

Increasing organ yield through a lung management protocol

Gift of Life Michigan determined that the largest gap between the number of organ donors and the number of organs transplanted has been in the number of lungs transplanted. The literature was reviewed for lung donor management strategies and other organ procurement organizations were surveyed for existing donor management guidelines to improve lung function. On the basis of pulmonary physiology and the knowledge gained from the literature search, Gift of Life Michigan developed a lung donor management protocol that has been very effective. In 4 years, the number of lungs transplanted has increased from 37 to 135, representing a 265% improvement. (*Progress in Transplantation*. 2010;20:28-32)

**Cyndy E. Kirschbaum, RN,
BSN, CPTC, Sarah Hudson
RN, BSN, CPTC**
Gift of Life Michigan, Ann Arbor

Corresponding author: Cyndy Kirschbaum, RN, BSN, CPTC, 3861 Research Park Drive, Ann Arbor, MI 48108 (e-mail: ckirschbaum@giftoflifemichigan.org)

To purchase electronic or print reprints, contact:
The InnoVision Group
101 Columbia, Aliso Viejo, CA 92656
Phone (800) 809-2273 (ext 532) or
(949) 448-7370 (ext 532)
Fax (949) 362-2049
E-mail reprints@aacn.org

For patients who have end-stage lung disease, lung transplantation is often the only available option. Few benefit from this treatment, however, because of the scarcity of lung donors.¹ Procurement coordinators from the clinical department at Gift of Life Michigan collected data on donors from 2003 through 2004 to identify areas for improvement (Figure 1). It was decided that a protocol could be developed to improve the lung recovery rate because the lungs were one of the organs recovered the least and therefore transplanted the least. The PDSA model (Plan, Do, Study, Act) was used for this quality improvement process.² After the data were reviewed, it was concluded that management of lung donors could be improved. Donor management was defined as starting after declaration of brain death when consent has been obtained and ending with organ recovery. Improved donor management would be reflected in an increase in the number of lungs recovered and transplanted.

Objective

The objective was to develop a lung donor management protocol to be implemented for all potential donors from 15 to 60 years old in order to increase the

number of lungs recovered and transplanted. In this retrospective study, data obtained on the donors when the protocol was implemented were compared with data collected before the protocol started to be used. These data were used to assess whether the protocol had an effect on the number of lungs recovered and transplanted. Small modifications of the initial protocol were made after periodic review of the data and as new information about lung donor management was published.^{3,4}

Design

Basic pathophysiology and anatomy were reviewed. Literature searches were conducted to obtain a scientific rationale for successful recruitment and management of lung donors. Lung protocols from other organ procurement organizations were also obtained and reviewed. Once all information had been collected, a protocol was developed to improve the quality and therefore the quantity of lungs recovered and transplanted. The protocol was approved by the Gift of Life Thoracic Committee.

Setting

The study was done in various acute care hospitals, ranging from small community hospitals to large

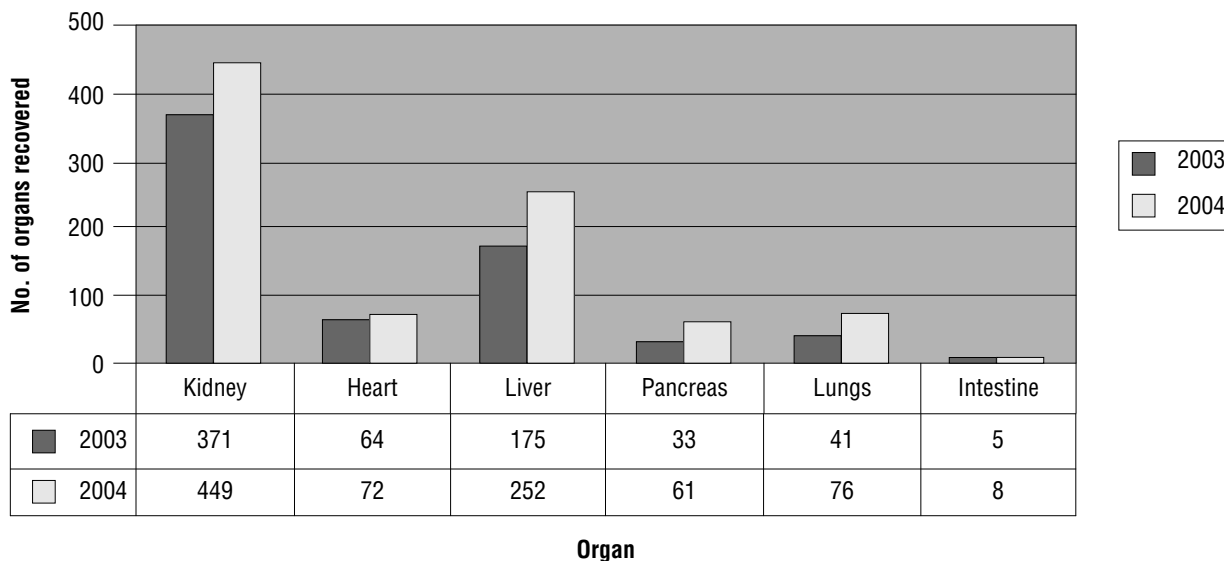


Figure 1 Number of organs recovered in 2003 and 2004 by organ type. Transplant data were not available for this period.

trauma centers including transplant centers, throughout Michigan. Types of nursing units included neurosurgical, pediatric, cardiovascular, surgical, and medical intensive care units (ICUs) and on occasion the emergency department.

Participants

The protocol was implemented for all consented brain-dead donors from 15 to 60 years of age. Medical history did not rule out any potential donor. The protocol was also used on consented donors who specifically declined to donate lungs in an effort to maintain oxygenation and optimize function of the other organs. The protocol was evaluated for use on a case by case basis for donors younger than 15 years of age or older than 60 years of age.

Interventions

A protocol was developed that included pharmacological treatment, manipulation of ventilator settings, physical interventions and recruitment maneuvers, diagnostic testing, and monitoring of hemodynamics. The following protocol is currently used at Gift of Life Michigan. Methylprednisolone (Solumedrol) is given to help decrease inflammation. A loading dose of 15 mg/kg methylprednisolone is given as an intravenous bolus as soon as possible after brain death is declared and consent is obtained, followed by 15 mg/kg every 6 hours.

Cefazolin (Ancef) is given as a broad-spectrum antibiotic primarily to help fight off infection in the upper and lower parts of the respiratory tract. The dose is 1 g every 8 hours. If the donor is allergic to penicillin, clindamycin (Cleocin) is given 600 mg every 8 hours. Donation coordinators are also guided to contact the

hospital pharmacist with results of Gram stain of sputum to assess if any changes in antibiotic dosing or selection are needed.

An intravenous bolus of 8 mg of naloxone (Narcan) is given as soon as possible after brain death is declared and consent is obtained. It is given in an effort to prevent or minimize neurogenic pulmonary edema.^{5,6} A 10-mg intravenous bolus of vecuronium bromide (Norcuron) is given simultaneously with the naloxone to decrease spinal reflexes and relax the diaphragm and other respiratory muscles to improve ventilation. Other paralytic agents are used if vecuronium bromide is not available. Albuterol (Ventolin) and ipratropium (Atrovent) are given for their bronchodilating effects on the smooth muscle in the lungs. Albuterol is given at 2.5 or 5.0 mg and/or ipratropium 0.5 mg every 4 hours. Both are given by in-line nebulizer or metered dose inhaler.

Respiratory therapists are advised by donation coordinators to avoid breaking the respiratory circuit as much as possible to prevent collapse of the alveoli. Acetylcysteine (Mucomyst) is used only if the donor has thick secretions and is given in conjunction with albuterol. The dose is 3 to 5 mL of 20% solution or 10 mL of 10% solution every 4 hours.⁷ Diuretics are commonly used to help decrease edema in the lung tissue. Furosemide (Lasix) and bumetanide (Bumex) are most commonly used because of their therapeutic effect of decreasing edema in lung tissue. They also act on the loop of Henle and cause excretion of sodium, the level of which is usually elevated in most brain-dead donors.^{8,9} Dosages are 20 to 80 mg for furosemide and 0.5 to 1.0 mg for bumetanide, both as an intravenous bolus. Mannitol (Osmitrol) is also part of the protocol but is used less often because of its effects on increasing sodium levels and serum osmolarity.¹⁰ It is dosed

at 300 to 400 mg/kg intravenously. Donation coordinators are encouraged to assess hemodynamic stability of the donor before administering any diuretic.

Two types of ventilator settings are used on organ donors. The first is volume ventilation assist control mode. The suggested tidal volume is 10 mL/kg of ideal body weight to a maximum of 12 mL/kg. The peak airway pressure should be maintained at less than 35 cm H₂O. If peak airway pressure exceeds 35 cm H₂O, tidal volume should be reduced or the ventilator setting should be changed to pressure control ventilation.¹¹ Respiratory rate should be adjusted to maintain the partial pressure of carbon dioxide (PaCO₂) between 35 and 45 mm Hg while maintaining the pH between 7.35 and 7.45. The second setting used is pressure control ventilation, during which peak pressures should be maintained at less than 35 cm H₂O. The rate should be adjusted to maintain pH between 7.35 and 7.45.^{12,13} In both types of ventilation, the positive end-expiratory pressure (PEEP) should be set at 5 to 8 cm H₂O. The fraction of inspired oxygen (FIO₂) will remain at 40% or the lowest possible FIO₂ to maintain adequate oxygenation.

Many maneuvers are used to open or recruit alveoli and improve oxygenation. A respiratory therapist should be present along with the donation coordinator for all maneuvers, and donor stability should be monitored. One maneuver used is a PEEP maneuver. The ventilator is set to a continuous positive airway pressure of 40 cm H₂O for 30 seconds, a process that is repeated every 20 minutes for a total of 3 times. If the donor does not tolerate 40 cm H₂O of pressure, this maneuver may be done at a lower pressure. Contraindications to this maneuver may include but are not limited to severe bronchospasm, bullous emphysema, untreated pneumothorax, unilateral lung disease (not including suspected atelectasis), and hemodynamic instability. This maneuver for recruitment of alveoli is also recommended to be performed once every time the ventilator circuit is broken. Flow rates are slowed to 40 to 50 L/min or inspiratory times are prolonged (without air trapping) in an effort to increase mean airway pressure resulting in less trauma and increased oxygenation.

Positioning the donor prone is another recruitment measure used, though not as often as the PEEP maneuver because it is considered a last option after all other methods have failed. Prone positioning is used only if the donor is hemodynamically stable. Nitric oxide (Ino-max) is rarely used but is an option. It is considered a salvage therapy to treat refractory hypoxia due to high pulmonary vascular resistance.¹⁴ Donation coordinators are to contact the resource manager before using nitric oxide on a donor. Finally, a PEEP valve is used when transporting the donor to the operating room to maintain alveolar recruitment.

Multiple tests are conducted on donors to evaluate lung function and to determine if alveolar recruitment

methods are necessary. These tests include arterial blood gas analyses (ABGs), chest radiography, and bronchoscopy. A baseline sample for ABG is collected at the set ventilator settings with a PEEP of 5 cm H₂O and the FIO₂ set at 100%. The goal is a PaO₂ greater than 300 (PaO₂/FIO₂ ratio greater than 3). ABGs are repeated every 4 to 6 hours with FIO₂ set at the donor's optimal lowest setting, usually between 30% and 40% FIO₂ and then a second ABG with FIO₂ set at 100%. A final ABG with FIO₂ set at 100% is completed 2 hours before surgery. Donation coordinators are to assess every ABG result and adjust the ventilator settings accordingly.

Chest radiography is used to evaluate lung fields for any abnormalities such as infiltrates, atelectasis, rib fractures, advanced lung disease, tumors, or any other abnormal finding. An initial chest radiograph is obtained as soon as possible after brain death and with consent, as needed throughout donor management and within 4 hours of recovery, to compare and further evaluate any changes in the lungs.

As soon as possible after consent and brain death, a bronchoscopy is completed to evaluate the endobronchial tree for abnormal anatomy secretions, lesions, and signs and symptoms of infection. The bronchial washings or secretions obtained from the bronchoscopy are sent to the laboratory for Gram stain and culture.

Basic bedside care of the donor includes chest physiotherapy, rotating the donor from side to side, suctioning of the endotracheal tube, placing the donor on a specialty bed if available, oral care, assessing for leaks in the endotracheal tube cuff, and maintaining the head of the bed at 30°. A specialty bed may be used to assist nursing staff with some of the bedside care. Chest physiotherapy every 2 to 4 hours as indicated will help mobilize any secretions that may be in the lung bases. Rotation of the donor every 1 or 2 hours also aids in mobilization of secretions and the opening of atelectatic regions. Suctioning of the endotracheal tube is recommended every 2 to 4 hours or more frequently if indicated by increased secretions.¹⁵ Oral care is recommended every 1 to 2 hours with deep glottic suction to aid in preventing aspiration or ventilator-associated pneumonia. Assessing for a cuff leak on the endotracheal tube and maintaining the head of the bed at 30° also aids in preventing ventilator-associated pneumonia.¹⁶

Donor hemodynamics are constantly monitored by the donation coordinator. A central venous catheter or a Swan Ganz catheter is placed to monitor central venous pressure, pulmonary artery pressure, and pulmonary artery wedge pressure. The goal is to maintain a central venous pressure of 6 to 10 mm Hg and a pulmonary artery wedge pressure of 8 to 12 mm Hg. A pulmonary management tool was also created and used for this data collection (Figure 2).

MEDICATIONS	
<input type="checkbox"/> Yes <input type="checkbox"/> No	Narcan 8 mg at beginning of case
<input type="checkbox"/> Yes <input type="checkbox"/> No	Solunedrol loading dose followed by every 6 hours
<input type="checkbox"/> Yes <input type="checkbox"/> No	Use of antimicrobial therapy
<input type="checkbox"/> Yes <input type="checkbox"/> No	Use of albuterol
<input type="checkbox"/> Yes <input type="checkbox"/> No	Inotropes/vasoactive drugs
<input type="checkbox"/> Yes <input type="checkbox"/> No	T4
VENTILATOR SETTINGS	
<input type="checkbox"/> Yes <input type="checkbox"/> No	Volume control with appropriate settings
<input type="checkbox"/> Yes <input type="checkbox"/> No	APRV
<input type="checkbox"/> Yes <input type="checkbox"/> No	Incremental PEEP
<input type="checkbox"/> Yes <input type="checkbox"/> No	Pressure control
TESTS	
<input type="checkbox"/> Yes <input type="checkbox"/> No	CXR
<input type="checkbox"/> Yes <input type="checkbox"/> No	Bronchoscopy ASAP
<input type="checkbox"/> Yes <input type="checkbox"/> No	ABGs-Baseline, O2 challenge, and every 4 hours
PHYSICAL MANAGEMENT AND CARE	
<input type="checkbox"/> Yes <input type="checkbox"/> No	Chest PT every 1 to 4 hours
<input type="checkbox"/> Yes <input type="checkbox"/> No	Tilt patient every hour
<input type="checkbox"/> Yes <input type="checkbox"/> No	Use of specialty bed where available
<input type="checkbox"/> Yes <input type="checkbox"/> No	Evaluate benefit of proning
<input type="checkbox"/> Yes <input type="checkbox"/> No	Oral care q 1-2 hours
<input type="checkbox"/> Yes <input type="checkbox"/> No	No ETT cuff leak
<input type="checkbox"/> Yes <input type="checkbox"/> No	HOB elevated at least 30 degrees
HEMODYNAMIC MONITORING AND TREATMENT	
<input type="checkbox"/> Yes <input type="checkbox"/> No	Transduced central line/ Swan Ganz for hemodynamic monitoring (thoracic preferred for adequate readings)
<input type="checkbox"/> Yes <input type="checkbox"/> No	Maintain CVP 6-10 mm Hg
<input type="checkbox"/> Yes <input type="checkbox"/> No	Maintain PAWP 8-12 mm Hg
Lungs: <input type="checkbox"/> Placed <input type="checkbox"/> Visualized OR <input type="checkbox"/> Recovered <input type="checkbox"/> Transplanted	
<input type="checkbox"/> PO2 at beginning of donor management on 100%	
<input type="checkbox"/> PO2 before OR on 100%	
*All items bolded MUST be given.	

Figure 2 Data collection tool used by donation coordinator.

Abbreviations: ABGs, arterial blood gas analyses; APRV, airway pressure release ventilation; ASAP, as soon as possible; CVP, central venous pressure; CXR, chest radiography; ETT, endotracheal tube; HOB, head of the bed; O2, oxygen; OR, operating room; PAWP, pulmonary artery wedge pressure; PEEP, positive end-expiratory pressure; PO2, partial pressure of oxygen; PT, physiotherapy; q, every; T4, levothyroxine.

Main Outcome Measures

The protocol was implemented in September 2005. Data were collected until December 2008. Review of

the data indicated that recovery and transplantation of lungs had increased by 265%. The number of lungs transplanted increased from 37 in 2004 to 135 in 2008

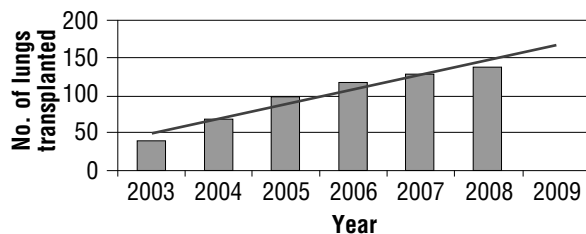


Figure 3 Number of lungs transplanted in past 6 years.

(Figure 3). Before the use of the protocol, the management of the lungs consisted of incremental PEEP and pressure control ventilation. Lungs that were considered transplantable had a PO_2 greater than 300 mm Hg at the start of donor management. Lungs that were not considered transplantable had a PO_2 less than 300 mm Hg. Data from years 2004 and 2005, before initiation of the protocol, showed the number of transplantable lungs increased from 58.9% to 66.0%. Data from years 2006 and 2007, after initiation of the protocol, showed the number of transplantable lungs increased from 66.0% to 83.7%. Changes such as dosing of methylprednisolone (Solumedrol), elevation of the head of the bed, oral care, and assessing for a cuff leak have been made to the protocol during the 3-year period to improve effectiveness after data indicated an increase in numbers of lungs recovered and transplanted (Figure 3).

The number of organs transplanted per donor has also increased since the protocol began being used. Data from 2005 show 3.59 organs transplanted per donor for standard criteria donors and 1.75 organs transplanted per donor for extended criteria donors. Data from 2008 show an increase in organs transplanted in both types of donors, 3.9 organs transplanted per donor for standard criteria donors and 1.81 organs transplanted per donor for extended criteria donors. As an organ procurement organization, we do not have the data on recipient outcomes; however, results of studies done by organ procurement organizations that have protocols similar to ours indicate a marked increase in the number of lung procurements.^{17,18}

Limitations

One limitation of this study is that no control group was used. The protocol was performed on every donor who met the criteria. Another limitation is that we cannot be positive that it was only the protocol itself that contributed to the increase in the number of lungs transplanted. Other factors such as more aggressive surgeons at transplant centers and exporting lungs outside of the United States to Canada may also have contributed to the increase. Although more aggressive centers may have been transplanting lungs or more lungs may have been exported to Canada, those lungs would not have been eligible for transplant had the protocol not been used to help maximize the donor

lung pool. The lung protocol can also be credited for maintaining lung function throughout donor management of lungs that are functioning well initially. Further studies are needed to assess all the possible reasons for the increase in number of lungs recovered and transplanted and also to assess the status of the recipients.

Acknowledgments

We thank the following people for their contributions during development of the lung data collection tool: Sheila Alston, RN, BSN, MBA, CPTC; Rita Unis, RN, BSN, CPTC; Karen Oldenburg, RN, BSN, CPTC; Lica Fenton, BS, CPTC; Mark Tudor, BS, CPTC; Josh Angel, BS, CPTC; and Robert Helm, RRT, CPTC. We thank Robert Helm, RRT, CPTC, and Angie Engerson, RN, BSN, CPTC, for their help with collection of data and Dr Michael Hagan, MHA, CMQ, for his help with the graphs.

Financial Disclosures

None reported.

References

1. United Network for Organ Sharing. <http://www.unos.org/data/about/viewDataReports.asp>. Accessed September 16, 2009.
2. Institute for Healthcare Improvement. <http://www.ihl.org/IHI/Topics/Improvement/ImprovementMethods/HowToImprove/>. Accessed September 21, 2009.
3. Hevesi Z, Lopukhin S, Angelini G, et al. Supportive care after brain death for the donor candidate. *Int Anesth Clin*. 2006;44:21-34.
4. Novitsky D, Cooper D, Rosendale J, et al. Hormonal therapy of the brain-dead donor: experimental and clinical studies. *Transplantation*. 2006;82:1396-1401.
5. Rogers B, Shackford R, Trevisani T, et al. Neurogenic pulmonary edema in fatal and non-fatal head injuries. *J Trauma*. 1995;39:860-868.
6. Peterson B, Ross J, Brigham K. Effects of naloxone on pulmonary vascular responses to graded levels of intracranial pressure in anesthetized sheep. *Am Rev Respir Dis*. 1983;128:1024-1029.
7. Acetylcysteine as a mucolytic agent. <http://www.rxlist.com/acetylcysteine-solution-drug.htm>. Accessed September 13, 2009.
8. Lasix. <http://www.rxlist.com/lasix-drug.htm>. Accessed September 18, 2009.
9. Bumex. <http://www.rxlist.com/bumex-drug.htm>. Accessed September 18, 2009.
10. Mannitol IV. <http://www.rxlist.com/mannitol-IV-drug.htm>. Accessed September 18, 2009.
11. Powner D, Delgado E. Using pressure-limited mechanical ventilation in caring for organ donors. *Prog Transplant*. 2001;11:174-179.
12. de Perrot M, Snell GI, Babcock WD, et al. Strategies to optimize the use of currently available lung donors. *J Heart Lung Transplant*. 2004;10:1127-1133.
13. Powner DJ, Darby JM, Kellum JA. Proposed treatment guidelines for donor care. *Prog Transplant*. 2004;14:16-26.
14. Inomax. <http://rxlist.com/inomax-drug.htm>. Accessed September 21, 2009.
15. Wip C, Naplitano L. Bundles to prevent ventilator-associated pneumonia: how valuable are they? *Curr Opin Infect Dis*. 2009;22:159-166.
16. Cason C, Tyner T, Saunders S. Nurses' implementation of guidelines for ventilator-associated pneumonia from the Centers for Disease Control and Prevention. *Am J Crit Care*. 2007;16(1):28-37.
17. Straznicka M, Follette D, Eisner M, et al. Aggressive management of lung donors classified as unacceptable: excellent recipient survival one year after transplantation. *J Thorac Cardiovasc Surg*. 2002;124:250-258.
18. Angel L, Levine D, Marcos R, et al. Impact of a lung transplantation donor-management protocol on lung donation and recipient outcomes. *Am J Respir Crit Care Med*. 2006;174:710-716.