A fine balance—one-lung ventilation in a patient with Eisenmenger syndrome

A. R. Heller*, R. J. Litz and T. Koch

Department of Anaesthesiology and Intensive Care Medicine, University Hospital Carl Gustav Carus, Harvard Medical International Associated Institution, Fetscherstrasse 74, D-01307 Dresden, Germany

**Corresponding author. E-mail axel.heller@mailbox.tu-dresden.de*

A 38-yr-old woman with an atrial septum defect and Eisenmenger syndrome was scheduled for a lung biopsy via thoracoscopy during one-lung ventilation. Fluids were given to increase central venous pressure to 8 mm Hg, an epidural catheter was inserted at the sixth thoracic intervertebral space and ropivacaine 0.3%, 6 ml were given. Careful balance of systemic and pulmonary vascular resistance is crucial in Eisenmenger syndrome, so norepinephrine (0.14 mg kg^{-1} min^{-1}) was infused before general anaesthesia was started with fentanyl 4 mg kg^{-1}, ketamine 2 mg kg^{-1}, pancuronium 1 mg and succinylcholine 2 mg kg^{-1}. Anaesthesia was maintained with propofol 4–8 mg kg^{-1} h^{-1}. To control pulmonary artery pressure, ventilation was performed with oxygen 100% and nitric oxide 20 ppm. Surgery and anaesthesia course were uneventful and the patient was extubated. However, pleural haemorrhage required treatment with blood components, re-intubation on the second postoperative day and removal of the haematoma by mini-thoracotomy. A step-by-step approach using a balanced combination of regional and general anaesthesia, controlled fluid administration, norepinephrine and inhaled nitric oxide preserved a stable circulation even during one-lung ventilation. The diagnostic value of lung biopsy must be weighed against the possibility of life-threatening haemorrhage.

Br J Anaesth 2004; **92**: 587–90

Keywords: anaesthetic techniques, epidural; complications, atrial heart septum defect; complications, pulmonary hypertension; lung, thoracoscopy

Accepted for publication: August 9, 2003

Eisenmenger syndrome is defined as increased pulmonary vascular resistance (PVR) with pulmonary hypertension resulting from a left-to-right shunt which can become bidirectional or right to left, caused by a variety of congenital cardiac anomalies.[1] Without correction, severe complications such as congestive heart failure usually occur from the third decade onward.[2] Other than sudden death (30%), important causes of death in patients with Eisenmenger syndrome are complications after non-cardiac surgery, such as congestive heart failure (25%) and haemoptysis (15%).[2]

Depending on the surgical procedure, perioperative mortality in patients with Eisenmenger syndrome is 4–25%.[3] The underlying reason is loss of control over the direction and flow of intracardiac shunt, with increasing right-to-left shunt reducing systemic oxygen delivery. Balance of systemic vascular resistance (SVR) and PVR is crucial during surgery.[3] Factors altering the balance of SVR and PVR include hypercarbia, hypothermia, atelectasis, uncontrolled vasodilation by anaesthetics, hypovolaemia, pain-induced stress, altered intrathoracic pressures by artificial ventilation, and hypoxia. The best anaesthetic technique (regional anaesthesia, general anaesthesia or a combination of both) to control SVR and intracardiac shunt is controversial.[3] Epidural analgesia alone or in combination with general anaesthesia can improve postoperative outcome, particularly in patients with other cardiovascular disease.[4]

We report the procedure and the precautions we took for one-lung ventilation (OLV) in a patient with Eisenmenger syndrome.

Case report

A 38-yr-old woman (164 cm, 47 kg) with severe secondary pulmonary hypertension because of a congenital atrial

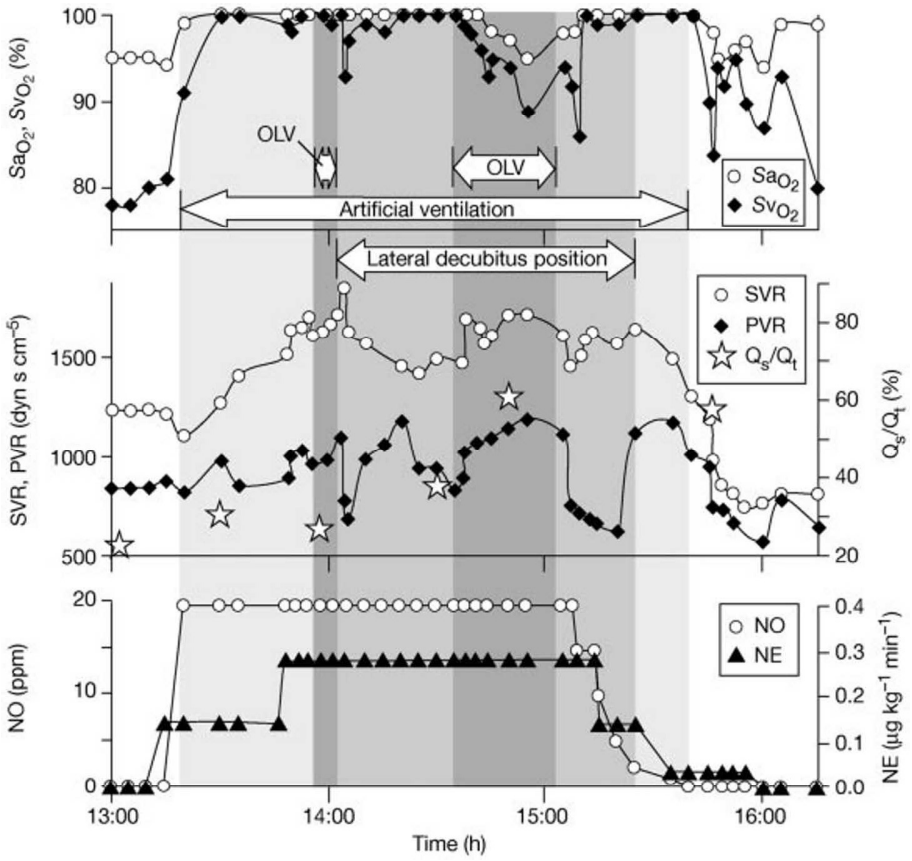

Fig. 1 Recordings during anaesthesia, showing arterial oxygen saturation (Sa_{O_2}), mixed venous oxygen saturation (Sv_{O_2}), systemic vascular resistance (SVR), pulmonary vascular resistance (PVR), right-to-left shunt (Q_s/Q_t), inhaled concentrations of nitric oxide (NO), infusion of norepinephrine (NE) and one-lung ventilation (OLV).

septum secundum defect was referred to our hospital for a thoracoscopic lung biopsy. On investigation mean pulmonary artery pressure (PAP) at rest was 59 mm Hg and PVR was 1025 dyn s cm^{-5}. Mean systemic artery pressure (MAP) was 86 mm Hg and SVR was 1618 dyn s cm^{-5}. Intra-atrial cross shunting was detected, with 17% right-to-left and 21% left-to-right shunt. Administration of the pulmonary vasodilator epoprostenol (18 ng kg^{-1} min^{-1}) decreased mean PAP to 49 mm Hg (PVR 521 dyn s cm^{-5}) while systemic pressure remained unchanged. Intra-atrial right-to-left shunt decreased to 5% while left-to-right shunt increased to 37%.

Perioperative procedure

Oral premedication was with midazolam 3.75 mg. Preoperative arterial P_{O_2} breathing air was 8.3 kPa, P_{CO_2} 4.01 kPa, pH 7.47, haemoglobin 12.7 g dl^{-1} and haematocrit 0.39. We placed an epidural catheter at the sixth thoracic intervertebral space (loss of resistance technique, test dose lidocaine 1%, 4 ml) and inserted a catheter in the left radial artery and a thermodilution fibreoptic pulmonary artery catheter (Opticath®, Abbott Laboratories, North Chicago, IL, USA) with the tip in the right pulmonary artery. The preoperative mean PAP ranged between 56 and 73 mm Hg. Systemic arterial oxygen saturation (Sa_{O_2}) and mixed venous oxygen saturation (Sv_{O_2}) were continuously monitored and ranged between 92 and 95% and 72 and 94%, respectively. I.V. fluid administration increased central venous pressure from 2 to 8 mm Hg (crystalloids 2000 ml and hydroxy ethyl starch 500 ml). Epidural analgesia (ropivacaine 0.3%, 6 ml) had no effect on arterial pressure or heart rate. Norepinephrine (0.14 µg kg^{-1} min^{-1}) was infused to maintain SVR (Fig. 1) before induction of general anaesthesia with fentanyl 4 µg kg^{-1}, ketamine 2 mg kg^{-1}, pancuronium 1 mg and succinylcholine 2 mg kg^{-1}. A left-sided 37F double-lumen endobronchial tube (Broncho-Cath™, Mallinckrodt, Athlone, Ireland) was inserted and the correct position was confirmed by bronchoscopy. Anaesthesia was maintained with propofol 4–8 mg kg^{-1} h^{-1} and intermittent doses of fentanyl (total 1.25 mg). Since epidural analgesia was performed, regional muscle relaxation was assumed and no further neuromuscular block was used.

After starting artificial ventilation with oxygen 100%, mean PAP remained stable at 60 mm Hg, whereas MAP declined by 14% to 76 mm Hg, despite norepinephrine infusion. PAP was reduced to maintain the SVR/PVR

balance using nitric oxide 20 ppm (INOvent, INO-Therapeutics Inc., Clinton, NY, USA) added to the inspired oxygen. Sv_{O_2} increased to 100%, while Sa_{O_2} remained at 100%. The increase of Sv_{O_2} to 100% was interpreted as an increase of the left-to-right shunt. When cardiovascular conditions were stable, a test run of OLV was done in the supine position. Because MAP decreased to 57 mm Hg, the dose of norepinephrine was increased to 0.28 $\mu g\ kg^{-1}\ min^{-1}$ to maintain SVR. Measured values remained within the range of 10% of double-lung ventilation. The patient was then placed on her left side for thoracoscopy. In this position Sv_{O_2} transiently decreased to 93% and PAP transiently increased (mean 73 mm Hg). Thoracoscopy was started when the circulation was stable. When a right pneumothorax was induced and left-sided OLV given, mean PAP increased to 78 mm Hg. MAP at this time was 106 mm Hg. Sa_{O_2} and Sv_{O_2} gradually decreased to 95% and 89%, respectively. A representative sample of lung (24 × 10 × 10 mm) was resected from the right pulmonary segment 3 with a 12 mm endoscopic stapler (Multifire EndoGIA 30–2.5, Autosuture, Norwalk, CT, USA). The right lung was gently re-inflated, with a decrease in PAP (mean 53 mm Hg). Weaning from nitric oxide was then started. Cessation of anaesthesia, weaning from ventilation and extubation reduced PAP further (mean 48 mm Hg). Thus, both norepinephrine infusion and nitric oxide inhalation were reduced gradually and discontinued. Throughout the procedure the heart rate remained between 55 and 75 beats min^{-1}. Postoperative pain relief was with continuous epidural administration of ropivacaine 0.2% 6 ml h^{-1}, giving analgesia of thoracic segments 3–8.

The patient was transferred to the intensive care ward and the first 16 h after surgery were uneventful. Significant blood loss from the chest drains occurred on the following day. At first conservative therapy was tried, but re-intubation of the trachea and inhaled nitric oxide had to be started on day 2. Evacuation of a pleural haematoma was done by thoracotomy on the third day after surgery. In total, infusion of packed red blood cells (3300 ml) and treatment of the coagulopathy with fresh frozen plasma (5500 ml), platelets (750 ml), fibrinogen (3 g) and antithrombin III (1500 IU) was necessary. The patient's condition stabilized over the next few days and the tracheal tube was removed on day 5. Continuous epidural analgesia with ropivacaine 0.2% 4 ml h^{-1} was maintained from the time of weaning from the ventilator until day 10.

The lung specimen showed medial hypertrophy and intimal cellular proliferation (Heath-Edwards grade I–II[5]) in two thirds and grade III–IV changes in the other third of the pulmonary arteries and arterioles. These changes are characterized by intimal fibrosis with obliteration of arterioles and small arteries (Grade III) and dilatation as well as plexiform lesions (Grade IV). Pulmonary artery changes of grade I–III are reversible, but not those of higher grades.

Discussion

The value of surgical repair of atrial septum defects in middle-aged patients remains controversial but long-term survival is greater than with medical therapy.[6] Recent advances in the understanding of pulmonary vasoregulation led to treatments including epoprostenol, nitric oxide or orally bioavailable compounds such as bosentan or beraprost.[7] In addition to lung transplantation, these agents offer new possibilities in treating pulmonary hypertension in Eisenmenger syndrome, particularly when combined with surgery for septum defects. Since outcome in Eisenmenger syndrome is closely related to lung histology, biopsy and histological classification[5] of the structural changes in the pulmonary arteries was considered necessary.

We prescribed a reduced dose of midazolam (3.75 mg) before surgery because of the risk of hypoventilation and hypoxia. In the anaesthetic management of Eisenmenger syndrome maintenance of SVR and PVR is crucial,[3] so PAP, Sv_{O_2} and central venous pressure were measured continuously. Fluid infusion and norepinephrine were used to maintain SVR and prevent any increase of right-to-left shunt after induction of general anaesthesia with vasodilation caused by propofol and changes of intrathoracic pressure caused by ventilation. Ketamine was chosen to induce general anaesthesia because it has sympathomimetic effects. Anaesthesia was maintained with propofol because it has less effect on hypoxic pulmonary vasoconstriction than volatile anaesthetics.[8] It was expected that propofol would cause less intrapulmonary shunt during OLV than volatile anaesthetics would have done. Reduced sympathetic activity by epidural anaesthesia was possible, but only small amounts of local anaesthetics were used before induction of general anaesthesia, and arterial pressure remained stable in this period. Analgesia was successful for 10 days after surgery, showing that the epidural was active. Since norepinephrine can constrict the pulmonary vessels[9] we were prepared to give inhaled nitric oxide to control PVR. In addition, excessive hypoxic pulmonary vasoconstriction during OLV with increased right-to-left shunt and decreased arterial oxygenation could be counterbalanced by vasodilation of well-ventilated areas of the lung with nitric oxide. Epoprostenol was available in case the patient was a 'nitric oxide non-responder'. Epoprostenol should only be used as a last resort because platelet aggregation might be severely affected by this prostacyclin analogue. Because of similar effects on platelets we did not consider aerosolized prostacyclin, which is as potent as nitric oxide for reversing pulmonary hypertension after cardiac surgery.[10]

Despite concerns over the use of neuraxial blockade and sympathetic block, with possible increased right-to-left shunting[11] we used an epidural for both intra- and postoperative analgesia. Intraoperative analgesia was with ropivacaine 18 mg. Until weaning from ventilation on day 5,

epidural analgesia was sustained with a continuous infusion of ropivacaine 8–12 mg h^{-1}. We wished to achieve analgesia of the surgical site and control circulatory changes (e.g. tachycardia, hypertension) without causing severe sympathetic block, and avoid side-effects of opioid analgesia, such as nausea or sleepiness. Our experience[12] and recent meta-analyses indicate better postoperative oxygenation and lower pulmonary infection rates after thoracic epidural analgesia combined with general anaesthesia, particularly in patients with co-existing cardiovascular disease.[4]

Postoperative haemorrhage occurs in 1.8% of videoscopic procedures.[13] A recent case report, published after this procedure, reported death after severe haemorrhage from inadequate endoscopic stapling and suggested that thoracoscopic lung biopsy is inadvisable in patients with pulmonary hypertension.[14] The diagnostic value of lung biopsy must be weighed against potential life-threatening haemorrhage.

Conclusion

We believe this is the first report of OLV in a patient with Eisenmenger syndrome. A combination of regional and general anaesthesia and a step-by-step approach (fluid administration, norepinephrine and inhaled nitric oxide) provided a stable circulation and satisfactory analgesia.

Acknowledgements

The authors are indebted to Sebastian N. Stehr MD (Department of Anaesthesiology, University Hospital Dresden) for proofreading the manuscript.

References

1 Wood P. The Eisenmenger syndrome or pulmonary hypertension with reversed central shunt. *BMJ* 1958; **2**: 701–9, 755–62

2 Daliento L, Somerville J, Presbitero P, *et al.* Eisenmenger syndrome: Factors relating to deterioration and death. *Eur Heart J* 1998; **19**: 1845–55

3 Martin JT, Tautz TJ, Antognini JF. Safety of regional anesthesia in Eisenmenger's syndrome. *Reg Anesth Pain Med* 2002; **27**: 509–13

4 Ballantyne JC, Carr DB, deFerranti S, *et al.* The comparative effects of postoperative analgesic therapies on pulmonary outcome: cumulative meta-analyses of randomized, controlled trials. *Anesth Analg* 1998; **86**: 598–612

5 Heath D, Edwards JE. The pathology of hypertensive pulmonary vascular disease: a description of six grades of structural changes in the pulmonary arteries with special reference to congenital cardiac septal defects. *Circulation* 1958; **18**: 533–47

6 Konstantinides S, Geibel A, Olschewski M, *et al.* A comparison of surgical and medical therapy for atrial septal defect in adults. *N Engl J Med* 1995; **333**: 469–73

7 Pass SE, Dusing ML. Current and emerging therapy for primary pulmonary hypertension. *Ann Pharmacother* 2002; **36**: 1414–23

8 Karzai W, Haberstroh J, Priebe HJ. Effects of desflurane and propofol on arterial oxygenation during one-lung ventilation in the pig. *Acta Anaesthesiol Scand* 1998; **42**: 648–52

9 Heller AR, Meier VK, Seifert J, Litz RJ. Thoracotomy and scoliosis surgery in a patient with an univentricular heart. *Anaesthesist* 2003; **52**: 218–23

10 Schulze-Neick I, Uhlemann F, Nurnberg JH, *et al.* Aerosolized prostacyclin for preoperative evaluation and post-cardiosurgical treatment of patients with pulmonary hypertension. *Z Kardiol* 1997; **86**: 71–80

11 Asling JH, Fung DL. Epidural anesthesia in Eisenmenger's syndrome: a case report. *Anesth Analg* 1974; **3**: 965–8

12 Heller AR, Litz RJ, Djonlagic I, *et al.* Combined anesthesia with epidural catheter. A retrospective analysis of the perioperative course in patients undergoing radical prostatectomy. *Anaesthesist* 2000; **49**: 949–59

13 Schafer M, Lauper M, Krahenbuhl L. A nation's experience of bleeding complications during laparoscopy. *Am J Surg* 2000; **180**: 73–7

14 Hasegawa S, Isowa N, Bando T, Wada H. The inadvisability of thoracoscopic lung biopsy on patients with pulmonary hypertension. *Chest* 2002; **122**: 1067–8