# NEW METHODS AND MODES OF OPERATION OF RO TYPE ARTIFICIAL LUNG VENTILATORS

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Methods of making respiratory treatment more effective include ventilation with a high frequency of respiratory cycles, with a positive expiratory pressure, unaided breathing through an apparatus under constant positive pressure, and finally, what is called intermittent mandatory ventilation. In some apparatuses manufactured in the west (for example, in the UV-1 Universal Ventilator, manufactured by Dräger) special functional units are provided for most of these methods. Additional simple accessories are provided for this purpose for certain other apparatuses [1, 2]. This paper describes methods of carrying out these methods of treatment using the RO-6 and RO-5 apparatuses, which are the most widely used types in Soviet hospitals.

This article does not attempt to discuss the advantages and disadvantages of the new methods, optimal ranges of their operation, or indications for and contraindications to their use; it simply describes how the various methods can be put into operation, once it has been decided to use them.

As accessories required to make possible the new techniques, those available in kits of commercially produced anesthetic and breathing apparatuses are recommended, or the simplest devices readily available and not requiring any special manufacture are suggested.

Adaptation of commercial artificial lung ventilators for operation under new conditions is naturally bound to give rise to certain limitations, for example affecting the range of available control of the parameters, the possibility of measuring and monitoring them, and so on.

The suggested recommendations are regarded as a temporary measure before modernization of the production of commercial RO-6 models by industry and the development of a new generation of artificial ventilators which will satisfy the most modern demands.

1. Ventilators with Positive Expiratory Pressure. This technique, known as positive end expiratory pressure (PEEP), is one in which a positive pressure, the value of which is usually set at 5-20 cm water and reaches higher values only in rare cases, is maintained by means of a specific device connected into the expiratory circuit. The raised pressure leads to an increase in the functional reserve capacity of the lungs, improves ventilation-perfusion ratios, and reduces venous shunting [3-5].

The cock for increasing the resistance to expiration included in the kit of the RO-5 and RO-6 apparatuses can be used to produce PEEP conditions. Introducing this cock reduces the velocity of the expired gas and can exclude the expiratory pause (Fig. 1, grid 3). PEEP produced by this method reduces premature closing of the respiratory passages optimally. However, the necessary value of PEEP is by no means always obtainable in this way. If a higher value of PEEP is needed, and also if it is considered desirable to obtain PEEP without reducing the velocity of expiration (Fig. 1, grid 2), the controllable protective valve of the inhalation anesthetic apparatus (Fig. 2, grid 5) must be connected to the outlet pipe of the apparatus (Fig. 2, No. 13) by means of a suitable rubber connecting piece. The most suitable protective valve is that of the Polinarkon-2 or Polinarkon-2P apparatus (the RO-6N apparatus has the same valve on its anesthetic unit). The cock for switching respiratory circuits (Fig. 2, No. 12) must be in the "half closed" position when the PEEP valve is fitted. The necessary value of PEEP is established by gradual movement of the load of the valve and is

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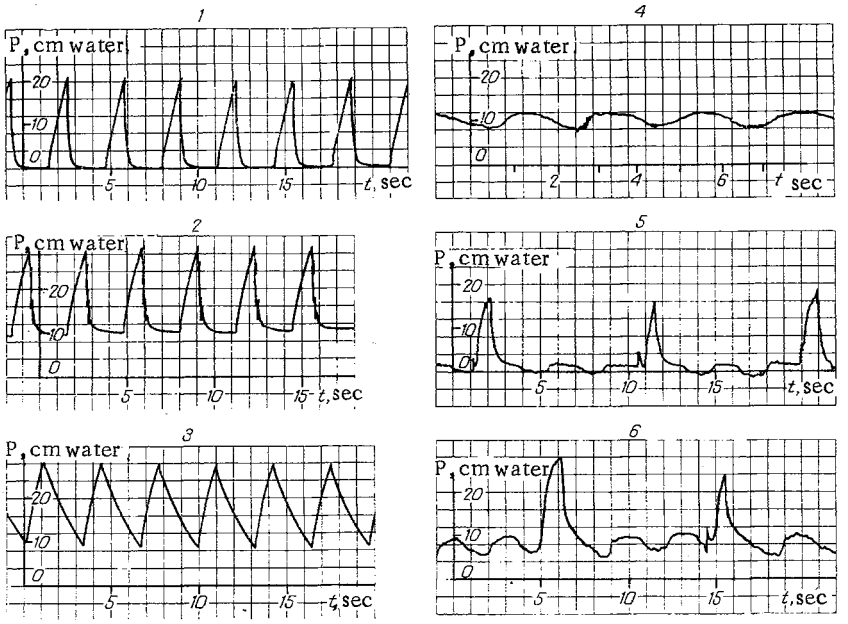


Fig. 1. Changes of pressure in the respiratory passages during use of the RO-6R ventilator under different operational conditions. 1) "Ordinary" ventilator with passive expiration: respiration rate 18 $min^{-1}$, respiratory volume 0.5 liter; 2) ventilator with PEEP, produced by connecting a PEEP valve, ventilation parameters the same; 3) ventilator with PEEP produced by connecting cock to increase resistance to expiration, ventilation parameters the same; 4) unaided breathing through apparatus under constant positive pressure (CPAP). Respiratory rate 25 $min^{-1}$, respiratory volume 0.5 liter. 5) Intermittent mandatory ventilation (IMV) without CPAP, activation of mandatory respiratory cycles every 12 sec; 6) IMV with CPAP, ventilation parameters the same. In programs 1-3 a model of the lungs with compliance of 0.02 liter/cm water and resistance 5 cm water · sec/liter was connected to the apparatus. Paper winding speed for programs 1-3 is 5 and 6.5 mm/sec, for program 4, 12 mm/sec.

monitored by the pressure-vacuum gauge of the apparatus. The distinguishing feature of this program is that, to avoid lowering of the respiratory volume supplied by the apparatus the value of PEEP must not exceed 20 cm water. Since under these circumstances the end-inspiratory pressure may exceed 30 cm water, to avoid scouring of part of the respiratory volume the protective valve of the apparatus itself (Fig. 2, No. 4) must be closed and the water seal disconnected.

2. Unaided Breathing under Constant Positive Pressure. The essence of this technique, known in English-speaking countries as Continuous Positive Airway Pressure (CPAP), is that the patient inhales gas unaided from a container in which a certain positive pressure is maintained, and breathes out through a device which creates a positive pressure of the same magnitude at expiration. The small fluctuations of pressure in the respiratory passages characteristic of unaided breathing take place under these circumstances relative, not to atmospheric pressure, but to a constant pressure raised usually by 5-20 cm water (Fig. 1, grid 4).

By the use of this technique premature expiratory closure of the respiratory passages can be prevented, the shunt from right to left reduced, and oxygenation of the blood thereby improved [6].

To obtain CPAP the same valve (Fig. 2, No. 5) must be used and connected in the same way as was described in the previous section. The subsequent procedure is as follows:

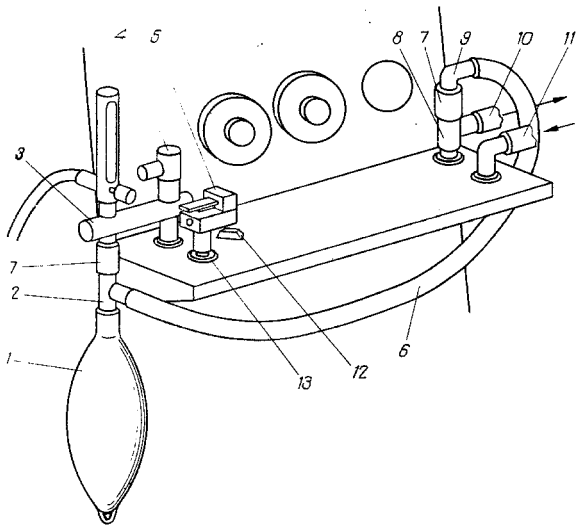


Fig. 2. Scheme of arrangement of additional parts on RO-6R and RO-6-03 apparatuses. 1) Breathing bag; 2) three-way cock; 3) oxygen supply unit; 4) protective valve; 5) PEEP valve; 6) corrugated hose; 7) rubber connector; 8) additional inspiratory valve; 9) right-angled tube; 10) inspiratory pipe; 11) expiratory pipe; 12) cock for switching respiratory circuits; 13) outlet pipe.

a) Unplug the apparatus from the electricity supply; the cock on the panel for switching modes of operation must be set in the position "ventilation by apparatus" position and the respiratory volume control must be set in the "minimal volume" position;

b) a three-way cock 2, with branches 15-20 mm in diameter, must be connected by means of the rubber connector 7 between the oxygen supply system 3 of the RO-6R and RO-6-03 apparatuses and the breathing bag 1, and the corrugated hose 6 must be connected to the free outlet branch of the three-way cock;

c) the free end of this hose is connected hermetically through the right-angled tube 9 and a suitable piece of rubber tube 7 to the head of the additional inspiratory valve 8 (the lumen of this valve must be open) and this valve is fitted into the inspiratory circuit instead of the right-angled tube;

d) the protective valve of the oxygen supply system 4 is set at the "300" position and the gas supply through the dosimeter is controlled initially so that it is a lattice higher than the patient's presumed unaided minute ventilation;

e) the apparatus is connected to the patient and the position of the load of the PEEP valve and the gas supply through the dosimeter are chosen so that fluctuations of pressure (i.e., the pressure difference between expiration and inspiration) with a range of 2-4 cm water relative to the chosen positive pressure level (5-20 cm water) are observed on the pressure and vacuum gauge of the apparatus.

It will be recalled that the breathing bag must have a capacity of not less than 5 liters and that the rate of gas supply to the bag must be approximately the same as the patient's rate of inspiration.

Under these conditions attention must be paid to the fact that the inspired gas does not pass through the humidifier of the apparatus, and its composition is determined by the gas supplied into the bag, without dilution with air. (This is possible if instead of the oxygen dosimeter unit, a dosimeter with air suction injector is fitted, such as the dosimeter unit of the Narkon-P apparatus.)

3. Intermittent Mandatory Ventilation (IMV). In this technique, the patient can breathe unaided through the apparatus, but at certain (preassigned) time intervals one respiratory cycle is carried out "mandatorily" by the apparatus, synchronously (SIMV) or nonsynchronously with the patient's respiratory activity. Being essentially a variant of assisted ventilation

of the lungs (this is particularly evident when SIMV is used), this procedure guarantees that the patient's ventilation never under any circumstances falls below that set on the apparatus. With a gradual lengthening of the intervals between "mandatory" cycles it is easier to reduce the patient's dependence on the apparatus during long-term artificial lung ventilation, and this is one of the important indications for the use of the IMV method [7].

The patient's spontaneous breathing through the apparatus can take place in the usual way with pressure drops at inspiration and expiration around the zero line (Fig. 1, grid 5) or (when indicated) according to the CPAP program (Fig. 1, grid 6). The IMV program can be carried out with apparatuses of the RO type which have an assisted lung ventilation unit with controlled sensitivity to the patient's breathing attempts. The rhythm of the mandatory inspirations is assigned by delays of the time relay of the assisted ventilation unit, amounting to 2, 4, 7, 12, and 20 sec (to obtain a delay of 20 sec, none of the time relay buttons should be pressed). The frequency of "mandatory" cycles which can be obtained also depends on the setting of the respiratory volume, minute ventilation, and $T_{exp}/T_{insp}$ ratio regulators. The minimal level of ventilation is determined by multiplying this frequency by the respiratory volume set on the apparatus. Although IMV obtained in this way is not synchronized with the patient's breathing attempts, the minute ventilation regulator and regulator of the ratio between the durations of expiration and inspiration can be used to ensure that the duration of mandatory inspiration is close to the duration of inspiration during spontaneous breathing.

If there are indications for IMV against the background of CPAP, this can be done by assembling the apparatus and controlling it in accordance with paragraphs b-e of the previous section (Fig. 2).

During IMV the inspired gas passes through the humidifier only during the mandatory inspirations. The respiratory volume can be measured during both spontaneous and mandatory breathing, but if CPAP is used corrections must be introduced for the excess gas supply.

The facilities described above greatly extend the functional possibilities of the RO-5 and RO-6 apparatuses. The technical measures necessary for the implementation of these programs were tested under laboratory conditions on models of the lungs, and then on patients in the intensive care and resuscitation department. The clinical aspects of the use of these facilities require further detailed study.

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