stretched and has other priorities. Other areas of protective legislation that are inadequate include the Health and Safety (First Aid) Regulations 1981, which do not apply to schools, and the Fire Precautions Act (1971), which has not been extended to schools.

Education services throughout Britain are in a stage of transition and there have been great changes in inner London. In April 1990 the Inner London Education Authority ceased to exist, and responsibility for education passed to newly established local authority education departments, which in Bloomsbury are those of Camden and Westminster. In many areas responsibility falls directly on the schools themselves under the local management initiative. The funding for education services comes in part from government grants and in part from the community charge. It has been calculated that, at least in London, there will be substantial cuts in funding of education services over the next few years.⁵

Even where local education departments are aware of the scale of the problem few resources will be available to rapidly upgrade facilities, and most schools will not be brought up to the standard of the 1981 regulations before these become legally enforceable in 1991. The commitment of the government to enforcing its own regulations is also doubtful: the Bloomsbury school that was found to have the most severe problems had recently had an application for a grant for minor work to upgrade its toilets rejected by the Department of Education and Science. This school had no toilets indoors for use by boys below the sixth form.

School nurses and doctors and public health

physicians have an important role with respect to health and safety in schools. They should be much more active in drawing attention to health and safety problems in schools and ensuring that standards are raised and maintained. Our survey led to the Department of Education and Science finding £89 000 for Camden voluntary aided schools (in which capital work is funded in part by direct departmental grants), and it put forward health, hygiene, and sanitation facilities as important issues for the new education departments of Camden and Westminster and the public health committee of Camden.

This is an example of what can be achieved. The government has an urgent task in reviewing legislation covering health and safety and fire prevention in schools and strengthening it. The Department of Education and Science and Department of Health have been approached about this. Far greater sums of money must be found if a serious attempt is to be made to tackle these widespread problems.

We thank the school nurses of Bloomsbury health district for their help in collecting data.

- 1 *The Education (School Premises) Regulations, 1981*. London: HMSO, 1982. (SI 909.)
- 2 Koopman J. Diarrhoea and school toilet hygiene in Cali, Colombia. *Am J Epidemiol* 1978;107:412-20.
- 3 Polakoff S. *Clinical hepatitis A*. London: Public Health Laboratory Service Communicable Disease Surveillance Centre, 1989. (Unpublished.)
- 4 Thomas MEM, Tillett HJE. Sonnei dysentery in day schools and nurseries: an eighteen-year study in Edmonton. *Journal of Hygiene* 1973;71:593-602.
- 5 Pyke N. Destined to have a very lean and hungry look. *Times Educational Supplement* 1990 February 23:13.

(Accepted 24 August 1990)

Royal Brompton Grand Rounds

Adult respiratory distress syndrome

Advances in diagnosis and ventilatory management

Royal Brompton and National Heart Hospital, London SW3 6HP
Case presented by:
J S Turner, FCPSA, *Doverdale fellow*

Chairman:
T W Evans, MRCP, *senior lecturer in thoracic medicine*

Discussion group:
D N Hunter, FCANAE, *research fellow*
B F Keogh, FCANAE, *consultant anaesthetist*
D M Hansell, FRCP, *consultant radiologist*
M N Sheppard, MRCPATH, *senior lecturer in pathology*
C J Morgan, FCANAE, *director of adult intensive care unit*
E A Shinebourne, FRCP, *consultant paediatrician*
D M Geddes, FRCP, *consultant physician*
M A Branthwaite, FRCP, *consultant physician*

Series edited by:
Dr K F Chung.

Br Med J 1990;301:1087-9

The adult respiratory distress syndrome is characterised by refractory hypoxaemia and decreased lung compliance secondary to high permeability pulmonary oedema.¹ Between 10 000 and 15 000 cases occur annually in Britain alone,² and although understanding of the mechanisms leading to the syndrome has improved considerably since it was first described, the associated mortality remains high.³ Conventionally, the syndrome is diagnosed on clinical grounds,⁴ and treatment is almost entirely supportive. The presented case illustrates some of the advances made in the diagnosis and ventilatory management of patients.

Case history

A 36 year old West Indian woman presented to another hospital in December 1989 with a three day history of increasing shortness of breath, right sided pleuritic chest pain, a cough with scanty rusty sputum, and fever. She was 32 weeks pregnant and had had no proteinuria or hypertension. In 1984 she had had pulmonary emboli for which she had been treated with warfarin for six months.

On examination she had clinical and radiological evidence of right lower lobe pneumonia. She had a leucocytosis (white cell count $18.3 \times 10^9/l$) and an arterial oxygen pressure of 8 kPa and arterial carbon dioxide pressure of 2.7 kPa when breathing room air. Bacteriological examination of sputum gave negative results. She was treated with intravenous erythromycin and cefuroxime and oxygen through a facemask.

She went into spontaneous labour and delivered a live infant vaginally, but she required a transfusion of four units of packed cells because of blood loss.

The next day radiography showed bilateral diffuse pulmonary infiltrates, but her pulmonary artery occlusion pressure was normal. She became hypoxaemic and mechanical ventilation was started. Pulmonary angiography showed no evidence of recurrent emboli, and dilatation and curettage of the uterus found no retained products of conception. Her gas exchange deteriorated further, she had a tracheostomy, and 12 days after admission she was transferred to the Brompton Hospital. Initial clinical assessment suggested that she had the adult respiratory distress syndrome induced by pneumonia, reaction to a blood transfusion,⁵ or gynaecological sepsis.

With an inspired oxygen concentration of 0.6 and 10 cm of positive end expiratory pressure her arterial oxygen pressure was 6.9 kPa. She was hypertensive, with a cardiac output of 11.8 l/min and a pulmonary artery occlusion pressure of 14 mm Hg. A full bacteriological screen gave negative results, and she was treated with piperacillin and gentamicin. Her renal function was normal, but there was biochemical evidence of mild hepatic dysfunction. The radiological findings and the confirmation of the diagnosis will be discussed later.

During the 24 hours after her transfer, her gas exchange deteriorated further despite the use of 10 cm of positive end expiratory pressure and her peak inflation pressure rose to 55 cm H₂O. She was there-

fore started on high frequency jet ventilation, which produced an impressive initial response in arterial oxygen pressure. The inspired oxygen concentration was reduced from 0.75 to 0.55 within 24 hours, and this increased her arterial to alveolar oxygen ratio from 0.13 to 0.19.

Her improvement continued until day five when, unfortunately, the posterior membrane of her trachea ruptured owing to an overinflated endotracheal tube cuff. Severe sepsis rapidly ensued, and her acute lung injury recrudesced. She was ventilated without an endotracheal tube cuff, and the tracheal stoma was reopened in the hope of reducing distension of the trachea. Her gas exchange improved, and bronchoscopy suggested that the tracheal lesion was healing. She had another episode of severe sepsis and her gas exchange in the preterminal period deteriorated despite maximal ventilatory techniques. She developed multiple pneumothoraces with large air leaks. *Pseudomonas aeruginosa* was grown from tracheal aspirates, candida was cultured from vaginal swabs and urine, and herpes simplex virus was isolated from skin vesicles. Despite appropriate antibiotics and antiviral and antifungal drugs she developed haemodynamic instability with both hypotension and hypertension. Inotropic support failed to arrest her decline, and she died 40 days after admission to hospital.

Discussion

DNH: Her initial chest radiograph showed an area of dense consolidation in the right lower lobe; the lungs were otherwise clear (fig 1). Twenty four hours later the consolidation was more extensive and contained an air bronchogram, and there was some nodular shadowing in the left lung. Ten days later her lungs had a "ground glass" appearance and there were widespread air bronchograms. These radiological features are consistent with the adult respiratory distress syndrome, although they may be seen in other conditions, including pulmonary oedema, viral pneumonias, and pulmonary haemorrhage. During the remainder of her illness the appearance of the lungs was unchanged. Her last radiographs showed alternating pneumothoraces, which were predominantly subpulmonary (fig 2).

MNS: At necropsy there was widening of the posterior membrane of the trachea but no evidence of mediastinitis. The lungs were solid and congested with large areas of fibrosis. Microscopic examination of the lungs showed a giant cell pneumonia (in keeping with herpetic infection), and the parenchyma was completely replaced by dense fibrosis containing many chronic inflammatory cells (fig 3). The uterus was enlarged, with a 4 cm diameter blood clot in the cavity. Microscopic examination of this showed calcified

FIG 1—Chest radiograph showing right lower lobe consolidation

FIG 2—Chest radiograph showing pneumothoraces and multiple chest drains

chorionic villi in keeping with retained products of conception. Cause of death was the adult respiratory distress syndrome with herpetic pneumonia.

DNH: Diagnosis of the adult respiratory distress syndrome has recently been facilitated by the measurement of the protein accumulation index.⁶ A scintillation counter with a fixed field of view is placed over the lung and transferrin is radiolabelled in vivo with the gamma emitter indium-113. If the patient has increased pulmonary vascular oedema transferrin will accumulate and the gamma counts recorded from the ¹¹³In will rise. To correct for possible changes due to an increase in the volume of intravascular blood beneath the probe red blood cells labelled with technetium-99 are used as an intravascular marker. If protein is accumulating extravascularly then the ratio of ¹¹³In counts to ⁹⁹Tc counts will rise with time, provided that the counts are corrected for decay. In our patient there was a rise in true ¹¹³In counts showing transferrin accumulation. The mean protein accumulation index was $0.18 \times 10^{-3}/\text{minute}$ (SE 0.08) in our series of 22 normal patients and $2.88 \times 10^{-3}/\text{minute}$ (SE 0.63) in 10 patients with the adult respiratory distress syndrome. The patient described here had a mean index of $2.0 \times 10^{-3}/\text{minute}$.

BFK: For the past year our unit has participated in a multicentre trial of a prototype ultra high frequency ventilator specifically designed for use in patients with the adult respiratory distress syndrome. Although previous studies have not established any advantage of this technique over conventional techniques⁷ a new philosophy has emerged based on aggressive recruitment and maintenance of lung volume and an attempt to harness proposed enhanced alveolar gas kinetics at the resonant frequency of the lung, thought to be roughly 5 Hz.⁸

The APT 1010 machine is a computer controlled ultra high frequency pulse generator capable of frequencies up to 20 Hz. The jet nozzle, situated at the proximal end of the endotracheal tube, entrains humidified oxygen enriched air from a bias gas source. Animal experiments with this machine have shown that swings in alveolar pressure are minimal, thus eliminating the local distending and shearing forces thought to be partly responsible for ongoing damage in patients with acute lung injury who are ventilated conventionally. Clearly, the recruitment of collapsed alveoli, which reduces the required inspired oxygen concentration, must be achieved with maintenance of adequate haemodynamics and oxygen delivery. Our patient's haemodynamics were maintained with a cardiac index averaging 5 l/min/m^2 , allowing our desired oxygen delivery to be achieved. There was a

FIG 3—Section of lung stained with haematoxylin and eosin showing destruction of the alveolar pneumocytes, interstitial chronic inflammation, and fibrosis

20% reduction in centrally measured peak inspiratory pressures, and a mean airway pressure of 25 cm H₂O was effective in maintaining oxygenation.

Her clearance of carbon dioxide was efficient, which is typical of our experience with such patients. After high frequency jet ventilation was introduced the frequency of 5 Hz had to be increased to prevent hypocapnia. Later, during her septic episode, the optimal frequency proved to be about 4 Hz. We saw no adverse effects of the technique, and the tracheal lesion responded well to ventilatory modification. The technique is, however, limited to supporting gas exchange until the lung recovers, and despite encouraging observations we were never able to eradicate the cause of her pulmonary disease.

EAS: You mentioned that the patient's cardiac output was about 10 l/min at admission and that you were using inotropic support. Was this not inappropriately high?

CJM: We would not consider it so. Shoemaker⁹ and Edwards *et al*¹⁰ have shown the importance of setting therapeutic targets for both oxygen delivery and oxygen delivery to extraction ratio. Patients with systemic sepsis and the adult respiratory distress syndrome develop delivery dependent oxygen consumption, and these targets therefore need to be high. We used inotropes to increase the cardiac output and maintain oxygen delivery in excess of 550 ml/min/m².

DMG: The use of high frequency jet ventilation in these circumstances presumably also requires the use of positive end expiratory pressure.

BFK: Yes, the centrally measured end expiratory or minimum airway pressure is always positive, but the importance of this is uncertain. Arterial oxygenation relates much more to mean airway pressure, which reflects alveolar pressure if inspiratory time is less than half of each pulse duration.

DMG: Is the technique of measuring protein accumulation index specific for the adult respiratory distress syndrome? What about pneumonia?

DNH: There is no detailed information regarding the protein accumulation index during pneumonia. Other techniques of measuring a protein leak in the adult respiratory distress syndrome, such as the clearance of inhaled diethylenetriaminepenta-acetic acid (DTPA), are much less specific than the accumulation index. DTPA scanning is, for example, considerably influenced by cigarette smoke, and this persists for some time after smoking has ceased.¹¹

MAB: I wonder if we could discuss some of the ethical considerations here. The patient was maintained in intensive care for 40 days. Did you not recognise the prognosis to be poor early on?

CJM: The increasing use of severity scoring systems

in intensive care units¹² has shown that the prognosis of severely ill patients can be fairly accurately gauged at an early stage. To a certain extent we were influenced by the fact that this woman was young and apparently fit before her admission to hospital and by the improvement in her oxygenation achieved with high frequency jet ventilation, which has proved especially successful in the United States and our own unit in young patients in whom the adult respiratory distress syndrome is associated with trauma.

TWE: This case has raised several important points relating not only to the investigation and management of these patients but to trends that may influence us increasingly with changes in health service management and administration. The diagnosis and definition of the adult respiratory distress syndrome have always been an important problem, and recently Murray *et al* devised a lung injury score designed to grade both anatomical and physiological disturbances.⁴ Thus the appearance on chest radiography, the degree of hypoxaemia, the amount of positive end expiratory pressure needed, and the respiratory system compliance are scored according to their degrees of abnormality. Such an approach permits the collection and comparison of epidemiological data and mortality figures. In diagnostic terms, however, quantifying the protein leakage across the alveolar capillary membrane is invaluable.

Newer ventilatory techniques, including pressure control inverse ratio ventilation,^{12,13} high levels of positive end expiratory pressure, prophylactic positive end expiratory pressure, extracorporeal membrane oxygenation, and high frequency jet ventilation are designed to improve oxygenation while reducing the risk of barotrauma, but have either not been assessed in a controlled manner or have been shown not to reduce mortality.¹⁴ An uncontrolled study of extracorporeal carbon dioxide removal showed a reduction in mortality in patients with the adult respiratory distress syndrome¹⁵ and a prospective randomised study of the technique is being carried out in the United States.

The important features of this case are the new techniques in the diagnosis and characterisation of the pathology that underlies the adult respiratory distress syndrome. Although high frequency ventilation was effective in maintaining oxygenation, the patient died as do many with multisystem failure. This emphasises the point that the adult respiratory distress syndrome is a systemic disturbance in which historically undue emphasis has been placed on respiratory support alone.

- 1 Ashbaugh DG, Bigelow DB, Petty TL, *et al*. Acute respiratory distress in adults. *Lancet* 1967;ii:319-23.
- 2 Wardle EN. Shock lungs; the post traumatic respiratory syndrome. *Q J Med* 1984;53:517-29.
- 3 Petty TL. Indicators of risk, course, and prognosis in adult respiratory distress syndrome (ARDS). *Am Rev Respir Dis* 1985;132:471.
- 4 Murray JF, Matthay MA, Luce JM, *et al*. An expanded definition of the adult respiratory distress syndrome. *Am Rev Respir Dis* 1988;138:720-3.
- 5 Popovsky MA, Moore SB. Diagnostic and pathogenetic considerations in transfusion-related lung injury. *Transfusion* 1985;25:573-7.
- 6 Rocker GM, Pearson D, Wiseman MS, Shale DJ. Diagnostic criteria for adult respiratory distress syndrome: time for reappraisal. *Lancet* 1989;ii:120-3.
- 7 Carlson GC, Howland WS, Ray C, *et al*. High frequency jet ventilation. A prospective randomized evaluation. *Chest* 1983;84:551.
- 8 Lin ES, Jones MJ, Mottram SD, *et al*. Relationship between resonance and gas exchange during high frequency jet ventilation. *Br J Anaesth* 1990;64:453-9.
- 9 Shoemaker WC. Relation of oxygen transport patterns to the pathophysiology and therapy of shock states. *Intensive Care Med* 1987;13:230-43.
- 10 Edwards JD, Brown GCS, Nightingale P, *et al*. Use of survivors' cardio-respiratory values as therapeutic goals in septic shock. *Crit Care Med* 1989;17:1098-103.
- 11 Hunter DN, Lawrence R, Morgan CJ, Evans TW. The use of radioisotopes in the estimation of pulmonary vascular permeability in the intensive care unit. *Intensive Care Med* (in press).
- 12 Tharratt RS, Allen RP, Albertson TE. Pressure controlled inverse ratio ventilation in severe adult respiratory failure. *Chest* 1988;94:755-62.
- 13 Lain DC, DiBenedetto R, Morris SL, *et al*. Pressure control inverse ratio ventilation as a method to reduce peak inspiratory pressure and provide adequate ventilation and oxygenation. *Chest* 1989;95:1081-8.
- 14 Matthay MA. New modes of mechanical ventilation for ARDS. How should they be evaluated? *Chest* 1989;95:1175-7.
- 15 Gattinoni L, Pesenti A, Mascheroni D, *et al*. Low-frequency positive-pressure ventilation with extracorporeal CO₂ removal in severe acute respiratory failure. *JAMA* 1986;256:881-6.