EXPERIENCES OF AN ARTIFICIAL VENTILATION UNIT

BY

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SUMMARY

Early experiences in an artificial ventilation unit are described. Four beds are available, three in cubicles and one in a completely enclosed room. This last is used for cases requiring isolation. Treatment is supervised by a consultant anaesthetist and by the consultant physician or surgeon referring the case, and a member of the anaesthetic staff is always present in the unit. The nursing staff is experienced, and the nurse/patient ratio is at least 1:1. They monitor blood pressure, pulse rate, temperature, respiratory rate, minute volume and inflation pressure. Bacteriological examination of chest secretions and urine is performed daily and chest radiography, serum electrolyte determinations and haematological examinations are performed regularly. Blood gas analysis is being used with increasing frequency. The case records of the first 160 patients, divided into seven categories, have been examined, and their treatment described. It is concluded that the best results are obtained in patients suffering from crush injuries of the chest, from respiratory failure due to drug overdosage, or from severe tetanus. The results obtained in the postoperative group are disappointing.

The need for a centralized artificial respiration unit in a major hospital is now fully accepted and for the past four years such a unit has been available in the Royal Infirmary, Edinburgh. Accommodation has grown from makeshift beginnings until there are now three beds arranged in cubicles and a fourth in an adjacent single room, the last being used for patients who, because of infection or a need for absolute quiet, require complete isolation. Near by is a small biochemical laboratory with the facilities for blood gas analysis. This number of beds has proved adequate as the unit was designed to treat certain categories of cases requiring artificial ventilation over a relatively short period. Patients with, for instance, neurological or chronic respiratory diseases are commonly treated in other specialized units in the area.

The unit is in the administrative charge of the Director of the Department of Anaesthetics. Clinical responsibility for the care of the patients is divided between a consultant anaesthetist, who is on duty for a period of a fortnight, and the physician or surgeon referring the patient to the ward. The hour-to-hour patient care is provided by one of the registrar anaesthetists who is present in the unit day and night.

The nursing staff is under the supervision of the Operating Theatre Superintendent. The ward is in the charge of an experienced staff nurse assisted by seven or eight other nurses, either registered or senior student nurses, so that the nurse/patient ratio is always at least 1:1.

EQUIPMENT

There are three large ventilators in the unit—a Smith-Clarke, a Cape and a Barnet. The two former are volume-cycled and the last time-cycled (Mushin, Rendell-Baker and Thompson, 1959), but in all three the stroke volume is determined by the operator. The pressure indicated on the machine provides useful information. A rise in inflation pressure indicates an increase in resistance, commonly due to retention of secretions or to the patient fighting against the machine, while a fall suggests that there is a leak in the circuit. Although these machines work on different principles, changes in pressure have the same significance, and this greatly simplifies supervision by the nursing staff. A Bird assistor-controller is also available, and has been found particularly useful when assisted rather than controlled respiration is indicated. The day-to-day
EXPERIENCES OF AN ARTIFICIAL VENTILATION UNIT

575

maintenance of this apparatus is the responsibility of the anaesthetic technician. A Waters canister system is kept beside each bed to inflate the lungs in an emergency, during a period of chest physiotherapy, and, as a temporary measure, to overcome efforts at spontaneous ventilation prior to establishing mechanical ventilation. This has been found more convenient than attempts to run ventilators by hand.

All patients with a tracheostomy must be supplied with humidified gases to avoid drying of secretions. The method of humidification depends on whether artificial pulmonary ventilation is required and whether the gas used is stored (and therefore dry) or is room air (which contains some moisture). A completely dry gas requires more efficient humidification than does room air. Room air supplied through a Barnet ventilator can be satisfactorily humidified by a condenser-humidifier (Mapleson, Morgan and Hillard, 1963) consisting of a gauze screen which is warmed and moistened by expired gases and which in turn warms and moistens the inspired gas. If, on the other hand, stored air or oxygen is supplied to the Barnet, these dry gases are passed through a water tank. Efficient built-in heated water tank humidifiers are provided with the Smith-Clarke and Cape ventilators. When a patient is breathing spontaneously through a tracheostomy, similar considerations apply. The technique of humidification employed again depends on whether or not the inspired gases are absolutely dry. If a tank humidifier is used the work of inspiration is minimized by having a fan blow the gas towards the patients (Feldman and Monro, 1963). If secretions become very viscid 20 ml of sterile physiological saline injected into the trachea has greatly facilitated the subsequent aspiration of the secretions (Simenstad, Galway and MacLean, 1962).

Humidifiers may act as reservoirs of infection (Baker, Lucas and Seiber, 1963) and we too have isolated Pseudomonas pyocyanea on one occasion from a tank humidifier. Since then, the humidifiers have all been cleaned with isopropyl alcohol after use, and kept dry until immediately before they are next used, when they are filled with distilled water (British Medical Journal, 1964). Further testing has revealed no potentially pathogenic organisms. Tubing which passes between the ventilator and patient is cleaned and then autoclaved before re-use.

Until recently, cuffed rubber tracheostomy tubes have been used and both the James and Oxford patterns found to be satisfactory. It has been claimed that tubes made of polyethylene produce less tissue reaction than do those of rubber, but it proved technically difficult to seal the inflatable cuffs to the tubes. This problem has recently been overcome (Whittard and Thomas, 1964) and such tubes are now in common use in this unit. When mechanical ventilation is no longer needed a silver tracheostomy tube with a hole in its convex surface is substituted for the cuffed tube. This has the advantage that, while the tracheostomy still remains patent, the tube may be occluded temporarily and the patient can talk and become accustomed to the increased work of breathing through his upper airway.

Tracheal aspiration is carried out by means of sterile rubber catheters, several of which are kept in a covered tray beside each bed. Both Tiemann and straight catheters have been used in the past. Tiemann catheters can be directed towards the left main bronchus more readily than can straight catheters, but they are no longer used because they easily damage the mucosa.

MANAGEMENT

Several patients were admitted directly from other hospitals, but the majority were referred either from the out-patient and casualty departments or from a medical or surgical ward in this hospital. Patients were seen by a consultant member of the staff of the unit before acceptance and in each case the general condition and, in particular, the respiratory function, was assessed both clinically and biochemically. Patients who responded satisfactorily to such conservative measures as bronchoscopy and pleural drainage or who required a tracheostomy for the removal of secretions but did not need artificial pulmonary ventilation were not usually admitted to the unit but were supervised in the general wards of the hospital. In 142 of the 160 patients admitted to this ward mechanical pulmonary ventilation was required. Most of them showed clinical or biochemical evidence of respiratory failure, or had severe crush injuries of the chest.
The ease with which patients accepted artificial pulmonary ventilation varied greatly from case to case. Initial control over respiration was usually established by hyperventilation, often by hand in the first instance, and by the administration of suitable doses of opiates. These drugs have the advantage that they are not only sedatives and respiratory depressants, but also relieve pain which may be present (Griffiths, 1961). Muscle relaxants were only used when these methods were insufficient, because muscular paralysis in an alert patient may be unpleasant.

Routine monitoring of vital functions is carried out by the nursing staff. They keep records on a specially designed 24-hour chart, at intervals dependent on the state of the patient, of arterial pressure, pulse rate, temperature, respiratory rate, minute volume, and inflation pressure. On the same chart, spaces are provided for recording particulars of fluid intake and output, drugs administered, observations on the amount and nature of tracheal aspirate, and on the state of the central nervous system.

A number of routine investigations are performed. Chest radiography is performed on all cases as often as necessary, at least daily on first admission and with decreasing frequency if progress is satisfactory. It is invaluable both in the diagnosis and in the evaluation of the progress of chest wall and lung damage, of infection or collapse of lung and of a pneumothorax or haemothorax. Daily serum electrolyte estimations supplement records of fluid intake and output. Measurements of haemoglobin level and red and white cell counts are made at intervals because it has become apparent that many patients, particularly after injury or operation, become anaemic. This is corrected by transfusion or by giving supplementary iron. The early detection and treatment of infection is essential and bacteriological examination is performed daily on specimens of urine and on tracheal secretions and a swab taken from the tracheostomy wound. A specimen of blood is sent for bacteriological culture if there is the possibility of septicaemia. Blood gas analysis was mainly performed on admission and during the period of withdrawal of mechanical assistance; with the completion of the nearby laboratory more frequent monitoring is practicable.

Tracheal suction is carried out whenever the presence of secretions is suspected. This may be suggested clinically by obvious bubbling in the patient's chest, or by a rise in blood pressure or pulse rate (due to either hypoxia or carbon dioxide retention). Rise in inflation pressure, with possibly a fall in minute volume, is a further valuable sign. In order to minimize any adverse effects of suction such as asphyxia or total collapse of lung, suction is applied only during the withdrawal of the catheter (Rosen and Hillard, 1960). Routine chest physiotherapy is carried out twice daily, and more frequently if necessary. The principal technique employed is rib-springing during expiration and this is more effective in removing secretions when accompanied by vigorous hand ventilation using a Waters canister circuit. The frequency of bronchoscopy depends largely on the individual consultant's views. Some employ it whenever secretions are difficult to remove or pulmonary collapse occurs; others prefer to deal with collapse by physiotherapy and tracheal suction, reserving bronchoscopy for cases in whom these measures are unsuccessful. Some perform the procedure through the mouth, others through the tracheostome; some use general anaesthesia and muscular relaxation, others use heavy sedation.

The maintenance of adequate nutrition and a satisfactory fluid balance is essential to ensure a rapid recovery of these patients, who are often extremely ill. Guidance is obtained from recorded input and output figures and from regular serum electrolyte and urea estimations. A Portex nasogastric tube, size 16 to 20 F.G., is passed on admission, and aspiration carried out at 2-hourly intervals. As soon as little or no aspirate is obtained, nasogastric feeding is started, firstly with water, later with water and milk, and later still with Complan. Aspiration is continued at intervals, and, if there is evidence of gastric stasis, the volume of fluid given through the tube is reduced. Until an adequate volume of fluid is being administered by the nasogastric route, the balance of requirements is provided intravenously. As soon as possible, oral feeding is started, the patient being encouraged to take sips of water at first. We have found that a co-operative patient can eat a light diet remarkably successfully, despite the presence of a cuffed tracheo-
EXPERIENCES OF AN ARTIFICIAL VENTILATION UNIT

An adequate supply of vitamins is provided. In addition to the care of the tracheostomy tube and the use of artificial ventilation, an exacting task in dealing with the general care of these very ill and often helpless patients. The ends of the beds are removed to facilitate access. Prevention of bed-sores is a special problem and involves frequent turning of the patient, and if this is precluded by injuries a ripple mattress is employed.

Many of these very ill patients develop urinary retention which may be followed by infection or by the development of bed-sores should overflow incontinence occur. If urethral catheterization is employed to deal with retention, there is a risk of introducing infection, however much care is taken to prevent this. The usual policy is to catheterize any patient in whom urinary retention has occurred and is expected to persist for several days. A catheter is not usually inserted in patients likely to micturate normally in 24 to 48 hours, as for example, in many cases of barbiturate poisoning.

It is often difficult to know when to start withdrawing mechanical pulmonary ventilation. Our practice is based partly on previous experience with a particular type of case, and partly on an assessment of how far the recovery process has progressed. It is only by trial of spontaneous respiration that its adequacy can be determined in a particular patient, and at this stage blood gas analysis is especially useful. At first the patient is allowed to breathe spontaneously for 5 to 10 minutes in the hour, and over the next 2 to 4 days the duration of spontaneous respiration is gradually increased until the patient is without mechanical ventilation all morning, then all day, and finally day and night. In some cases the process of achieving independence of the ventilator may be protracted because great care must always be taken to avoid tiring the patient unduly lest his condition deteriorate.

PATIENTS TREATED IN THE UNIT

During the period under discussion, 160 cases were treated in the unit and it is convenient to describe them in seven groups as shown in table I. The largest groups consisted of patients with chest injuries (32 per cent) and with postoperative respiratory insufficiency (30 per cent). Other common reasons for admission were neuromuscular disorders, poisoning by drugs and parenchymal lung disease, which together represented 31 per cent of admissions.

Chest and lung injuries (table II).

In the period under review a total of fifty-one patients were admitted on account of severe injury to the chest and lungs. Patients with only minimal damage to the thoracic cage and lungs were usually treated conservatively in the general surgical wards, their progress being followed with the help of chest radiography and blood gas analysis when indicated. The consultant anaesthetist on duty for the AVU was often asked to advise on the management of such patients. Some, although initially considered to have only minor damage, later showed evidence of deterioration due to retention of secretions or to paradoxical movements of the chest and were transferred to the AVU for more intensive treatment including tracheostomy and artificial ventilation.

| Table I | Patients treated during the period under review. |
|-----------------|------------------------|-----------------|
| Total           | Survival               | Died            |
| Chest injuries  | 51                      | 44              | 7               |
| Postoperative   | 48                      | 17              | 31              |
| Neuromuscular   | 18                      | 11              | 7               |
| Poisoning       | 17                      | 15              | 2               |
| Lung disease    | 15                      | 11              | 4               |
| Postcardiac arrest | 8                      | 3               | 5               |
| Head injuries   | 3                       | 1               | 2               |
| Total           | 160                     | 102             | 58              |

<table>
<thead>
<tr>
<th>Table II</th>
<th>Chest injuries.</th>
</tr>
</thead>
<tbody>
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<td>All cases</td>
<td>Chest injury only</td>
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<tr>
<td>Survival</td>
<td>44</td>
</tr>
<tr>
<td>Died</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
</tr>
</tbody>
</table>
ation would be needed, it was considered more practical to keep them under observation in the AVU.

In one of these patients a tracheostomy was not performed, artificial ventilation being considered unnecessary in view of continuing satisfactory blood gas values. The other patient had had a tracheostomy performed prior to admission but artificial ventilation was not found to be necessary.

In most of the patients admitted because of a crush injury to the chest tracheostomy was performed and artificial ventilation instituted for at least a few days. Secretions can thus be readily aspirated from the respiratory tract, analgesics can be given freely without worrying about any resultant respiratory depression, and satisfactory healing of the fractured ribs can occur without resort to surgical fixation (Griffiths, 1961). Other important aspects of treatment included intrapleural drainage, which was carried out if pneumothorax or haemothorax occurred, and blood transfusion where necessary. Many of these patients were very ill, having sustained damage to other parts of the body. Bony injuries were very common and damage to abdominal viscera had always to be excluded. Laparotomy was performed in ten patients in the present series and in five of these a ruptured viscus was found to be present.

In table II this group of patients has been subdivided into those with a chest injury only, those with an associated minor injury, and those with an associated major injury. The term "minor injury" refers to a single fracture of a bone of an upper limb. "Major injuries" are more severe injuries, including fractures of bones of the lower limbs, fractures of the skull and damage to abdominal viscera. In many ways this is an unsatisfactory method of classification because it ignores the degree of damage to the thoracic cage and lungs. It is very difficult to assess the damage, however, and this may increase over the period of treatment. Despite the shortcomings of the method of classification the results show that among the nineteen cases with at the most a minor injury associated with the chest injury, there were no deaths, whereas of thirty-two patients with an associated major injury seven (22 per cent) died. The overall mortality was thus 14 per cent, which compares favourably with that of 76 per cent in a previous series of cases treated in this hospital (Griffiths, 1960).

In two patients death was due to traumatic aneurysm of the thoracic aorta. In one the aneurysm ruptured, but in the other the harmful effects were produced by pressure on a main bronchus and on the pulmonary veins with resultant pulmonary oedema and bronchopneumonia.

The lungs of one patient were extensively bruised and oedematous and it became increasingly difficult to maintain ventilation and oxygenation; death eventually occurred as a result of respiratory failure.

These three patients were all cases of "crushed chest with other major injuries" but, in fact, died as a result of their chest injuries. Another patient died of a pulmonary embolism, which occurred prior to admission. In two patients, death was principally due to infection.

This occurred in one case around the site of a gastric fistula, and in the other the sites of bilateral compound tibial fractures became grossly infected.

Another patient died as the result of a ruptured liver, complicated by pulmonary oedema, uraemia, bronchopneumonia and hypovolaemia.

Postoperative respiratory insufficiency (table III).

There were forty-eight cases in this group; seventeen (34 per cent) survived. Of the patients admitted from the cardiothoracic surgical unit three survived and ten died. All patients who have had open-heart surgery, and a number who have had other thoracic operations, are treated in the cardiothoracic unit, with assisted ventilation by means of the Bird ventilator, in the immediate postoperative period (MacRae and Masson, 1964). Only when these measures were ineffective, and the progress poor, were patients admitted to the AVU for controlled ventilation.

Twenty-one patients, of whom eight (38 per cent) survived, were admitted after abdominal operations. Respiratory insufficiency developed in three cases of chronic bronchitis, who all died. In three patients huge ventral hernias were repaired, and the patients were subsequently unable to breathe adequately; two survived and one died. Five cases died of severe peritonitis, and one died in hepatic coma after lienorenal anastomosis. Two patients who developed acute
renal failure died, and also one who had multiple pulmonary emboli.

**TABLE III**

<table>
<thead>
<tr>
<th>Thoracic</th>
<th>Open heart</th>
<th>Others</th>
<th>Abdominal</th>
<th>Others</th>
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</thead>
<tbody>
<tr>
<td>Survival</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Died</td>
<td>10</td>
<td>6</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>11</td>
<td>21</td>
<td>3</td>
</tr>
</tbody>
</table>

Two patients were admitted suffering from multiple injuries, but with no chest injury.

One of them was a miner who had been crushed between hutches and had injuries to the pelvic viscera and iliac arteries, and dislocations of his right sacroiliac and hip joints. Bilateral disarticulation was performed at the hips two days later, following haemodialysis, and he was admitted to the AVU because respiratory inadequacy became apparent. Gangrene of the muscular lining of his pelvis developed, accompanied by severe metabolic acidosis; death occurred three days later. Postmortem examination revealed acute renal tubular necrosis, pulmonary haemorrhages and multiple small brain haemorrhages.

The second man had fractures of both legs, pelvis and skull, and was admitted to the AVU because he developed pulmonary oedema following overtransfusion with blood and plasma. Artificial ventilation was carried out for seven days, after which he was returned to the orthopaedic ward for further treatment for his injuries.

**Neuromuscular diseases.**

This was a heterogeneous group, tetanus being the only disease which occurred on more than one occasion. For a hospital which serves an area in which there is a great deal of agriculture, the number of patients (five) admitted suffering from tetanus was remarkably low. The infectious diseases unit in Edinburgh has, in the same period, admitted only one other case, who was treated with chlorpromazine (Murdoch, personal communication, 1964). The diagnosis of tetanus was not made with certainty in the one fatal case. In all the patients with tetanus admitted to the AVU a tracheostomy was performed. The spasms were controlled by sedation in three cases; the other two patients required curarization and artificial ventilation.

One of these, a boy aged 16 years, was admitted with tetanus. He worked in a sawmill, and frequently cut his fingers. No single injury was clearly to blame for his illness. He was admitted to the infectious diseases unit with a history of dysphagia for 2 weeks and trismus for 1 week. Twenty-four hours later he required tracheostomy, curarization and artificial ventilation after two episodes of clonic movements associated with cyanosis. He was admitted that day, May 13, 1964, to the AVU. For 10 days after admission he had a severe ileus and attacks of vasospasm were noted to occur at intervals, alternating between all four limbs and associated at times with a tachycardia and hypertension. These phenomena were thought to be associated with his tetanus. Three attempts were made to reduce the amounts of curare used, but only after 18 days was it possible to discontinue this and allow spontaneous respiration, the condition then being controlled by 12 grains of phenobarbitone and 250 mg of promazone in 24 hours. These drugs were slowly reduced in amount and none was needed after 31 days in the ward. At no time was there infection of his respiratory or urinary tracts. When discharged he had good power and movement in all limbs, but required some assistance when walking, and his jaw was still a little stiff but rapidly improving.

One case each of eclampsia, disseminated sclerosis, alcoholic neuritis, myasthenia gravis, status epilepticus (probably secondary to virus encephalitis), and thrombosis of the middle cerebral artery, were successfully treated as was one patient the cause for whose respiratory paralysis was not found. Single, fatal, cases of neuromyelitis optica, subarachnoid haemorrhage, ascending myelitis, cerebral venous thrombosis, amyotonia congenita and massive midbrain haemorrhage were cared for in the unit.

**Poisoning (table IV).**

The seventeen patients treated in this unit for an overdose of drugs represent only a small proportion of such cases entering the hospital, as most of them are cared for in a special ward.

**TABLE IV**

<table>
<thead>
<tr>
<th>Poisonings</th>
<th>Barbiturate</th>
<th>Salicylate</th>
<th>Barbiturate + Salicylate</th>
<th>Other mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Died</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

There they are nursed by an experienced staff, and drug elimination is accelerated, where indicated, by forced diuresis (Ohlsson and Frishedt, 1962) and by either haemodialysis or peritoneal dialysis. Attention is paid to the adequacy of the patients' airways and orotracheal intubation carried out where necessary. If respiratory insufficiency develops patients are admitted to the AVU, but only for such time as artificial ventilation is necessary.
Tracheostomy was performed in two cases shortly after admission in circumstances in which it would not now be considered either necessary or desirable. Present policy is that an orotracheal tube is left in position for 24 to 36 hours, after which time the situation is reviewed. In practice, most patients start to breathe spontaneously before this time has elapsed.

Four further cases, however, required a tracheostomy. In one a tracheostomy was required because a complication of oral intubation occurred.

This 37-year-old woman was admitted on August 5, 1962, having taken 70 to 80 tablets of butobarbitone, and with a serum barbiturate level of 8.6 mg per cent. The blood pressure was only maintained by the use of intravenous metaraminol, and she was apnoeic. The orotracheal tube was removed after 48 hours, but laryngeal oedema developed, and a tracheostomy was necessary. This was allowed to close after 5 days. The next day the patient was returned to the poisons unit, and from there was admitted to a mental hospital for treatment of her depressive illness.

Two patients were admitted on whom a tracheostomy had already been performed.

One had inhaled vomitus and his right lung had collapsed; cavitation of this lung developed later.

A child aged 16 months was given adult doses of salicylates for a fortnight because of "teething", and was admitted to the unit for care of a tracheostomy made to facilitate aspiration of secretions when a staphylococcal pneumonia developed; he died 18 hours after admission.

Tracheostomy was performed on one patient on the day after admission.

This patient had a high serum barbiturate level that persisted even after haemodialysis, and a long period of artificial ventilation was anticipated; mechanical pulmonary ventilation was needed for 5 days.

*Disease of the lung parenchyma.*

Fifteen cases are included in this category and, of these, eleven survived and four died. This high success rate is gratifying but it must be admitted that great care was taken in selecting cases in whom survival was thought possible. These patients were all in respiratory failure, most commonly as the result of an acute exacerbation of chronic bronchitis and emphysema.

One patient had a suspected virus pneumonia and survived after artificial ventilation for 13 days.

Another patient was admitted suffering from Good-
A healthy woman, aged 25 years, had an ovarian cystectomy performed under general anaesthesia. The operation and anaesthesia were uneventful until during observation because she was unconscious and spastic. The second patient, a woman aged 39 years, had a cardiac arrest during a dilatation and curettage operation performed because of a severe secondary post-partum haemorrhage. Internal cardiac massage and artificial ventilation resulted in a return of spontaneous cardiac activity but she remained deeply unconscious, spastic and apnoeic. She was transferred to the AVU, where artificial ventilation was continued until she died 6 days later. At no time did her condition improve. In this case the cardiac arrest was probably due to the combination of anaesthesia and hypovolaemia due to haemorrhage.

The causes of cardiac arrest in the remaining four patients were diverse.

One patient who was grossly uraemic had a cardiac arrest in a medical ward during a Jacksonian fit. He was admitted to the AVU after resuscitation but died later.

Another man had a cardiac arrest due to hypovolaemia and respiratory obstruction resulting from a self-inflicted throat injury. He too later died.

In a further patient the cause of cardiac arrest was uncertain even after postmortem examination.

A woman, aged 29 years, appeared to have been in good health up till April 7, 1962. On this day she had three syncopal attacks each lasting 2 to 3 minutes. She had a further attack on April 8 in the medical outpatient department. This was followed by a cardiac arrest due to ventricular fibrillation. She was resuscitated by external cardiac massage, artificial ventilation and external defibrillation. She was admitted to the AVU, deeply unconscious, breathing spontaneously through an oral endotracheal tube, but 7 hours later she had a further final cardiac arrest. Postmortem examination revealed pulmonary oedema, congestion of the liver and cerebral changes secondary to hypoxia. There was no clear indication of the cause of the cardiac arrest.

The last patient in this group had a chronic bronchitis and cardiac arrest occurred 30 minutes after the intravenous injection of morphine 15 mg and cyclizine 50 mg administered because he was believed to have had a myocardial infarction. His condition was satisfactory and he was discharged from the unit 10 days after the cardiac arrest.

None of the three patients who survived to leave hospital appeared to have sustained any permanent cerebral deficit.

Head injuries.

Patients who are admitted to this hospital with head injury are treated in the neurosurgical unit. If they develop respiratory inadequacy, they usually remain in that unit, under the supervision of the consultant anaesthetists who work in the neurosurgical service, and are subjected to a regime similar to that employed in the AVU.

Three such patients have been admitted to the AVU suffering from particularly severe respiratory insufficiency.

A racing motorist died 2 days after suffering extensive cerebral damage, and bilateral fractured ribs with lung lacerations and haemopneumothoraces.

A second man needed intermittent positive pressure ventilation for only 2 days after being admitted from another hospital following an accident in which he was knocked unconscious and had two ribs fractured. Exploratory burr-holes revealed no evidence of intracranial bleeding.

The third patient was struck by a falling rock. He was never unconscious, but suffered a depressed fracture of his right parietal bone. He developed pulmonary oedema and required artificial ventilation for 3 weeks. The cause of the pulmonary oedema was not established, but the possibility of a short period of traumatic asphyxia due to a crushing injury, with no rib fractures, was not excluded. Postmortem examination demonstrated that there had been momentary cerebellar tonsillar impaction and partial infarction of the medulla. There was also generalized cerebral atrophy.

Infection.

Respiratory infection, commonly by the *Staphylococcus aureus* or *Pseudomonas pyocyaneus*, is a common complication in patients treated in this unit, and Braid and Slawson (1965, in preparation) have noted a 75 per cent incidence among 100 patients. Careful bacteriological screening and prompt treatment have been most successful in preventing the serious consequences of such infections and of the thirty-nine patients who died, only seven were killed by infection (in five of these patients, the infection was present on admission to the AVU). In a further twenty patients, infection may have contributed to the fatal dence of myocardial infarction. His condition was satisfactory and he was discharged from the unit 10 days after the cardiac arrest.

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outcome. Tracheostomy and intermittent positive pressure ventilation is often a lifesaving procedure, and chest infection must be accepted as a penalty to be paid for survival.

Urethral catheterization is known to have been performed in 115 patients (records are incomplete in a number of others). Thirty-six (31 per cent) of these patients developed a urinary infection, commonly with \( B. \) \( \text{coli} \). Of fourteen patients known not to have been catheterized, only one became infected.

**DISCUSSION**

Since the pioneer work in Copenhagen, described by Lassen (1953) and Ibsen (1954), it has become common to treat patients with respiratory insufficiency by intermittent positive pressure ventilation. Like other workers (Fairley and Chambers, 1960; Safar et al., 1961) we have been impressed by the improvement in results when such patients are cared for in a special unit, staffed by experienced medical and nursing personnel.

A study of the literature shows that the relative incidences of the various causes of respiratory insufficiency vary widely from unit to unit, as shown in table V. Cases of crushed chest injury and of postoperative respiratory insufficiency provide the major part of the work of this unit. This is partly accounted for by the fact that other specialized units care for many of the patients who suffer from head injuries, from drug overdosage, or from chronic respiratory or neurological disorders.

A number of changes have taken place since the unit was established in March 1961. The present cubicalized accommodation was made possible by the acquisition of further space to supplement the original two neighbouring but unconnected rooms. The provision of a well-equipped laboratory near by has resulted in closer biochemical control, blood gas analysis being used much more frequently than in the early days. At first, medical cover was provided by informal arrangement between colleagues, but it was soon found more satisfactory to arrange duties of both consultant and junior staff according to a roster, which is made up whether there are patients in the unit or not. It is desirable that an adequately trained doctor be present whenever a patient is dependent upon a mechanical ventilator.

In general, the management of patients in the unit is similar to that reported from other centres (Fairley, 1961; Norlander et al., 1961; Spalding and Smith, 1963), but there are differences in detail. It is common practice in many units to deflate the cuff of the tracheostomy tube at intervals, in an attempt to avoid mucosal ischaemia. In order that their patients may speak, Safar and his colleagues (1961) sometimes leave the cuff only partially inflated. It is our custom to leave the cuff inflated because even though the nasopharynx be aspirated immediately before deflation some secretions lying immediately above the cuff may be aspirated into the lower respiratory tract. It is important that the cuff should be inflated only with the minimum amount of air necessary to provide an airtight seal. Serious complications of tracheostomy have occurred twice only. One patient developed tracheal stenosis, some weeks after leaving the unit; a cuffed tube had been

| TABLE V |
|-------------------------|---------|---------|---------|---------|
| **Percentage incidence of causes of respiratory insufficiency.** | Westminster¹ | Southampton² | Belfast³ | Toronto⁴ |
| Crushed chest | 4 | — | 3 | 10 |
| Postoperative respiratory insufficiency | 28 | 11 | 13 | 17 |
| Parenchymal lung disease | 24 | 9 | 15 | 27 |
| Poisoning | 20 | 13 | 17 | 18 |
| Neurological (including postcardiac arrest) | 22 | 29 | 27 | 22 |
| Tetanus | — | 23 | 27 | 22 |
| Head injury | 2 | 9 | 5 | 9 |
| Miscellaneous | — | 6 | 5 | 73 |
| **Total number of cases** | 50 | 62 | 200 | 204 |

¹ Robbie and Feldman (1963).
² Pearce (1961).
³ Dundee and Gray (1963).
⁴ Fairley (1961).
in place for 14 days. Another patient coughed out part of a tracheal ring 10 days after tracheostomy, while the tube was still in place. Robbie and Feldman (1963) avoid the use of tank humidifiers because of the possibility that they may act as a reservoir of infection. The writers employ these humidifiers and since adopting the technique described above for cleaning the tanks no potentially pathogenic organisms have been grown from swabs taken from the tanks either before or after their use.

The treatment of patients suffering from crushed chests differs from that of Reid and Baird (1965) who suggest that artificial ventilation should be instituted only in those cases where $P_{aCO_2}$ is raised. Blood gas analysis is undoubtedly of great value in the management of these patients, but it is thought that, when a tracheostomy has in any case been performed, there are no obvious disadvantages, and a number of advantages, in using intermittent positive pressure ventilation. Broken ribs are splinted and therefore much less painful; analgesics, if needed, can be given without fear of causing respiratory depression, and the work of breathing is reduced. Infection is very common in patients who have tracheostomy performed; its incidence is unaffected by the use of intermittent positive pressure ventilation.

The information given in this paper shows that the results of treatment in this unit varied considerably between the different groups of patients. The best results have been obtained in patients with a crush injury of the chest, with respiratory insufficiency due to drug overdosage, or with tetanus, whereas the results of the treatment of postoperative respiratory insufficiency have been disappointing.

ADDENDUM

Since this paper was submitted, a patient (number 217) developed a tracheo-oesophageal fistula, presumably due to the long-continued presence of a tracheostomy tube. She was a 21-year-old woman, with a twelve-year history of syringomyelia, who developed a severe chest infection with respiratory failure when the syrinx extended. She was artificially respired for 22 days and latterly required increasing amounts of air in the cuff of her tracheostomy tube in order to provide an airtight seal. She died of asphyxia when stomach contents flooded her airways. It has been suggested that this fistula may have been a trophic lesion.

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REFERENCES


LES EXPERIENCES D'UN SERVICE DE RESPIRATION ARTIFICIELLE

SOMMAIRE
On décrit les expériences antérieures d'un service de respiration artificielle. Il y a quatre lits, trois dans un box et un dans une chambre complètement close. Cette dernière est utilisée dans les cas où il faut l'isolement.

Le traitement est dirigé par un anesthésiste consultant et par le médecin ou le chirurgien consultant responsable du cas, et un membre de l'équipe des anesthesistes est toujours présent dans le service. Le personnel infirmier est entrainé, et le rapport infirmière/malade est au moins de 1/1. Elles surveillent la tension artérielle, le pouls, la température, la fréquence respiratoire, le volume minute et l'augmentation de pression. Des examens bactériologiques des sécrétions pulmonaires et de l'urine sont faits chaque jour, et une radiographie pulmonaire, le titrage des électrolytes du sérum et les examens hématologiques sont faits régulièrement. On étudie avec une fréquence croissante l'analyse des gaz du sang. On a examiné les observations des cent soixante premiers malades divisés en sept catégories, et on décrit leur traitement. La conclusion est qu'on obtient les meilleurs résultats chez les malades souffrant de traumatismes thoraciques, de défaillance respiratoire due à un surdosage médicamenteux, ou de tétanos grave. Les résultats obtenus dans le groupe post-opératoire sont décevants.

ERFAHRUNG MIT EINER ABTEILUNG FÜR KÜNSTLICHE BEATMUNG

ZUSAMMENFASSUNG

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(Chief Medical Officer, Scottish Home & Health Dept.)

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