ASSISTED VENTILATION IN THE POST-BYPASS PERIOD

BY

W. R. MACRAE AND A. H. B. MASSON

Department of Anaesthetics, Edinburgh University and Royal Infirmary, Edinburgh

SUMMARY

A regime for the postoperative ventilatory management of patients who have undergone operations under cardiopulmonary bypass is described and the problems discussed. It is recommended that the endotracheal tube be left in position for 24 hours, if this can be done without the use of unduly large amounts of analgesics, and mechanical ventilatory assistance is given by a patient-triggered ventilator. If further ventilatory assistance is required, the ventilator can be used with a facepiece. Should the patient's condition deteriorate, early tracheostomy is carried out. Continuous assisted ventilation through the tracheostomy tube will maintain the patient's condition and reduce the number of cases requiring full control of ventilation.

This paper describes a method of management of pulmonary ventilation in patients who have had an operation under cardiopulmonary bypass. A proportion of such patients requires ventilatory assistance because of pulmonary complications, cardiac complications, increased metabolic demands due to pyrexia and, in many cases, debility and fatigue. To date, the technique to be described has been used in 48 patients.

Pulmonary complications.

The pulmonary difficulties may arise from pre-existing disease, from the effects of thoracotomy, or from the effects of cardiopulmonary bypass. The patient with long standing pulmonary hypertension from any cause is at a disadvantage. After thoracotomy pulmonary ventilation may be impaired by pain, by atelectasis of major or minor degree, by infection or by bronchospasm. The complications which are specifically attributable to bypass itself are not well understood but there is certainly a diminution in diffusing capacity (Schramel et al., 1958) and pulmonary capillary damage may be produced by inadequate venting of the left heart (Littlefield et al., 1958).

Cardiac complications.

Cardiac complications may contribute to the impairment of ventilatory efficiency. A low output may result in gross hyperpnoea. Low output states not infrequently follow (and indeed precede) bypass operations and are due to myocardial damage, valvular inefficiency or arrhythmias. In these circumstances, the danger of fluid overload of the circulation and latent or overt pulmonary oedema is obvious.

Metabolic effects.

The body's demands for oxygen and production of carbon dioxide are usually elevated since there is often a marked pyrexia, more than would be expected following simple thoracotomy. A temperature of 103°F, such as is frequently found for three or four days after operation raises the basal metabolic rate by about 30 per cent (Best and Taylor, 1961) and, if dyspnoea is present, this alone can account for a further marked increase in basal metabolic rate. The frequency of very high temperatures (over 102°F) seems to be less following the use of plastic bag oxygenators than after disc oxygenators which require a large volume of blood for priming (Paton, 1963).

THEORY

The importance of reducing the demands for oxygen is obvious and this can be achieved by lowering the body temperature and by preventing dyspnoea. Although the oxygen consumption of the respiratory muscles may at rest be only 2–3 per cent of the total oxygen consumption of the body, this proportion may rise as high as 50 per
cent if the work of breathing is increased (Cherniak and Cherniak, 1961).

One solution to this problem is that employed by Dammann and his colleagues (1963) who reduced respiratory work by controlling pulmonary ventilation in these patients for several days after the operation. Spontaneous respiration being abolished, the patient is rested and his metabolic demands reduced.

While there may be a difference of opinion about the necessity for prophylactic postoperative control of ventilation, there is no dispute about the necessity for therapeutic controlled ventilation if alveolar hypoventilation occurs. The use of controlled ventilation makes very heavy demands on medical and nursing staff, however, and is not necessary for prophylaxis. Some form of respiratory assistance is advantageous, particularly in the early stages of the postoperative period.

**METHOD**

The scheme outlined in figure 1 is employed. Immediately after operation, the endotracheal tube is left in position, the patient is disconnected from the anaesthetic machine and mechanical ventilation of the lungs established by a Bird ventilator (Mushin, Rendell-Baker and Thomson 1959) set to trigger with his own respirations. The trigger adjustment at this stage is usually set at its most sensitive position. Air is entrained, which gives an inspired oxygen concentration of about 36 per cent. The humidifier of the machine is used and tracheal toilet is carried out as required using an aseptic technique. The patient's mouth is washed out by the nursing staff from time to time and salivary secretions removed to make the patient more comfortable. It is important to prevent coughing or gagging on the tube and morphine is used in doses sufficient to prevent this. It is surprising to find how easily the majority of patients tolerate the tube, even when fully conscious. It is also striking that adequate ventilation can be maintained even when comparatively large doses of morphine are employed. On this regime, it is the exception rather than the rule during the first 24 hours to find a carbon dioxide tension which deviates from the normal range and the respiratory rate is usually between 16 and 20 b.p.m. It is important to explain the procedure carefully to the patient on the day before operation and the opportunity is taken then to instruct him in the use of the ventilator with a facepiece.

The tube is removed if there is persistent gagging or bucking, marked salivation, or when the patient otherwise indicates that the presence

---

**Fig. 1**

Scheme illustrating methods of managing pulmonary ventilation in patients who have had an operation under cardiopulmonary bypass.
of the tube is intolerable. The aim is to keep the endotracheal tube in position for 24 hours. This time has not yet been exceeded because of the possible danger of traumatizing the vocal cords in a patient who is conscious and not paralyzed. It would be even more satisfactory if ventilation could be assisted for 72 hours by which time the patient would be better able to ventilate adequately and cough effectively because the pain at the operation site would have diminished and cardiopulmonary function would be stabilized.

When the endotracheal tube is removed, there are three courses open:

1. Oxygen can be supplied through a disposable plastic facepiece.
2. Pulmonary ventilation can be assisted by means of the Bird ventilator and a facepiece.
3. Tracheostomy can be performed, after which ventilation can be assisted or controlled.

The patients who come into the first group require no further assistance to ventilation. Spontaneous respiration is permitted, with oxygen delivered through a disposable plastic facepiece. The chest is auscultated frequently and radiographs taken when required. Blood gas tensions are estimated as often as is thought necessary and a clinical assessment made of the work required to maintain these tensions. A rising respiratory rate is a bad prognostic sign.

A minority of patients, those who are very ill with obvious cerebral, cardiac, pulmonary or perhaps renal complications, come into the third group. These patients will probably need assisted ventilation for several days. They are, therefore,
subjected to tracheostomy and respiration is assisted by a Bird apparatus. The decision as to whether or not controlled ventilation must be used will be made after careful measurements of blood gases and respiratory rate, study of the radiographic findings and clinical assessment of the adequacy of the assisted ventilation.

There remains an intermediate group of patients not falling into either of these categories. In these patients ventilation is assisted, if possible, for a further 24 hours or so using a facepiece which is, of course, removed for feeding, mouth care, or whenever the patient finds it irksome. It is, in fact, easier to keep the endotracheal tube in position than it is to keep a properly fitting facepiece on the patient. The main difficulty is in obtaining a fit which is gas tight and at the same time reasonably comfortable. A requisite of this phase is that the patient is fully conscious and able to adjust or remove the mask if need be. There would be the danger of inflating the stomach if the patient were semiconscious.

Bird with Endotracheal Tube

![Diagram](https://example.com/diagram.png)

![Graph](https://example.com/graph.png)

Aortic valve replacement: Melrose machine.

The respiratory rate was more rapid than usual and the carbon dioxide tension was slightly elevated even with the endotracheal tube in position. Following its removal, the respiratory rate remained much the same but the carbon dioxide tension rose. Because of the patient's inability to cough up thick purulent secretions and because of the persistent elevation of the carbon dioxide tension, a tracheostomy was carried out. Thereafter, both respiratory rate and carbon dioxide tension fell to normal levels. This is an example of the case who failed with the facemask but early tracheostomy allowed assisted ventilation to improve the situation.
condition of the patient improves after some time, the facepiece is removed and oxygen given with a plastic facepiece. If it deteriorates, a tracheostomy is performed.

After the continuous use of the ventilator has been stopped, it is used as an adjunct to physiotherapy and has proved to be of value. For 10 minutes before physiotherapy, the patient uses the machine either with a face- or mouth-piece. A bronchodilator can be added to the inhaled gases if required. There is little doubt that this combined method adds to the comfort of the patient and the effectiveness of physiotherapy.

While continuous use of the machine usually produces good even expansion of both lungs, it does not necessarily prevent the occurrence of lobar collapse and one such complication has occurred. Postoperative pain is relieved both by the morphine, which can be freely given as ventilation is being assisted, and by minimizing the respiratory effort required to maintain ventilation. One patient who had had a thoracotomy six months before was particularly appreciative of this “analgesic” effect of IPPR. The following case histories illustrate some of these points.

**Case 1** (fig. 2). The patient was a 42-year-old woman with severe mitral incompetence and moderate stenosis with minimal pulmonary hypertension. A mitral plication was carried out with cardiopulmonary bypass using a plastic disposable oxygenator with a haemodilution technique. The endotracheal tube was left in position for 24 hours and she tolerated this well, little sedation being required. On removing the endotracheal tube she breathed spontaneously with a disposable facepiece delivering oxygen and, although her respiratory rate increased, it did not exceed 24 b.p.m. and the blood gas levels remained satisfactory.

This is an example of the first type of patient who is given ventilatory assistance for a short time only and thereafter progresses well.

**Case 2** (fig. 3). The patient was a young man of 32 with severe aortic incompetence and stenosis whose aortic valve was replaced with a Starr-Edward prosthesis during cardiopulmonary bypass with the Melrose machine. The endotracheal tube was left in position for 24 hours and ventilation was assisted by the Bird ventilator. The tube was then removed and ventilation was assisted with the ventilator and facepiece. Despite this, collapse of the right lower lobe occurred. Tracheostomy was performed after bronchoscopy, because he was having considerable difficulty in coughing up thick purulent sputum. Thereafter ventilation was assisted continuously by the Bird ventilator and there were no further pulmonary or cardiovascular complications.

This is an example of an extremely ill patient whose condition deteriorates despite assistance via the facepiece because of pulmonary lobar collapse and who required tracheostomy. He did, however, develop a degree of renal failure and suffered a cerebrovascular accident which resulted in his death on the 9th postoperative day.

**Case 3** (fig. 4). This patient, a 37-year-old woman, with severe mitral incompetence and moderate stenosis had had a previous closed mitral valvulotomy three years previously. She was severely disabled with breathlessness and was having attacks of paroxysmal nocturnal dyspnoea. A mitral plication was carried out with cardiopulmonary bypass using a plastic disposable oxygenator with a haemodilution technique. The endotracheal tube was left in position for 24 hours and she tolerated it well with little sedation. Her condition at this time was reasonably good, but she appeared very tired. She settled well on the facepiece with assistance from the Bird ventilator for the next 12 hours.

This is an example of the intermediate type of case who is likely to benefit from ventilatory assistance continued beyond the first 24 hours.

**DISCUSSION**

By the early use of this form of ventilatory assistance, it is hoped to prevent ventilatory deterioration of the patient during the first critical 24 hours. The Bird ventilator is quite satisfactory for this purpose. A Cyclator (BOC) has been used (successfully) in an emergency but the absence of a sensitive triggering mechanism and any form of humidifier are serious disadvantages. Sandison, McCormick and Sykes (1963) found that patient triggered ventilation was inadequate to deal with existing hypoventilation. If, however, patient-triggered ventilation is carried on from the immediate postoperative period alveolar hypoventilation is much less likely to occur. Its use in the patient who has already developed alveolar hypoventilation with a very rapid respiratory rate is not rewarding. Since spontaneous respiration exists at all times, these patients can be managed in a busy unit with no more than the usual special nursing facilities which they normally enjoy. In the event of any untoward occurrence, the patient can safely be disconnected from the machine and given an oxygen-rich mixture to breathe while medical assistance is summoned.
Not the least of the advantages of this assisted respiration is in the avoidance of unnecessary tracheostomies. From time to time, a patient is unable to achieve adequate ventilation in the few hours after operation. This may be a temporary phenomenon lasting less than 24 hours. Nothing is lost by delay provided adequate ventilation is maintained in the meantime. The ability of the patient to maintain normal blood gas levels with the minimum of respiratory work is noteworthy.

This regime has also been used in some non-bypass patients whose ventilation at the end of operation was not quite sufficient.

REFERENCES


LA VENTILATION ASSISTEE APRÈS OPERATION AVEC BYPASS

SOMMAIRE

Description d’un régime de ventilation post-opératoire chez des malades opérés sous bypass cardiopulmonaire. Discussion des problèmes qui en résultent. On recommande de laisser en place le tube endotratéchal pendant 24 heures, si cela est possible sans trop d’analgésiques, et d’assurer une assistance ventilatoire mécanique par un ventilateur actionné par le malade lui-même. Si une assistance ventilatoire plus longue s’avérait nécessaire le ventilateur peut être utilisé avec un masque facial. Si l’état du malade empruntait, on ferait une trachéotomie précoce. L’assistance ventilatoire continue à travers le tube de trachéotomie maintiendra l’état du malade et réduirà le nombre de cas exigeant un contrôle respiratoire complet.

ASSISTIERTE BEATMUNG IM ANSCHLUSS AN DEN EXTRAKORPORALEN KREISLAUF

ZUSAMMENFASSUNG


BOOK REVIEW


This book should be studied by all who feel impelled to write a book on methods. They will quickly realize the magnitude of the task and appreciate that such a book should not be attempted by those who lack the extraordinary degree of practical experience and application shown by these authors. Much of the book relates to techniques which are unfamiliar in Great Britain, where few are experienced in such measurements as metabolic rate during exercise, intra-pulmonary gas mixing or the more recherché aspects of bronchospirometry. The detail of many sections is remarkable and the section on the use of the Van Slyke manometric apparatus calls for special mention. Alongside the account of procedure, are parallel sections in small print emphasizing details and sources of error. Step-by-step instructions are given for many techniques, including the Haldane and Scholander apparatus and Riley’s method of bubble tonometry. The translation is excellent and at no time would the grammatical construction suggest that the book had been written in any language other than English.

It is no fault of the authors’ that the English translation has appeared about four years after the German version, and probably about six years after the completion of the manuscripts. Consequently, few references are later than 1957, although short sections which describe electrometric determination of Pco₂ and Po₂ appear to have been inserted at the time of translation. Apart from these we find no mention of many of the recent advances which have had such an impact on the study of respiratory problems. We look in vain for any account of capillary pH electrodes, microonometers, the Lloyd Haldane apparatus or the Wright respirometer. The sections dealing with electrodes for measurement of Pco₂ and Po₂ do little more than mention these developments, and will offer no help to those who seek guidance in the detailed execution of these techniques. One also misses any discussion of recent methods of presentation of acid-base disturbances, although it is good to see that Brønsted’s definitions of acids and bases are used. The section on physical methods of gas analysis also lags behind current practice. Gas chromatography receives no mention and surely more space should be devoted to infra-red absorption than to thermal conductivity.

In view of these unfortunate omissions, the book cannot be recommended as a principal source of information on modern methods of measurement respiratory function. However, for those individuals and institutions who are able to afford the book, it merits a place on four counts. Firstly, it is unchallenged as an up-to-date description of the older methods. Secondly, it will prove an invaluable source book for the methods which are less familiar in this country. Thirdly, it refutes the theory that prophets are not recognised in their own country by giving due emphasis to the European workers and the German workers in particular. Few readers will fail to be surprised in reading of the magnitude of the European contributions to the field. Finally, although the book omits so many recent developments, the basis of each section is essentially sound and thorough. For the serious student this will not be wasted reading, and he will welcome an English translation of the work of this distinguished group of authors.

J. F. Nunn