MANAGEMENT OF SEVERE RESPIRATORY INSUFFICIENCY ASSOCIATED WITH PAINFUL CONDITIONS IN THE THORAX OR ABDOMEN

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DURING the last few years the medical profession has been faced with an increasing number of cases of severe respiratory insufficiency associated with painful conditions in the chest or abdomen. There are two main reasons for this phenomenon. The first is the great advance in surgery and anaesthesia, which has enabled surgeons to undertake major thoracic and abdominal operations on patients with poor respiratory reserve, such as advanced emphysema or massive pulmonary fibrosis. The second is the increase in serious automobile accidents causing extensive damage to the thoracic cage.

The common denominator in all these cases is a lack of adequate ventilation. This might be due to the pre-existing pulmonary disease (e.g. emphysema, fibrosis), or to trauma to the chest wall with paradoxical respiration.

Pain from the thoracotomy or laparotomy wound, or from the site of fracture in a "stove-in chest," is a very important factor in restricting the patient's respiratory movements and causing further hypoventilation.

Bronchospasm, excessive mucus or blood in the tracheo-bronchial tree, the presence of marked haemothorax or pneumothorax and abnormal air/blood interface in the lungs all contribute, to a greater or lesser extent, to the picture.

ILLUSTRATIVE CASE

Mr. W. F., a 52-year-old white male, was admitted to the University Hospital, Saskatoon, on 13th of October, 1961, with marked difficulty in breathing. He has worked in a gold mine for 12 years, mostly underground, and has suffered from progressive dyspnoea and wheezing since 1940. Pulmonary tuberculosis was diagnosed in 1943, but no active treatment was given. He has done very little work since 1957. In 1960 he developed pneumonia and had a positive culture for tuberculosis, for which he was treated at the Sanatorium, being released in April, 1961.

On examination the patient was found to be dyspnoeic and wheezy, though in no acute distress. He was using all his accessory respiratory muscles, particularly during expiration, and showed all the signs of advanced emphysema. Respiratory rate: 20/min.; blood pressure: 170/90 mm. Hg; pulse rate: 80/min.

PREOPERATIVE INVESTIGATIONS

Chest X-ray. Marked emphysema, large emphysematous bulla on left lower lobe, old tuberculous lesion in right upper lobe.

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Ventilation studies

Expiratory reserve volume	1,020 c.c.
Inspiratory capacity	1,200 c.c.
Total vital capacity	2,220 c.c. (58% of predicted)
One second vital capacity	450 c.c. (20% of total V.C.)
Maximum breathing capacity	18 L./min. (16% of predicted)

Diagnosis. Obstructive ventilatory insufficiency, severe chronic pulmonary emphyse and emphysematous bullae.

Blood studies

Total plasma CO_2 content	21 mm. CO_2/L.
Haemoglobin	13.4 gm. %

E.C.G. Sinus rhythm, P pulmonale, left axis deviation, definitely abnormal curve.

PROPOSED PROCEDURE

Left thoracotomy, excision of emphysematous bulla, and elective tracheostomy. Operation scheduled for 1:00 p.m. on the 20th of October, 1961.

ANAESTHETIC MANAGEMENT

Patient was premedicated with meperidine 25 mg. and atropine 0.6 mg. Induction of anaesthesia was carried out with thiopentone 100 mg., nitrous oxide – oxygen and halothane, and the patient was intubated with a No. 11 Latex reinforced cuffed tube. Anaesthesia was maintained with nitrous oxide – oxygen and halothane with assisted respiration. No relaxants were used. The procedure lasted about four hours. Total blood loss was 3,000 c.c., total blood replacement 2,500 c.c. Patient left the operating room fully conscious and in good condition at 5:30 p.m.

POSTOPERATIVE MANAGEMENT

In the recovery room, the patient was connected to a Bird Mark 7® Assistor-Ventilator. Condition—very satisfactory.

0+1 day. Satisfactory. Respirator taken off at 4:30 p.m. Chest X-ray showed increased amount of fluid and infiltrations in left lower long, left pleural effusion, and considerable subcutaneous emphysema on left hemithorax.

0+2 days. 5:00 p.m.: Respiration very distressed. Vigorous tracheal suctioning produced a large mucous plug and respiration immediately improved.

9:15 p.m.: Respirations again very distressed. Marked surgical emphysema in thorax, neck, and face, including eyelids. Vigorous suctioning and bronchoscopy were tried without any improvement. Mechanically assisted respiration was tried for a few minutes and then stopped because the patient was very irritable and uncooperative and because of the marked increase of the surgical emphysema with the positive pressure. Isoproterenol, meperidine, and aminophylline were tried but without any effect on the severe bronchiolar spasm and respiratory distress. Patient was left fighting for breath for the rest of the night.

0+3 days. Patient very distressed. Rapid, weak pulse and extensive surgical emphysema.

7:00 p.m.: Slight improvement after changing chest tube. Patient very exhausted. Bird respirator reattached without too much increase in the surgical emphysema. Liberal doses of meperidine and pentobarbital given.

0+4 days. Patient extremely exhausted from lack of sleep, excessive expiratory efforts, and pain from the thoracotomy wound, despite the very high doses of pentobarbital and meperidine given throughout the night. Bird respirator stopped because of the patient's extreme irritability.

11:00 a.m.: A continuous epidural analgesia was decided upon. Epidural space canulated with the patient in the sitting position. Xylocaine 2 per cent, 25 c.c., with epinepherine was injected. This was subsequently changed to 2 per cent xylocaine without epinepherine,

because of the development of excessive tachycardia. A level of T_1 was achieved and maintained thereafter with hourly injections of xylocaine 2 per cent, 20 c.c., into the epidural space. Mechanically assisted respiration was restarted using the Bird ventilator and a cuffed James tracheostomy tube. Respirations and colour improved markedly. Patient became drowsy.

5:00 p.m.: Surgical emphysema substantially reduced. Occasional bouts of restlessness were easily controlled with small doses of pentobarbital.

0+5 days. Condition greatly improved. Surgical emphysema disappeared from face and neck.

1:00 p.m.: Epidural vinyl tube damaged. Patient became restless. Another epidural tube was inserted. Patient settled satisfactorily, except for occasional tremors in face and arms which were controlled with small doses of pentobarbital intramuscularly. James tube changed to a right-angled Oxford tube (only large-size tube available at the time). Patient seemed to be very well.

0+6 days. Uneventful. Patient in excellent condition. Chest X-ray showed no change.

0+7 days. Patient still doing well.

2:00 p.m.: Chest drainage tubes stopped working. Patient required increasing amounts of phenylepherine to maintain his blood pressure.

5:00 p.m.: Left side of the chest not moving at all with ventilation. Chest X-ray showed complete collapse of the left lung.

6:30 p.m.: Tracheo-bronchial suctioning and bronchoscopy were of no avail. Condition deteriorated very rapidly and patient became moribund.

7:00 p.m.: Colour very poor. Epidural catheter taken out. Patient left on assisted respiration and fast phenylepherine drip.

0+8 days. 1:00 a.m.: Epidural block completely wore off. Patient became restless and unmanageable. Meperidine in large doses produced no effect. Assisted respiration stopped because of continuous coughing. Patient allowed to breathe spontaneously through the circle absorber of a Boyle Anaesthetic Machine.

6:00 a.m.: Patient much quieter. Colour, blood pressure, and pulse markedly improved. Left hemithorax moving well.

8:45 a.m.: Mechanically assisted respiration started. Patient conscious and co-operative. Colour excellent and chest X-ray showed re-expansion of the left lung.

12:00 noon: Phenylepherine drip stopped. Blood pressure well maintained.

0+9 days. Condition continued to improve. All chest tubes taken out.

0+10 days. Excellent condition. Surgical emphysema completely disappeared. Venous blood sample showed pH 7.48, pCO_2 36 mm. Hg, oxygen saturation 70 per cent.

0+11 days. Improving. Patient showing dependence on mechanical respirator.

0+12 days. Patient taken off respirator for two hours. Walked around for 15 minutes.

0+13 days. Off respirator for 3 hours 30 minutes. Arterial blood sample taken at the end of period of spontaneous ventilation showed a pCO_2 of 58.

0+14 days. Off respirator for 6 hours.

0+15 days. Off respirator for 8 hours.

0+16 days. Off respirator for 12 hours. No change during the next two days.

0+19 days. Patient put on the respirator for 1 hour in 24 hours.

0+20 days. Patient breathing spontaneously entire 24 hours of the day. Patient discharged from the recovery room on the 14th of November (i.e., 0+25 days). tracheostomy tube still in place.

Tracheostomy hole completely closed on 14th of December, 1961 (0+55 days). Patient discharged on the 16th of December, 1961 (0+57 days).

Discussion

The suggested line of management is mainly as follows: (A) ensure a good airway, tracheostomy; (B) ensure adequate ventilation by: (I) mechanical

assistance of the patient's respirations using a sensitive ventilator, (II)[1] relief of pain with continuous epidural analgesia.

A. PATENCY OF THE AIRWAY

TRACHEOSTOMY

There is no doubt that a well-executed tracheostomy provides the best airway for a patient who is suffering from severe respiratory insufficiency, particularly if a mechanical respirator is to be used. The advantages of tracheostomy are:

1. Free and unobstructed airway at all times.
2. Reduction of the dead space by about 70 ml. in the average adult.[1]
3. Ease of assisting the patient's respirations by connecting him to a mechanical assistor.
4. Far better access to the tracheo-bronchial tree for performing adequate toilet.

However, it is very important to realize that tracheostomy has many disadvantages, restrictions, and complications. These may, indeed, lead to the death of the patient if the medical and nursing personnel attending him are unaware of them. They will be discussed here in some detail:

1. *Site of the tracheotomy.* Tracheotomies should be made as high as possible but not higher than the second ring. Many surgeons are unaware of the fact that a tracheotomy made for the purpose of inserting a cuffed tube to faciliate the mechanical assistance of the patient's respirations is not the same as a tracheotomy made just to ensure a clear airway, using the ordinary non-cuffed metal tube. A low tracheotomy always carries the risk of the tracheostomy tube entering one bronchus. This would probably not lead to any serious results when a non-cuffed metal tube is used, as it allows air to pass around it. When, a cuffed tube is used, however, the space around the tube is sealed off. This leads to the ventilation of only one lung, often with serious consequences. It is most frustrating to realize too late that an average-size tube cannot be used because it is too long, and that a smaller tube snaps out of the tracheotomy because it is not long enough.

2. *Size of the tracheotomy opening.* The largest possible opening should be made to allow the use of a large tube. Apart from the obvious advantages of having a larger airway with less resistance to respiration, particularly during the expiratory phase, a larger tube will fit the trachea more snugly, thus obviating the necessity of overinflating the rubber cuff. If, on the other hand, a smaller tube is used, the cuff must be overinflated to effectively seal off the trachea. This often leads to bursting of the cuff, necessitating the changing of the tube. This can be very harassing to the nursing and medical staff and expensive for the hospital.

3. *Type of cuffed tube to be used.* There are various types of cuffed tracheostomy tubes on the market. A gently curving tube with smooth walls is preferred by most people. Tubes with acute angles or wire spirals in their substance are rather unsatisfactory, as they make adequate suctioning of the trachea and bronchi difficult or even impossible. A right-angled tube was used for a period of 24 hours in the case described in this paper with the result that the patient was inadequately suctioned and developed a massive collapse of his left lung.

4. *Humidification of the inhaled air.* Inspired air, under normal conditions, is humidified and cooled or warmed in the nose by virtue of the very rich capillary network in the nasal mucosa. This function is completely abolished when a patient breathes through a tracheostomy tube. Apart from the obvious deleterious effects of dryness on the tracheo-bronchial mucosa and secretions, it must be emphasized that gas exchange between alveoli and pulmonary capillaries occurs only when these gases are in solution and it is conceivable that extreme dryness may interfere with gas exchange in the lungs, thus adding to the seriousness of the patient's condition.

5. *Tracheo-bronchial toilet.* This is one of the most important procedures in the care of these patients. It is unfortunate that many important details are often missed by the nursing staff, who are usually entrusted with this job. (*a*) The inflated cuff of the tracheostomy tube exerts a constant pressure on the tracheal mucosa, leading to devitalization and even sloughing. The cuff should be deflated every 4 to 6 hours for a period of 10 to 15 minutes, if possible. Furthermore, during this period, the patient will be able to use his vocal cords to communicate verbally with the nurses and doctors. This might seem to be an unimportant detail, but one must remember that it can be very agonizing to the patient not to be able to speak. (*b*) Intelligent use of the suction catheter is one of the advantages of having a tracheostomy. Excessive zeal, however, can do more harm than good. Prolonged periods of suctioning not only sucks blood and mucus from the trachea and bronchi, but also sucks air from the lungs. This can lead to a phase of acute hypoxia. Too frequent suctioning can cause trauma to the tracheal and bronchial mucosa and should be avoided. To avoid contaminating the trachea with acid gastric contents, the suction tube used for suctioning the trachea should never be used for suctioning the mouth. (*c*) Cuffed tracheostomy tubes should be changed at least once every 24 hours. It is often very tempting to leave alone a patient who is quiet and ventilating well, to avoid disturbing him by changing the tube. This invariably leads to an appalling accumulation of dried-up mucus and blood in the lumen of the tube, which in turn leads to poorer ventilation and increased airway resistance.

B. VENTILATION

Medical and nursing personnel looking after these cases soon come to realize that the mere use of a mechanical ventilator is no guarantee that the patient is actually ventilating satisfactorily. Pain, bronchospasm, air or fluid or both in the pleural cavity, mediastinal or subcutaneous emphysema, and an uncooperative, delirious patient may all interfere and render the mechanical respirator completely ineffective. It is our belief that a continuous epidural block plus the use of a sensitive mechanical respirator provides the most satisfactory answer to most of these problems.

1. MECHANICALLY ASSISTED RESPIRATION

1. *Choice of mechanical ventilator.* Any sensitive assistor-respirator is suitable for this purpose. We prefer the Bird Mark 7 ® assistor-respirator for the following reasons: (*a*) The machine is very compact and thus occupies a small space.

This can be a great advantage if the machine is to be used in a crowded Recovery Room or Intensive Therapy Unit. (*b*) It is sensitive enough to be used either as a patient-triggered assistor, or as a self-triggering respirator. (*c*) It incorporates an air mixing device, which supplies the patient with a mixture of 45 per cent oxygen to 55 per cent air. (*d*) It incorporates a nebulizer that can be used as a humidifier or to deliver medication by inhalation. (*e*) The length of both the inspiratory and expiratory phases can be easily adjusted to meet the patient's requirements. (*f*) It is economical. Oxygen consumption is low, particularly if the oxygen-air mixture is used.

2. *Pattern of ventilation.* Most of these patients have a varying degree of bronchospasm, either as a reflex phenomenon from the trauma and the presence of secretions and blood in the bronchial tree, or as a pre-existing asthmatic tendency in the severely emphysematous patient. Accordingly, the machine should be adjusted to deliver a fairly prolonged inspiratory phase, to allow more time for the gases under pressure to overcome the airway resistance. It is worth mentioning at this point that a combination of prolonged inspiration and moderate positive pressure is far superior to a very high positive pressure and a relatively short inspiratory phase, in this type of case. If the patient is not triggering the machine, the expiratory pause must also be prolonged to allow time for the air to escape from the lungs; otherwise there would be grave danger of progressively enlarging the residual volume of the lungs, or even of rupturing an emphysematous bulla.

3. *Induction and termination of mechanically assisted respiration.* These are difficult phases in the course of the management of these patients. A fair number of patients resent or even actively resist the commencement of intermittent positive pressure ventilation. This often results in uneven and inadequate ventilatory patterns, even when the patient is under a fairly high epidural block. In such cases we find it advisable to start the ventilation manually with a bag attached to the tracheostomy tube until the patient settles down. This usually takes from 1 to 2 hours. As to the termination of mechanically assisted respiration, we found that the majority of our patients become extremely dependent on the machine, and they get panicky when forced to breathe on their own without mechanical assistance. These patients must be "weaned" off the respirator gradually and over a period of days. An arterial blood sample should be taken when the patient has been off the respirator for at least two hours. Fairly normal figures of pCO_2, pH, and O_2 saturation would indicate that the patient's ventilatory power is adequate.

4. *The use of a negative phase in the respiratory cycle.* Some people get the impression that a negative phase during the expiratory period would help this painfully protracted phase. This, however, is quite wrong. A negative phase will only cause collapse of the small bronchioles, leading to trapping of air distally, and should therefore be avoided.

5. *Stabilization of a flail chest.* Intermittent positive pressure ventilation not only maintains adequate ventilation of the patient but also effectively stabilizes a flail or "stove-in" chest. This will obviate the necessity of applying external traction on the chest wall or of tight bandaging.

II. CONTINUOUS EPIDURAL BLOCK

This might seem to be a rather drastic measure in these cases but we feel that its advantages more than justify its routine use. The advantages of continuous epidural analgesia are:

1. *Relief of pain and sedation.* There is no question but that this technique gives excellent analgesia without resort to depressant drugs like the opiates. Narcotics not only depress respiration centrally but also precipitate a marked degree of bronchospasm in a large percentage of these patients. Apart from the analgesia, epidural blocks produce general sedative effects. These may be due to the systemic effects of the absorbed local anaesthetic agent used or to the lack of afferent impulses from the major part of the body surface. Alternative methods of pain relief, suggested by some surgeons, are the injection of local anaesthetic agents at the site of fracture, or posteriorly to block the intercostal nerves. In our opinion, however, these methods are tedious, necessitating frequent injections, and lacking other advantages to be found with the use of an epidural block.

2. *Relaxation of the thoracic muscles.* This reduces to a minimum resistance of the chest wall to inflation, thus allowing the use of less positive pressure. In the case described in this paper massive surgical emphysema promptly disappeared once the epidural block was commenced. This is probably due to the fact that it abolished the forced expiratory efforts of the patient, which must have been creating a very high positive pressure in the chest, thus forcing air into the subcutaneous space at the site of the thoracotomy wound.

3. *Relief of bronchiolar spasm.* This is one of the important advantages of epidural analgesia in these patients. The mechanism of this relief is hard to explain. One may theorize that an epidural block, by interrupting afferent stimuli, breaks the reflex arc responsible for the increased tone of the bronchiolar musculature.

4. *A fair margin of safety.* An epidural block wears off within 2 to 3 hours after the last dose has been given and can thus be discontinued if the patient shows any untoward manifestations.

5. *Requires less work by the nursing staff.* Once the quantity and timing of the xylocaine injections are adjusted it becomes fairly simple for the nurses to deal competently with this aspect of the care, provided they are aware of the complications, and provided there is a medical man available to deal with such complications if and when they arise.

Disadvantages of continuous epidural analgesia are:

1. Because of the relatively poor condition of many of these patients aseptic precautions sometimes are not strictly enforced while doing the epidural puncture. It is imperative, however, that this should not be so.

2. Positioning these patients for the epidural puncture is often difficult, particularly if they are suffering from fractured ribs. Great attention should be paid to the patient's ventilation throughout the procedure because of the risk of producing a prolonged period of severe hypoxia whilst all attention is diverted to the procedure of inserting the needle.

3. Hypotension occurs in a moderate number of cases, particularly immediately after the administration of a dose of Xylocaine ®. The patient must have

a good intravenous drip running at all times. We always prepare and have ready for use a phenylepherine infusion and, in our experience, hypotension has never been a reason for abandoning the technique.

4. Manifestations of Xylocaine® toxicity occur occasionally in the form of slight twitchings of the facial muscles, and occasionally as a rise in the blood pressure. This is due to the rapid absorption of the drug from the epidural space. A small dose of secobarbital or pentobarbital is all that is required to control these manifestations.

5. The vinyl tube can be left in place in the epidural space for four or five days before it is changed. Tubes left in place for longer periods are liable to deteriorate and break.

6. When the epidural block is finally terminated, some patients become restless as analgesia wears off, particularly if some pain persists. During this period the patient should be well sedated, with moderate doses of meperidine. In the case described in this paper, however, this restlessness proved to be a blessing. The patient probably coughed violently enough to expand his collapsed lung despite the fact that bronchoscopy and vigorous suctioning had been unsuccessful.

III. MISCELLANEOUS MEASURES

1. *Chest tubes.* When the patient has had either a thoracotomy or a severe injury to the chest, there is bound to be some degree of pneumothorax and possibly haemothorax on the affected side. One or more chest tubes connected to a water seal are a necessity. Great attention should be paid to the patency of these tubes at all times.

2. *Gastric tubes.* Acute gastric dilatation is a frequent complication of chest injuries and thoracotomies in the severely emphysematous patient. This causes marked splinting of the diaphragm and embarrassment of respiration and it is surprising how improved these patients look and feel after the stomach has been emptied. It must be remembered, however, that continuous gastric suction causes water and electrolyte imbalance, which must be corrected simultaneously.

RÉSUMÉ

Nous rencontrons de plus en plus des cas d'insuffisance respiratoire grave porteurs de pathologies douloureuses du thorax ou de l'abdomen. Ce qui caractérise tous ces cas, c'est une ventilation inadéquate. Cela est dû à la douleur, à la respiration paradoxale, au bronchospasme et à des sécrétions excessives.

La ligne de conduite que nous suggérons consiste surtout: à assurer la libération des voies respiratoires par une trachéotomie, à ventiler le malade mécaniquement avec un assisteur-respirateur sensible et à soulager la douleur et le bronchospasme à l'aide d'une analgésie épidurale continue. Nous avons parlé des avantages et des limites de ces différents procédés et nous avons présenté un cas qui illustre bien cette ligne de conduite.