6801-MAS/C1 (Minerva Anestesiol 2011;77:1-2)

CASE REPORT

Extracorporeal carbon dioxyde removal for additional pulmonary resection after pneumonectomy

M. IACOVAZZI [1], N. ORESTE [1], P. SARDELLI [2], B. BARRETTARA [2], S. GRASSO [3]

[1]Unit of Anesthesia and Resuscitation, Local Health Unit Bari, San Paolo Hospital, Bari, Italy; [2]Unit of Thoracic Surgery, Local Health Unit Bari, San Paolo Hospital, Bari, Italy; [3]Unit of Anesthesiology and Resuscitation, Department of Emergency and Organ Transplantation, Aldo Moro University, Policlinic University Hospital, Bari, Italy

ABSTRACT

Additional pulmonary surgery in a previously pneumonectomized patient requires apnea during surgical manipulation of the surviving lung. We report on a novel approach to manage the intraoperative apnea period, combining apneic oxygenation and minimally invasive, low flow extracorporeal CO_2 removal. A 69-year-old man previously submitted to left pneumonectomy was scheduled for wedge resection of a single right upper lobe lesion. During the intraoperative apnea period, oxygenation was maintained through apneic oxygenation with continuous positive airway pressure (CPAP) of 5 cmH_2O and inspiratory oxygen fraction (FiO_2) of 1 and respiratory acidosis was prevented through extracorporeal CO_2 removal, performed with the Decap® system (Hemodec, Salerno, Italy), a veno¬venous pump-driven extracorporeal circuit including a neonatal membrane lung. The extracorporeal circuit was connected to the right femoral vein, accessed via a 14 Fr double lumen catheter. The blood flow through the circuit was 350 mL/min and the sweep flow of oxygen through the membrane lung was 8 L/min. The intraoperative apnea period lasted 13 minutes. Our approach allowed maintaining normocapnia ($PaCO_2$ 38,5 and 40 mmHg before and at the end of the apnea period, respectively), preserving oxygenation (P/F ratio 378, 191, 198 and 200 after 3, 6, 9 and 12 min of apnea, respectively). Our report suggests that the minimally invasive CO_2 removal associated with apneic oxygenation is an useful technique for managing anesthesiological situations requiring moderate apnea periods.

Key words: Pulmonary surgical procedures – Apnea - Pneumonectomy.

Additional pulmonary surgery in a previously pneumonectomized patient is a relatively rare procedure requiring apnea in order to allow surviving lung manipulation.[1-5] Several approaches have been since now proposed in order to manage the intraoperative apnea period, including apneic ventilation [6] apneic oxygenation plus continuous positive airway pressure (CPAP),[7] gentle hand ventilation [3] or alternating periods of ventilation and apnea [4] but, despite acceptable oxygenation may be achieved through these techniques, severe respiratory acidosis limits the time available for surgical manipulation.[8] Cardiopulmonary bypass, extracorporeal membrane oxygenation (ECMO) and pumpless interventional lung assist CO^2 removal are suitable alternatives but the serious risk of complications limits their use to complex surgical procedures.[9, 10] We report on a novel approach to manage the intraoperative apnea period, combining apneic oxygenation and “minimally invasive” extracorporeal CO^2 removal. The latter technique, recently validated to manage respiratory acidosis arising from low-tidal volume lung-protective

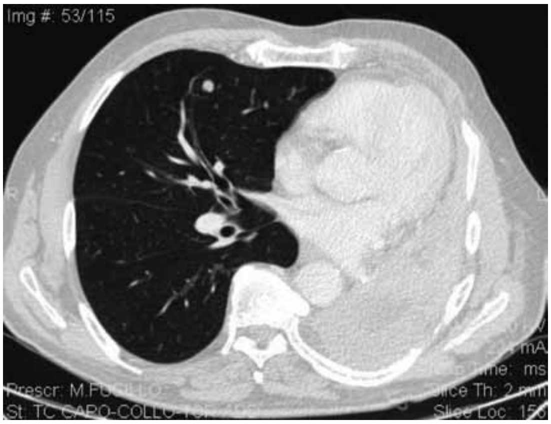

Figura 1.

ventilation in patients with the acute respiratory distress syndrome (ARDS),[11] consists in a veno-venous pump-driven extracorporeal circuit including a neonatal membrane lung. An advantage of the technique is that it requires a relatively low blood flow (300-400 mL/min) in order to efficiently remove CO_2 [12] and therefore requires small diameters catheters, minimizing the risks of venous cannulation.

Case report

In December 2009, a 69-year-old man previously submitted to left pneumonectomy for squamous cell carcinoma (non-small cell lung cancer) stage IA (February 2008) and to colectomy for adenocarcinoma (February 2009), was diagnosed a single right upper lung lobe lesion (Figure 1). Subsequent histological examination was compatible with a metastasis of colorectal adenocarcinoma. A wedge resection (through an antero-lateral thoracotomy performed on the fifth intercostal space) was planned. Written informed consent was obtained by the patient.

Patient history was negative except for a moderate hypertension, well controlled with calcium-antagonists. Preoperative patient's cardio-respiratory fitness and functional capacity, as quantified by the metabolic equivalent of the task scale (MET) was 6, indicating a low risk for postoperative cardiopulmonary complications.[13] Preoperative arterial blood gas analysis showed pH 7.43, $PaCO_2$ 41.3 mmHg, PaO_2 83.8 mmHg while breathing room air, and the patient was not on long term oxygen therapy. Spyrometry showed forced expiratory volume in the first second (FEV1) of 1.36 L (47% predicted), forced vital capacity (FVC) 2.30 L (60% predicted) and FEV1/FVC 59% (79% predicted). Preoperative transthoracic echocardiography showed a moderately hypertrofic left ventricle with normal ejection fraction and normal right ventricular dimensions without evidence of tricuspid regurgitation. Other preoperative examinations included: routine lab tests, chest X-ray, spiral thoracic CT scan, bronchofiberoscopy and 12-lead electrocardiogram. Overall, the patient was considered suitable to undergo the surgical procedure, also considering the minimal dimension of the lesion (Figure 1) and the limited amount of lung parenchyma to be removed.

Standard monitoring, including invasive blood pressure, heart rate and lead II continuous electrocardiogram, pulse oximetry, capnometry, capnography and oesophageal temperature, was instituted at the beginning of the procedure (Datex-Ohmeda Anesthesia Monitor, GE Healthcare). Cardiac output was measured through the continuous pulse pressure waveform analysis (Flotrac Vigileo, Edwards).[14] A midthoracic epidural catheter was inserted at T5-T6 level and a 5 mL epidural test dose of 0.2% lidocaine was injected. For subsequent CO_2 removal, the right femoral vein was accessed *via* double lumen catheter (14 Fr, Arrow International Inc. Reading, PA, USA) inserted through the Seldinger technique under echocardiographic guidance.

After general anesthesia induction, a cuffed endo-tracheal tube (Internal Diameter 8 mm) was inserted and the patient was ventilated in the controlled flow limited mode, with tidal volume (VT) of 6 mL/kg, respiratory rate (RR) 14 breaths/min, using oxygen in air with inspiratory oxygen fraction (FiO_2) set at 0.4, zero end-expiratory positive pressure (ZEEP) and inspiratory:expiratory ratio (I:E) 1:2. The patient was placed in left lateral decubitus. In order to allow surgical manipulation during the wedge resection procedure, mechanical ventilation was interrupted. During the apnea period, a continuous positive airway pressure level of 5 cmH_2O (Whisperflow, Philips Respironics, Murrysville, PA, USA) with an inspiratory oxygen fraction (FiO_2) of 1 was applied.[7, 15] Contemporarily, CO_2 was partially removed through the Decap system (Hemodec, Salerno, Italy). Briefly, it consists in a extracorporeal circuit driving venous blood flow through a membrane lung (Polystan SAFE, Maquet, Rastatt, Germany) by means of a non-occlusive roller pump (0-500 mL/min). CO_2 diffusing from blood to the membrane lung is removed by a sweep flow of 100% oxygen, delivered at a constant rate of 8 L/min. Exiting the membrane lung, blood is driven to a hemofilter (Medica D200, Medolla, Italy) and the resulting plasmatic water is recirculated trough the membrane lung by a peristaltic pump (0-155 mL/min). The membrane lung and the hemofilter are coupled in series in order to increase the pressure inside the membrane lung, minimize the need for heparin and enhance dissolved CO_2 extracting capacity.[12] The circuit priming volume, including the membrane lung and the hemofilter is 140-160 mL. In order to prime with heparin the membrane lung and the hemofilter, the circuit was primed with saline plus heparin 5 UI/kg. However, in order to not interfere with systemic coagulative parameters, the circuit was washed with saline before patient connection and both the starting heparin dose and the continuous pre-membrane heparin infusion that are suggested for the Decap system use in the intensive care context were skipped. Indeed, recent data show that, in patients deemed to be at risk of bleeding such as postoperated patients, continuous

Table I.—*Hemodynamics and gas exchange parameters.*

	Preapnea	3 min apnea	6 min apnea	9 min apnea	12 min apnea	Post apnea
HR (beats/min)	62	50	52	52	51	50
MAP (mmHg)	72	68	65	65	64	70
CO (L/min)	4.4	4.5	4.5	4.5	4.3	5.1
FiO_2	0.4	1	1	1	1	0.4
PaO_2 (mmHg)	172.4	377.8	191	198	199,9	132,2
$PaCO_2$ (mmHg)	38.5	34.3	41.7	40.7	40	39.4
pH	7.4	7.39	7.37	7.36	7.37	7.36
HCO_3 -(mmol/L)	23.5	20.4	23.6	22.9	22.4	21.8
BE	-1	-3.9	-1.6	-2.2	-2.7	-3.4

HR: heart rate; MAP: mean arterial pressure; CO: cardiac output; FiO_2: inspiratory O_2 fraction; PaO_2: arterial O_2 partial pressure; $PaCO_2$: arterial CO_2 partial pressure; HCO_3: bicarbonate; BE: base excess.

veno-venous hemofiltration with a flow as low as 200 mL/min is feasible for brief periods and does not induce risks of thrombosis.[16] Blood flow through the circuit was set to 350 mL/min. At the time of resumption of mechanical ventilation, blood flow was gradually reduced to the lowest value (50 mL/min) and turned off in 1-2 min.

The whole surgical procedure lasted three hours and was carried out without intraoperative complications. The apnea period lasted 13 min. Table I shows the main cardiovascular and gas exchange parameters recorded 10 min before apnea, each 3 min during apnea and, finally, 10 min after apnea.

At the end of the intervention a fiber optic bronchoscopy showed patency of all lobar bronchi, propofol and remifentanyl infusion were discontinued. The patient resumed spontaneous breathing and was successfully extubated. In the immediate postoperative period the patient was admitted in the recovery room for vital parameters monitoring and transferred to the ward after 8 hours with an Aldrete Score of 10.[17] He was discharged from the hospital six days after. At the follow-up performed 40 days after surgery, the patient was in healthiness and referred he had resumed its physiological activities.

Discussion

We deemed appropriate combining apneic oxygenation with a minimally invasive extracorporeal CO_2 removal technique in order to improve patient safety during the apnea period. Due to the rareness of the presented surgical case, our decision to test this new approach was not based on our previous experience on similar cases but instead on the examination of the literature. Indeed, despite episodes of hypercapnia up to a $PaCO_2$ of 100 mmHg resulting from deliberate hypoventilation or apnea during general anesthesia were not associated with serious consequences in several reports,[8, 18] the potential risks of severe hypercapnia are well known.[19] It depresses myocardial contractility,[20] increases the arrhythmogenic potential of propofol and halotane, causes profound cardiovascular depression during general anesthesia combined with epidural analgesia [21] and, finally, may induce acute cerebral hyperemia.

In our patient, the recently introduced Decap device was able to maintain normocapnia during a prolonged apnea period despite the low flow through the device (only 7,7 % of cardiac output Table I). We must acknowledge, as a limitation of our report, that we did not quantify either CO_2 metabolic production during the apnea nor the amount of CO_2 removed by the device. One could speculate that, given the concomitant effects of general and epidural anesthesia, CO_2 metabolic production was severely depressed in our patient, explaining, at least in part, our results. However, a previous study by Fraioli *et al.* accounts for a linear fourfold $PaCO_2$ increase in anesthetized patients undergoing a 15 min apnea period [22] and recent data account for a $PaCO_2$ increase of 175% during a 10 min apnea test performed in CPAP for diagnosing of brain death.[7] According to these evidences, we can affirm that in our patient normocapnia during apnea was achieved thanks to decapneization.

Conclusions

Our report suggests that the minimally invasive CO_2 removal associated with apneic oxygenation is an useful technique for managing anesthesiological situations requiring moderate apnea periods.

References

1. Grodzki T, Alchimowicz J, Kozak A, Kubisa B, Pierog J, Wojcik J *et al*. Additional pulmonary resections after pneumonectomy: actual long-term survival and functional results. Eur J Cardiothorac Surg 2008;34:493-8.
2. Kishi Y, Taniguchi H, Nakagawa M, Kita T, Mammoto T, Kanbara N *et al*. [Anesthesia for partial pulmonary resection in a postpneumonectomy patient]. Masui 2002;51: 261.
3. Kudoh O, Sonoda S, Kikkawa A, Arita H, Miura K, Kugimiya T. [Anesthetic management of surgical intervention for contralateral pneumothorax after left pneumonectomy]. Masui 2007;56:80-3.
4. Suzuki Y, Katori K, Mayama T, Shiratake T, Hamada T, Higa K. [Anesthetic management for thoracoscopic partial lobectomy in a patient with one lung]. Masui 2002;51:921-3.
5. Terzi A, Lonardoni A, Scanagatta P, Pergher S, Bonadiman C, Calabro F. Lung resection for bronchogenic carcinoma after pneumonectomy: a safe and worthwhile procedure. Eur J Cardiothorac Surg 2004;25:456-9.
6. Babinski MF, Smith RB, Bunegin L. Continuous-flow apneic ventilation during thoracotomy. Anesthesiology 1986;65:399-404.
7. Levesque S, Lessard MR, Nicole PC, Langevin S, LeBlanc F, Lauzier F *et al*. Efficacy of a T-piece system and a continuous positive airway pressure system for apnea testing in the diagnosis of brain death. Crit Care Med 2006;34:2213-6.
8. Morisaki H, Serita R, Innami Y, Kotake Y, Takeda J. Permissive hypercapnia during thoracic anaesthesia. Acta Anaesthesiol Scand 1999;43:845-9.
9. Ishikawa N, Sato H, Hiranuma C, Takizawa M. A surgical intervention using percutaneous cardiopulmonary support for contralateral pneumothorax following pneumonectomy. Ann Thorac Cardiovasc Surg 2001;7:235-6.
10. Wiebe K, Poeling J, Arlt M, Philipp A, Camboni D, Hofmann S *et al*. Thoracic surgical procedures supported by a pumpless interventional lung assist. Ann Thorac Surg 2010;89:1782-7; discussion 1788.
11. Terragni PP, Del Sorbo L, Mascia L, Urbino R, Martin EL, Birocco A *et al*. Tidal volume lower than 6 ml/kg enhances lung protection: role of extracorporeal carbon dioxide removal. Anesthesiology 2009;111:826-35.
12. Livigni S, Maio M, Ferretti E, Longobardo A, Potenza R, Rivalta L *et al*. Efficacy and safety of a low-flow veno-venous carbon dioxide removal device: results of an experimental study in adult sheep. Crit Care 2006;10:R151.
13. Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof E, Fleischmann KE *et al*.: ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery): developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. Circulation 2007; 116: e418-99.
14. Cecconi M, Dawson D, Casaretti R, Grounds RM, Rhodes A. A prospective study of the accuracy and precision of continuous cardiac output monitoring devices as compared to intermittent thermodilution. Minerva Anestesiol 2010 [Epub ahead of print].
15. Glover GW, Fletcher SJ. Assessing the performance of the Whisperflow continuous positive airway pressure generator: a bench study. Br J Anaesth 2009;102:875-81.
16. Uchino S, Fealy N, Baldwin I, Morimatsu H, Bellomo R. Continuous venovenous hemofiltration without anticoagulation. Asaio J 2004;50:76-80.
17. Aldrete JA, Kroulik D. A postanesthetic recovery score. Anesth Analg 1970;49:924-34.
18. Quinlan JJ, Buffington CW. Deliberate hypoventilation in a patient with air trapping during lung transplantation. Anesthesiology 1993;78:1177-81.
19. Feihl F, Perret C. Permissive hypercapnia. How permissive should we be? Am J Respir Crit Care Med 1994;150:1722-37.
20. Shibata K, Futagami A, Taki Y, Kobayashi T. Epidural anesthesia modifies the cardiovascular response to marked hypercapnia in dogs. Anesthesiology 1994;81:1454-60.
21. Walley KR, Lewis TH, Wood LD. Acute respiratory acidosis decreases left ventricular contractility but increases cardiac output in dogs. Circ Res 1990;67:628-35.
22. Fraioli RL, Sheffer LA, Steffenson JL. Pulmonary and cardiovascular effects of apneic oxygenation in man. Anesthesiology 1973;39:588-96.

Received on January 4, 2011 - Accepted for publication on March 8, 2011.

Corresponding author: S. Grasso, MD, Aldo Moro University, Department of Emergency and Organ Transplantation, Unit of Anesthesiology and Resuscitation, Policlinic University Hospital, Piazza Giulio Cesare 11, Bari, Italy. E-mail: sgrasso@rianima.uniba.it