THE WORK OF A RESPIRATORY UNIT IN A NEUROLOGICAL HOSPITAL

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THE management of respiratory failure in poliomyelitis has advanced by crisis rather than by planned progress. When the 1946 epidemic struck Great Britain, the supply of cabinet-type respirators was woefully inadequate, a situation from which we were rescued by the energy and munificence of Lord Nuffield, who produced large numbers of this type of respirator. A similar situation arose in Copenhagen in 1952, when 2,722 cases of poliomyelitis occurred in a period of five months, 316 of which had respiratory complications (Lassen, 1953). This crisis was not without benefit, because it led to the development of the method of treating respiratory failure by intermittent positive pressure respiration (IPPR).

The story of IPPR provides a fascinating chapter in medical history. Though it was developed in response to the problem of respiratory failure in poliomyelitis, it rapidly became apparent that it would be of value in a variety of other diseases. There are many conditions in which the primary lesion is potentially reversible, but in which death from respiratory failure is not uncommon. Examples are temporary muscular paralysis in polyneuritis and myasthenia gravis, obstruction of the airway in deep unconsciousness due to head injury and barbiturate poisoning, and impairment of the movement of the chest wall by the muscle spasm of tetanus or by extensive trauma. Attempts had been made to treat some of these conditions by tracheotomy and the use of a cabinet-type respirator, but the practical difficulties encountered when nursing seriously ill patients in a cabinet-type respirator led to it being used rather as a last resort than as a routine method of treatment. The introduction of IPPR, the establishment of special units to provide this treatment, and the increased awareness of the importance of preventing and treating respiratory failure has revolutionized the position.

The present paper describes the experience of the Batten Respiratory Unit since its inception in 1954. During this period 229 patients have been

TABLE 1
ANNUAL ADMISSION RATE OF PATIENTS WITH THREATENED RESPIRATORY FAILURE

Year	Males	Females	Total
1953 (Aug.-Dec.)	4	1	5
1954	11	9	20
1955	11	9	20
1956	9	14	23
1957	16	18	34
1958	19	22	41
1959	32	32	64
1960 (Jan.-Jun.) ..	12	10	22
Total ..	114	115	229

admitted to the Unit, the number admitted each year being given in Table 1. This shows that the demand for treatment has increased annually, and the scope and application of the treatment have become more widely known.

An indication of the many types of illness which may require the services of a respiratory unit is given by Table 2, which shows the diagnoses of the patients admitted to Batten Unit. The number of patients in each category is not a true measure of the incidence of respiratory complications, for the type of patient sent for treatment reflects to a large extent the fact that the Unit is situated in a neurological hospital. The picture in an isolation hospital has been described by Kelleher, Medlock and Powell (1956) and in a general hospital by Barber, Chambers, Fairley and Woolf (1959).

The first group in Table 2 contains those cases in which disease of the muscle or of the lower motor neurone produces muscular paralysis. This may affect only the respiratory muscles, producing the so-called spinal type of respiratory paralysis; it may affect the bulbar muscles (bulbar paralysis), thereby permitting the accumulation of secretions in the pharynx and their inhalation; it may produce a combination of the two, known as bulbospinal paralysis. Poliomyelitis is the best recognized member of this group, but polyneuritis is in many ways a more gratifying condition to treat, because in the vast majority of cases there is no residual disability (Bendz, 1955; Dreifuss, Hurwitz and John, 1957). Myasthenia gravis is ad-

TABLE 2
DIAGNOSES OF PATIENTS AND MORTALITY

	No. of Patients	No. Died	% Mortality
A.			
(1) Poliomyelitis ..	48	3	6
(2) Polyneuritis ..	39	10	26
(3) Myasthenia gravis ..	16	7	44
(4) Polymyositis ..	1	1	100
(5) Motor neurone disease	5	3	60
	109	24	22
B.			
(1) Encephalitis ..	13	4	31
(2) Meningitis ..	7	1	14
(3) Cerebral tumours ..	13	11	85
(4) Cerebrovascular accidents ..	49	26	53
(5) Brain stem lesions (multiple sclerosis) ..	8	—	—
(6) Head injury ..	1	—	—
(7) Barbiturate poisoning	3	—	—
	94	42	45
C.			
Spinal cord lesions ..	15	1	7
D.			
(1) Tetanus ..	3	—	—
(2) Status epilepticus ..	1	—	—
E.			
Chest conditions ..	2	1	50
F.			
Miscellaneous ..	5	1	20
	229	69	30

obvious indication for IPPR, for in severe cases, and in myasthenic crises, respiratory failure is the greatest hazard. The treatment of incurable conditions such as motor neurone disease seems inadvisable. The onset of a respiratory infection, or of carbon dioxide retention and narcosis, is often a blessed relief to the patient, and the artificial maintenance of life under these circumstances seems unwarranted.

The second group comprises those conditions in which acute cerebral disease or trauma involves the respiratory centre, either directly or indirectly by pressure, or in which loss of consciousness interferes with protective reflexes such as coughing and swallowing. Lesions in the brain stem are especially liable to these hazards. The eight examples of brain stem lesions listed in Table 2 were all believed to be due to multiple sclerosis, and made a good functional recovery. Cerebrovascular lesions and encephalitis may also be localized to the brain stem and patients frequently make a good recovery from their primary lesion.

The third group consists of lesions of the spinal cord which produce paralysis of the intercostal muscles, the diaphragm, or both. Transverse myelitis from its various causes, tumours

and trauma are examples. The respiratory paralysis is frequently reversible even in traumatic lesions. The acute injury may be associated with functional interruption of pathways in the spinal cord, either by oedema or because of spinal shock, and function may be restored if the patient does not perish meantime from respiratory failure.

The action of the respiratory muscles may be impaired, not only by paralysis but also by prolonged spasms. This may occur in tetanus and in status epilepticus. The latter can usually be controlled by the intramuscular injection of paraldehyde, but may require assisted respiration (Evanston, 1959). Paralysis of the respiratory muscles is induced by muscle relaxant drugs, and respiration maintained by IPPR (Honey, Dwyer, Smith and Spalding, 1954). A similar situation may arise following extensive injury to the chest wall. Expansion may be impaired by pain, or by mechanical difficulty, so that carbon dioxide retention occurs. An extensive thoracotomy, especially if accompanied by pulmonary infection, may produce the same result. Analgesics, narcotics and nerve blocks to reduce pain, combined with a temporary period of IPPR, which may be carried out through an endotracheal tube for periods up to 24 hours, may avert respiratory failure. IPPR has also been used in cases of carbon dioxide retention occurring when respiratory infection supervenes in a patient with chronic emphysema (Marshall, 1956), but new methods have now made this redundant (Campbell, 1960a, b).

Classification of the Respiratory Difficulty

Not all patients admitted to the Unit with threatened respiratory failure required definitive treatment by tracheotomy or assisted respiration. Table 3 shows that just under half were in fact so treated. The management of the remainder is, however, an important part of the work of a respiratory unit. Respiratory obstruction by secretions in the pharynx, or by inhaled vomit, can often be averted by nursing the patient in the semi-prone position with the head down, and by applying suction to the pharynx. If the latter procedure is to be done efficiently it requires considerable skill, which is best acquired by concentrating experience and facilities in a special unit. It is also difficult to decide in the early stages of an illness which patients are going to develop respiratory failure. Transfer of such patients to a unit in which they can be closely observed, and immediate action taken in case of failure, is better than waiting until they are already in failure.

The type of respiratory difficulty encountered in those patients who required definitive treat-

TABLE 3
TYPE OF RESPIRATORY ASSISTANCE GIVEN

	No. Treated	No. Died
Cabinet-type respirator ..	13	4
IPPR ..	61	22
Tracheotomy only ..	22	10
Endotracheal tube only ..	2	—
No definitive assistance ..	134	34
	232*	70

* Three patients were treated by cabinet-type respirator and IPPR.

TABLE 4
TYPE OF RESPIRATORY DIFFICULTY ENCOUNTERED IN PATIENTS GIVEN DEFINITIVE TREATMENT

	No. of Patients	No. Died
Spinal	30	9
Bulbar	18	7
Bulbospinal:		
Specific involvement of brain stem structures ..	38	12
Deep unconsciousness ..	6	6
Respiratory obstruction ..	3	2
	95	36

ment and the mortality of each type is given in Table 4. Patients with involvement of both bulbar and spinal muscles predominate. This combination is generally considered to be most lethal, but in this series the mortality was no greater than in the group with spinal respiratory paralysis, and less than in the pure bulbar cases. With such variegated material, however, comparisons are difficult. For example, of the seven patients with bulbar paralysis who died, three had extensive vascular lesions of the brain stem and three had neoplasms. In the latter group treatment was started at a stage when the primary diagnosis was still in doubt. The seventh patient had encephalitis. Likewise in the spinal group there were several examples of neoplasms which turned out to be inoperable and contributed to the high eventual mortality.

The possibility that the primary lesion may be irreversible is not a contraindication to tracheotomy and assisted respiration as long as the diagnosis remains in doubt. These patients are often admitted as emergencies and are already anoxic. It is difficult in these circumstances to ascertain the nature of the primary lesion, or to assess how much of the clinical picture is the result of the anoxia. The institution of respiratory aid permits an accurate diagnosis to be made. It is rare for the outcome to be a matter of regret,

because when the primary lesion is irreversible the patient does not usually survive as a chronic respiratory invalid. But when the primary lesion does not present acutely, as in motor neurone disease, the institution of respiratory aid is usually regretted as the patient may survive for many months in a distressing condition.

The Method of Treatment

When the Unit was opened in 1953 IPPR was still in the experimental stage. Though it was developed as a substitute, in a crisis in which cabinet-type respirators were in short supply, it was soon appreciated that it had definite advantages in certain situations. The management of bulbospinal paralysis in a cabinet-type respirator had always been unsatisfactory, and accompanied by a high mortality. This was because the strong negative phase sucked pharyngeal secretions into the lungs despite the most expert care. This danger had been met to some extent in the United States by adapting the neck fittings in cabinet-type respirators so that the patient could have a cuffed-tracheotomy tube inserted. But in Great Britain this method had never appeared very satisfactory. IPPR overcame this difficulty, and moreover greatly facilitated nursing and physiotherapy because of the ease of access to the patient.

Initially the use of IPPR was confined to patients with bulbospinal paralysis, but as experience has grown its use has been gradually extended. While it would be untrue to say that it has completely replaced the cabinet-type respirator, there is certainly less and less tendency to use the latter. This tendency is clearly reflected in the practice of the Batten Unit, where the cabinet-type respirator has not been used in the last two years. The trend is especially true of the management of diseases other than poliomyelitis. As has already been mentioned, the diagnosis of the primary lesion may initially be in doubt, and repeated neurological examination, lumbar puncture and radiographic investigation may be required, all of which are more easily carried out when the method of artificial respiration is IPPR. The relative mortality associated with the different methods of treatment cannot be compared in our series, because of the wide variety of conditions for which it was undertaken.

The Management of the Patient

The principles governing the management of patients receiving prolonged IPPR have been well described by Smith, Spalding and Russell (1954) and Kelleher, Medlock and Powell (1956). First and foremost is the necessity of early diagnosis, and the undertaking of tracheotomy and the

induction of IPPR as a planned event rather than as an emergency measure. A reluctance to recommend tracheotomy until a patient is cyanosed and in serious danger is still occasionally encountered. Tracheotomy in these circumstances may be extremely hazardous, for it may have to be performed as an emergency operation by an inexperienced person and anoxic patients are a poor anaesthetic risk. When the operation is carried out as a planned procedure by a skilled person the risk is negligible. The hazard of pulmonary infection through the tracheostome is much less than that of delaying tracheotomy until respiratory obstruction or failure are present.

The recognition of threatened respiratory failure is still a clinical problem, and lack of biochemical or physiological facilities is no handicap. Interference with respiratory function is first met by increased respiratory efforts on the part of the patient. The respiratory rate rises, the alæ nasi flare, speech comes in short bursts, and the accessory muscles of respiration are brought into play. These efforts suffice to maintain the normal level of blood gases, hence their estimation is no guide to the needs of the patient. Indeed, when the threat is mainly anoxic, the increased ventilatory efforts may reduce the CO_2 tension below normal, which may be quite misleading (Dickinson, Wilson and Graham, 1953; Wilson and Dickinson, 1954). Recognition by the clinician at the bedside that the patient is making excessive efforts to maintain respiration is therefore the best and earliest warning that respiratory failure is threatening.

When the increased effort on the part of the patient is no longer adequate to maintain normal levels of blood gases, anxiety, restlessness, inability to sleep and confusion appear. Certainly by this stage he requires assistance, and to wait until he becomes cyanosed, however slightly, is to wait far too long. Indeed, a case can be made for instituting assisted respiration at the first stage of increased, but adequate, effort because in poliomyelitis at least, motor activity at this stage aggravates the subsequent paralysis (Russell, 1947, 1949).

Once assisted respiration has been instituted the patient's respiratory efforts are no longer available as a guide to his state. Regular recordings of the blood pressure and pulse rate are of value, for retention of CO_2 is accompanied by a rise in both. But a method of estimating the CO_2 (Smith, Schuster and Spalding, 1959; Campbell and Howell, 1960) is of great value at this stage. The minute volume is set at a level which may be calculated from a nomogram (Radford, 1955), and subsequent adjustments made as required, usually by altering the stroke volume rather than

by changing the rate. In practice patients tend to be hyperventilated. This is because a level of ventilation which maintains the blood gases within normal limits is uncomfortable for the patient who desires a greater degree of expansion of the lung (Opie, Smith and Spalding, 1959). The hyperventilation does not, however, appear to have deleterious effects.

There is one difficulty which may arise in patients whose respiratory failure has developed gradually, and who have become accustomed to high blood levels of CO_2 . The induction of assisted respiration quickly brings the CO_2 level down to normal, and this sudden change may be accompanied by profound hypotension and loss of consciousness (Joels, Hurwitz and Dreifuss, 1957). This is not due, as was at one time thought, to interference with the venous return to the right atrium by the positive pressure phase, for adding CO_2 to the air supplied by the pump rapidly restores the patient. If the amount of added CO_2 is gradually reduced over 24 to 48 hours the patient adjusts satisfactorily.

The general management of the patient is an important factor in determining recovery. The nursing and the physiotherapeutic care must be of a high standard. Feeding by intra-nasal tube needs care and patience, as a degree of paralytic ileus is often present in the conditions for which patients receive IPPR. Regular estimation of the electrolyte balance is required. Bladder function is frequently affected also, and may require an indwelling catheter with either regular irrigation or tidal drainage.

The greatest hazard is undoubtedly that of pulmonary collapse due to obstruction of a bronchus by mucus. Patients are unable to rid themselves of bronchial secretions except by suction via an endotracheal catheter. This must be carried out skilfully and persistently if the air passages are to be kept clear. When a patient receiving IPPR experiences a 'sudden collapse', though many explanations are often proffered, the commonest cause is in fact obstruction of a bronchus. In the series of chronic respiratory patients reported by Blossom and Affeldt (1956) seven of fifteen deaths were due to respiratory complications. In the present series there were ten deaths from pulmonary collapse following bronchial obstruction, one from obstruction of the tracheal tube, and one from multiple abscesses.

Infection increases the risk of bronchial obstruction, hence every measure to minimize infection must be employed. Foremost among these is good physiotherapy applied to the chest at frequent intervals combined with posturing the patient between treatments so as to encourage drainage from the bronchi. The question of

prophylactic antibiotics is more difficult. Resistant strains of organisms appear readily, and may spread rapidly through a unit. It has therefore seemed best to us to rely primarily on avoidance of infection and the use of physiotherapy, and to reserve antibiotics for the treatment of an established infection which is known to be due to a sensitive organism.

When the patient begins to recover, the problem of weaning from the respirator arises. Short periods off the respirator, well within the patient's limits of tolerance and frequently repeated, appear to be the best method of gaining his confidence. The duration of the periods can be extended gradually until the patient is no longer receiving artificial respiration. The next step is to replace the tracheotomy tube by one of smaller bore, and to release the cuff. Later the tube can be corked, but left *in situ* until it is apparent that the patient can effectively clear his bronchial secretions unaided. At this point the tube can be finally removed. With patients whose power of coughing is seriously impaired this is a critical stage, and reinsertion of the tube may be necessary, but

with patience the tube can usually be removed. A small percentage of patients never become independent of a respirator, but some of these are able to return home either with a cuirass type of respirator or with a mobile IPPR machine (Desmarais, Alcock and Hildes, 1956). Four of the present series have done this.

The development of an effective vaccine against poliomyelitis makes it likely that artificial respiration will be required less and less for the treatment of this disease. But, as the experience in the Batten Unit has shown, artificial respiration, and especially IPPR, has a wide application outside the field of poliomyelitis, and, when used with discretion and efficiency, can be a valuable adjunct to therapy.

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