Clinical Anaesthesia File

Anaesthetic management of a patient with a descending thoracic aortic aneurysm and severe bilateral bullous pulmonary parenchymal disease

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The anaesthetic management of the surgical repair of a descending aortic aneurysm in a patient with large, bilateral, pulmonary bullae is described. Anaesthesia for descending aortic surgery normally involves unilateral, positive-pressure ventilation, an option which poses some risk of barotrauma in the presence of bilateral bullae. Patients with bullous disease commonly have severe lung disease and thorough preoperative assessment and preparation are necessary. Intraoperatively, bilateral rupture of the bullae could be catastrophic and preparations should be made for this possibility. In order to diminish this risk, a surgical technique including preemptive collapse of the bulla by minithoracotomy and tube drainage, with use of a bronchial blocker to the affected part of the lung may be used. If rupture occurs, then high frequency jet ventilation may be effective. Use of a double lumen endobronchial tube may be advantageous for patients with either unilateral and bilateral bullae. Anaesthesia for patients with bullae should avoid positive-pressure ventilation and nitrous oxide in order to limit the risk of barotrauma from a ball valve mechanism. In this case, the risk of barotrauma was reduced by performing an inhalational induction of anaesthesia and limiting peak inflation pressures during thoracotomy. It was elected to use positive-pressure ventilation through a double lumen endobronchial tube following chest incision. A high frequency jet ventilator was available but not employed. Anaesthetic management was complicated by the presence of pleural adhesions, surgical approach directly through a bulla, and the requirement for one lung ventilation.

La conduite anesthésique appropriée à la résection d'un anévrysme de l'aorte descendante découverte chez un patient porteur de grosses bulles bilatérales d'emphysème est discutée. L'anesthésie habituelle pour une chirurgie de l'aorte descendante nécessite une ventilation mécanique unilatérale et constitue ainsi un risque additionnel pour le porteur de bulles emphysema-teuses bilatérales. Ces patients ont ordinairement des affections pulmonaires graves et l'évaluation et la préparation préopératoires prennent une importance spéciale. Pendant l'intervention, la rupture de bulles bilatérales peut être catastrophique et il faut se préparer à cette éventualité. Pour minimiser ce risque, une technique chirurgicale qui inclut le collapsus préventif de la bulle par minithoracotomie et drainage, avec installation d'un bloqueur bronchique sur la partie atteinte du poumon. Si une rupture survient, le passage à la ventilation par jet à haute fréquence peut être salutaire. Le tube endobronchique à double lumière peut présenter des avantages aussi bien dans les cas de bulles unilatérales que bilatérales. Chez ces patients, il vaut mieux s'abstenir de ventiler avec une pression positive et du protoxyde d'azote afin de limiter le risque de barotraumatisme par soupape. Dans ce cas-ci, on a réussi à limiter le risque de barotraumatisme en réalisant une induction par inhalation et en réduisant la pression d'inflation de pointe pendant la thoracotomie. Après l'incision thoracique, on a choisi d'utiliser la ventilation mécanique avec un tube endobronchique à double lumière. Un ventilateur à jet à haute fréquence était prêt mais n'a pas été utilisé. La gestion de l'anesthésie a été compliquée par des adhérences pleurales, par la rencontre d'une bulle d'emphysème à l'incision et par l'obligation de ventiler un seul poumon.

A 27-yr-old man presented seven years after a motor vehicle accident. After the accident, a CT scan of his thorax showed an abnormality of the descending aorta. Unfortunately, the patient was lost to follow-up. A CT scan, repeated at the time of this admission, showed an aneurysmal dilatation of the proximal descending aorta, with a maximal diameter of 4.5 cm. Subsequently angiography showed a 7.5 by 8.5 cm pseudoaneurysm of the descending aorta distal to the left subclavian vein (Figure 1). The patient was scheduled for resection of the aneurysm.

At the time of the accident, the patient suffered bilateral femoral fractures complicated by fat embolism, and severe adult respiratory distress syndrome. He developed bilateral pneumothoraces which were refractory to treatment. He had 17 chest tubes placed in total. Complications included bilateral empyemas and bronchopleural fistulas and he required mechanical ventilation for four weeks. High-frequency jet ventilation was required for several days.

FIGURE 1 Angiography of thoracic aortic aneurysm.

FIGURE 2 Computed tomographic scan of thorax.

His current CXR showed several bilateral large pneumotaces, as shown on the CT image in Figure 2.

What are the anaesthetic considerations?

Choice of the anaesthetic technique for elective resection of a descending thoracic pseudoaneurysm depends on several elements: (1) the patient's general health, (2) the surgical technique, (3) management of haemodynamic instability during resection, (4) the method of providing one lung ventilation, (5) consideration of spinal cord and

renal protection, (6) and postoperative analgesia.¹ These are reviewed in brief below; however, this patient's management is complicated by the presence of the bullae.

Bullae are air-containing thin-walled cavities which arise from destruction of normal alveolar tissue. the presence of air trapping allows the tissue to expand to several times its original size. In most cases, some communication exists between the conducting passages and the bullae; otherwise the entrapped air would be absorbed and the bullae would collapse. The major anaesthetic management concerns are: (1) those for patients with severe lung disease, (2) the consequences of air trapping and further inflation of the bullae (especially with positive-pressure ventilation), and (3) the adverse effects of nitrous oxide. Since the blood gas partition coefficient of nitrous oxide is 34 times that of nitrogen, gas-filled spaces absorb nitrous oxide much more rapidly than nitrogen can egress.*

Positive-pressure ventilation should be avoided in the presence of bullae because of the risk of air trapping and consequent barotrauma, including pneumothorax. From Laplace's law, it follows that for the same intraluminal pressure, wall tension is proportional to radius.² Hence large bullae are prone to rupture and may produce large bronchopleural fistulae. If the bullae do not communicate with the airways, nitrous oxide may present more of a problem than positive-pressure ventilation. Inspiratory and expiratory chest radiographs, or ventilation-perfusion scans may determine if communication with the airways is present. Even if a bleb is non-communicating, its walls may be thin, with limited distensibility, posing the risk of rupture during surgical manipulation or positive-pressure ventilation.

In this case, operative management normally requires collapse of the left lung, usually with the provision of positive-pressure ventilation.¹ Due to the risk of barotrauma, high-frequency jet ventilation may be an alternative. Large bullae have been resected while providing ventilation using a single lumen endotracheal tube and jet ventilation.³ A further complicating factor is the presence of the large left-sided bulla, which will be penetrated during the left thoracotomy and might result in a large gas leak. Rupture of this bleb may lead to loss of airway pressure and alveolar ventilation (or tension pneumothorax if the chest is unopened). This provides a further indication for use of a double lumen endobronchial tube.

Intraoperative rupture of the bulla in the right lung during left thoracotomy might result in complete inability to ventilate the patient; the left lung would be collapsed

and the right would be compromised by a pneumothorax.

At this point it would be necessary to investigate further the patient's pulmonary function and the plan of the surgeon.

Arterial blood gas analysis was normal apart from a PaO_2 of 65 mmHg breathing room air. Pulmonary function tests showed an FVC and FRC 70% of predicted, and $\text{FEV}_{10}/\text{FVC}$ of 85%, with no response to bronchodilators. No additional pulmonary function tests had been performed. The patient's ECG was normal.

The surgeon planned a left thoracotomy followed by simple clamping of the aorta with no shunting or bypass procedures. His major concerns about the pulmonary disease were the potential adherence of the visceral to parietal pleura with consequent blood loss during dissection resulting in poor exposure.

How would you proceed?

Decisions must be made about the extent of patient monitoring; the method used to control the airway; the means to ventilate the lungs and oxygenate the patient intraoperatively; and the methods used to preserve spinal cord and renal function. Large bore intravenous catheters, and rapid infusion and cell-saving devices are useful options. A right-sided precordial stethoscope would aid detection of the development of a pneumothorax on that side. Given the complexity of this case (one lung anaesthesia in a patient with preexisting lung disease and risk of major blood loss), an oximetric pulmonary artery catheter might be of use to allow continuous assessment of oxygen delivery even during times of poor peripheral perfusion.

Assuming that this patient was of normal height and weight and had a normal upper airway anatomy, it would be advantageous to maintain spontaneous ventilation during an inhalational induction of anaesthesia followed by placement of a double lumen endotracheal tube, with confirmation of accurate positioning by fiberoptic bronchoscopy. Alternatively, awake intubation might be employed, but meticulous topical anaesthesia of the airway would have to be employed to prevent coughing. Positive-pressure ventilation would be required once the chest was open to maintain adequate oxygenation and ventilation. However, peak airway pressure should be limited and the arterial CO_2 content may be allowed to rise.

If an air leak occurred following surgical incision of the bleb on the left side, it could be controlled by selective ventilation of the right lung with the double lumen tube. At this point, gentle positive-pressure ventilation could

*Cohen E. Simultaneous bilateral bullectomy for bullous emphysema with severe pulmonary insufficiency. 16th Annual Meeting 1994. Society of Cardiovascular Anesthesiologists, 116-22.

be introduced (monitoring airway pressure and breath sounds through the precordial stethoscope to detect a right-sided pneumothorax).

Spinal cord and renal protection would be limited to methylprednisolone and mannitol. Drainage of CSF would be an option, but is not seen to be a major advantage in my institution.

Clinical course

The monitoring chosen for this patient was as described above, though a non-oximetric pulmonary artery catheter was employed. A rapid infusion device, a high-frequency jet ventilation system, and red cell saver were available but not used. A #39 French left-sided double lumen endobronchial tube was placed following an inhalational induction (oxygen and halothane) of anaesthesia, and tube placement was confirmed before and after positioning with a paediatric fiberoptic bronchoscope.

The left lung was firmly adherent to the chest wall and dissection of the lung was difficult. The large thick-walled bleb on the left side was entered during the dissection and proved to communicate with the airway. Positive-pressure ventilation of the dependent lung was commenced only after opening the chest, and continued without difficulty. Peak inflation pressures were limited to 10–15 cm H₂O and the PaCO₂ was allowed to increase to 65 mmHg. Pulse oximetry readings of 93–7% were achieved using an FiO₂ of 1.0 during the period of one lung ventilation. No pneumothorax occurred on the right side.

General considerations

1 *Bullous emphysema*

Patients with bullous emphysema usually have preexisting lung disease and careful preoperative evaluation of pulmonary function should be performed. The major risk arises from barotrauma due to air trapping from a ball valve mechanism, which may result in pulmonary compression, pneumothorax, mediastinal shift, and bronchopleural fistula. As indicated in the management of this case, nitrous oxide should be avoided, positive-pressure ventilation limited, and a double lumen tube is desirable. When positive-pressure ventilation is required during one lung anaesthesia, then the patient should be carefully observed for pneumothorax and efforts made to limit peak inspiratory pressure even if CO₂ is allowed to climb. Manual ventilation and expiratory retard have been recommended.⁴

Plans should be made for management of bilateral rupture of bullae. Although not required routinely, it would

seem prudent to ensure the presence of a high-frequency jet ventilator and personnel knowledgeable in its use. High-frequency jet ventilation has been shown to be superior to conventional ventilation in the presence of large air leaks due to bronchopleural fistula.⁵

An alternative plan would be to collapse the bulla by minithoracotomy and tube drainage combined with a bronchial blocker positioned by fiberoptic bronchoscopy.⁶ The aneurysm could then be repaired electively at a later time. It is less likely that this approach would be useful in the present case because of the presence of pleural adhesions.

2 *Descending thoracic aortic aneurysm repair*

SURGICAL TECHNIQUE

The surgical technique may involve simple cross-clamping of the aorta with or without cooling of the patient, placement of a shunt, or partial cardiopulmonary bypass techniques to improve blood flow to the lower extremities during cross-clamping. Simple cross-clamping requires an expeditious surgeon since, during the period of cross-clamping, blood supply to the lower extremities, kidneys, and spinal cord will be reduced to the small contribution provided by collateral vessels. Temporary shunts to bypass the resected segment of the aorta are prone to leak from their anastomoses, and may obscure the surgical field. The distal flow and pressure they provide are unpredictable. The option of partial bypass may involve either an oxygenator and systemic heparinization (in the case of femoral venous to femoral arterial bypass), or simply a centrifugal pump without heparinization (left atrio-femoral bypass).

Since femoral venous to arterial bypass requires full heparinization, the risk of bleeding is increased; only some of the blood lost during bypass can be returned to the circuit and re-infused. Furthermore, the arterial flow to the lower extremities will be limited by venous return to the pump, although additional volume added to the pump reservoir might allow some temporary increase in arterial flow. Left atrio-femoral bypass with a centrifugal pump avoids use of systemic heparinization but precludes the option allowing shed blood to return to a pump reservoir. Also, since removal of blood from the left atrium to the centrifugal pump will diminish left ventricular preload, the potential exists for wide variation in blood pressure both proximal and distal to the cross clamp. In essence, the blood pressure and flows in the upper and lower circulations would need to be continuously balanced.

MANAGEMENT OF MAJOR HAEMODYNAMIC ALTERATIONS

These include hypertension and hypotension related to

placement and removal of the cross clamp, blood loss, and management of the circulation with partial bypass. The use of two large bore peripheral intravenous catheters as well as a central line is recommended. Arterial cannulation of the right (vs left) radial artery is recommended, since pressure in the left subclavian artery may be affected by the cross clamp. If femoral venous to arterial bypass is considered then blood pressure monitoring may also be required in the lower extremities. Use of pulmonary artery catheters remains controversial^{7,8} but may be of advantage if the patient's left ventricular function is markedly depressed or if left atrio-femoral bypass is used. Rapid infusion devices and red cell saving equipment may be of use in cases where considerable blood loss is expected.

ONE LUNG VENTILATION

Surgery to the descending thoracic aorta is considered a major indication for a double lumen endobronchial tube (or bronchial blocker).² A double lumen tube is needed to enhance surgical exposure, or for left lung isolation to manage pulmonary haemorrhage from surgical trauma (especially in the heparinized patient).

A paediatric fiberoptic bronchoscope may aid both placement and confirmation of tube position, particularly since the aneurysm may distort the airways.

SPINAL CORD AND RENAL PROTECTION

Interruption of blood flow may compromise blood supply to the spinal cord and kidneys. Anaesthetic manipulations to provide spinal cord protection remain controversial. Suggested measures to improve cord viability include measures that lower CSF pressure such as intravenous mannitol (25 g), CSF drainage, corticosteroid administration (methylprednisolone 3 mg · kg⁻¹), intrathecal papaverine, CSF drainage and the mechanical interventions described above used to improve blood flow distal to the cross clamp.

Renal protection is also controversial and a number of pharmacological interventions have been suggested including mannitol, loop diuretics, low-dose dopamine infusion, and calcium channel blockers. The duration of aortic cross-clamping is the most important single factor. Maintenance of adequate urine output (>0.5 ml · kg⁻¹ · hr⁻¹) is recommended for these patients.

POSITIONING

Descending thoracic aortic surgery requires a left thoracotomy which is most commonly performed in the right lateral decubitus position. Meticulous attention should be paid to positioning to reduce the risk of injuries to the brachial plexus and right common peroneal and ulnar nerves.

Conclusion

A case is described of descending aortic aneurysm surgery in a patient with large, bilateral, pulmonary bullae. Descending aortic surgery requires one lung, positive-pressure ventilation and thereby poses some risk of bilateral barotrauma and potential inability to ventilate the lungs. In this case, the trachea was intubated with a double lumen endobronchial tube following spontaneous ventilation with oxygen and halothane. A jet ventilator was available in the event of bilateral rupture of bullae. The anaesthetic management is described and principles of management outlined.

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