BRIEF COMMUNICATIONS

MEASUREMENT OF LUNG OXYGEN CONSUMPTION IN A PATIENT AFTER DOUBLE-LUNG TRANSPLANT

Kang H. Lee, MA, MBBChir, MRCP,^a Philippe Rico, MD,^a Arthur J. Boujoukos, MD,^a Robert J. Keenan, MD,^b and Michael R. Pinsky, MD, FCCP,^a Pittsburgh, Pa.

A 48-year woman underwent double-lung transplantation for treatment of severe emphysema. She required venous-arterial extracorporeal membrane oxygenation (ECMO; Bio-Medicus pump, model 540T; Bio-Medicus, Inc., Eden Prairie, Minn.; Medtronic/Carmada Bioactive Surface with Maxima Hollow Fiber oxygenator CB 1380; Medtronic, Inc., Minneapolis, Minn.) to correct severe hypoxemia and cardiovascular instability. A postoperative chest radiograph demonstrated bilateral alveolar infiltrates compatible with acute lung injury.

On the second postoperative day, we measured oxygen consumption (Vo_2) and carbon dioxide excretion (Vco_2) by means of respiratory gas analysis with a metabolic cart (Deltatrac; SensorMedics Corp., Yorba Linda, Calif.). Blood flow through the pulmonary circulation was varied by adjusting the ECMO flow rates during the study interval. The patient was ventilated with a Puritan-Bennett 7200e ventilator (Puritan-Bennett Corp., Portable Ventilator Division, Boulder, Colo.) set on a tidal volume of 600 ml with a respiratory rate of 4 breaths/min, positive end-expiratory pressure of 10 cm H_2O , and inspired oxygen fraction of 0.5. With the ECMO flow at 5 L/min, there was a nonpulsatile pulmonary arterial tracing with a mean pressure of 8 mm Hg, which was inferred to reflect no flow in the pulmonary artery. The simultaneous nonpulsatile radial arterial tracing confirmed the absence of aortic valve opening. These settings were maintained for 10 minutes, during which time the readings stabilized to yield, during a 5-minute period: Vo_2 , 7.8 ± 1.7 ml/min (mean $\pm$ standard deviation); and Vco_2 , 18.3 ± 1.6 ml/min (Table I). Respiratory quotient (RQ) was 1.97 ± 0.05 .

When the ECMO flow rate was reduced gradually to 2 L/min, there was a return of pulmonary artery flow. This was evidenced by the reappearance of pulsatile pulmonary arterial and radial arterial tracings. Furthermore, a thermodilution cardiac output was measured at 3.43 L/min. Vo_2 increased progressively and stabilized (after 5 min-

Table I. Data showing the effects of changing ECMO flow rates on Vo_2 and Vco_2 as measured by respiratory gas analysis

Time (hr:min)	Vo_2 (mL/min)	Vco_2 (mL/min)
ECMO flow rate 5 L/min, nonpulsatile arterial pressure		
12:39	30.1	38
12:40	18.3	27
12:41	15.2	30
12:42	12.8	21.6
12:43	11.2	22.7
12:44*	7.7	19.6
12:45*	8.2	18.4
12:46*	9.7	18.3
12:47*	6.9	19.6
12:48*	5.1	15.7
ECMO flow rate 2 L/min, cardiac output 3.43 L/min		
13:43	46.5	77.6
13:44	41.5	75.9
13:45	43.4	76.1
13:46	47.7	75.5
13:47	53.6	78.0
13:48*	67.2	83.4
13:49*	65.9	80.5
13:50*	68.4	80.0
13:51*	70.1	81.2
13:52*	72.1	79.8

* Selected time periods after 5-minute stabilization to represent Vo_2 and Vco_2 values for that ECMO flow rate.

utes) at 68.7 ± 2.4 ml/min, Vco_2 at 81.0 ± 1.5 ml/min, and RQ was reduced to 1.18 ± 0.05 (Table I).

Discussion

Lung Vo_2 represents the amount of oxygen consumed by the lung tissues directly from the alveoli. This volume has previously been measured directly in isolated lung preparations.¹ The ability of the lung tissues to extract oxygen directly from the alveoli has particular significance for the preservation of donor lungs. Preservation is better when the lung is insufflated with 100% oxygen.² Lung Vo_2 has also been measured in intact animals and in human beings by assuming that it is represented by the difference between oxygen uptake through the mouth by respiratory gas analysis and the product of arteriovenous oxygen content difference and cardiac output ($\text{Vo}_2 \text{ Fick}$). Patients

From the Departments of Anesthesiology and Critical Care Medicine^a and Surgery,^b University of Pittsburgh Medical Center, Pittsburgh.

Accepted for publication April 6, 1995.

Address for reprints: Kang H. Lee, MD, Division of Critical Care Medicine, Room 604A, Scaife Hall, University of Pittsburgh Medical Center, 200 Lothrop St., Pittsburgh, PA 15213.

J THORAC CARDIOVASC SURG 1995;110:1764-5

Copyright © 1995 by Mosby-Year Book, Inc.

0022-5223/95 \$5.00 + 0 12/54/65326

after cardiac bypass operation and patients with adult respiratory distress syndrome have also been found to have a measurable and significant lung Vo_2 .^{3,4} This method, however, engenders the potential error of underestimating Vo_2 Fick by neglecting the bronchial circulation, which is known to have increased flow during inflammatory lung disorders. Our patient therefore provided an unique opportunity to measure true lung Vo_2 because the bronchial circulation had been interrupted with the double-lung transplant and venous-arterial ECMO at the high flow rate eliminated pulmonary blood flow. In effect, we had a nonperfused lung in vivo, and any measured oxygen consumption at the mouth therefore represented true lung Vo_2 .

The measured lung Vo_2 our patient is probably higher than normal because the lungs had obvious reperfusion injury. The actual value therefore may reflect increased metabolic activity during inflammation, or, alternatively, Vo_2 for nonoxidative purposes (e.g., oxygen radical formation). We presume that if the latter were true there would be no corresponding increase in carbon dioxide production, and RQ therefore would fall. The calculated RQ was high, however, especially during conditions of no pulmonary blood flow. This RQ probably reflected the presence of anaerobic metabolism leading to metabolic acidosis and an increase in Vco_2 from bicarbonate buffering of lactic acid (gas-exchange threshold).⁵ The potential anaerobic conditions in double-lung transplants that result from high-flow venous-arterial ECMO support without pulmonary blood flow have been a source of concern because they may lead to ischemic injury to the anastomosis site.

In summary, we have demonstrated the first direct measurement of human lung Vo_2 in vivo for lungs with reperfusion injury.

REFERENCES

1. Date H, Matsumura A, Manchester JK, Cooper JM, Lowry OH, Cooper JD. Changes in alveolar oxygen and carbon dioxide concentration and oxygen consumption during lung preservation. The maintenance of aerobic metabolism during lung preservation. *J THORAC CARDIOVASC SURG* 1993;105:492-501.
2. Weder W, Harper BD, Shimokawa S, et al. Influence of intraalveolar oxygen concentration on lung preservation in a rabbit model. *J THORAC CARDIOVASC SURG* 1991;101:1037-43.
3. Takala J, Keinanen O, Vaisanen P, Kari A. Measurement of gas exchange in intensive care: laboratory and clinical validation of a new device. *Crit Care Med* 1989;17:1041-7.
4. Gill RS, Cunningham DG, Sharpe MD. Oxygen consumption in sepsis: contribution of the lung [Abstract]. *Am J Respir Crit Care Med* 1994;149:A414.
5. Patessio A, Casaburi R, Carone M, Appendine L, Donner CF, Wasserman K. Comparison of gas exchange, lactate and lactic acidosis thresholds in patients with chronic obstructive pulmonary disease. *Am Rev Respir Dis* 1993;148:622-6.

SUPRACLAVICULAR LUNG BIOPSY

Francis Robicsek, MD, *Charlotte, N.C.*

Open lung biopsy, however technically simple, carries a significant degree of postoperative discomfort. Because of the severe underlying disease in most patients, it also carries appreciable surgical morbidity and even mortality. Recently introduced video-assisted thoracoscopic techniques alleviated this problem somewhat, but they certainly did not eliminate it. To significantly decrease postoperative discomfort and shorten recuperation time, we recommend that "supraclavicular technique" described here be considered in patients in whom the apexes of the lung are pathologically involved.

A transverse 5 to 6 cm incision is made just above the superior margin of either the right or the left clavicle,

depending on the planned biopsy site. The subcutaneous fat is dissected off, and the anterior scalene muscle is exposed and divided. In this process, careful attention is given to identifying and protecting the phrenic nerve. The subclavian artery is retracted downward, exposing the anterior portion of the first rib. A 3 to 4 cm segment of the exposed first rib is stripped of its periosteum and resected. At that point, the surgeon will already see the apex of the lung under the cupola of the parietal pleura. The pleural cavity is then entered and the apex of the lung is inspected. Usually there is no difficulty in viewing most, if not the entirety, of the upper lobe. An appropriate site is selected on the lung, grabbed with a forceps, and brought through the surgical incision (Fig. 1). A tissue sample from the lung of appropriate size is then excised, and the excision site is either "tied off" or sutured. A 28F rubber catheter is inserted through the surgical incision into the pleural cavity and connected to a water-sealed drainage. The incision is closed layer by layer. If there is no continued air leakage the catheter may be conveniently removed at the end of the procedure after 2 to 3 hours.

Throughout the years we have used this method in

From the Department of Thoracic and Cardiovascular Surgery and The Heineman Laboratory for Research, Carolinas Medical Center, Charlotte, N.C.

Accepted for publication May 31, 1995.

J THORAC CARDIOVASC SURG 1995;110:1765-6

Copyright © 1995 by Mosby-Year Book, Inc.

0022-5223/95 \$5.00 + 0 12/54/66603