circulatory systems is the Engström (1953) respirator. This machine has the advantage that it combines positive-pressure inflation with a mechanical compression of the lower aperture of the thorax during expiration. Because of this, a lower inspiratory pressure is effective, which is an advantage for the circulation. Bang's respirator shows some promise, but our experience is not yet sufficient to evaluate its usefulness during the acute phase.

There is no doubt that the Engström respirator should be used in the acute stage of respiratory insufficiency to minimize the risk of shock. This risk is especially high in the first week of the disease. Later it seems the circulatory system becomes adjusted to compensate for the positive pressure. If an Engström respirator is not available, correctly performed manual positive-pressure ventilation should be used.

After the acute phase a change may be made to any of the other methods of artificial ventilation.

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THE ANAESTHETIC MANAGEMENT OF PATIENTS WITH POLIOMYELITIS AND RESPIRATORY PARALYSIS

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In 1952 Denmark suffered from a severe epidemic of poliomyelitis. Not only was the number of cases high but the incidence of bulbar cases was higher than in any previous epidemic.

In the years 1934-44 76 patients were admitted with respiratory paralysis due to poliomyelitis and 80% of these died. At least 51 had bulbar poliomyelitis, and 48 (94%) of these died. The mortality was equally high in the following years.

In 1952 5,722 cases were notified, and 3,722 of these passed through Blegdams Hospital. In the period July 7, 1952, to March 2, 1953, 349 cases of respiratory and/or swallowing insufficiency were treated. Up to August 26 31 patients with respiratory paralysis were treated, and 27 of these died, 19 within three days of admission. This state of affairs, and also the fact that the hospital had only seven respirators and the epidemic was just beginning, made the situation catastrophic. It was necessary to look for new methods of treatment, and, at the suggestion of the anaesthetists, manual intermittent positive-pressure ventilation was introduced. This was by far the most commonly used method during the whole epidemic. The introduction of this type of ventilation was the beginning of large-scale co-operation between epidemiologists and anaesthetists in Denmark.

At an early stage the following measures were adopted in order to intensify the treatment and also

to improve the results: (1) Patients who were likely to develop respiratory complications were transferred to special wards for observation, and recording of blood pressure, pulse, respiration, etc. (2) Tracheostomies were done under general anaesthesia and cuffed tubes were used to seal the trachea from the pharynx. (3) Manual intermittent positive-pressure ventilation was carried out as a supplement to the respirators or instead of them. (4) Secondary shock was treated effectively.

The measures we adopted to solve our problems are not claimed to be ideal, but they may be of interest to others faced with similar circumstances.

Treatment of the Typical Patient with Respiratory Paralysis

It soon became evident that active treatment of the severely ill patient must begin before he arrives at the centre—the fever hospital—because these patients do not tolerate transport in the acute stage of the illness. Several times within the first months it happened that patients came to Copenhagen from provincial hospitals and had to be tracheotomized and ventilated before removal from the ambulance. From the experience of these desperate cases we agreed that the logical thing was to do the tracheostomy before transport, so that ventilation and aspiration could be done during transit. For this reason a team, consisting of an otologist, an anaesthetist, and a nurse, was ready at any time to fetch a patient to the centre by car or plane, with or without tracheostomy. All equipment for resuscitation, anaesthesia, and operation was ready, packed, in the admission centre of the hospital.

The period of observation may vary from a few seconds to several weeks. As we have mentioned, in some cases tracheotomy had to be done before they reached the centre; in other cases at the moment of arrival in hospital. At the other extreme were patients who never had to have tracheotomy, but who had to be watched closely in the observation wards for long periods.

The patients transferred to observation wards were those with (a) respiratory insufficiency, (b) pharyngeal paralysis, (c) a combination of these, and (d) rapidly ascending paralysis, in which respiratory or swallowing insufficiency could be expected to develop in a matter of minutes.

The aim of the minute-to-minute observation was to correlate clinical findings with laboratory values and thereby to obtain indications for the different types of treatment which could be offered—namely, postural drainage, mechanical respirator (tank or cuirass), tracheotomy, and tracheostomy with manual intermittent positive-pressure ventilation.

Where there was difficulty in swallowing we looked for secretions in the pharynx, and also got the patient to swallow a teaspoonful of water from time to time.

Respiratory insufficiency presents itself in the form of paralytic cough, weak or paradoxical excursions, and, in the later stage, excitement, confusion, elevation of blood pressure, and cyanosis. Further secretions may accumulate in the airways and atelectasis occur. It was of some value to follow the changes in vital capacity with a small spirometer, which could be used at the bedside.

The correlation between clinical observations and laboratory findings is mentioned in detail by Astrup *et al.* at page 780 of this issue.

The Tracheostomy

Indications for tracheostomy differ. In the deeply asphyxiated patient it is done as an urgent measure. Tracheostomy is carried out in the bulbar type with vagal paralysis if the airways cannot be cleared by suction and drainage; in the bulbo-spinal type with swallowing paralysis, and stagnation of secretions; in encephalitis, when the patient is excited or comatose or the respiration irregular with long periods of apnoea; and in respiratory paralysis,

where no mechanical respirator is available and intermittent positive-pressure ventilation is necessary. The main indication is therefore the patient's inability to clear the airways sufficiently or to secure adequate ventilation. In very ill patients tracheotomy could be done without anaesthesia, but with oral intubation and aspiration, and the anti-shock treatment could be instituted at the same time.

In the early period the tracheotomies were done under local analgesia. However, too many of the patients died during or after the procedure because of asphyxia due to aspiration from the stomach and also because they were not ventilated enough during the operation. For these reasons we now regard local analgesia as unsuitable in patients whose need for tracheostomy is urgent.

The majority of the tracheotomies were done under cyclopropane in a semiclosed to-and-fro CO₂-absorption system and with orotracheal intubation. The anaesthesia equipment was all standardized and allowed the set to be used for artificial ventilation, which is a great advantage where a large number of cases have to be treated at the same time. When orotracheal intubation is done a stomach tube is passed and the stomach emptied. In most patients this tube was left in for drainage and also for feeding.

In a few cases thiopentone-succinylcholine with nitrous oxide or oxygen or oxygen-ether anaesthesia was used, but most anaesthetists seemed to prefer cyclopropane, probably because one is able to assess the patient's spontaneous breathing soon after the operation.

It is very difficult to assess the anaesthetic complications. Cyclopropane is rapid in action and a potent agent, but its administration requires a certain amount of experience. It should be given only if a trained anaesthetist has his finger on the pulse all the time. Also, respiratory arrest will often take place as soon as the anaesthetic is administered and the patient ventilated with a sufficient amount of oxygen. For these reasons we cannot exclude the possibility that some of the circulatory complications are due to the anaesthetic or the technique, but this is not the general impression.

Intubation is often difficult owing to the secretions and to the fact that it is preferable to do it under light anaesthesia.

When the patient is anaesthetized, the endotracheal tube in place, and the stomach tube introduced, there is ample time to carry out the tracheotomy. High tracheotomy was performed in all cases to allow the tube to be placed high enough in the trachea to avoid accidental displacement of its tip into the right main bronchus, which might lead to atelectasis of the left lung. The cuffed tube and the to-and-fro equipment are illustrated in the Diagram.

Once the tube is in place all kinds of complications may occur (sliding up and down, going against the wall, obstruction from secretions, splitting of the tube, etc.); this is demonstrated by the fact that the otologists had 1,500 emergency calls in a period of four months only, in the hours between 7 p.m. and 7 a.m.

In a few cases tracheotomy was carried out while the patient was in a tank respirator. We feel that he should be out of the respirator while the operation is being done, because the technical difficulties of anaesthesia and operation are so many when one has access only to the patient's head and neck.

Surgical complications were extremely rare. In most cases the tracheostomy was made easier because a tube was already in the trachea, making this structure easy to identify. In one case, however, this proved to be a disadvantage: a

gastric tube in an infant was mistaken for an endotracheal tube: the repair of the oesophageal fistula was easy later on. In a few cases there was profuse haemorrhage; we also saw two cases of pneumothorax, the aetiology of which was difficult to decide. The low incidence of complications may have had something to do with the fact that general anaesthesia was used and also that the tracheostomy was a high one.

The Period Immediately after Tracheostomy

This is often a critical time, and it is advisable to have the patient watched by an anaesthetist. A high proportion of the patients with obstructed airways will develop pulmonary oedema, especially if gastric contents have been aspirated into the bronchi. For this reason it is wise to assist the respiration in the first few hours after tracheostomy and to increase the pressure in the bag slightly if there is any suspicion of pulmonary oedema.

The most important factor in the treatment of pulmonary oedema is positive-pressure breathing. When that is done the usual precautions should be taken: the circulation should not be overloaded (if fluid must be given because of shock, it should be in the form of double-strength reconstituted serum). If the oedema persists, venesection is done, the posture is changed, and other usual measures are taken. It is well to remember that too high a pressure during inflation may in itself cause pulmonary oedema.

Respiratory Problems

This paper is not a comprehensive discussion of respiratory problems, since these are mentioned in detail in the paper by Dr. Astrup *et al.* (p. 780). However, it should be stressed that the rate of manual ventilation should be 16–25 a minute in adults and 20–30 in children, and that it should be carried out with due respect to sufficient ventilation and circulation. Inspiration is rapid (one second), and the pressure in the airways should always be allowed to fall to 0 in between respirations. The reservoir bag is kept half filled. The to-and-fro system is supplied with a mixture of 50–50 nitrogen and oxygen, which was found to be a satisfactory combination, the high oxygen percentage preventing anoxic anoxia, and the nitrogen preventing oxygen poisoning. In the period when pure oxygen was used a relatively large number of patients complained of a burning sensation behind the sternum, which may very well have been due to oxygen poisoning. The administration of pure oxygen may have had something to do with the development of atelectasis, but it is difficult to prove this.

The flow of gases is usually held at 5–6 litres a minute and the system is semiclosed. By avoiding the closed system one gets the full benefit of the "buffering" of the canister and bag, which is of real value when ventilation is carried out by persons who have had only a short period of emergency training.

The great advantage of manual ventilation is that access to the patient is easy; one can follow the movements of the thorax, take x-ray pictures, and superintend breathing exercises at any time. It is obvious that a patient in a tank respirator is less easily accessible, atelectasis will occur unnoticed and may persist, thus becoming more difficult to combat.

Suction from the bronchi and the pharynx was done routinely with catheters of the Nélaton and Tiemann type. The catheters were kept under bicarbonate or antiseptic fluid in separate jars. In patients without spontaneous respiration, suction should not take more than 15 seconds at a time and may have to be done in stages.

If this simple form of suction is insufficient to clear the bronchi, the tracheal tube must be removed and suction done direct through the tracheostomy with a catheter of larger calibre. Probably all tubes ought to be changed at regular intervals. This was impossible in this epidemic because of the many and various duties which had to be covered at all times.

In cases of persistent atelectasis, bronchoscopy has to be done one or more times. If the lumen in a bronchus

is obstructed by swelling of the mucosa it may be of benefit to blow oxygen on the obstructed part. It is safe to say that we became more and more conservative in regard to bronchoscopy as time went on, the general impression being that the amount of secretions increases after bronchoscopy. Tapotement and "squeezing" of the thorax seemed to have much greater effect, especially if suction from the bronchi was done simultaneously. Frequent changes in position are also of importance, to avoid atelectasis.

Problems of Organization

Previous to this epidemic no anaesthetist had ever worked regularly at the fever hospital. Now we were suddenly faced with the problem of recruiting a minimum of 40 persons trained in anaesthesiology who could cover the following field of work: (1) anaesthesia for the tracheotomies; (2) ventilation of tracheostomized patients; (3) cleaning of the lungs, treatment of atelectasis; and (4) treatment of shock. It took us only a few days to find that this work could not possibly be covered by the already functioning personnel without help from outside on a large scale. At one time during the epidemic, when 900 poliomyelitis patients had already been admitted, 75 patients were under manual artificial ventilation on the same day. For this it was necessary to employ 250 medical students to do the ventilation, 260 nurses from outside to sit at the bedside and attend to the patients' requirements, and 27 hospital workers to change cylinders and control the machinery: within these 24 hours 250 10-gallon (45.5-litre) cylinders were used.

The working plan of the anaesthetists was this. Each of the four big hospitals (the University Hospital, the Municipal Hospital, the Bispebjerg Hospital, and the County Hospital) covered a 24-hour period with its anaesthesia staff, under the direction of the senior anaesthetist, who spent the full period in the fever hospital. He did the anaesthesia and supervised his assistants. The latter, together with the epidemiologists and the otologists, supervised the medical students. Usually there was one anaesthetist in each of the three wards where the patients with respiratory and pharyngeal paralysis were treated. The anaesthesia staffs of the other Copenhagen hospitals (Finsen Institute, Orthopaedic Hospital, Municipal Chest Hospital) formed a very useful reserve.

At a relatively early stage it was decided to have lung physiotherapists working with selected patients who were apt to develop repeated atelectases. This arrangement proved very successful, and a total of 34 physiotherapists were active during the period of the epidemic. As previously mentioned, the procedure seemed most beneficial when physiotherapist and anaesthetist worked together.

It would take too long to go into details regarding the organization of the other groups of personnel. The organization and distribution of the patients were briefly mentioned in the introduction.

Technical Problems

When news about the epidemic had spread in Copenhagen equipment of all kinds poured into the hospital in a steady stream. It was soon found necessary to co-ordinate all these different types of material and also make an attempt to standardize the equipment. For this reason one man (an engineer) was appointed as consultant to the hospital. All requisitions went through him, and he, on the other hand, promised to procure the items with no delay. This system turned out to be a very good one.

The different types of respirator were supplied by various firms. A large number were borrowed from the other Scandinavian countries.

Equipment Around a Patient Under Manual Artificial Ventilation.—Oxygen cylinder with nitrogen and oxygen in 50% mixture. Reducing valve and flowmeter. Compressed-air cylinder with regulator, and injector suction aggregate. To-and-fro system (see Diagram) with two canisters and bag.

A special problem is the soda-lime for the canisters. Most preparations contain too much dust and present a potential danger of blowing dust into the patient's lungs. Actually only two preparations were suitable for use in this kind of treatment. Another problem was that the stores of soda-lime in Denmark were much too small to cover the demand, and we had to send for help from Great Britain, Sweden, and Norway several times: we got the help very promptly. It is estimated that about 100,000 blood-pressure measurements were taken during the five months, and there had to be a large number of B.P. cuffs in the hospital.

Anaesthetic Equipment.—Two anaesthetic machines, transportable, with suction; laryngoscopes with two blades; tracheal tubes in all sizes, with and without cuff; introducer for tubes; masks in three sizes; extra reservoir bags; airways of all sizes; suction catheters of different types with glass connexions; and stomach tubes. All equipment was kept in the operating-room, and was packed on trays and in boxes for immediate use in any part of the hospital where tracheostomies might have to be done. Furthermore, in each of the three wards an emergency set with equipment for manual intermittent positive-pressure ventilation and for intubation was kept. Finally, the admission ward was equipped with the previously mentioned complete set for the team which would go out to the provincial hospitals.

Conclusion

This report is an attempt to answer some of the questions of practical interest to those who will be concerned with the treatment of a large group of patients with poliomyelitis and respiratory and/or pharyngeal paralysis under emergency conditions. We have omitted the theoretical deliberations, which will all be found in the report under preparation and also in the paper which follows.

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EFFECT OF PHENYLBUTAZONE ON URIC ACID METABOLISM

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Phenylbutazone ("butazolidin") has been said to be effective both in acute gout and in the later chronic stages. Amongst the varied clinical effects of this drug such claims stand out as of particular interest. Kuzell and his colleagues (1952) found that it had "a marked analgesic effect" on the acute attack within a few minutes, and other workers have confirmed this (Kidd *et al.*, 1952). There is, however, considerable disagreement about its effect, if any, on uric acid metabolism itself. Most workers are agreed that lowered blood uric acid levels follow the administration of phenylbutazone. Kuzell *et al.* claimed a "striking diminution of serum uric acid in all patients treated," without, however, putting forward any data. There followed the interesting suggestion that this lowering of blood levels was not associated with a comparable increase in uric acid excretion in the urine (Kuzell and Schaffarzick, 1952; Engleman, 1952). Kersley *et al.* (1953), studying 14 cases of rheumatoid arthritis treated with phenylbutazone, could find no change in uric acid excretion, although they noted sodium retention. On the other