EXPERIENCE WITH FIFTY PATIENTS TREATED WITH ARTIFICIAL VENTILATION

BY

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SUMMARY

Experience gained during the treatment of fifty patients with respiratory failure is presented. The overall survival rate was 44 per cent, although some pathological conditions proved more amenable to treatment than others. The care of these patients involved the use of mechanical ventilators, and to obtain the best results the patients should be treated in a unit where there is a continuously high standard of nursing care and medical supervision. In such a unit problems which arise are more likely to be successfully overcome—problems of humidification, of the care of the tracheostomy, of monitoring ventilation, of preventing cross infection, and of accurate instructions for the nursing staff. In a general hospital there is a wide range of medical and surgical disease which may result in respiratory insufficiency and be successfully treated.

Tracheostomy and artificial ventilation have been used increasingly in the treatment of respiratory insufficiency since the epidemic of poliomyelitis in Denmark in 1952 (Lassen, 1953; Ibsen, 1954). Fifty patients with respiratory insufficiency were treated by artificial ventilation at Westminster Hospital from January 1958 to August 1962. This paper presents the results of experience of these, with particular reference to the difficulties and dangers encountered and the measures taken to overcome them. Tracheostomy and mechanical artificial ventilation are associated with a morbidity and mortality which can only be reduced to a low figure with adequate facilities and care. Experience has shown that the number of diseases amenable to this treatment has increased and errors in technique have become less frequent.

Respiratory insufficiency is present when the arterial blood has either a raised carbon dioxide tension and/or a lowered oxygen saturation in relation to the normal range, though exceptions occur in congenital heart disease and compensated metabolic alkalosis (Fletcher, 1962). Artificial ventilation is indicated in patients with respiratory insufficiency that is either progressive, or producing symptoms, but which has not responded to drug therapy or tracheostomy.

Table I shows the range of diseases treated. The three largest groups of patients are:

- postoperative patients (14);
- patients with chronic bronchitis and emphysema (11);
- barbiturate comas (10).

Of the fifty patients treated, twenty-two were discharged from hospital; five, though successfully treated for respiratory failure, died from other causes more than ten days later; and twenty-three died during artificial ventilation.

THE AIRWAY

Obstruction from oral endotracheal tubes.

Prolonged ventilation of patients using an oral endotracheal tube is dangerous because of the risk of airway obstruction due to the blockage of the lumen with inspissated secretions, kinking in the oropharynx or biting on the tube. Unrecognized obstruction in the lumen of oral endotracheal tubes by secretions occurred twice, once after 8 hours and on the other occasion after 10 hours in use. No method of humidifying the inspired air was in use.

Case No. 1.

In one of these patients the tube was removed in time to prevent any permanent harmful effects from the greatly increased airway resistance and hypoxia, and this patient survived.

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BRITISH JOURNAL OF ANAESTHESIA

TABLE I

<table>
<thead>
<tr>
<th>Respiratory failure from</th>
<th>Number of patients</th>
<th>Adequate spontaneous respiration re-established</th>
<th>Number discharged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central causes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbiturate overdosage</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Head injury</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Postoperative causes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac surgery</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Surgery involving the chest wall</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pulmonary surgery</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other surgery</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic bronchitis and emphysema plus infection</td>
<td>11</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Hyaline membrane</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Peripheral causes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple rib fractures</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Disseminated sclerosis</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Myelomalacia</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>50</td>
<td>27</td>
<td>22</td>
</tr>
</tbody>
</table>

CASE No. 2.
The other patient was an Indian student being treated for barbiturate poisoning. Instructions had been given to the nursing staff to aspirate the endotracheal tube every half-hour. Unfortunately this patient was not being nursed in the respiratory unit ward and in spite of endotracheal suction, the tube became progressively obstructed. Hypoxic restlessness was misinterpreted as evidence of lightening coma and sedatives were administered. Cardiac arrest occurred while a nurse was aspirating the endotracheal tube—presumably the suction catheter acted as a stopper completing the airway obstruction. The obstructed tube was removed and his heart action restored by internal cardiac massage but the patient died two days later, in spite of mechanical artificial ventilation, without any sign of recovering consciousness.

Kinking of a soft oral endotracheal tube precipitated cardiac arrest in another patient.

CASE No. 3.
This patient had just been turned to relieve her pressure areas and prevent hypostatic pneumonia when she became acutely anoxic and died. It was found that the endotracheal tube had been twisted in the oropharynx with resultant obstruction of the lumen.

To overcome these mishaps only large armoured endotracheal tubes are used and these are left in place for periods up to 8 hours. A metal oral airway is tied in place alongside the tube to prevent biting. A tracheostomy is then carried out within 8 hours unless there is good reason to expect that an artificial airway will not be required for a much longer period, as, for example, in a patient recovering from a barbiturate overdose, or in one with a hopeless prognosis.

Laryngostomy.
In an emergency, when no endotracheal equipment is available or when intubation of the trachea is impossible, laryngostomy rather than tracheostomy should be performed to overcome obstruction of the upper respiratory tract (Abbey, 1960). This has been necessary on two occasions.

CASE No. 4.
A patient suddenly collapsed during lunch and impacted a meat bolus in his larynx. Asphyxia and cardiac arrest ensued. Inflation of the lungs was impossible due to laryngeal obstruction and a laryngostomy was carried out. Artificial ventilation through the laryngostome was satisfactory and internal cardiac massage restored the heart's action. An elective tracheostomy was then carried out to allow prolonged ventilation. This patient died two days later without regaining consciousness, and at autopsy cerebral haemorrhage from a cirsoid aneurysm was demonstrated.

CASE No. 5.
The second instance occurred during laryngoscopy in a patient with advanced carcinoma of the larynx. There was copious haemorrhage after biopsy and the laryngeal airway was much reduced. After cardiac arrest laryngostomy was carried out as a route for efficient ventilation and external cardiac massage quickly restored the pulse. A formal tracheostomy was then fashioned and the laryngostomy closed. This patient was artificially ventilated for 24 hours and made a full recovery.
Tracheostomy and tracheostomy tubes.

Whenever possible a tracheostomy is carried out under general anaesthesia with an endotracheal tube in place. Tranquil conditions and the sure airway allow a careful unhurried operation. A large tracheal opening through the second and third tracheal rings is preferred. It may be very difficult to replace a large tracheostomy tube in a patient with a thick neck, especially during the first 48 hours after operation. For this reason it is advisable to stitch an anterior inferior tracheal flap to the skin so that it forms a tract permitting easy replacement or change of the tube (Björg, 1960). The right main bronchus was inadvertently intubated in one patient with a low tracheostomy.

Radcliffe or James tracheostomy tubes have been used in all patients although these tubes have been found to have serious disadvantages. They are manufactured from red rubber and have bonded inflatable tracheal cuffs. Red rubber irritates the mucosa and ulceration of the trachea has been seen. Erosion is most obvious where pressure has occurred, as at the fulcrum of the tracheal flap, at the site of the cuff, and at the end of the tube.

The cuff is inflated to make an airtight fit in the trachea and is deflated for 2 minutes every hour to allow free circulation through the area of tracheal mucosa that has been compressed.

CASE No. 6.

In a tetraplegic patient suffering from severe myelomalacia and atherosclerosis this routine was unfortunately not followed and the cuff was only released every 4 to 6 hours. The lateral pressure of the cuff caused necrosis of the tracheal wall extending to the innominate artery, and death resulted from massive haemorrhage after five weeks of artificial ventilation (fig. 1).

CASES No. 7 and 8.

Two patients who had total correction of tetralogy of Fallot under profound hypothermia required tracheostomy and artificial ventilation. These patients had rubber cuffed tracheostomy tubes in situ for seven and fourteen days until they died. One of the contributing causes of death was recurrent bleeding from the tracheal mucosa ulcerated by the tracheostomy tube, especially the cuff (fig. 2).

The mucosa in these patients is very hyperaemic and a cuffed tube should not be left in place for longer than is absolutely necessary.

As with cuffed endotracheal tubes during general anaesthesia the cuff occasionally bulges over the distal end of the tracheostomy tube. This is especially liable to happen if there is any traction on the proximal end of the tube. The nursing staff should be aware of this complication and instructed to release the cuff immediately if the airway becomes obstructed.

The Radcliffe tube has a sharply angled curve which hinders the passage of a large suction catheter and has led to inspissation of secretions. Most patients have been ventilated through a James tracheostomy tube, and this tube should be stitched to its rubber flange to prevent displacement during tracheal toilet. If the tube remains free of secretion it is changed every seven days, and is then discarded because stretching of the cuff makes it unreliable.

Tracheal softening.

Softening of the trachea may occur in associa-
Erosion of the tracheal mucosa, most extensive at the level of the tracheostomy tube cuff, after two weeks.

**Erosion of the tracheal mucosa, most extensive at the level of the tracheostomy tube cuff, after two weeks.**

FIG. 2

FIG. 3

Tracheogram taken in a left anterior oblique position showing tracheostomy tube and dilated trachea.

**Tracheal aspiration.**

Difficulty in swallowing has been a frequent problem in patients with cuffed endotracheal tubes. There may be reluctance to swallow even fluids, or paroxysms of coughing and regurgitation may occur while attempting to swallow food. Undoubtedly tracheal aspiration occurs in many cases. The tracheogram in figure 3 was produced when attempting a barium swallow on the patient who was reluctant to swallow and the radiograph was the first evidence that tracheal aspiration had occurred. It is possible that the swallowing reflex is deranged either because the tracheal fixation prevents the normal elevation of the larynx or because the cuff of the tube bulges posteriorly, compressing the oesophagus.

**Infants.**

Four infants have been ventilated through Magill flexometallic endotracheal tubes. There was one survivor.

**Case No. 10.**

This day-old baby had a large defect in the left side of the diaphragm. This was successfully repaired but the baby developed respiratory insufficiency requiring artificial ventilation for two days. At the end of this time his spontaneous respiration through the endotracheal tube was adequate. Following extubation, breathing became obstructed at laryngeal level and a tracheostomy was performed. It is probable that...
EXPERIENCE WITH PATIENTS TREATED WITH ARTIFICIAL VENTILATION

the laryngeal oedema which necessitated the tracheostomy resulted from the presence of the red rubber tube for two days. Non-irritating plastic tubes were found to be less reliable in maintaining a patent airway in this patient. The child would not tolerate decannulation until it was ten months old.

HUMIDIFICATION
Humidification is achieved most easily by passing the inspired atmosphere over a heated water bath. If the patient is being artificially ventilated the water bath is included in the inspiratory line from the machine. If the patient is breathing spontaneously a fan is used to blow air or oxygen-enriched air over the surface of a water bath at a rate of about 30 l./min.

East humidifiers have been used in association with all the ventilators and the East blower-humidifier for patients breathing spontaneously through a tracheostomy. These humidifiers are potentially dangerous, as the thermostats are unreliable and the setting must be frequently checked against a thermometer. The construction of the water bath prevents easy cleaning and sterilization and the fan on the blower-humidifier is noisy.

The danger of infecting patients is greatly increased by the use of a water bath as these vessels provide a suitable nidus for the growth of ward contaminants such as Pseudomonas pyocyaneus. The addition of oxygen will further encourage the growth of many bacteria.

There has been one death hastened by considerable superadded pyocyaneus infection and this bacterium was cultured from the sputum of five patients in whom either ventilators with an East humidifier or an East blower-humidifier had been used.

The risk of infection is reduced by keeping the water temperature at 50°C (Lacey, personal communication, 1963), by regular cleaning of the humidifier with formalin vapour (Wyman, personal communication, 1963), and by placing a bacterial filter on the inspiratory line of the ventilator (Bishop, Roper and Williams, 1963).

An alternative blower-humidifier which cannot overheat, and which can be dismantled for autoclaving, has been developed in conjunction with Oxygenaire (Feldman and Monro, 1963). This machine has an almost silent fan motor.

When the lungs are fairly normal a satisfactory degree of humidity can be achieved by use of a heat and moisture exchanger (Toremalm, 1960). The principle used is the same as the condensation of moisture on a cold window pane (Mapleson, Morgan and Hillard, 1963). Warm moist air is exhaled through a large cold surface, and as the exhaled air cools, water condenses on the surface of the heat and moisture exchanger, and is available for the inspired air to take up. The efficiency of the apparatus will depend on attaining the greatest difference in temperature between the exhaled air and the condensing surface. The disposable Toremalm heat and moisture exchanger will be available in this country but it is expensive.

A cheap condenser with disposable inserts has been developed with Oxygenaire (fig. 4). The condensing inserts of this apparatus may be fitted into the endotracheal catheter mount of patients being artificially ventilated—two condensers are recommended for an adult, and one for a child. This condenser has been used with success on some of our patients.

There is a considerable advantage to be gained by excluding a water bath humidifier from the ventilator circuit. The amount of supervision required is decreased and the potential bacterial incubator is removed from contact with the gases inspired by the patient.

SECRETIONS
Sterile latex whistle-tipped catheters are preferred for aspiration of secretions from the pharynx, trachea and right bronchial tree. A large catheter (11 English gauge) and a powerful reliable suction apparatus are desirable. A bronchoscopic catheter with a good terminal hole is used for blind suction of the left bronchial tree (9 English gauge) (Pinkerton, 1955). The catheters are sterilized and individually packed. A catheter is only used once before resterilization. In patients with an intact effective cough reflex it is usually sufficient to suck out the trachea, the carinal reflex is then invoked and the patient will cough. Suction is only continued for up to 20 seconds at a time, the patient being allowed rest for a minute between suctions. This prevents hypoxia and exhaustion.

The injection of 5 ml of sterile saline or 5 per cent sodium bicarbonate through the tracheostomy is an excellent stimulus to mobilizing secretions.
and expectoration. No marked improvement has been found following the use of a mucolytic enzyme such as chymotrypsin. Solutions of 0.1 to 1.0 per cent isoprenaline sulphate have been insufflated through the tracheostomy using a Rogers crystal spray. This has occasionally been beneficial in lessening bronchospasm and facilitating the aspiration of secretions, though it sometimes produced an alarming tachycardia.

The frequency of tracheal toilet is laid down by the anaesthetist according to the amount of sputum, the degree of superadded infection, the presence or absence of a cough reflex, the risk of trauma to an inflamed tracheobronchial tree and the state of exhaustion of the patient. Figure 5 illustrates a striking example of the end result of inefficient suction.

CASE NO. 11

This patient had sustained spinal cord damage at the level of the fifth cervical vertebra resulting in tetraplegia. A tracheostomy was carried out as his coughing was ineffective. He was kept alive for a year at Westminster Hospital before being sent to a hospital for the chronic sick. In spite of efforts that had been made to advise on the care of the tracheostomy, the tracheobronchial tree was not effectively aspirated and he died in five days.

VENTILATORS

The ventilators in use have been the Radcliffe positive and positive-negative machines, the Beaver Mark II, the Blease P6, and the patient-triggered P7, and in children the modified Starling pump has been used. All these machines can utilize room air, are powered by electricity and have a non-rebreathing circuit. With the exception of the non-return flap valve on the Beaver, all the other ventilators have mechanically operated valves. The Radcliffe machines can be powered from a 12-volt battery when required in an emergency or for transporting patients.

The Beaver Mark II is simple but noisy and the flap valves require changing 2-hourly because of water condensation. It was only used if other machines were not available. The Radcliffe machines have proved very satisfactory with a minimum of attention. The connections are best labelled A-A, B-B, etc., to avoid confusion in assembly. The Blease ventilators have been very reliable but they are too complex to be adjusted by nursing staff, and labelling of connections is also required. When pressures above 30 cm H₂O are required from the modified Starling pump the
EXPERIENCE WITH PATIENTS TREATED WITH ARTIFICIAL VENTILATION

Type of ventilation.

In the majority of patients adequate artificial ventilation has been achieved using intermittent positive pressure. Some patients with bronchiolo-alveolar disease have been found to benefit from a negative (subatmospheric) phase although in others the rapid deflation has appeared to increase the severity of air trapping.

The use of patient-triggered ventilation has been disappointing. In general only patients with very advanced disease have received artificial ventilation and they usually had such rapid respiratory rates that patient-triggering was abandoned. In one patient with respiratory insufficiency it was considered to be positively indicated.

ADJUSTMENT OF VENTILATION

In all patients ventilation is adjusted to try to achieve and maintain a mixed venous carbon dioxide tension as near normal as possible. The minute volume is recorded every half-hour with a volumeter, e.g., Wright's respirometer or Dräger volumeter. In conscious patients with normal lungs this may be compared with reference to the Radford nomogram (Radford et al., 1954). The suitability of the selected minute volume is checked once or twice a day by an estimation of mixed venous carbon dioxide tension. The method used is a modification of the rebreathing technique of sampling alveolar gas (Plesch, 1909; Scurr, 1956) and its subsequent analysis, using a portable Dräger carbon dioxide analyzer (Taylor, 1964). It is in the large group of unconscious patients, especially those with pulmonary disease, that frequent estimations of the mixed venous carbon dioxide are required to judge the efficacy of the artificial ventilation.

This simple rebreathing method has been adequate to control the level of ventilation for periods of up to several months and in patients with severe lung disease. In a few patients it has been thought desirable to check the analysis by arterial sampling. In only one patient was there a clinically significant discrepancy. This patient had a large lung abscess which was demonstrated at autopsy.

GENERAL MANAGEMENT

Medical and nursing care.

Patients are now admitted under the care of a physician or surgeon to a specific respiratory unit ward. The nursing staff on this ward have had considerable experience in the management of unconscious patients and in the care of patients with tracheostomy and receiving artificial ventilation. It has proved most unsatisfactory to nurse these patients in various wards at different times or at the same time, as the centralization of trained attendants and equipment is essential. No patient being artificially ventilated is left without personal supervision either by day or night.
Table II

**Special respiratory unit chart completed for twelve hours. There is a gummed edge to join the charts in series.**

**RESPIRATORY UNIT CHART (12 Hours)**

<table>
<thead>
<tr>
<th>Frequency of Duty</th>
<th>Expected Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly or P. R. N.</td>
<td>Suck trachea and bronchi</td>
</tr>
<tr>
<td>Hourly</td>
<td>Rate of pump 16</td>
</tr>
<tr>
<td>Hourly</td>
<td>Airway + 12</td>
</tr>
<tr>
<td>Minute</td>
<td>Pressure 3</td>
</tr>
<tr>
<td>Hourly</td>
<td>Volume 6 - 8 litres</td>
</tr>
<tr>
<td>Hourly</td>
<td>Release cuff for 2 min.</td>
</tr>
<tr>
<td>Hourly</td>
<td>Re-inflate with 5 ml.</td>
</tr>
<tr>
<td>Hourly</td>
<td>Oxygen flow to ventilator 5 L/min.</td>
</tr>
<tr>
<td>Hourly</td>
<td>Nebulizer 1 ml. 0.1% isoprenaline</td>
</tr>
<tr>
<td>Hourly</td>
<td>Humidifier temperature 50°C</td>
</tr>
<tr>
<td>Hourly</td>
<td>Patients Colour</td>
</tr>
<tr>
<td>Hourly</td>
<td>Turn patient</td>
</tr>
<tr>
<td>Hourly</td>
<td>Oral Toilet</td>
</tr>
<tr>
<td>P. R. N.</td>
<td>Physiotherapy</td>
</tr>
<tr>
<td>Remarks</td>
<td>9.40 a.m. Patient tried off ventilator for 4 min. on O2</td>
</tr>
</tbody>
</table>

**A.M. NAME** Miss Joan Smith

**WARD** Burdett

**DATE** 12/11/61

**Hospital Number** X 1234

**ANESTHETIST ON CALL** Dr. Jones

**ROOM TELEPHONE NO.** 325

**BUZZER NO.** 60
EXPERIENCE WITH PATIENTS TREATED WITH ARTIFICIAL VENTILATION

siderable responsibility falls upon the nursing staff and a resident anaesthetist must be available for advice and assistance at all times. Printed instructions are issued to the nursing staff. These indicate the relevant principles involved in this specialized form of patient care. A special respiratory unit chart (Table II) has been developed on which the instructions and timing of nursing duties are indicated. This chart does not include observations which are made on routine hospital charts (for example, pulse rate, blood pressure and fluid balance) so that wasteful duplication of recordings is avoided. The chart is a valuable record of nursing duties and provides continuity when there is a change of staff.

The patient’s specific treatment is managed by the physician or surgeon in charge, together with the otolaryngologist and the anaesthetist. The anaesthetist’s role is to perform such duties as are necessary to maintain the patient’s life while medical or surgical treatment is being carried out. Therapy, nursing duties and physiotherapy must be synchronized for the maximal benefit and minimal exhaustion of the patient.

Ventilator management.

Conscious or semiconscious patients usually settle to the machine’s respiratory rate quite quickly, provided that the minute volume delivered is adequate. If they do not synchronize their respirations with the machine, sedatives are given. Drugs that have been suitable are phenobarbitone sodium 180 mg, pethidine 50 mg, morphine 10 mg, and papaveretum 20 mg. These are given by intramuscular injection, or if a more rapid effect is required half doses are given slowly intravenously. A combination of phenobarbitone sodium 180 mg and perphenazine 5 mg has been successful in some patients. The drugs are repeated as often as required provided that the blood pressure is not below 90 mm Hg systolic. Patients with raised carbon dioxide levels usually accept artificial ventilation. The most difficult patients in whom to establish artificial ventilation have been those with cerebral irritation. One patient continued to resist artificial ventilation in spite of 20 ml paraldehyde and 100 mg pethidine. Sodium amytal and d-tubocurarine were ultimately required but even then the effect was not prolonged.

Different patients stabilize at different alveolar carbon dioxide levels. The level may be above normal in some patients with chronic lung disease. Realization that it will not always be possible or advisable to reduce the mixed venous carbon dioxide level to 46 mm Hg may avoid unnecessarily prolonging the period of artificial ventilation.

Patients are weaned off artificial ventilation slowly, starting with 5 minutes every hour or two and increasing this gradually over days if necessary to 20 minutes every half-hour. Especially in the tentative early stages without ventilation it is wise to give an oxygen supplement to minimize the risk of hypoxia. Moistened oxygen or oxygen and air are led through wide-bore tubing from either a blower-humidifier or an atomizer to a mask or plastic box over the tracheostomy tube. Precautions are taken with regard to flow and size of reservoir mask or box to prevent undue re-breathing. At first ventilation is resumed at night. This allows a sedative to be given with safety and a good night’s sleep is thus ensured. After two successive days without the aid of the ventilator its use at night is abandoned. The conscious sensible patient is a good judge of when he requires to return to artificial ventilation. The ventilator should not be removed from his room until he is fully recovered as suddenly removing the machine from the room may induce a feeling of panic in the patient. Care must be exercised in conversation in front of patients who may be paralyzed but mentally alert (Fairley, 1961).

DISCUSSION

Use of artificial ventilation.

During the past few years fifty patients with respiratory failure have been treated by artificial ventilation with an overall mortality of about 50 per cent. Death has been due in most instances to progression of the disease process which precipi-
tated the respiratory failure. A few patients had irreversible brain damage which failed to respond to any form of therapy. Some of the other fatalities may have been preventable in the light of later experience and these cases have been discussed in some detail.

Artificial ventilation was only used when all other forms of more conservative therapy had failed. It is probable that the majority of the patients who survived would have died from respiratory failure if artificial ventilation had not been used. These patients are best treated in a simple respiratory unit with trained nursing and medical staff. Only in this way can the mortality of ventilator treatment itself be reduced. With increasing experience and familiarity these very ill patients can be successfully managed with quite simple biochemical control and a minimum of expensive apparatus provided that adequate medical and nursing supervision is available.

**Barbiturate overdosage.**

Treatment has been most successful in the group of patients suffering from barbiturate poisoning. This should be a completely recoverable condition provided that the patient has not suffered from the effects of prolonged hypoxia or hypotension. Very few of these patients require artificial ventilation. Either a dose insufficient to precipitate respiratory failure has been taken or the dose has been so massive that death from hypotension and respiratory depression has occurred before the patient is discovered. The ten patients treated by artificial ventilation, therefore, represent only a small proportion of the patients admitted with barbiturate-induced coma. There were two fatalities.

**Case No. 13.**
A woman of 76 years arrived in a very poor condition with a temperature of 91°F. Ventilation was required for 36 hours and, although adequate spontaneous respiration returned, she never recovered consciousness and died two months later.

**Case No. 14.**
A patient was admitted from another hospital, deeply unconscious, having fixed dilated pupils, and having taken massive doses of drugs including at least 120 grains (8 g) of barbiturates. She required large doses of vasopressor drugs and artificial ventilation, but died three days later. At autopsy the findings included bronchopneumonia, hepatic and renal necrosis.

Blood barbiturate levels have not been found to be as consistently helpful in assessing prognosis as was at first anticipated (Wise, 1958). One patient required artificial ventilation with a blood barbiturate of 2.5 mg per cent (as phenobarbitone), while another was almost fully conscious with a level of 11.5 mg per cent (as phenobarbitone). The patient who takes barbiturates habitually develops a very high tolerance to the drug. In other patients the barbiturate effect may have been potentiated by alcohol.

**Cardiac arrest and direct brain damage.**

Two of the patients with cardiac arrest were subsequently discovered to have taken an overdose of barbiturates. Both patients were apparently dead upon admission but were successfully resuscitated by internal cardiac massage. Both required artificial ventilation and vasopressor infusions to maintain life.

**Case No. 15.**
The first patient was cooled for five days after he developed convulsive fits and required six days of artificial ventilation. He never recovered consciousness and died six weeks later.

**Case No. 16.**
This patient had a temperature of 91°F on admission and was allowed to rewarm slowly. After 36 hours of artificial ventilation she was able to maintain adequate spontaneous respiration and soon regained consciousness. Two days after regaining consciousness she had returned to her normal mental state and was later discharged to her former employment. She has since required plastic surgery to her tracheostomy scar.

In unconscious patients bipolar electroencephalograms have been of interest. The first patient had a completely iso-electric e.e.g. whenever it was taken; the second had a relatively normal e.e.g. when taken after 12 hours of artificial ventilation (fig. 6). Electroencephalographic recordings have been used to assess the cerebral damage of patients in long-term ventilation (Fairley, personal communication, 1961).

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Our experience is in agreement with Hunter (1960) that a patient who ceases to breathe as a result of direct brain damage will not recover unless there is a rapidly reversible localized condition, such as a subdural haematoma. All the patients who stopped breathing, either as a result of head injury or a cerebrovascular accident, died in spite of artificial ventilation. Before embarking
on ventilator treatment of such a patient, consideration of the site and nature of the lesion should be taken into account. Medullary damage is essentially irreversible.

**Chronic bronchitis.**

The most gratifying results of treatment by artificial ventilation have been obtained in patients who are respiratory cripples. In these patients ventilation of the lungs was instituted only when all other methods had failed. Many patients suffering from acute or chronic bronchitis associated with emphysema and cardiac failure are successfully treated by administration of oxygen together with a respiratory stimulant, or by tracheostomy. Patients who have not responded to these measures are very seriously ill. In spite of this, seven of eleven patients in whom ventilation of the lungs has been carried out have returned to normal life after treatment. It is very striking to observe the rapidity with which some of these desperately ill patients, deeply cyanosed, comatose from hypercarbia and hypoxia, with gross right heart failure, have improved on artificial ventilation with oxygen. Once these patients are adequately oxygenated, cardiac failure decreases, distended neck veins regress, the pulse rate falls, consciousness is regained and a large diuresis follows. The hypoxia induced by the pulmonary disease places an intolerable burden on the hypoxic myocardium working against an increased pulmonary vascular resistance. After this vicious circle is broken by adequate oxygenation the results are dramatic. In patients who have progressed to cerebral depression from hypercarbia, with its concomitant depression of the cough reflex and secondary central depression of respiration, tracheostomy and artificial ventilation with an oxygen-rich mixture can be lifesaving.

One of these patients returned to work with a permanent tracheostomy.

**Case No. 17.**

This patient was treated first in 1959 when ventilation was carried out for three separate periods of two days and he was discharged with a permanent tracheostomy. He returned with sputum retention and cardiac failure in 1962 when he again improved with five days of artificial ventilation.

The following death occurred.

**Case No. 18.**

This patient was rather exceptional in that the bronchitis had been treated with chloramphenicol which had led to aplastic anaemia. The patient also had steroid induced diabetes mellitus.

**Postoperative respiratory failure.**

Of the fourteen patients treated for postoperative respiratory failure eight died in spite of artificial ventilation, three others died subsequently from causes other than respiratory failure and three made good recoveries. The three successes all had surgery involving the chest wall. One is the child with eventration already referred to (case no. 10).

**Case No. 19.**

The second was a bronchitic man upon whom an extensive resection of stomach had been performed through a thoraco-abdominal exposure. Postoperatively spontaneous respiration was unsatisfactory and artificial ventilation was instituted for 24 hours when it was appreciated that air was leaking through the abdominal drain and diaphragm, causing a pneumothorax on spontaneous respiration. This was corrected with an underwater seal.

**Case No. 20.**

The third recovery occurred in a myasthenic patient who, following thymectomy, breathed well for only 36 hours. He was rested without neostigmine and artificially ventilated for three weeks. Over the next two weeks ventilation was gradually discontinued with the help of neostigmine.
Other postoperative pathological states included cardiopulmonary problems following open heart surgery, respiratory failure after lung resection, operative and postoperative cardiac arrest, post-adrenalectomy patients with lymphangitis carcinomatosa, and one patient with bronchopneumonia who made a good recovery but died three weeks later from myocardial ischaemia.

Peripheral causes.

Several patients with multiple rib injuries have been seen but only two have required ventilation. Both made a good recovery from this lesion although one of them, after twenty-four days of artificial ventilation, was disoriented and blind because of accompanying head injuries. Two other patients with peripheral respiratory failure required ventilation. A patient with disseminated sclerosis was respired until death some four months later, and a patient with myelomalacia of the cord had the fatal haemorrhage from erosion of the innominate artery during ventilator treatment.

Scope of artificial ventilation.

This series of fifty patients treated at Westminster Hospital over the past few years indicates the importance and scope of artificial ventilation in the treatment of respiratory insufficiency. Undoubtedly earlier experiences led to a reduction in the errors in technique and resulted in a greater proportion of successful results in the patients later in the series. Sixty-two per cent of the patients suffered from medical disorders which had failed to respond to more conservative therapy. There is a smaller percentage of surgical patients in this series compared with some other reports (Gilston, 1962; Norlander et al., 1961) because of the more rigid criteria used to define respiratory failure.

REFERENCES