ANAESTHETIC MANAGEMENT FOR CHILDREN WITH ALVEOLAR PROTEINOSIS USING EXTRACORPOREAL CIRCULATION

Report of two cases

M. LIPPMANN, M. S. MOK AND K. WASSERMAN

SUMMARY

This report demonstrates the results following massive simultaneous lavage of both lungs in two brothers suffering from pulmonary alveolar proteinosis with severe hypoxaemia, using partial extracorporeal bypass.

The use of extracorporeal circulation during open heart surgery is established. "Pulmonary alveolar proteinosis" is being diagnosed more frequently. In adults, we have treated this condition using lung lavage with very good results. This technique has not been applied to small children and infants because of a lack of endobronchial tubes (Carlen's) for children. The following is a report of two children suffering from hypoxaemia secondary to a type of pulmonary alveolar proteinosis, who underwent bilateral lung lavage using "partial extracorporeal circulation."

Patient 1

A 4-year-old boy was born at full term, the son of healthy parents, after an uneventful pregnancy. The birth weight was 2.5 kg. The patient developed normally for 10 months, when he began to have multiple upper respiratory and middle ear infections which were treated with various antimicrobial agents.

The patient was admitted to another hospital at age 18 months with bilateral pneumonia without significant fever. Chest x-rays at that time revealed perihilar infiltrates and possible mediastinal lymphadenopathy. Extensive investigations, including sweat chloride concentration, serum protein electrophoresis, immunoglobulins, cerebrospinal fluid analysis and electroencephalography revealed no abnormality.

The patient was admitted to hospital at age 18 months with bilateral pneumonia without significant fever. Chest x-rays at that time revealed perihilar infiltrates and possible mediastinal lymphadenopathy. Extensive investigations, including sweat chloride concentration, serum protein electrophoresis, immunoglobulins, cerebrospinal fluid analysis and electroencephalography revealed no abnormality.

During the next 12 months, the patient was admitted to hospital on three further occasions with respiratory distress. At age 30 months, an open lung biopsy established the diagnosis of pulmonary alveolar proteinosis. The patient's pulmonary status deteriorated progressively and, aged 3 years, after a cyanotic episode, he had a cardiac arrest. He was resuscitated successfully and ventilation was controlled via a tracheostomy. The patient remained in hospital, and an oxygen-rich environment was maintained for approximately 1 year.

Arterial blood-gas tensions measured 1 month later were: $P_{aO_2} 8$ kPa, $P_{aCO_2} 11$ kPa* and pH 7.38 units. Ventilation was controlled with a volume-preset respirator. On numerous occasions in the following few months, mixtures containing various proportions of potassium iodide, acetylcysteine, hydrogen peroxide, ethanol and neomycin were instilled into segments of both lungs. Large amounts of secretions were aspirated and this was always associated with an improvement in the auscultatory findings over both lungs. The patient's appetite decreased during this period and he became increasingly cachectic. Severe pulmonary insufficiency persisted. While breathing 80% oxygen, which was delivered by a volume-controlled respirator, the arterialized capillary $P_{O_2}$ ranged between 8.5 and 11.3 kPa. When the inspired oxygen concentration was reduced to 60%, his arterialized capillary $P_{O_2}$ decreased to as little as 3.5 kPa.

The patient was transferred to Harbor General Hospital for pulmonary lavage. On admission, he was cyanosed, alert and talkative but extremely emaciated. The arterial pressure was 100/60 mm Hg; heart rate was 120 beat/min and regular; respiratory rate 30/min; rectal temperature 36.5 °C; weight was 13 kg; height was 980 mm. The fingers and toes showed marked clubbing. There were generalized rhonchi but no rales on auscultation of the lungs. The patient's chest x-ray on admission is shown in figure 1.

* 1 kPa = 7.5 mm Hg.
Two days after admission, the patient underwent bilateral simultaneous lung lavage under general anaesthesia with partial cardiopulmonary bypass. The patient was premedicated with pethidine 10 mg, pentobarbital 15 mg and atropine 0.3 mg. Anaesthesia was induced with ketamine 100 mg i.m. The trachea was intubated with a 6.5-mm endotracheal tube following the injection of suxamethonium 40 mg i.v. Anaesthesia was maintained with halothane 0.5-1% in oxygen at a flow rate of 4 litre/min. Following recovery from suxamethonium, tubocurarine was given; the total dose for the procedure being 9 mg. The myoneural block was antagonized at the end of the procedure with neostigmine 1 mg and atropine 0.5 mg. Blood from both femoral veins was pumped through a Bentley disposable oxygenator and returned to the femoral artery at a flow of 600-700 ml/min. The arterial systolic pressure varied between 60 and 80 mm Hg during the procedure (fig. 2).

When extracorporeal circulation was established, the lungs were ventilated with 100% oxygen for 10 min to achieve nitrogen washout, then both lungs were allowed to collapse by occluding the endotracheal tube for 5 min. This degassing procedure ensures better mixing of the lavage fluid and the alveolar debris, and decreases the amount of bubble formation. The degassed lungs were then filled with lavage fluid from a gravity feed reservoir. The lavage fluid remained in the lungs for 5 min and then drained under the influence of gravity through a tube which terminated at a height of 25 cm below the mid-point of the chest (fig. 2). The filling and emptying process was repeated until the effluent solution, which was characteristically turbid at the beginning, became clear. During a period of 51 min, six lavage cycles were performed on this patient, using approximately 600 ml of normal saline for each cycle. $P_{O_2}$ of the oxygenator varied between 86 and 93 kPa. During the bypass and lavage, the average $P_{O_2}$ of blood sampled from a radial artery catheter varied between 3.3 and 4 kPa. Bronchoscopy was performed after the last.
lavage to facilitate aspiration of the remaining traces of saline. Immediately after lavage and bronchoscopy, the arterial $P_{O_2}$ with the patient breathing 100% oxygen, was 50.6 kPa. The patient tolerated the entire procedure well.

Two weeks after lavage, with the patient breathing air, $P_{A_{O_2}}$ was 6.3 kPa. This contrasted with 2.6–3.5 kPa before lavage while breathing 60% oxygen. The patient was discharged 1 month later after being gradually weaned from the respirator. On discharge, he was placed in an oxygen tent in which he received oxygen from a tracheal mist collar. Two months after discharge, the tracheostomy tube was removed uneventfully, having been in place for 1 year. However, to abolish cyanosis, it was necessary to continue a low-flow oxygen via a face mask at 3–4 litre/min (fig. 3).

**Patient 2**

The brother of the first patient was born at full term following a normal pregnancy, complicated only by a third trimester urinary tract infection in the mother. His weight at birth was 3.8 kg.

At age 3 months, the patient began to have multiple upper respiratory infections without fever. At 8 months, he suffered from pneumonia followed by numerous episodes of cyanosis which became progressive and persistent. The remainder of the patient’s history paralleled that of his brother. The results of laboratory data obtained during the first and subsequent admissions revealed no abnormalities except $P_{A_{O_2}}$ values in the range of 2.6–3.5 kPa when the patient breathed room air. A chest X-ray revealed bilateral perihilar infiltrates. Open biopsy of the lung confirmed the diagnosis of pulmonary alveolar proteinosis.

When the patient was aged 30 months, both he and his brother were transferred to Harbor General Hospital. The patient was pale, cyanosed and very frail on admission. The heart rate was 120 beat/min; respiratory rate 44/min; rectal temperature 37.5 °C; weight 10 kg. Auscultation of the lungs revealed bronchovesicular breath sounds but no wheezes or rales (fig. 4). The nail beds were cyanotic and the fingers and toes showed marked clubbing.

One month after his brother’s lung lavage, this patient underwent similar simultaneous bilateral lung lavage through an endotracheal tube. Premedication consisted of pethidine 20 mg, pentobarbitone 10 mg and atropine 0.3 mg i.m., given 1 h before the procedure. Anaesthesia was induced with halothane 1% in 4 litre/min oxygen by mask, and a 5-mm orotracheal tube was inserted after administration of suxamethonium 20 mg i.m. Muscle relaxation was maintained by four intermittent i.m. injections of suxamethonium to a total dose of 160 mg. Blood from both femoral veins was passed through the oxygenator at a rate of approximately 450 ml/min, and returned to the patient through the femoral artery. The patient’s lungs were lavaged in a fashion similar to that described before. After five lavage cycles, using a total of 2000 ml of saline and 34 min on bypass, the procedure was terminated. During the procedure,
arterial $P_{O_2}$ was between 3.3 and 4 kPa. During 100% oxygen breathing after the lavage, $P_{O_2}$ was 43.3 kPa.

Nineteen days after this procedure, the patient was discharged weighing 11 kg and progressing satisfactorily although requiring intermittent oxygen by mask. The patient gained more than 3 kg in weight and learned to walk within 2 months of discharge. He has remained asymptomatic since discharge from hospital (fig. 5) but requires a continuous supplement of low flow oxygen by nasal cannula.

**DISCUSSION**

Pulmonary alveolar proteinosis is a relatively infrequent disease in adults and there are only five documented cases in children (Rosen, Castleman and Liebow, 1958; Barnatter, 1966; Wilkinson, Blane and Hagstrom, 1968). All of these children died within 12-24 months despite various types of therapy including segmental lung lavage. The outcome is unpredictable in these patients even if massive lung lavage is used. Three of the patients showed histological features similar to those found in adults with the disease. The two other patients showed histological abnormalities which were primarily those of diffuse interstitial pneumonitis and fibrosis. One of these children underwent segmental lung lavage, which was unsuccessful for technical reasons (Barnatter, 1966).

Experience with lung lavage has been limited to the treatment of adults with pulmonary alveolar proteinosis. The adult form of the disease has been reported by several authors (Ramirez, Kieffer and Ball, 1965; Ramirez, 1967; Wasserman, 1968; Wasserman, Blank and Fletcher, 1968).

Massive unilateral lung lavage has been used with benefit in adults with disorders such as pulmonary alveolar proteinosis, but has not been applied to children and infants. The main reason for this is that endobronchial intubation with, for example, a Carlen's tube, is necessary for one lung to be filled with saline during the lavage treatment while the other is used for gas exchange. There are no endobronchial techniques for small children. However, both lungs may be lavaged simultaneously through an endotracheal tube provided respiratory gas exchange can be affected by some other method.

The technique of “washing” the lungs combined with partial extracorporeal circulation is a unique therapeutic approach to the problem.

Different types of fluids have been used for lavage. Initially, Ramirez, Kieffer and Ball (1965) used saline with acetylcysteine and heparin. Buffered saline solution has been recommended subsequently (Ramirez, 1967), but Wasserman and his group (1968), after several studies, found that saline alone was equally effective (Wasserman, 1968). Saline also allows for a more complete resorption of any fluid remaining after lavage than would be possible if high molecular weight solute were present. This is important in simultaneous bilateral lung lavage because gas exchange must be restored immediately following the procedure.

**REFERENCES**


**CONDUITE DE L’ANESTHESIE SUR DES ENFANTS ATTEINTS DE PROTEINOSE A L’AIDE D’UNE CIRCULATION EXTRACORPORELLE**

**Rapport concernant deux cas**

Ce rapport décrit les résultats obtenus après un lavage massif simultané des deux poumons de deux frères souffrant d’une protéinose alvéolaire pulmonaire avec hypoxémie grave. On a employé une dérivation extra-corpselle partielle.

**HANDHABUNG DES NARKOTIKUMS FUR KINDER MIT PROTEINOSE BEI ANWENDUNG EINES EXTRAKORPOREALEN KRIEISLAUFS**

**Bericht über zwei fälle**

Dieser Bericht demonstriert die Ergebnisse einer massiven, gleichzeitigem Spülung beider Lungen bei Anwendung eines partiellen, ausserkörperlichen Kollateralkreislaufs in zwei Brüdern, die an Lungenalveolen-Proteinose mit schwerer Hyposämie litten.
CONTROL ANESTESICO EN NIÑOS CON PROTEINOSIS EMPLEANDO CIRCULACION EXTRACORPOREA
Informe sobre dos casos

SUMARIO
Este informe demuestra los resultados consecutivos al lavado masivo simultáneo de ambos pulmones en dos hermanos que padecían proteinosis alveolar pulmonar con severa hipoxemia, empleando derivación parcial extracorpórea.