients. *Intensive Care Med.* 1996;22:101-7.
8. Szpilman D. Near-drowning and drowning classification: a proposal to stratify mortality based on the analysis of 1,831 cases. *Chest.* 1997; 112:660-5.
9. Orłowski JP, Abulleil MM, Phillips JM. The hemodynamic and cardiovascular effects of near-drowning in hypotonic, isotonic, or hypertonic solutions. *Ann Emerg Med.* 1989;18:1044-9.
10. Rumbak MJ. The etiology of pulmonary edema in fresh water near-drowning. *Am J Emerg Med.* 1996;14:176-9.
11. Bierens JJ, van der Velde EA, van Berkel M, van Zanten JJ. Submersion in The Netherlands: prognostic indicators and results of resuscitation. *Ann Emerg Med.* 1990;19:1390-5.
12. Ender PT, Dolan MJ. Pneumonia associated with near-drowning. *Clin Infect Dis.* 1997;25:896-907.
13. Sachdeva R. Near drowning. *Crit Care Clin.* 1999;15:281-6.