INTERMITTENT MANDATORY VENTILATION OF THE LUNGS WITH THE RO-6 RESPIRATOR

É. M. Nikolaenko

UDC 615.816.2

Recently the method of intermittent mandatory ventilation (IMV) has achieved ever-increasing popularity [1]. The essence of IMV is that the patient's spontaneous breathing is interspersed with artificial (mandatory) inspirations, the frequency of which is gradually reduced, and the patient thus disaccustoms himself to the IMV apparatus and adapts himself to spontaneous ventilation of the lungs. Several specially designed respirators with facilities for IMV now exist in the west (the Dräger UV-1, Erica Engström, Bird Ventilator, Cape, Bear, etc.), and adaptations to certain artificial lung ventilators enabling the lungs to be ventilated under IMV conditions also have been described.

Many years of experience of IMV when disaccustoming patients to artificial ventilation of the lungs in the writer's clinic, using western and Soviet respirators, has given a favorable impression of this method and it can be recommended for more widespread application in clinical resuscitation and intensive care practice. The aim of this communication is not to analyze IMV from clinical and physiological points of view, but simply to demonstrate that IMV is a feasible proposition with Soviet respirators of the RO type, to indicate the essentials which must be observed during IMV, and to point out the problems concerning the equipment required for this technique that must be solved in the course of further improvement and development of apparatuses for assisted respiration. The optimal arrangement of the additional circuit for IMV using the RO-6 respirator is shown in Fig. 1.

The system of rotameters with injector 1 is connected by the three-way cock 2 to the inlet pipe of the respirator 3. The side tube of the three-way cock 2 is connected by the corrugated tube 6 to the three-way cock 8, which also connects the bellows 7 to the additional inspiratory valve 9. The inspiratory hose is connected to the side tube of this valve, and the humidifier 13 and transducer of the oxygen concentration meter 12 may also be included in its circuit. The volumeter 15 and connector 16 are connected to the three-way cock 14, connecting the inspiratory and expiratory hoses through a corrugated tube. A valve controlling the positive end expiratory pressure 4 is mounted on the outlet pipe 5, located on the uppoer panel of the stand of the apparatus, or on the analogous pipe located below. We have used the Bennet humidifier, the Biomarina oxymeter, and the PEEP AMBU valve, but the apparatus for IMV can be completely assembled from parts and components of anesthetic apparatuses and respirators of Soviet manufacture. During IMV oxygen is supplied through an oxygen rotameter, and the sum of its flow with the air drawn in through the injector must exceed the patient's respiratory minute volume. The air–oxygen mixture is supplied into the bellows 7, from which it passes through the additional inlet valve, humidifier, and O_2 gauge into the patient's respiratory tract. The excess of gas passes into the expiratory circuit, from which it enters the atmosphere through the PEEP valve and the upper or lower outlet pipe 5, depending on the position of the respiratory circuit switch. The frequency of artificial (mandatory) inspirations is set by the time relay of the assisted ventilation system with the sensitivity of the trigger mechanism set at its lowest level (the handle is turned clockwise as fast as the stop) or after disconnecting it and the "Program 1" button pressed. The minimal frequency of mandatory inspiration in the factory model of the apparatus is 3 min^{-1} (under these circumstances none of the buttons of the relay must be pressed). The simple readjustment of the system allows an expectancy time of 40 sec to be obtained, which means that the number of mandatory inspirations can be reduced to 1.5 min^{-1}. The volume of mandatory inspiration is chosen in accordance with the clinical situation, and the ratio $T_{exp}:T_{insp}$ is set at 3:1, so that the mandatory inspiration is faster, allowing for the fact that it is not synchronized with the patient's spontaneous breathing.

Research Institute of Transplantology and Artificial Organs, Ministry of Health of the USSR, Moscow. Translated from Meditsinskaya Tekhnika, No. 6, pp. 39-42, November-December, 1983. Original article submitted April 22, 1983.

 0006-3398/83/1706-0216$07.50

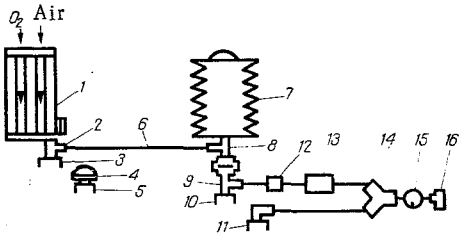

Fig. 1. Arrangement of additional circuit for IMV with the RO-6 apparatus. 1) Rotameter with injector; 2) three-way cock; 3) inlet tube of RO-6 apparatus; 4) PEEP valve; 5) outlet tube of RO-6; 6) connecting hose; 7) bellows; 8) three-way cock with rubber connector; 9) additional inspiratory nozzle; 11) expiratory nozzle of RO-6; 12) oxymeter transducer; 13) humidifier; 14) three-way cock; 15) volumeter; 16) adaptor.

Ventilation of the lungs with PEEP, which increases the functional reserve capacity of the lungs and improves ventilation–perfusion ratios and blood oxygenation, has become the principal trend in the treatment of patients with severe acute respiratory failure [2-4]. In many clinical situations it is important to maintain a raised pressure in the respiratory tract in the period of transition from artificial to spontaneous ventilation of the lungs also. The combination of IMV and spontaneous ventilation under CPAP, which provides a solution to this problem [5], can be provided by the scheme described above with the RO-6 respirator. For this purpose the necessary pressure level in the respiratory tract is set by the PEEP valve and monitored by the pressure and vacuum gauge of the respirator, and the bellows is located with an appropriate weight to maintain a positive pressure throughout the phase of inspiration. The same level of end-expiratory pressure is maintained during mandatory inspiration also.

Patient S., a man aged 43 years, for instance, was treated by tentorotomy for an acute cerebrovascular disturbance and cerebral dislocation, for 4 days by artificial ventilation of the lungs on the RO-6R apparatus. On the 5th day, when consciousness had returned, steps were taken to withdraw the patient from the respirator by means of a combination of IMV and CPAP (Fig. 2). As will be clear from Fig. 2, a gradual decrease in the frequency of artificial inspiration was not accompanied by any change in gas composition of the alveolar air and blood, and the value of Q_s/Q_t rose only when PEEP was discontinued.

On the basis of analysis of the literature and our own experience the following essential specification can be drawn up for the IMV method: 1) ability to control $F_I \cdot O_2$ within wide limits; 2) maintenance of positive pressure throughout the respiratory cycle; 3) humidifying and warming of the respiratory gases; 4) simplicity of control and ease of comprehension by the staff; 5) measurement of the patient's respiratory volumes; 6) safety for the patient; 7) impossibility of rebreathing and of an increase in the dead space of the apparatus; 8) economy in gas consumption; 9) ability to perform IMV and AVL with the same arrangement of the respiratory circuit of the apparatus; 10) possibility of sterilization.

Let us examine how these demands are satisfied by the version of IMV with the RO-6 respirator described above.

If the standard O_2 supply unit of the RO-6R apparatus is used it is impossible to control $F_I \cdot O_2$, and during spontaneous inspirations the patient receives practically pure oxygen. During mandatory inspiration a small portion of air from the atmosphere is added to the oxygen and $F_I \cdot O_2$ lies between 1.0 and 0.9. Oxygen in high concentrations is harmful for the lungs and, consequently, the impossibility of controlling $F_I \cdot O_2$ is a serious shortcoming of this version of IMV. By using a system of rotameters and injector (for example, from the Narkon-P apparatus or the anesthetic attachment to the RO-6 apparatus) it is possible to control $F_I \cdot O_2$ between 1.0 and 0.8 by taking in air from the atmosphere, and if compressed air is supplied through the NO_2 rotameter, it can be controlled between 0.21 and 1.0. This last version provides a complete solution to the problem of $F_I \cdot O_2$ control in respiratory mixtures during IMV.

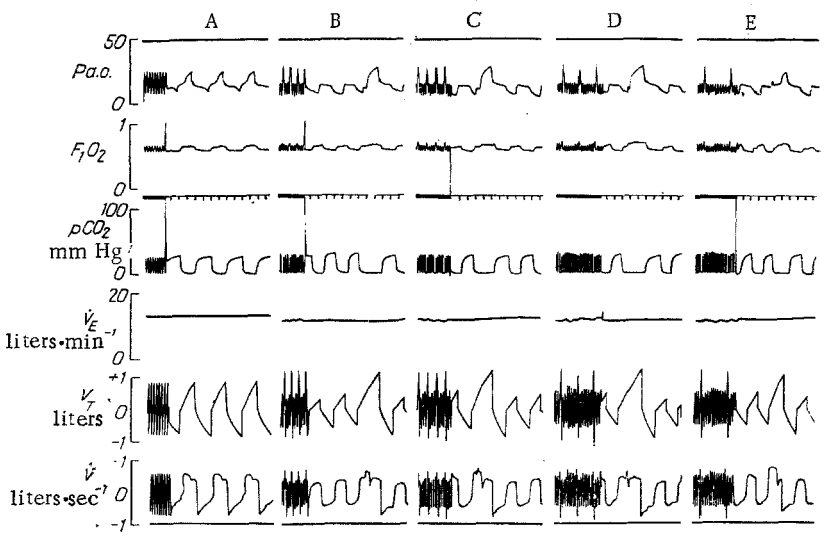

Fig. 2. Time course of respiratory parameters of patient S. during withdrawal from dependence on the respirator. A) IMV + PEEP + 10; B, C, D, E) IMV with spontaneous ventilation under positive pressure with frequency of mandatory inspirations of 7, 4, 2, and 1.5 min^{-1}, respectively.

During ventilation with CPAP the lungs at the end of expiration remain inflated and the patient has to do extra work to overcome the elastic pull of the lungs, if he breathes in from a bag in which the pressure is close to atmospheric. The increase in inspiratory effort and negative pressure in the alveoli reduce the prophylactic effect of CPAP to zero and contribute to atelectasis formation.

The use of CPAP combined with IMV can overcome this shortcoming and it can be done in one of two ways. In the first method, a 5-liter bag is used as inspired gas reservoir. However, to maintain a positive pressure close to CPAP throughout the respiratory cycle, the gas flow must be not less than twice the respiratory minute volume, or in other words 25-30 liters·min^{-1}. A gas flow of this magnitude cannot always be obtained by means of a system of rotameters, and high oxygen consumption is required, which contravenes item 8 of the demands listed above. A more stable pressure in the respiratory tract and more economical consumption of gases can be achieved by the use of a suitably loaded bellows as the reservoir. By this method of CPAP with IMV the pressure in the respiratory tract during inspiration falls by not more than 0.1 kPa during a gas flow a little above 10 liters·min^{-1} [6].

Humidification and warming of the respiratory gases are important factor in the prevention of pulmonary complications. However, this problem has not yet been solved, and we use the Bennet humidifier, connected into the inspiratory circuit. This method of connecting the humidifier increases the compression volume and calls for a corresponding increase in the volume of mandatory inspiration.

The suggested version of IMV does not make work with the respirator much more complicated and is quite easy for staff familiar with respiratory apparatus to understand and control. An essential condition for effective use of the combined IMV—CPAP method is corrected control of the gas flow and pressure in the respiratory passages, which may change during a change in the patient's breathing.

By measuring the patient's respiratory volumes during withdrawal from the respirator it is possible to check the effectiveness of restoration of spontaneous ventilation and to control the IMV program. However, with a combination of IMV and CPAP, not only air breathed out by the patient, but also the extra gas flow passes through the volumeter which, as usual, is connected to the expiratory pipe of the apparatus, and this makes measurement more difficult. Under these conditions of ventilation the volumeter must be located between the three-way cock of the respiratory hoses and the pipe to the patient. The increase in dead space in this case is negligible (25-30 ml) and does not contravene item 7.

As in any other version of assisted respiration, in IMV the gas composition of the blood must be carefully monitored and with any increase in P_aCO_2 or metabolic disorders the frequency of the mandatory inspirations must be increased. For the patient's safety automatic adjustment of frequency and (or) volume of mandatory inspirations against the background of spontaneous ventilation seems to be more reliable. However, this problem raises more difficult technical considerations and a solution to it is still awaited.

The gas flow is controlled by the perfectly reliable valve system of the RO-6 respirator and the high inflow of fresh gas, which rules out the risk of rebreathing. Meanwhile, if the patient's tidal volume is limited, the dead space and compression volume of the apparatus during IMV be relatively large, and this may lead to CO_2 accumulation.

The suggested scheme of an additional circuit on the RO-6 apparatus enables both ordinary AVL with PEEP and also of IMV with CPAP to be carried out without any reconstruction.

All the additional components providing the gas flow for IMV with CPAP are located outside the main circuit, they do not come into contact with the patient's expired air, and they are easily dissembled for sterilization of the apparatus in the usual way.

LITERATURE CITED

1. J. B. Downs, E. F. Klein, D. Desautels, et al., Chest, 64, 331 (1973).
2. D. G. Ashbaugh, T. L. Petty, D. B. Bigelow, et al., J. Thorac. Cardiovasc. Surg., 57, 31 (1969).
3. V. L. Kassil' and N. M. Ryabova, Artificial Ventilation of the Lungs in Resuscitation [in Russian], Moscow (1977).
4. É. M. Nikolaenko and I. R. Kulmagambetov, Anest. Reanimatol., No. 2, 64 (1981).
5. J. Pfitzner, Anaesthesia, 31, 410 (1976).