

## RESPIRATORY MANAGEMENT IN ACUTE TRAUMATIC TETRAPLEGIA

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THROUGHOUT the world, the majority of patients with acute traumatic tetraplegia are managed in the surgical, neurosurgical or orthopaedic wards of General Hospitals. They may later be transferred to Spinal Injuries Centres, but in the initial stages their care rests in the hands of those who see such cases only occasionally, and who cannot be fully familiar with their detailed management. As a consequence, not only do results suffer but there is little to be found in the literature concerning the complexities of the detailed management of the tetraplegic patient.

In the State of Victoria a unique opportunity is offered for the study of this problem by the presence of a large comprehensive Spinal Injuries Centre in a community which has a high cervical cord accident rate, the two main causes of which are motor-car accidents and diving accidents. All cases of spinal cord injury are admitted to this Centre, 70 per cent. within the first 24 hours of the accident. It is thus possible to discuss the respiratory management of the acute tetraplegic patient on the basis of experience which has been gained in the course of treating a consecutive series of 100 patients with acute cervical injuries, 91 of them with major spinal cord damage. These patients were admitted during the four-year period July 1959 to June 1963.

**Early Management.** In the earliest stages after the accident, and often prior to admission to a Special Centre, these patients are likely to vomit, and, seriously injured, lying supine, and with their ability to cough impaired by intercostal paralysis, they are particularly liable to the aspiration of vomitus and hence to the later development of pulmonary complications. To avoid vomiting it is suggested that, immediately the diagnosis of a cervical cord injury is made, a nasogastric tube should be passed and the stomach emptied. Furthermore, the majority of these patients will develop a paralytic ileus, and sometimes also an acute dilatation of the stomach. Accordingly, the naso-gastric tube should be left *in situ* and the stomach thereafter aspirated hourly. Oral fluids should be prohibited and an intravenous infusion commenced. It is not appropriate in this paper to discuss the details of the intravenous management in terms of fluid volume, electrolytes and calories, but the need to avoid overhydration must be mentioned. Tribe (1963) has drawn timely attention to the association of spinal shock in cervical lesions with apparent oligæmic shock and the consequent dangers of overtransfusion and pulmonary oedema. In the first 7 to 10 days these patients are in a phase of fluid retention, and a fluid intake of 1 litre per 24 hours (plus the replacement of the volume of fluid lost by gastric aspiration) is usually adequate.

**Assessment of the Patient.** When a patient with tetraplegia is admitted to hospital it is vital to assess his respiratory status at the earliest opportunity. Firstly must come a neurological evaluation, which will permit the distinction to be made between the patient who has a complete motor lesion and the patient whose motor

lesion is incomplete and has a more favourable prognosis. The patient whose lesion is complete will have total intercostal paralysis, but if the lesion is at or below the level of the sixth cervical segment the diaphragmatic innervation is intact and the prognosis accordingly more favourable. If the level is at the fifth cervical segment there is partial diaphragmatic innervation, and ventilation is materially reduced. With a level at the fourth cervical segment the diaphragm is deprived of its major segmental nerve supply and function is grossly impaired.

To follow the neurological evaluation, the patient must be assessed in relation to a number of highly important, but variable, factors. These must include associated thoracic injuries, pre-existing medical conditions such as chronic bronchitis or asthma, and the aspiration of either water or vomitus. Associated head injuries which are often present in the tetraplegic victims of motor-car accidents are also of major significance in the respiratory assessment.

This assessment should be complemented by a physiological assessment. Clinical features such as the patient's colour, the respiration rate and the use of the accessory muscles of respiration are a useful guide, but are alone inadequate. It is the practice to make initial and repeated estimations of the patient's respiration rate, tidal volume and vital capacity. For these latter estimations the Wright 'Respirometer' (British Oxygen Co. Ltd., 1959) is used. This instrument, in addition to being simple and convenient for bedside use, is also useful in that it may be used either with a face mask, attached directly to a tracheostomy tube or to the exhalation valve of the Bird Intermittent Positive Pressure Respirator.

In the management of these patients, clinical observation, assessment of respiratory function, serum electrolytes and arterial blood gas analyses are used. It is possible to assess a patient's respiratory status with some accuracy, to follow his progress, and also to take therapeutic action in anticipation of clinical deterioration.

It is opportune to emphasise that in these patients an impairment of respiratory function and a paralytic ileus frequently co-exist. For example, to determine whether the signs of a developing acidosis are due to carbon dioxide retention or to an electrolyte imbalance necessitates frequent and continued investigations.

If metabolic disorders of acid-base balance can be excluded, a rising serum bicarbonate or a rising arterial carbon dioxide tension are the most significant observations in assessing deterioration of respiratory function. Estimations of the arterial oxygen saturation have not been proved to be of great value in these patients.

**The Nursing Régime.** It is the usual practice in managing acute spinal cord lesions to turn the patient at two-hourly intervals throughout the day and night in order to avoid the effects of pressure upon the skin. However, the acute tetraplegic patient is often severely shocked, and these frequent and repeated manoeuvres have often been found to aggravate and prolong the shocked state. It is now the practice to nurse these patients initially on an alternating pressure air mattress (Drägerwerk, 1960) which is placed on the top of the standard pack bed (Guttman, 1959) and to leave the patient lying on his back, undisturbed, for the first 48 hours. It is then necessary to decide when the patient's general condition is sufficiently good to permit the commencement of turns, and when the dictates of his chest require his being turned to facilitate the drainage and aspiration of secretions.

The management of the chest is basically that of keeping the air passages free from secretions. The naso-pharynx is aspirated at frequent and regular intervals, drainage from the lungs being facilitated by alternately elevating the head and the

foot of the bed. Both physiotherapists and nursing staff must be skilled in the techniques of assisted coughing and of teaching the patient to achieve maximal inspiration by the use of the accessory muscles of respiration.

**Drugs.** To prevent infection, prophylactic antibiotics, in the form of penicillin, 3 mega units daily, and chloramphenicol, 1.5 g. daily, are used, and are usually administered continuously in the intravenous infusion. If, later, pulmonary infection should supervene, the antibiotics are changed according to the sensitivity of the organism.

Inhalations of a nebulised 1.25 per cent. solution of sodium bicarbonate are given prior to each aspiration of the naso-pharynx and each session of chest physiotherapy. The proprietary preparations 'Alevaire' and 'Tergemist' have been given an extensive trial, but have not proved superior to sodium bicarbonate. It should also be mentioned that when a patient is being given continuous assisted respiration with the Bird Respirator, sodium bicarbonate is administered continuously through the drip nebuliser which is fitted to this apparatus.

These inhalations prevent the dehydration of the bronchial mucosa, and assist in rendering the bronchial secretions less viscous. For the same purpose proteolytic trypsin derivatives may be given. The use of crystallised alpha-chymotrypsin by intramuscular injection and of oral alpha-chymotrypsin has been described by Teitel *et al.* (1960), Taub (1960), and Bruce and Quinton (1962). These drugs are now used as a routine, 'Parenzyme' by intramuscular injection of 1 ml. daily, or, later, when the patient is able to tolerate oral medication, 'Chymoral,' two tablets six-hourly.

Many of these patients have a lesion of the cervical sympathetic system, as evidenced by their development of a Horner's Syndrome and congestion of the nasal mucosa. The excessive secretions which result may be minimised by the four-hourly use of nasal drops such as 'Neosynephrine', 0.25 per cent. in isotonic buffered solution.

**Indications for Tracheostomy.** One of the most important problems in the respiratory management of the tetraplegic patient is that of tracheostomy. The performance of an unnecessary tracheostomy is to be deprecated, as the procedure has definite complications, but undue reluctance may lead to tracheostomy being performed too late, even irretrievably late. It is essential that the indications for tracheostomy in the tetraplegic patient shall be clearly understood and that the physician keep these indications in his mind, being prepared to perform the tracheostomy as a matter of urgency immediately it is indicated.

The present practice is to perform a tracheostomy if it should be indicated by one or more of the following features: (1) a neurological status which renders the patient unable to respire adequately and spontaneously, (2) the development of acute pulmonary complications, (3) the presence of associated chronic pulmonary disease, (4) the inability to deliver sputum into the mouth in spite of skilled physiotherapy, (5) the inability of the patient to co-operate with the physiotherapist by reason of coma, stupor, or exhaustion, (6) the clinical indications for bronchoscopy.

The indications for tracheostomy stem from the practical experience which has been gained in the treatment of acute tetraplegic patients. To illustrate this experience, a consecutive series is presented (Table I, pp. 256-257) of twenty patients,

all of whom had either complete lesions, motor complete lesions, or lesions which although motor incomplete, included total intercostal paralysis. The study of these patients included estimations of tidal volume and vital capacity made with a Wright Respirometer. It is felt that the following conclusions can be drawn from the series:

1. There are a few patients (*e.g.* Case 15) in whom there is immediate respiratory failure, and in whom tracheostomy and assisted respiration are a life-saving emergency.

2. There are those patients (*e.g.* Cases 2 and 19) in whom—without pulmonary complications—there is early evidence of respiratory insufficiency. The recognition of the early signs of respiratory insufficiency is vitally important, and demands urgent tracheostomy before either the patient becomes exhausted or pulmonary complications ensue.

3. In the majority of tetraplegic patients, respiratory function is adequate under basal conditions and in the absence of respiratory complications.

4. In these patients it is only if respiratory complications occur that tracheostomy is indicated (*e.g.* Cases 4, 10 and 11). Tracheostomy should then be performed urgently.

5. Even in motor complete lesions at the fourth cervical segment, tracheostomy is not necessarily indicated (*e.g.* Case 8).

6. In the absence of pre-existing pulmonary disease, old age is not necessarily an indication for tracheostomy (*e.g.* Cases 8 and 20).

It is certainly not possible to equate the level of the spinal cord lesion or the age of the patient with the necessity for tracheostomy, as is illustrated in the following case history:

A 76-year-old widow (Table I, Case 8) with mild congestive cardiac failure tripped in her backyard, and fell forwards, striking her head on the path. She became immediately tetraplegic, and lay, unable to move, until she was found 9 hours later. She was admitted to the Spinal Injuries Centre 11 hours after the accident. Examination showed her to have a complete sensorimotor paralysis below the fourth cervical segment, the result of hyperextension disruption at C4/5 in a spondylitic spine. The patient's general condition was very good, she was in no respiratory distress and she had a tidal volume of 360 ml. with a vital capacity of 850 ml. The patient's progress was entirely uneventful. There was no change in the level of the paralysis, and repeated estimations of the tidal volume gave readings between 310 and 340 ml. At no time were there any respiratory complications or embarrassment, and she remained in excellent general health until, 11 weeks after the accident, she died suddenly of a coronary occlusion.

In general terms, tracheostomy is never indicated as a routine, and each case should be fully assessed by all available means, and treated on its merits. In the absence of respiratory complications, the performance of a tracheostomy for the purpose of maintaining a clear airway is unnecessary, but in the presence of pulmonary infection the adequate aspiration of secretions may often only be achieved if a tracheostomy is first performed.

**Management of the Tracheostomy.** When a tracheostomy is performed for any reason it is the practice to introduce a cuffed tracheal tube, thus anticipating the possible necessity for assisted respiration. The tracheostomy should be made sufficiently large to take a No. 8 or 10 James tube, thus facilitating aspiration and ensuring that the stoma is large enough to permit the entry of a bronchoscope.

TABLE I

Case No.	Sex	Age (Yrs.)	Spinal Cord Lesion		Time Between Injury and Admission (Hours)	Tidal Volume (ml.)	Vital Capacity (ml.)	Tracheostomy	Time of Tracheostomy	Comments
			Level	Type						
1	M	20	C6	Motor Complete	12	200	1240	No	-	No respiratory complications. Patient survives.
2	M	18	4	Complete	6	100	350	Yes	12 hr. after admission	Respiratory insufficiency—tachypnoea. Patient survives.
3	M	49	5	Incomplete	13	350	1100	No	—	No respiratory complications. Patient survives.
4	M	25	5	Complete	4	350	1250	Yes	4th day	2nd Day—T.V. 300 ml., V.C. 700 ml. General condition satisfactory. Chest Clear. 3rd Day—I.S.Q. 4th Day—Collapse L.L.L., consolidation R.U.L.—Respiratory insufficiency. Tracheostomy. Patient survives.
5	M	18	6	Complete	1	320	1100	No	—	No respiratory complications. Patient survives.
6	M	22	6	Motor Complete	6	250	1150	No	—	ditto.
7	M	54	5	Incomplete	2	550	1600	No	—	ditto.
8	F	76	4	Motor Complete	11	360	850	No	—	No respiratory complications. Patient died suddenly of coronary occlusion at 11 weeks.
9	M	53	5	Complete	9	360	1400	No	-	No respiratory complications. Patient survives.
10	M	26	5	Complete	56	260	900	Yes	12 hr. post-accident	Tracheostomy performed at another hospital for difficulty in aspirating pulmonary secretions. Patient survives.
11	M	17	5	Complete	36	205	900	Yes	19th Day	Patient well till 19th day, when he developed bilateral bronchopneumonia. Rapid progression of respiratory insufficiency. Tracheostomy. Patient survives.

12	M	19	6	Motor Complete	9	490	1400	No	—	No respiratory complications. Patient survives.
13	M	19	5	Incomplete	25	405	900	No	—	ditto.
14	M	36	5	Complete	9	220	750	No	—	Pre-existing severe ankylosing spondylitis. No respiratory complications, or embarrassment.
15	F	13	4	Incomplete	3	45	—	Yes	Immediately on admission	Patient survives. Severe atlanto-axial fracture-dislocation, with a cord lesion virtually complete below C4. Admitted in acute respiratory failure. Urgent tracheostomy. After a stormy course the patient recovered spontaneous respiration and has made a good functional recovery.
16	M	68	7	Incomplete	3	330	1360	No	—	No respiratory complications. Patient survives.
17	F	15	7	Incomplete	3	200	1100	No	—	Associated injuries resulted in left pleural effusion. Patient survives.
18	M	60	4	Incomplete	5	650	1150	No	—	No respiratory complications. Patient survives.
19	M	17	4	Complete	9	300	850	Yes after admission	36 hr.	Gradual fall of T.V. to 180 ml. and V.C. to 500 ml. p. CO <sub>2</sub> rose to 34.5 m.e./l. Tachypnoea. Tracheostomy. Patient survives.
20	M	80	6	Complete	8	350	1300	No	—	No respiratory complications. Patient died of myocardial failure on 23rd day.

Whilst the performance of a tracheostomy may be a life-saving procedure, it is a procedure not without its own inherent dangers. Unless special precautions are taken to prevent infection, dehydration and trauma of the respiratory mucosa, a severe tracheo-bronchitis will follow. This problem is discussed by Grant *et al.* (1962), who describe a vicious circle of tracheo-bronchitis with dehydration, sputum retention and careless suction leading respectively to drying of the mucosa, infection of the bronchi, trauma and ulceration, with the perpetuation by these factors of a progressive tracheo-bronchitis.

Amongst the measures which are used to prevent a tracheo-bronchitis are: (1) the use of rigid aseptic precautions for tracheal aspiration, and the insistence that only adequately skilled nurses are permitted to perform this vital task, (2) the avoidance of over vigorous and excessive suction, (3) constant humidification of the inspired air or air-oxygen mixture, (4) hourly instillation of 1 ml. of sodium bicarbonate solution to facilitate hydration of the sputum, (5) six-hourly instillation of an appropriate antibiotic. In a spinal ward the prevailing organisms are commonly *B. Proteus*, *B. Coli* and *Pseudomonas pyocyaneus*, and these organisms frequently predominate in a sputum culture from the tetraplegic patient with a tracheostomy. Framycetin (Soframycin) is an appropriate antibiotic, and 2 ml. of a 20 per cent. solution in normal saline are instilled, (6) the cuff of the tracheostomy tube is not inflated unless intermittent positive pressure respiration is being employed, or unless unconsciousness permits gravitation of saliva.

**Assisted Respiration.** The tetraplegic patient may require assisted respiration either because of the extent of his respiratory paralysis, or because of the supervention of respiratory complications which further reduce his already impaired function.

Much thought has been given to the question of the most suitable respirator for the particular needs of the tetraplegic patient. The complexity of the medical and nursing task, with the need to consider such factors as the management of the fracture—dislocation of the cervical spine in various positions of skull traction, the need for repeated neurological examinations, frequent chest physiotherapy, nursing to avoid the effects of pressure, and the necessity to cater for gastric aspiration, intravenous infusion and the urethral catheter—all these added together combine to make the tank respirator unsuitable for the management of the acute tetraplegic patient.

The first alternative to be tried was the Bennett Intermittent Positive Pressure Respirator (Biggs, 1961), and this had the great advantage of being easy to operate and allowing complete access to the patient for all medical and nursing purposes. However, it has proved wholly unsuitable for use in patients who require totally assisted respiration for prolonged periods. The automatic cycling devices are only designed for short-term usage, and have failed on a number of occasions, leaving the unsatisfactory alternative of maintaining the patient by manual operation of the respirator.

A Bird Intermittent Positive Pressure Respirator (Mark 8) (Biggs, 1961) is now being used, and has proved completely satisfactory. It is robust, reliable and permits more accurate and flexible control of the patient's respiration than is possible with the Bennett Respirator. The addition of the negative pressure phase is regarded as an additional reason for considering this respirator more suitable.

**Bronchoscopy.** If a tetraplegic patient should develop an area of pulmonary collapse due to the blockage of a bronchus by a plug of sputum, or if it should be difficult to clear copious sputum by indirect aspiration, bronchoscopy and direct aspiration is indicated on theoretical grounds. But, in a patient with a fracture-dislocation of the cervical spine and a cervical spinal cord lesion, the necessary positioning to pass a bronchoscope through the mouth is highly dangerous. However, bronchoscopy may be performed through a tracheostomy stoma without the slightest movement of the head from the position of choice for the treatment of the injury to the cervical spine, and, from experience, it is now considered that bronchoscopy is an invaluable technique in the treatment of the appropriate pulmonary complications in the tetraplegic patient, but it must only be performed through a tracheostomy. If bronchoscopy is indicated in a patient who does not already have a tracheostomy, then a tracheostomy should be performed to permit the bronchoscopy and to permit the subsequent bronchial toilets which will almost certainly prove necessary.

**Results.** The management of the acute tetraplegic patient is a most difficult and exacting task, requiring the closest collaboration between doctors of various specialities, nurses and physiotherapists. The importance of the respiratory management is underlined by the fact that, of those patients who survive the immediate accident but die within the first few weeks, nearly all die from pulmonary complications.

It is difficult to obtain well-analysed figures for the mortality rate in acute tetraplegia, and, in particular, for the mortality rate which is directly, or largely, due to respiratory paralysis and its sequelae. It is also apparent that the only valid comparative figures are those for the mortality rate of patients with a complete spinal cord lesion.

Two series are suitable for comparison with the present series, those of Durbin (1957) and Norton (1962). These series are accurately comparable, and are also of value in that they illustrate the difference in the volume of experience which may be gained in a Spinal Injuries Centre compared with an orthopaedic service. This point returns to the argument made at the commencement of this paper (Table II).

TABLE II

	Durbin	Norton	Present Series
Period of time . . . . .	9 yrs.	9 yrs.	4 yrs.
Number of cases of cervical injury . . . . .	75	88	100
Neurological involvement . . . . .	42	41	100
Roots only . . . . .	16	6	9
Cord lesions . . . . .	26	35	91
Complete . . . . .	15	21	39
Incomplete . . . . .	11	14	52
Deaths . . . . .	15	4	17
Number of complete lesions . . . . .	15	21	39
Acute respiratory deaths . . . . .	14	3	7



However, it is submitted that even these figures do not give a true picture of the results which may be obtained in the treatment of the acute tetraplegic patient, and the manner in which results may be improved with experience. Accordingly, a separate analysis is made of the acute mortality due to respiratory failure in complete tetraplegia (Table III).

TABLE III  
Acute Deaths due to Respiratory Failure  
(complete lesions only)

Year	Cases	Deaths	Percentage
1959-60	10	5	50
1960-61	10	2	20
1961-62	13	0	Nil
1962-63	6	0	Nil
Total	39	7	18

This experience is at variance with the statement of Durbin (1957) that 'complete tetraplegia is nearly always fatal, death usually occurring from broncho-pneumonia with hyperpyrexia a few days after the injury'.

To obtain good results it is considered imperative that the tetraplegic patient be transferred to a Spinal Injuries Centre with a minimum of delay. It cannot be overemphasised that results are dependent upon a comprehensive plan of treatment, and upon a highly trained team of doctors, nurses and physiotherapists.

#### SUMMARY

1. A régime for the respiratory management of the acute tetraplegic patient is described.
2. Reference is made to a consecutive series of 100 patients with acute cervical injuries, and to the results obtained.

#### RÉSUMÉ

1. Le traitement des complications respiratoires dans les cas de tétraplégie d'origine traumatique.
2. Cet article comporte d'une part la description du traitement respiratoire dans les cas de tétraplégie traumatique aiguë. D'autre part l'auteur réfère à une étude portant sur 100 malades avec atteinte cervicale aiguë et les résultats obtenus.

#### ZUSAMMENFASSUNG

1. Die Behandlung der Atmungsstörungen bei akuten Tetraplegikern wird beschrieben.
2. Eine Serie von hundert Fällen mit akuter Tetraplegie und die Behandlungsergebnisse werden beschrieben.

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