Management of severe viral bronchiolitis and severe acute asthma*

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Severe viral bronchiolitis and severe acute asthma are common causes of acute respiratory insufficiency in infants and children beyond the neonatal period. Both are associated with considerable morbidity and can be fatal if management is inadequate. However, it is possible to reduce mortality to a minimum with appropriate therapy.

The term 'status asthmaticus' is not used in this review because of uncertainty about precise definition. By 'severe acute asthma' is meant an acute episode of respiratory distress and wheezing not responding to conventional oral and/or inhalational bronchodilator therapy and which if continued unchecked would become life-threatening.

The approach to management outlined here has been used by the authors for the past 7 years. During each 12 months they see about 30 babies with severe acute bronchiolitis and about 40 children who between them have approximately 60 episodes of severe acute asthma. No patient with uncomplicated severe acute asthma under the authors' care has died in hospital during this period, though an 8-year-old child with very severe asthma who developed a tracheobronchitis caused by influenza A2 virus died in acute respiratory failure. Causes of death in the 4 fatal cases of viral bronchiolitis are outlined in Table I.

Pathophysiology

In both diseases the major pathology is obstruction in the medium and smaller airways. In bronchiolitis this is due to inflammatory oedema and exudate and in asthma to mucosal oedema, mucous plugging, and bronchial muscle spasm. In infants under 12 months of age with asthma, obstruction is due mainly to mucosal oedema and mucus, as

TABLE I

Causes of death in infants with acute viral bronchiolitis

	No. of patients
Cardiorespiratory arrest after intubation but before institution of artificial ventilation	1
Mechanical blockage of endotracheal tube	1
Disseminated intravascular coagulation	1
Secondary bacterial bronchopneumonia and probable immune deficiency	1

bronchial and bronchiolar muscle is poorly developed (Engel, 1962).

As a consequence of widespread airways obstruction, the work of breathing is increased and ventilation-perfusion inequalities develop. P_{aO_2} is invariably below normal if the patient is breathing air. Initially, with severe acute asthma, hypoventilation may produce a low P_{aCO_2} , but with progress of the disease hypercapnia develops (Simpson, Forfar, and Grubb, 1968). In acute bronchiolitis it is less common to see hypocapnia even in the initial stages of the illness.

Dehydration from poor fluid intake often associated with vomiting is common, particularly in smaller children. This, combined with hypoxia, poor cardiac output, and increased muscular work, frequently results in metabolic acidosis.

General principles of management

A high standard of nursing care is essential in the management of these sick children. Older children with asthma are often very apprehensive, and a confident approach by the nursing staff can play an important part in allaying anxiety. In addition to good general nursing care, there are certain specific measures that are important in general management.

Minimal handling. All infants and small children with acute respiratory distress should have

*In the 'Personal practice' series of articles authors are invited to give their own views on some current practical problem.

the minimum of disturbance. Only essential investigations are undertaken. A chest *x*-ray is usually taken and arterial blood collected for gas analysis. As all patients have an intravenous infusion, there is no disturbance for feeding, though small amounts of fluid may be given by mouth to help allay restlessness. Sedatives are not used because of the risk of central depression.

Oxygen. As hypoxia is invariably present, oxygen is an important part of therapy and is administered to infants under the age of 18 months in a plastic oxygen cot (Fig. 1). The bottom and four sides of the cot are made of soft, clear plastic and the removable roof is also a plastic sheet. The infant lies on a soft rubber mattress. Such a cot allows close observation of the baby and high concentrations of oxygen are obtained which fall only marginally when the roof is partly removed for nursing procedures. An initial oxygen concentration of 40% is used, but this is increased as indicated by the clinical status and level of PaO_2 . In children over the age of 5 or 6, oxygen is administered by a face mask usually starting with a flow of 4.0 l./minute. It is very difficult to administer oxygen efficiently to children aged from 18 months to 5 years in a way that does not disturb them. They will not tolerate any form of face mask and become very apprehensive in tents. Further, it is difficult to obtain an adequate oxygen concentration in a tent if it is being opened repeatedly. Despite its disadvantages, the authors generally are forced to use an oxygen tent in children of this age group because

of the lack of any alternative method of administering oxygen. Oxygen level in the tent is measured frequently to ensure that some benefit is being obtained.

Fluids. An intravenous infusion of 0.25% saline in 5% dextrose is given at about $1\frac{1}{2}$ times normal maintenance. If blood pH is less than 7.25 and metabolic acidosis is present, sodium bicarbonate is added to the infusion at a dose calculated by the formula $0.25 \times \text{body weight in kg} \times \text{base deficit}$. This is an approximate calculation and it does not accurately take into account metabolic response to an acute rise in PaCO_2 . There is a possibility of producing further hypercapnia by the use of bicarbonate, but it is wise to attempt to keep pH above 7.25. The authors have not been impressed that sodium bicarbonate increases responsiveness to β -adrenergic stimulators.

Pharmacological agents

Bronchiolitis. Pharmacological agents have no effect on the course of acute viral bronchiolitis. In the very ill infant, the authors generally use antibiotics (a combination of methicillin and gentamicin) in case they are unable to detect early signs of secondary bacterial infection.

Asthma. Three groups of drugs, β -adrenergic stimulators, methyl xanthines, and corticosteroids are of value in the management of severe acute asthma in children over the age of 12 months. Generally a combination of one drug from each

FIG. 1.—Small infant being nursed in oxygen cot.

group is used, though steroids are not necessary in all cases. Xanthines and β -adrenergic stimulators act synergistically via the adenylcyclase, 3'5'-AMP system (Orange *et al.*, 1970), and one of the major effects of corticosteroids is to sensitize the β -adrenergic receptors (McCombs, 1972). To administer corticosteroids alone, as has been suggested by some writers, is to lose a major part of their pharmacological activity, and adequate control may not be obtained even with massive doses until a β -adrenergic stimulator is added (Rebuck and Read, 1971). In infants under 12 months of age, steroids alone are of value because of the small amount of bronchial and bronchiolar muscle. Severe asthma in this age group can be particularly difficult to manage.

β -adrenergic stimulators. Though most children admitted to hospital with acute asthma will have received β -adrenergic stimulators without adequate response, these are continued unless dosage has been

excessive. They are given by inhalation, using a Bennett twin jet nebulizer driven by a Repco clinical air pump* which has an output of 6.0 l./minute (Fig. 2). The standard drug has been orciprenaline 2% solution 0.25 ml diluted to 2 ml with isotonic saline or with 10% propylene glycol in isotonic saline for children under the age of 8 years, and orciprenaline 2% 0.5 ml diluted to 2 ml for children over 8 years. More recently, salbutamol 0.5% respirator solution has been used in similar dosage and appears equally effective. An inhalation usually takes about 10 minutes to administer and is repeated 4-hourly. In the past 6 months the authors have used salbutamol intravenously in a dose of 2.5 μ g/kg repeated 3-hourly. This appears a very effective bronchodilator and causes no significant fall in P_{aO_2} (Table II). It is particularly useful in children aged from 1 to 4 years who

*Available in Australia from Warren and Brown P/L, 119 Ballarat Rd., Footscray, Victoria 3011.

FIG. 2.—7-year-old child receiving an inhalation of orciprenaline from a Bennett nebulizer being driven by a Repco clinical air pump.

become upset with the use of a face mask. Intravenous salbutamol will probably become the authors' standard β -adrenergic stimulator for use in acute asthma.

TABLE II
Effect of intravenous salbutamol on PaO_2

Before	After
79	80
124	142
70	64

Aminophylline. Unless aminophylline has been used excessively before admission it is administered intravenously in a dose of 3 to 4 mg/kg given over 10 minutes and repeated 6-hourly. The authors have not seen any side effects from the drug in this dosage provided attention is paid to the correction of dehydration and metabolic acidosis. It is used with caution in any child who has been vomiting.

Corticosteroids. If the patient does not respond rapidly to the β -adrenergic stimulator and/or intravenous aminophylline, or is seriously ill at the time of admission, or has received corticosteroids in the previous 6 months, methyl prednisolone 1 mg/kg is given intravenously and repeated every 4 hours. If the patient is very ill or if the maintenance dose of steroids is above 10 mg prednisolone per day, the dose of methyl prednisolone is doubled for the first 12 to 24 hours. Beneficial effects of steroids are seen 4 to 6 hours after the initial dose.

Antibiotics. Antibiotics are not routinely used in patients with acute asthma even when corticosteroids are administered, but are reserved for patients with evidence of associated bacterial infection. As this is uncommon, fewer than 10% of patients receive them. If antibiotics are used, ampicillin is the drug of choice in children over the age of 12 months, and a combination of methicillin and gentamicin in children under that age because of the risk of staphylococcal or Gram-negative infection.

Assessment of progress

Assessment of progress is basically clinical. Observations of colour, level of conscious state, pulse rate and quality, respiratory rate, degree of respiratory effort and of breath sounds in the chest provide the basic information. When practicable, repeat arterial blood gas studies are carried out to supplement clinical findings. If the clinical state is

deteriorating, manifested by disturbed conscious state, cyanosis in high oxygen concentration, rising pulse rate, rising or falling respiratory rate, ineffective respiratory effort as indicated by decreasing intensity of wheezing and decreasing breath sounds in the chest, and it is felt the child is likely to die, mechanical ventilation is started. There is no absolute level of $PaCO_2$ that indicates the need for ventilation. The authors have managed babies with bronchiolitis whose $PaCO_2$ has been in excess of 90 mmHg without ventilation and their subsequent progress has been quite satisfactory. However, in asthma once the $PaCO_2$ is above 60 to 65 mmHg, artificial ventilation should be seriously considered; but again the final decision is made on the basis of overall clinical assessment, in conjunction with blood gas findings.

Artificial ventilation.

Bronchiolitis. Once it has been decided that artificial ventilation is necessary, full control over the patient's airway and ventilation must be achieved as rapidly as possible if unnecessary hypoxia is to be avoided. The patient is pre-oxygenated with 100% oxygen by face mask for 1 to 2 minutes, and a large dose of d-tubocurarine (1 mg/kg) is then injected intravenously, an orotracheal tube passed, and intermittent positive pressure ventilation started by hand. Secretions are aspirated and sent for culture.

The oral endotracheal tube is then replaced by a polyvinyl chloride nasotracheal tube, since this is more readily fixed and will not kink inside the patient. It is positioned under x-ray control so that its tip lies approximately 1 cm above the carina, and is securely fixed (Stocks, 1970).

The choice of size of tube is very important. Too large a tube will compress the subglottic mucous membrane and may lead to subglottic oedema or stenosis. Too small a tube will allow an excessive leak of gases from the larynx, and in view of the high inflating pressures required, will make it difficult to achieve adequate alveolar ventilation. Ideally there should be a slight leak of gases from the larynx when the lungs are inflated, but if a tube allows a large leak and the size above is occlusive, the larger tube should be used.

The patient is next attached to a mechanical ventilator. Because of their availability, we prefer the Bennett PR2 or Bird Mark 8, driven by oxygen. However, many types may be used satisfactorily, provided that they are mechanically reliable, have a small apparatus dead space, can deliver tidal volumes within the range of 20 to 100 ml over approximately 1 second with a pressure in the breathing circuit of up to 50 cm H_2O , and allow for a

prolonged expiratory phase. It must be possible to vary the inspired oxygen concentration, and to provide a water vapour content of the inspired gases of at least 40 mg/l. For this latter purpose, we add to the circuit a hot water bath type of vaporizer, the Donnelly Wilson respiratory gas humidifier, and set its temperature so that the gases reach the patient at a temperature of at least 35 °C (Stocks, 1973).

To obtain adequate inspiration through the narrowed airways, a slightly prolonged inspiratory phase of about 1 second is usually necessary, and the driving pressure from the ventilator usually has to be set within the range of 30 to 50 cm H₂O. A prolonged expiratory phase of 2 to 4 seconds is required, since expiratory flow through the still more narrowed airways depends entirely on intra-alveolar pressure. Even with this, expiration is often not completed before it is essential to start the next inspiratory phase. The mean intra-alveolar pressure remains high, which in turn raises the venous pressure, and this may lead to generalized (including cerebral) oedema. For this reason fluid intake is reduced to about 70% of standard requirements.

When an adequate gaseous exchange, as judged on clinical grounds, is being achieved, it should be checked by measuring the PaCO₂ and PaO₂. It is difficult to estimate the required tidal volume by clinical criteria, and commonly the ventilator pressure has to be increased. An inspired oxygen concentration of 50 to 60% will usually achieve a satisfactory PaO₂. The concentration is reduced as the patient's condition improves. PaCO₂ estimations are repeated at least twice daily, and the inspiratory pressure adjusted accordingly.

Complete muscular paralysis during the acute stage is maintained by giving d-tubocurarine 1 mg/kg intravenously whenever movement is seen. It is necessary to have the maximum possible pressure gradient from the endotracheal tube to the alveoli during inspiration, and the presence of any tone within the respiratory musculature will reduce this and rapidly lead to a rise in the PaCO₂ and fall in the PaO₂.

The management of the paralysed patient on a ventilator presents many serious problems. Continuous observation is necessary to ensure that the machine is working and inflating the patient adequately. We have designed an electronic alarm in the circuit which will sense whenever the inspiratory pressure fails to reach a set level and if the expiratory pressure fails to return to zero once in every 10 seconds. Every precaution should be taken to ensure that the endotracheal tube does not come out or become blocked with secretions, but

nursing staff must be able to cope should these occur.

In the majority of patients, 2 to 3 days of mechanical ventilation are necessary. When the inspiratory pressure to achieve adequate ventilation falls below 30 cm H₂O, a trial period off the ventilator is usually indicated. The action of the muscle relaxant is allowed to partially wear off, and is then reversed with atropine (25 µg/kg) and neostigmine (50 µg/kg). Spontaneous ventilation with 50% oxygen humidified with the hot water bath and delivered to the patient with a T-piece is maintained for 24 hours before the endotracheal tube is removed. If ventilation is judged to be inadequate because of the presence of cyanosis, restlessness, or hypoventilation, the patient is re-paralysed and ventilation restarted.

If assisted ventilation is required for longer than 2 to 3 days, adequate reversal of the muscle relaxant with atropine and neostigmine may be impossible. If so, ventilation is controlled with another agent, such as morphine, for 8 to 12 hours before attempting to discontinue mechanical ventilation. The action of morphine and residual neuromuscular paralysis are both reversed with atropine and tetrahydroaminacrine (2 mg/kg) or with a combination of neostigmine and nalorphine.

This technique has been adequate for all patients except those with left ventricular failure from congenital cardiac disease. The majority of these patients will eventually be able to be managed in similar fashion, but progress and recovery are often stormy. As bronchiolitis improves, cardiac failure may become predominant in necessitating the continuance of mechanical ventilation. In this case the introduction of a positive end-respiratory pressure of up to 10 cm H₂O may be indicated, and eventually will allow weaning from the ventilator. Occasionally, corrective or palliative cardiac surgery is required before dispensing with respiratory assistance.

Asthma. The management of patients with asthma is similar. The muscle relaxant used is alcuronium (0.5 mg/kg), as it causes less histamine release than does d-tubocurarine. As most patients are severely ill and their memory likely to be confused, it may not be necessary to give any sedative or anaesthetic agent, but if these are needed, they should be given very cautiously as falls in blood pressure may occur. The agent of choice for use before induction of paralysis is ketamine, because it tends to maintain blood pressure. Even so, hypotension may occur with the institution of intermittent positive pressure ventilation, but this

can usually be readily controlled by infusing normal saline. For more prolonged sedation, phenobarbitone in a dose of 4 mg/kg or morphine (0.2 to 0.4 mg/kg) may be used.

Inspiratory pressures of up to 50 cm H₂O with respiratory rates of 8 to 12 per minute and an inspiratory : expiratory ratio of 1 : 2 to 1 : 4 may be necessary to achieve adequate ventilation. As the expected period of ventilation is short, oxygen concentrations of 80 to 100% are used.

When the pressure required has fallen to approximately 30 cm H₂O, as it usually does within 6 to 12 hours, the neuromuscular paralysis is reversed with atropine and neostigmine and a trial of spontaneous ventilation started. If within 30 to 60 minutes it appears that ventilation will be adequate, the patient is extubated and high oxygen concentrations are administered by face mask.

In the past 7 years we have artificially ventilated 34 patients with acute viral bronchiolitis, and 9 with asthma.

Convalescence

Most patients who do not require artificial ventilation show considerable improvement after 24 to 36 hours. The concentration of oxygen is gradually reduced as the condition of the patient stabilizes. Full therapeutic dosage of methyl prednisolone, orciprenaline, or salbutamol, and aminophylline is maintained until the clinical condition is satisfactory and the intravenous infusion is stopped.

Methyl prednisolone is replaced by oral prednisolone and is rapidly reduced over 3 to 4 days. The usual regimen is 30 mg prednisolone in the first 24 hours after the infusion is stopped; 15 mg in the second; and 5 mg or the maintenance steroid dose, should it be larger, in the third; and the normal maintenance dose or the steroids stopped in the fourth 24 hours. Oral theophylline in a dosage appropriate to the child's age together with inhalations of orciprenaline or salbutamol are continued. The majority of patients with severe asthma will be on long-term bronchodilators and

after another 2 to 3 days normal maintenance therapy is resumed. Sodium cromoglycate is restarted after the intravenous infusion is stopped.

Discussion

With this approach to management of severe bronchiolitis and severe acute asthma, the authors feel that they have reduced morbidity to a minimum and hopefully eliminated mortality. Death from acute viral bronchiolitis has resulted from unusual medical complications or from inexperience with the use of artificial ventilation when this was first introduced.

The authors have not used bronchial lavage in children with severe asthma and believe that it should not be necessary if facilities for artificial ventilation are adequate. There is now evidence that substantial lung damage occurs during lavage.

Meticulous medical and nursing care is essential in managing severely ill children with acute airways obstruction. This, combined with proper administration of pharmacological agents and the occasional use of artificial ventilation, should insure a satisfactory outcome in virtually all patients.

REFERENCES

- Engel, S. (1962). *Lung Structure*, p. 26. Thomas, Springfield, Illinois.
- McCombs, R. P. (1972). Diseases due to immunologic reactions in the lungs. *New England Journal of Medicine*, **286**, 1186.
- Orange, R. P., Ishizaka, T., Ishizaka, K., Koopman, W. J., and Austen, K. F. (1970). Pharmacologic inhibition of the release of the chemical mediators elicited by the interaction of IgE antibodies with specific antigen. *Clinical Research*, **18**, 534.
- Rebuck, A. S., and Read, J. (1971). Assessment and management of severe asthma. *American Journal of Medicine*, **51**, 788.
- Simpson, H., Forfar, J. O., and Grubb, D. J. (1968). Arterial blood gas tensions and pH in acute asthma in childhood. *British Medical Journal*, **3**, 460.
- Stocks, J. G. (1970). Prolonged endotracheal intubation in paediatric intensive care. In *Progress in Anaesthesiology*, p. 447. Proceedings of the Fourth World Congress of Anaesthesiologists, 1968. Excerpta Medica, Amsterdam.
- Stocks, J. G. (1973). The management of respiratory failure in infancy. *Anaesthesia and Intensive Care*, **1**, 486.

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