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Intraoperative Hypoxemia Complicating Sequential Resection of Bilateral Pulmonary Metastases

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Resection of multiple bilateral pulmonary lesions may be accomplished by right and left thoracotomies staged separately or by median sternotomy performed for one-stage bilateral resection. We report here two cases of severe hypoxemia occurring during median sternotomy for sequential resection of multiple pulmonary metastases.

CASE REPORTS

Case 1

A 58-yr-old, 95-kg man was scheduled for median sternotomy to resect multiple recurrent pulmonary metastases. Six years prior to admission (PTA), a right upper extremity chondrosarcoma was treated with wide surgical excision, chemotherapy (intraarterial adriamycin, 60 mg total), and radiation. He subsequently developed bilateral pulmonary metastases. Five years PTA, 30 tumor nodules were resected during right and left thoracotomies 1 month apart. Coexisting medical problems included a history of myocardial infarction 6 yr PTA, adult-onset diabetes, hypertension, and smoking (one pack per day for 35 yr). His medications included atenolol, nifedipine, and chlorpropamide.

Preoperative forced vital capacity and forced expiratory volume in 1 s were 2.85 l (61% of predicted) and 2.14 l (58% of predicted), respectively. A flow-volume loop was compatible with mild obstructive airway disease. Reduced lung volumes were believed to be related to previous resection of lung tissue. A room air arterial blood gas (ABG) showed an arterial oxygen tension (Pa_{O_2}) of 82 mmHg, an arterial carbon dioxide tension (Pa_{CO_2}) of 43 mmHg, a *p*H of 7.38, and a hematocrit of 40%. Baseline blood pressure (BP) was 122/86 mmHg.

Right internal jugular and right radial artery catheters were inserted. Monitoring included ECG, capnography, and pulse oximetry (hemoglobin oxygen saturation [Sp_{O_2}]). General anesthesia was induced with midazolam 0.05 mg/kg, fentanyl 5 μg/kg, droperidol 0.026 mg/kg, sufentanil 3.2 μg/kg, and vecuronium 0.1 mg/kg. A 39-Fr left double-lumen endotracheal tube was placed, and proper position was confirmed by auscultation and fiberoptic bronchoscopy. Anesthesia and neuromuscular relaxation were maintained with sufentanil 9.5 μg/kg (total), midazolam 0.2 mg/kg (total), and vecuronium. BP remained 95–140/60–80 mmHg throughout. Prior to one-lung anesthesia, fractional inspired oxygen concentration (FI_{O_2}) was 0.45 and thereafter FI_{O_2} was increased to 1.0. During one- and two-lung ventilation, tidal volume was 1 l, peak inspiratory pressure 29–34 cmH_2O, and respiratory rate 10 breaths per min. End-tidal carbon dioxide concentration varied between 36 and 53 mmHg. An ABG prior to one-lung ventilation demonstrated a Pa_{O_2} of 139 mmHg, a Pa_{CO_2} of 48 mmHg, and a *p*H of 7.30.

After median sternotomy, ventilation of the right lung was interrupted and eight metastatic nodules and a segment of the right upper lobe were resected. During the last portion of the resection, an ABG showed good oxygenation but significant hypercarbia, with a Pa_{O_2} of 315 mmHg, a Pa_{CO_2} of 57 mmHg, and a *p*H of 7.25. Next, the right lung was reexpanded for several minutes, and then left-lung ventilation was interrupted, whereupon the Sp_{O_2} decreased to 70%. BP at this point was 120/65 mmHg. After a brief period of two-lung ventilation, Sp_{O_2} increased to 100% but again declined to 70% despite right-lung ventilation and left-lung continuous positive airway pressure (CPAP) at 10 cmH_2O. Correct position of the double-lumen endotracheal tube was confirmed by visual inspection of both lungs and reinspection with the fiberoptic bronchoscope. Because of the inability to maintain Sp_{O_2} during one-lung ventilation, further surgical resection was not undertaken. An immediate postoperative chest radiograph revealed patchy densities in the right apex and at the bases, consistent with pulmonary contusion. Recovery was uncomplicated and the patient was discharged on the 10th post-operative day.

Case 2

A 32-yr-old 70-kg woman was scheduled for median sternotomy and resection of bilateral pulmonary metastases of adenoid cystic carcinoma of the right tonsil. Subsequent to radiation and chemotherapy (adriamycin 180 mg/m^2, *cis*-platinum, and fluorouracil [5-FU]), multiple pulmonary metastases had been discovered. Her past medical history was otherwise unremarkable. Pulmonary function tests were normal, and a room air ABG showed a Pa_{O_2} of 93 mmHg, a Pa_{CO_2} of 41 mmHg, and a *p*H of 7.35. After sedation and application of ECG and pulse oximeter monitors, right internal jugular and right radial arterial catheters were placed. Anesthesia was induced with fentanyl 6 μg/kg, diazepam 0.08 mg/kg, and thiopental 1.4 mg/kg, and intubation was facilitated with succinylcholine 1.6 mg/kg. BP remained 90–130/55–80 mmHg during the case. A 37-Fr left double-lumen endotracheal tube was placed and its position verified by auscultation. Anesthesia was maintained with isoflurane 0.25–2%, and additional fentanyl 23 μg/kg was given over 4.5 h. Muscle relaxation was maintained with pancuronium. An FI_{O_2} of 1.0 was used throughout. During two-lung ventilation tidal volume was 650 ml, with a respiratory rate of 8 breaths per min and a peak airway pressure of 15 cmH_2O.

Median sternotomy was performed, and ventilation to the left lung was interrupted. Tidal volume remained constant, but the respiratory rate was increased to 10 breaths per min, and an ABG demonstrated a Pa_{O_2} of 339 mmHg, a Pa_{CO_2} of 32 mmHg, and a *p*H of 7.48. Over the next 90 min, approximately ten metastatic nodules were resected. While the same ventilatory parameters were maintained, the left lung was reexpanded; ventilation to the right lung was interrupted; and approximately ten nodules were resected. Sp_{O_2} remained 97–100% and an ABG showed a Pa_{O_2} of 83 mmHg, a Pa_{CO_2} of 39 mmHg, and a *p*H of 7.41. After 100 min, the right lung was reexpanded, whereupon

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there was an immediate and precipitous decrease in the Sp_{O_2} to 60%. BP at this time was 95/60 mmHg, and inspired isoflurane was 1%. Visual inspection of both lungs revealed no apparent atelectatic segments of lung. The endotracheal tube was suctioned, with minimal return of secretions or blood. The Sp_{O_2} remained at this level for several minutes and returned to 100% only after extremely vigorous manual hyperventilation. Fiberoptic bronchoscopy demonstrated no blood clots or mucous plugs. A postoperative chest radiograph showed only postsurgical changes with no infiltrate or atelectasis. An ABG with FI_{O_2} of 1.0 yielded a Pa_{O_2} of 402 mmHg, a Pa_{CO_2} of 37 mmHg, and a *p*H of 7.42. Recovery was uncomplicated and the patient was discharged on the 12th postoperative day.

Discussion

The nadirs for intraoperative Sp_{O_2} represent intrapulmonary shunts of approximately 50% or more.[1] Although ABG analysis was not done during the acute episodes, pulse oximetry usually is accurate during severe hypoxemia.[2] We postulate that these severe hypoxemic episodes resulted from extreme surgical manipulation of the lung. Local pulmonary trauma may release vasodilators that interfere with hypoxic pulmonary vasoconstriction (HPV).[3,4]

Oxygenation during one-lung ventilation is dependent on the extent of redistribution of blood flow to each lung.[5,6] Application of Benumof's model[4,7] to case 1 suggests that the operative lung sustained an increase in blood flow from 30 to 75% of cardiac output when ventilation was interrupted to the contralateral lung. Such an increased flow, perfusing injured pulmonary parenchyma, could impose a significant shunt. The patient in case 2 had significant hypoxemia when it was least expected, *i.e.*, when two-lung ventilation was resumed. At this time, blood flow to the second operative lung increased from approximately 25–30 to 55% of cardiac output. It is not clear why severe hypoxemia did not result after only one lung had been operated upon, as occurred in case 1, but its absence at that point is possibly related to a smaller degree of trauma to the initial operative lung.

Other less likely causes could have contributed to these hypoxemic events. The patient in case 1 developed significant hypercapnia secondary to inadequate alveolar ventilation. Both hypercapnia and hypocapnia can affect pulmonary vascular tone, thereby disrupting HPV.[8,9] Nifedipine also may have interfered with HPV.[4] Direct visualization of the lungs eliminated major atelectasis as a factor. Advanced age, combined with a history of smoking and previous pulmonary resection, may have been deleterious for the first patient. Although both patients had chemotherapy, neither received agents known to induce pulmonary toxicity. Pulmonary edema from any cause also is unlikely, since neither patient had evidence of this on their postoperative chest radiographs. While the type of anesthesia has not been demonstrated to have a significant clinical effect on oxygenation during one-lung ventilation,[10,11] clinical evaluations have not been performed in the setting of one-stage sequential bilateral one-lung ventilation. The potential for isoflurane to attenuate HPV has been reported,[10] and although this effect is generally not clinically significant, it may serve to potentiate other deleterious effects on HPV during one-lung ventilation. Narcotics do not appear to affect HPV.[11]

The lateral position is usually used for thoracic surgery, thus minimizing the shunt through the nondependent lung. In the supine position, 55% of cardiac output goes to the right lung, while in the right lateral and left lateral positions, right-lung blood flow is 65 and 45%, respectively.[7] Because HPV is 50% effective in decreasing a shunt imposed by one-lung ventilation, the supine position promotes an additional approximately 5% of cardiac output to perfuse the nonventilated lung.

A trial of CPAP to the nonventilated lung is indicated when hypoxemia occurs during one-lung ventilation.[12] This was unsuccessful, however, in reversing the hypoxemia in case 1. It is likely that surgical trauma and anesthesia decreased the functional residual capacity in these patients and that positive end-expiratory pressure (PEEP) could have been beneficial. In the second case, vigorous and rapid ventilation may have resulted in "auto-PEEP" (PEEP secondary to inadequate exhalation) sufficient to correct the hypoxemia. Hyperventilation may also have been detrimental, based on the effects of hypocapnia on HPV and the effects of increased mean airway pressure on pulmonary vascular tone.[4] Dependent (ventilated) lung PEEP has a variable effect on oxygenation during one-lung ventilation, but it appears to work best when oxygenation is poor.[12] Based on this, a trial of PEEP should be considered if hypoxemia occurs during sequential one-lung ventilation.

Our two cases illustrate some of the problems that may occur when sequential one-lung ventilation is used for resection of bilateral pulmonary metastases. Surgical manipulation and damage may initiate pathophysiology that ultimately manifests at the time when blood flow is increased to a damaged lung. CPAP was unable to reverse hypoxemia in one of our patients, and hyperventilation appeared to be helpful in the other. Consideration should be given to using PEEP when hypoxemia occurs during sequential one-lung ventilation.

References

1. Nunn JF: Distribution of pulmonary ventilation and perfusion, Applied Respiratory Physiology. London, Butterworths, 1987, pp 170–172
2. Sendak MJ, Harris AP, Donham RT: Accuracy of pulse oximetry during arterial oxyhemoglobin desaturation in dogs. ANESTHESIOLOGY 68:111–114, 1988
3. Piper P, Vane J: The release of prostaglandins from lung and other tissues. Ann N Y Acad Sci 180:363–385, 1971
4. Benumof JL: Special physiology of the lateral decubitus position,

the open chest and one-lung ventilation, Anesthesia for Thoracic Surgery. Philadelphia, WB Saunders, 1987, pp 112–120
5. Nomoto Y: Preoperative pulmonary blood flow and one-lung anaesthesia. Can J Anaesth 34:447–449, 1987
6. Hurford WE, Kolker AC, Strauss HW: The use of ventilation/perfusion lung scans to predict oxygenation during one-lung anesthesia. ANESTHESIOLOGY 67:841–844, 1987
7. Benumof JL: Isoflurane anesthesia and arterial oxygenation during one-lung ventilation (editorial). ANESTHESIOLOGY 64:419–422, 1986
8. Barer GR, Howard P, McCurrie JR: The effect of carbon dioxide and changes in blood pH on pulmonary vascular resistance in cats. Clin Sci 32:361–376, 1967
9. Suggett AJ, Barer GR, Mohammed FH, Gill GW: The effects of localized hypoventilation on ventilation/perfusion (V/Q) ratios and gas exchange in the dog lung. Clin Sci 63:497–503, 1982
10. Domino KB, Borowec L, Alexander CM, Williams JJ, Chen L, Marshall C, Marshall BE: Influence of isoflurane on hypoxic pulmonary vasoconstriction in dogs. ANESTHESIOLOGY 64:423–429, 1986
11. Yamada M, Ochiai R, Takeda J, Nagano M: Does anesthetic technique affect the oxygenation during one-lung anesthesia? (abstract). Can J Anaesth 37:S164, 1990
12. Benumof JL: Conventional and differential lung management of one-lung ventilation, Anesthesia for Thoracic Surgery. Philadelphia, WB Saunders, 1987, pp 284–286

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Rectal Methohexital Causing Apnea in Two Patients with Meningomyeloceles

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Induction of anesthesia with rectal methohexital is a common practice in pediatric anesthesia. We present two children with meningomyeloceles in whom apnea developed following the administration of rectal methohexital.

CASE REPORTS

Case 1. A 3-yr-old, 10-kg child with a midthoracic meningomyelocele was scheduled for bilateral ureteral reimplants. Her medical history was remarkable for impaired respiratory function requiring chronic oxygen therapy (*p*H 7.43, oxygen tension [P_{O_2}] 89 mmHg, carbon dioxide tension [P_{CO_2}] 37 mmHg, total carbon dioxide 27 mM, and hemoglobin oxygen saturation 96%, while breathing 1 l/min oxygen per nasal cannula). The hematocrit was 35%. A "sleep study" (including continuous pulse oximetry) done prior to a tonsillectomy–adenoidectomy demonstrated only "trivial changes in breathing pattern, which may be consistent with an obstructive airway". A ventriculoperitoneal shunt was in place and was clinically assessed as functioning by her neurosurgeon. She was receiving phenytoin for a seizure disorder and had not had a seizure in the month preceding surgery.

Rectal methohexital had been used in three previous anesthetics (at a dosage range of 25–30 mg/kg) without incident. This technique was chosen again at her mother's request to ease separation of the child from her mother. A 27-mg/kg dose of 10% methohexital was given rectally. Two minutes after administration the child lost consciousness in her mother's arms. The child was then placed supine on a stretcher and was observed to be apneic, with ensuing cyanosis. Her lungs were quickly ventilated without difficulty *via* a mask, and her trachea was intubated 1 min later. There were no physical signs of seizure activity, and the child's muscle tone was flaccid with no evidence of any respiratory effort. Cardiovascular status was stable as assessed by ECG and blood pressure monitoring, and the child underwent surgery without incident.

Case 2. A 10-yr-old, 18-kg child with a low thoracic meningomyelocele was scheduled for heel-cord lengthening. The child showed marked developmental delay, making communication difficult. A clinically functioning ventriculoperitoneal shunt was in place, and the child was receiving phenytoin for a generalized seizure disorder. She had not had a seizure in the preceding month. Her medical history was otherwise unremarkable.

The patient had received rectal methohexital on a previous anesthetic without incident. On this occasion, at the mother's insistence, the child received 10% methohexital rectally for a total dose of 28 mg/kg. Within 3 or 4 min the child was noted to be apneic. Positive pressure ventilation of her lungs *via* a mask was followed by tracheal intubation over the next few minutes. There were no physical signs of a seizure, and she remained apneic. The child's blood pressure and ECG were stable, and she underwent surgery without complications. Her postoperative condition was unchanged from that existing prior to the rectal methohexital administration.

DISCUSSION

Rectal methohexital is commonly used to induce anesthesia and ease the separation of young children from their parents and can be particularly useful in patients with a meningomyelocele. These patients may have some degree of mental retardation, making communication difficult, and in addition, the anxiety of repeated hospitalizations, limited intravenous access, and extreme "needle phobia," despite paresthetic lower limbs, make inhalational or intravenous induction techniques less desirable.

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