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CASE REPORTS

Xenon anaesthesia for laparoscopic cholecystectomy in a patient with Eisenmenger's syndrome†

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There are few reports on anaesthesia for patients with Eisenmenger's syndrome requiring non-cardiac surgery and none of the use of xenon. We describe the use of xenon with a closed-circuit system in a patient with Eisenmenger's syndrome having a laparoscopic cholecystectomy.

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Eisenmenger's syndrome describes patients with an anomalous circulation leading to obliterative pulmonary vascular disease, where reversal of a left-to-right shunt has occurred.[1]

More patients with congenital heart disease now survive into adulthood, including patients with Eisenmenger's complex, a non-restrictive ventricular septal defect, with increased pulmonary vascular resistance that relieves the left ventricle of excessive volume overload and not increasing afterload on the right ventricle.[2] The longer these patients survive, the more likely they are to need non-cardiac surgery, such as a cholecystectomy.[3] In patients undergoing such procedures, peri-operative cardiac morbidity is a leading cause of peri-operative death.[3] Patients with Eisenmenger's syndrome are at particular high risk, with mortality reaching 30%, partly because they are vulnerable to changes in haemodynamics during the procedure.[3]

Xenon anaesthesia can be useful when cardiovascular stability is needed.[4 5] We therefore decided to use xenon for anaesthesia in a patient with Eisenmenger's syndrome presenting for laparoscopic cholecystectomy.

Case report

A 51-yr-old woman (1.51 m, 66 kg) with Down's syndrome was scheduled for a laparoscopic cholecystectomy because she had suffered from typical cholelithiasis for 6 months. Preoperative evaluation of the patient showed severe cyanosis, peripheral oxygen saturation (Sp_{O_2}) 86%, with clubbing of the fingers, secondary polycythaemia (haemoglobin 187 g l^{-1}, haematocrit 0.55) and oxygen requirement during exercise. She took diclofenac 50 mg orally for gall bladder pain. Arterial blood pressure was 140/80 mm Hg and heart rate 76 beats min^{-1}. Heart sounds included a loud second sound, an ejection click and a grade II diastolic murmur, loudest in the left parasternal region. The lungs were clear and hepatomegaly was not present. Echocardiography showed dilation of the pulmonary artery trunk with its branches, dilation of the right atrium, a hypertrophied right ventricle and mild tricuspid valve regurgitation. Peak pulmonary valve velocity was 1.2 m s^{-1} and there was pulmonary valve regurgitation with a velocity of 4.3 m s^{-1}. Pulmonary hypertension was caused by a perimembranous ventricular septal defect. Systolic and diastolic function of the left ventricle was normal, with an ejection fraction of 65%. Dilation of the left atrium was caused by two regurgitant jets from the mitral valve.

Written consent to use xenon was given by the patient's legal representative. The evening before the operation, the patient was premedicated with oxazepam 10 mg and ranitidine 150 mg. On the day of operation she took her

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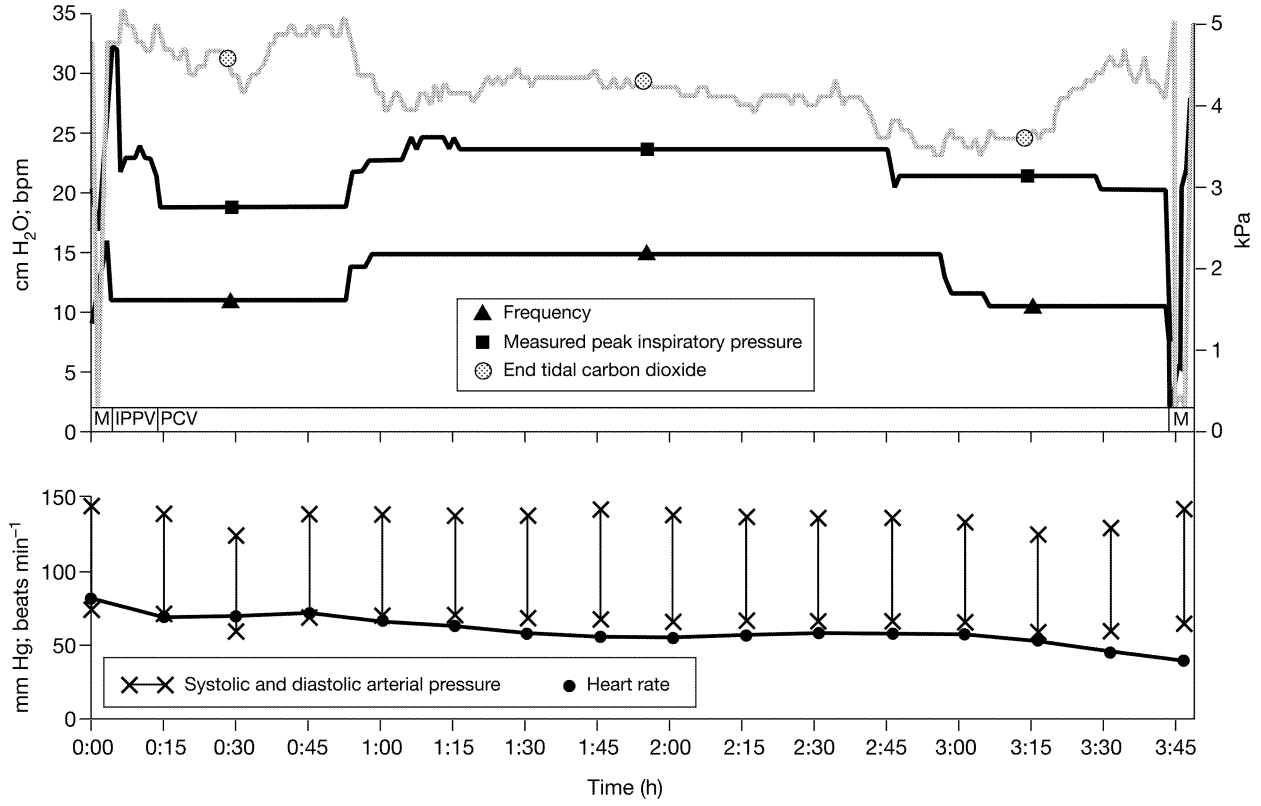

Fig 1 Systolic and diastolic arterial pressure (mm Hg), heart rate (beats min^{-1}), ventilator settings, frequency (b.p.m.), measured peak inspiratory pressure (cm H_2O) and end-tidal carbon dioxide (kPa). M=manual ventilation or spontaneous breathing; IPPV=intermittent positive-pressure ventilation; PCV=pressure-controlled ventilation.

routine analgesic medication, to which ranitidine 150 mg and lorazepam 1 mg were added.

In the operating room, basic anaesthetic monitoring was started. Before induction of anaesthesia, antibiotic prophylaxis for endocarditis (amoxicillin 1 g and gentamicin 240 mg) were given i.v. The patient was given 100% oxygen for 3 min for washout of nitrogen and at the same time phenylephrine infusion was started at 1.5 μg kg^{-1} min^{-1}. After sufentanil 25 μg and ketamine 40 mg i.v., a radial artery was cannulated. Induction of anaesthesia was continued with a further dose of ketamine 60 mg i.v. and then *cis*-atracurium 13 mg i.v. After tracheal intubation, the patient was connected to and ventilated with a closed-circuit anaesthetic machine (Physio, Haarlem, The Netherlands), using intermittent positive-pressure ventilation with settings of $F_{I_{O_2}}$ 1.0, frequency 1 1itre min^{-1}, tidal volume 540 ml, positive end-expiratory pressure (PEEP) 5 cm H_2O and I/E ratio 1:1.2 (Fig. 1). A cannula was placed in an internal jugular vein and a nasogastric tube was inserted along with a 5 MHz multi plane transoesophageal echoprobe (MPTE) probe for peroperative transoesophageal echocardiography (Sonotron Vingmed CFM 800, Vingmedsound Als, Horten, Norway). Xenon was then added to give a concentration of 60% (Fig. 2). The ventilator was reset to pressure-controlled ventilation with settings of PEEP 5 cm H_2O, inspiratory pressure change 13 cm H_2O, $F_{I_{O_2}}$ 0.30, frequency 1 1itre min^{-1} and I/E ratio 1:1 (Fig. 1). Two additional doses of sufentanil were given i.v., 15 μg at the start of surgery and 10 μg just establishing the pneumoperitoneum. Muscle relaxation was monitored continuously with a nerve stimulator (TOF-Guard; Biometer, Odense, Denmark). Additional doses of i.v. *cis*-atracurium were given as needed. When the inspired xenon fraction reached 60%, the phenylephrine infusion was decreased to 1.0 μg kg^{-1} min^{-1} because blood pressure and heart rate remained stable (Fig. 1), decreased to 0.5 μg kg^{-1} min^{-1} 10 min later and stopped 30 min after the pneumoperitoneum had been established. Ringer's lactate was given by infusion. Because the patient had not had any oral intake, we gave 22 ml kg^{-1} in the first hour then 7.5 ml kg^{-1} h^{-1}. In the first hour we also gave 500 ml of a colloid. Cardiac filling status was monitored by transoesophageal echocardiography using the transgastric short-axis mid-papillary view, and shunting through the perimembranous ventricular septal defect was assessed with a four-chamber view.

The increased end-tidal carbon dioxide ($F_{E_{CO_2}}$) after pneumoperitoneum had been countered by increasing the inflation pressure to 18 cm H_2O, peak pressure 23 cm H_2O and the frequency to 15 b.p.m. (Fig. 1). Arterial blood samples were analysed immediately in an ABL 505 and an OSM 3 haemoxymeter (both from Radiometer, Copenhagen, Denmark) for blood gases and haemoglobin

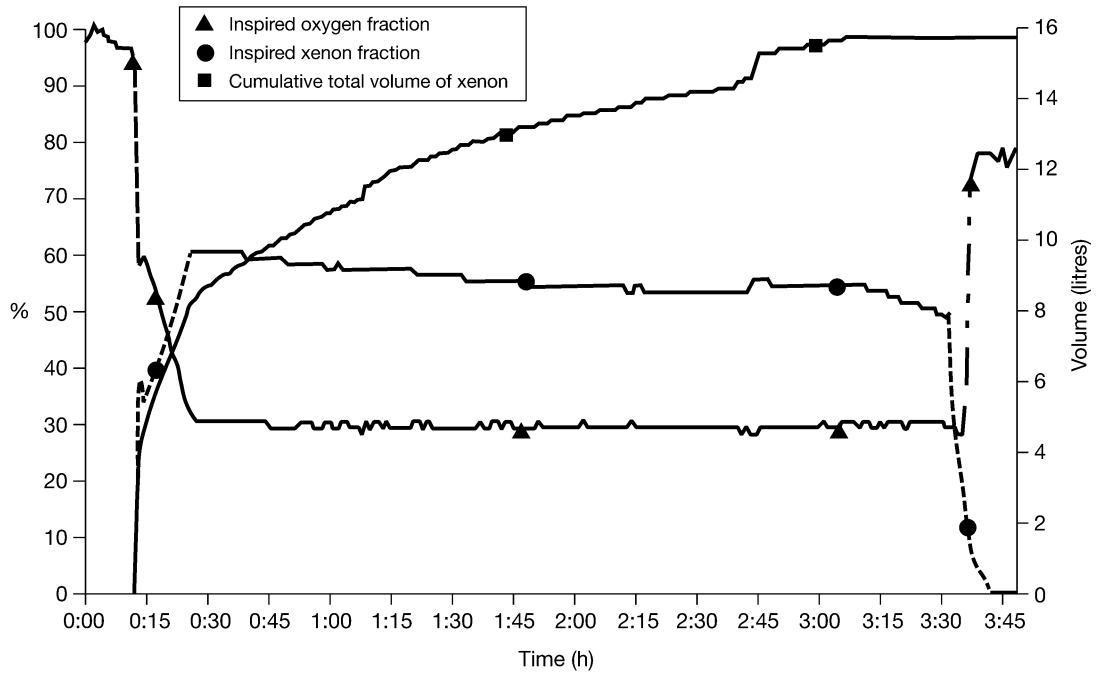

Fig 2 Inspired oxygen fraction (%), inspired xenon fraction (%) and cumulative total volume of xenon (litres).

Table 1 Results of blood sample analysis and results for $F_{I_{O_2}}$, $S_{p_{O_2}}$ and $F_{E_{CO_2}}$. $F_{I_{O_2}}$=inspired oxygen fraction; $S_{p_{O_2}}$=peripheral oxygen saturation; $F_{E_{CO_2}}$=end-tidal carbon dioxide; Hb=haemoglobin; P_{CO_2}=partial pressure of carbon dioxide; P_{O_2}=partial pressure of oxygen; HCO_3^- = bicarbonate ion; BE=base excess; S_{O_2}=blood gas oxygen saturation. Arterial samples were taken from the radial artery and the venous sample was drawn from the internal jugular vein. ND=no data available. 1=after induction of anaesthesia; 2=after starting pneumoperitoneum; 3=in the recovery room.

Variable	Arterial (1)	Arterial (2)	Venous (2)	Arterial (3)
$F_{I_{O_2}}$	1.0	0.30	0.30	0.21
$S_{p_{O_2}}$ (%)	99	93	93	88
$F_{E_{CO_2}}$ (kPa)	4.7	4.7	4.7	ND
Hb (g litre^{-1})	176	155	148	166
pH	7.39	7.34	7.32	7.35
P_{CO_2} (kPa)	5.9	6.4	6.7	6.6
P_{O_2} (kPa)	62.1	9.5	5.3	6.8
HCO_3^- (mmol litre^{-1})	26.2	25.1	25.2	26.1
BE (mmol litre^{-1})	1.3	–0.9	–1.1	0.3
S_{O_2} (%)	100	93	71	84

(Table 1) respectively. Intra-abdominal pressure was maintained at less than 16 mm Hg. At the end of the laparoscopy the patient was placed in the Trendelenburg position for a short time to allow surgical access. Surgery was uneventful. Morphine 7 mg i.v. was given 30 min before the operation finished. After the release of the pneumoperitoneum, inflation pressure was reduced to 15 cm H_2O and frequency to 11 b.p.m. (Fig. 1). Neuromuscular block was not antagonized. The patient breathed spontaneously 7 min after washout of xenon started, and 5 min later the trachea was extubated. After 90 min in the recovery room the patient was discharged to a normal surgical ward with additional oxygen 2 litre min^{-1} via a nasal tube for 24 h. Paracetamol 1 g three times a day orally, with additional morphine intramuscularly if required (only a single dose of 5 mg was given), was prescribed to maintain post-operative analgesia. The patient made an uneventful recovery and was discharged home 4 days after operation.

Discussion

The cornerstone of the anaesthetic management of patients with Eisenmenger's syndrome is maintenance of the preoperative systemic vascular resistance (SVR).[6]

Xenon anaesthesia is particularly useful when cardiovascular stability needs to be maintained.[4] Before xenon is used, nitrogen must be washed out of the lungs. High-flow pure oxygen over a period of at least 5 min is recommended.[4] We gave 100% oxygen before and after endotracheal intubation (Fig. 2).

Ketamine has been recommended as the drug of choice for induction because it has little effect on pulmonary and

systemic vascular resistance, whereas thiopentone and propofol decrease SVR.[7] For the same reason, atracurium and vecuronium have been recommended for muscle relaxation.[8] Pretreatment with phenylephrine to prevent changes in SVR is also recommended, although it may cause similar vasoconstriction in both pulmonary and systemic circulations and therefore have only little effect on the shunt direction.[7]

We gave phenylephrine during induction with sufentanil, ketamine and *cis*-atracurium. The cardiovascular stability provided by xenon allowed the initial infusion rate to be reduced, after xenon had been washed in, to its preset level. Because carbon dioxide insufflation into the peritoneal cavity could cause hypotension, we stopped the infusion 30 min after pneumoperitoneum had been initiated; no resulting haemodynamic changes were observed (Fig. 1).

This haemodynamic stability forms a sharp contrast to an earlier case report in which anaesthesia had been maintained with 1–2% enflurane after induction with etomidate, which induced a 40% decrease in mean arterial pressure.[6] In patients with Eisenmenger's syndrome, halothane, enflurane and isoflurane can all cause systemic hypotension because of a varying combination of myocardial depression and vasodilation.[7] Although propofol was not used for maintenance of anaesthesia in these latter studies, similar haemodynamic changes might occur because low-dose propofol (1–2 mg kg^{-1}) gives anaesthetic conditions similar to an opioid–volatile anaesthetic technique with enflurane in cardiac patients before cardiopulmonary bypass.[9]

Patients with Eisenmenger's syndrome have lost the ability to adapt to sudden changes in haemodynamics because of a fixed pulmonary disease.[3] The value of a pulmonary artery flotation catheter in management is controversial.[3 6 7] Oesophageal echocardiography allowed non-invasive monitoring of cardiac filling, monitoring of the shunt and monitoring of possible gas embolism during gas insufflation of the peritoneal cavity. Monitoring of intra-arterial pressure, allowing continuous measurement and blood gas determination, is generally accepted.[3 6 7]

Low inflation pressures, with maintenance of Pa_{CO_2} to prevent deleterious effects on the intracardiac shunt during mechanical ventilation[10], were obtained by the use of pressure-controlled ventilation and frequency adjustment during pneumoperitoneum (Fig. 1).

Doses of muscle relaxant should be kept to the minimum compatible with performance of the surgical procedure.[10] In this way, no reversal agent of neuromuscular blockade was necessary at the end of the procedure in the present case, so that undesirable effects on the cardiovascular system were avoided.[10] The low blood gas partition coefficient of xenon (0.115) permits more rapid recovery than when nitrous oxide is used,[5 11] and early tracheal extubation, recommended for patients with Eisenmenger's syndrome, can be achieved.[6] Because morphine was given before the end of surgery, the recovery time of our patient was prolonged. However, 7 min after washout of xenon started, achieved by increasing $F_{I_{O_2}}$ to 80%, the patient breathed spontaneously and 5 min later she was extubated uneventfully (Fig. 1).

Although xenon is a rare and expensive gas, a closed-circuit system can reduce the cost of xenon anaesthesia.[4] When xenon is given by this method, approximately 6 litres is taken up in the first hour in an average adult, and 9–15 litres in the first 2 h of xenon administration.[4] Since 1997 we have used the PhysioFlex closed-circuit anaesthetic machine for xenon administration. The total xenon uptake in our patient was 15.6 litres after 3 h and in the first hour 11.6 litres was taken up (Fig. 2). This means that longer anaesthetic procedures are more cost-effective. The surgical procedure also interferes with the absorption of xenon.[12] About an extra litre of xenon was absorbed by our patient when the operating table was returned from the Trendelenburg position to the normal position with simultaneous release of the pneumoperitoneum (Fig. 2; 2:45 h). Xenon anaesthesia for this patient cost an extra $150. Avoiding one day in the intensive care unit saves about $350. A previous study reported that patients with Eisenmenger's syndrome who underwent relatively minor procedures were monitored post-operatively on a normal ward, but overnight observation in an intensive care unit is usually recommended.[3 7] A patient undergoing laparoscopic cholecystectomy was scheduled pre-operatively for a one-night post-operative stay in the intensive care unit.[6]

This case shows that cardiovascular stability can be obtained by the use of xenon anaesthesia in a patient with Eisenmenger's syndrome. It also shows that avoiding admission to the intensive care unit by the use of xenon can be cost-effective if a closed-circuit system such as the PhysioFlex is used and the duration of the surgical procedure is long enough. Monitoring by transoesophageal echocardiography during anaesthesia should be considered for patients with Eisenmenger's syndrome. Xenon anaesthesia proved satisfactory for laparoscopic cholecystectomy in a patient with Eisenmenger's syndrome.

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